

CONFIRMED  
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Specification for

# Investment castings in metal —

**Part 1: Carbon and low alloy steels**

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## 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	Institution of Mechanical Engineers (Automobile Division)
British Constructional Steelwork Association	Institution of Production Engineers
British Ironfounders' Association	Institution of Structural Engineers
British Mechanical Engineering Confederation	Lloyd's Register of Shipping
British Steel Industry*	Ministry of Defence
Concrete Society	Ministry of Defence (Army Department)*
Council of Iron Producers	National Association of Drop Forgers and Stampers
Council of Ironfoundry Associations	Oil Companies Materials Association
Department of Employment	Process Plant Association
Department of Trade and Industry (Marine Division)	Royal Institute of British Architects
Engineering Equipment Users' Association	Shipbuilders' and Repairers' National Association
Federation of Civil Engineering Contractors	Society of Motor Manufacturers and Traders Ltd.*
Greater London Council	Steel Castings Research and Trade Association*
Institute of British Foundrymen*	Tin Research Association
Institute of Iron and Steel Wire Manufacturers	
Institute of Marine Engineers	

The Government department 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 Bronze and Brass Founders	Light Metal Founders' Association
British Investment Casters' Technical Association	Ministry of Defence (Aviation Supply)

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# Foreword

This British Standard, which has been prepared under the authority of the Iron and Steel Industry Standards Committee, has been revised to meet the needs of industry in the rapidly growing field of investment castings. The advantages of investment castings of the type described in this standard are the complexity of the shapes that can be cast, and the accurate approach to final form that can be obtained without a large amount of machining which may be difficult. These advantages apply particularly to material that is extremely hard or tough.

The scope of the new edition has been enlarged and it is now being published in four parts. The other parts which complete the series are as follows:

- *Part 2: High alloy steels, nickel and cobalt alloys;*
- *Part 3: Vacuum melted alloys;*
- *Part 4: Non-ferrous alloys.*

It is intended that the Izod impact values given in Section 2 of this Part will be replaced by, Charpy V-notch impact values when sufficient data is available.

Stress unit conversions are given in Appendix B.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

## Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 18, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

## 1 General requirements

### 1.1 Scope

This Part of this British Standard specifies requirements for carbon and low alloy steel investment castings complying with the general requirements of this Section and with the appropriate requirements of Section 2.

NOTE The titles of the British Standards referred to in this standard are listed on the inside back cover.

### 1.2 Definitions

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

#### 1.2.1

##### **investment castings**

the production of castings by a process which involves the investment of an expendable pattern with a refractory slurry

#### 1.2.2

##### **remelting stock**

metal supplied in cast or wrought form, the chemical composition of which has been established by analysis

#### 1.2.3

##### **melt**

the product of a single furnace charge used to produce castings, or the amount of metal tapped from the furnace without any further addition of metal excluding deoxidants to the furnace or ladle (when a continuous process is employed)

#### 1.2.4

##### **heat treatment batch**

castings of similar mass and dimensions produced from melts conforming to the same material specifications and heat treated together

### 1.2.5 Heat treatment definitions

#### 1.2.5.1

##### **annealing**

heating to and holding at a suitable temperature, followed by cooling at a suitable rate, for such purposes as:

- 1) inducing softness
- 2) improving machinability
- 3) improving cold working properties
- 4) obtaining a desired structure
- 5) removing stresses.

NOTE When applicable, the more specific terms, i.e. full annealing, isothermal annealing, sub-critical annealing or stress relieving should be used.

*Full annealing.* Heating to and holding at some temperature above the austenite transformation range, followed by cooling slowly through the transformation range.

*Isothermal annealing.* Heating to and holding at some temperature above the austenite transformation range, then cooling to and holding at a suitable temperature until the austenite to pearlite transformation is complete, and finally cooling to room temperature.

*Sub-critical annealing.* Heating to and holding at some temperature below the austenite transformation range, followed by cooling at a suitable rate.

*Stress relieving.* Heating to and, if necessary, holding at some temperature generally below the austenite transformation range, usually followed by slow cooling, for the sole purpose of relieving internal stresses.

#### 1.2.5.2

##### **normalizing**

heating to and, if necessary, holding at a suitable temperature above the austenite transformation range, followed by cooling in air, in order to modify the grain size, render the structure more uniform, and usually to improve the mechanical properties

**1.2.5.3****hardening**

increasing the hardness of steel by quenching from a temperature within or above the austenite transformation range

**1.2.5.4****tempering**

heating hardened or normalized steel to some temperature below the austenite transformation range, and holding for a suitable time at that temperature, followed by cooling at a suitable rate. This process is usually applied for the purpose of producing a desired combination of mechanical properties

**1.2.5.5****blank carburizing**

the carburizing heating cycle applied to a test bar but conducted without the carburizing medium

**1.2.5.6****grain refining**

heating from some temperature below the austenite transformation range to a suitable temperature above that range, followed by cooling at a suitable rate

**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 should be supplied in appropriate cases.

- 1) The number of this British Standard together with the type number and grade (if applicable) given in Section 2, e.g. BS 3146-1. CLA 1/A.
- 2) The condition in which the castings are to be supplied (see 1.9 and the relevant material specification in Section 2).
- 3) Whether non-destructive testing is required and, if so, which of the types specified in 1.13.
- 4) Whether consultation is required before castings are rectified.
- 5) Whether a certificate is required giving details of analysis, mechanical testing and non-destructive testing as appropriate.
- 6) Any special requirements of the purchaser.

**1.4 Method of manufacture**

The method and control of the manufacture of remelting stock shall be at the discretion of the melting stock manufacturer unless otherwise agreed between the founder and the melting stock manufacturer.

The method and control of the manufacture of castings shall be at the discretion of the founder unless otherwise agreed between the founder and the purchaser.

**1.5 Freedom from contamination**

All reasonable precautions shall be taken to prevent contamination during storage of materials used for the production of melts.

**1.6 Chemical composition**

**1.6.1 Remelting stock.** The chemical composition of stock for remelting shall be within the limits of the relevant material specification, unless otherwise stated on the founder's order. Residual elements and other elements not listed in the relevant material specification shall not be added deliberately, except for finishing the cast. No further additions shall be made to the cast or melt after the final analysis sample has been taken. The melting stock manufacturer shall supply to the founder the results of analysis for those elements specified. Care shall be taken to prevent contamination of the metal from preceding casts or melts.

**1.6.2 Castings.** The chemical composition of the castings shall conform to the relevant material specification. Residual elements and others not listed in the relevant material specification shall not be added deliberately except for the purpose of finishing the melt. All reasonable precautions shall be taken to prevent the addition of such elements arising from scrap or other materials used in the manufacture of the metal, and the purchaser by agreement with the founder may set a limit to one or more residual elements.

An analysis for residual elements is not normally carried out unless there is reason to suspect the presence of such elements in excessive amounts.

Care shall be taken to ensure that contamination of the metal does not occur from preceding heats.

If so stated on the enquiry and order, the founder shall supply a certificate of the chemical analysis on a basis agreed between the founder and the purchaser.

## 1.7 Tolerances

The castings shall conform to the tolerances as specified on the casting or drawing.

## 1.8 Freedom from defects

Castings shall be free from harmful defects. In the event of material proving defective during subsequent manufacturing operations, such material shall be deemed not to comply with the requirements of this standard, notwithstanding any previous certificate of satisfactory testing, provided the material has not been improperly treated after delivery. Surface or superficial imperfections may be removed, providing such rectification does not materially affect the strength, appearance or use for which the casting is intended. Any castings which have been subjected to rectification shall conform to such tolerances as are specified in 1.7.

## 1.9 Heat treatment

In the case of alloys which may be supplied in either the “as-cast” or heat treated condition, the condition required at the time of delivery shall be stated on the enquiry and/or order. In Section 2, if a temperature range is stated, a suitable temperature within that range shall be selected to give the required properties. Care shall be taken to prevent excessive oxidation or decarburization during any heat treatment process.

## 1.10 Provision and preparation of mechanical test samples

Test samples shall be provided by one of the following methods:

- 1) from separately cast test bars from an identical charge and cast under similar conditions;
- 2) from integrally cast test bars;
- 3) cut from castings.

In the case of test bars provided as required in 1) and 2), they shall conform to one of the types in Figure 1. The “carrot” type test sample is to be preferred.

NOTE 1 The properties obtained do not necessarily represent the properties of the castings themselves.

Unless otherwise agreed between the purchaser and the founder, where the material specification states that it is suitable for carburizing or nitriding, additional test samples shall be supplied to accompany castings through final heat treatment. The number of additional samples required shall be stated on the order.

NOTE 2 In alloys where mass effect becomes a factor during heat treatment, the ruling section of the test sample should be considered in relation to the ruling section of the casting.

## 1.11 Mechanical tests

**1.11.1 General.** Where the specified properties are dependent on heat treatment and unless otherwise agreed between the purchaser and the founder, one full set of tests per heat treatment batch shall be carried out. The test bars shall be heat treated with the castings they represent.

In all other cases, the type of tests and the frequency of testing shall be agreed between the purchaser and the founder.

**1.11.2 Tensile test.** The tensile test shall be carried out in accordance with BS 18-2. Test pieces shall be machined from test samples in the finally heat treated condition.

**1.11.3 Hardness test.** The hardness test shall be carried out in accordance with the requirements of BS 240-1, unless the Brinell test is considered unsuitable when other methods may be used. Considerable caution should be exercised when converting other hardness scales to Brinell (see BS 860).

**1.11.4 Case depth and hardness test.** Where the founder is required to carry out nitriding or carburizing, test samples shall be provided in accordance with the requirements of **1.10**.

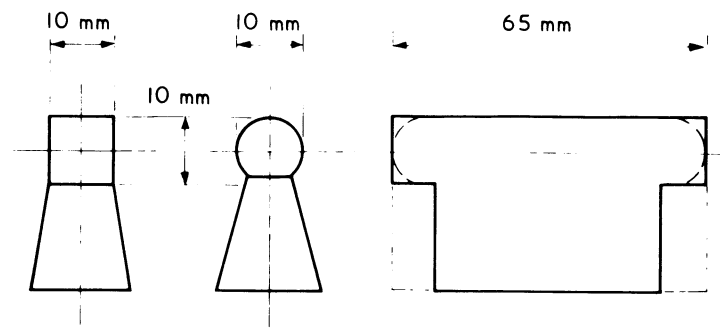
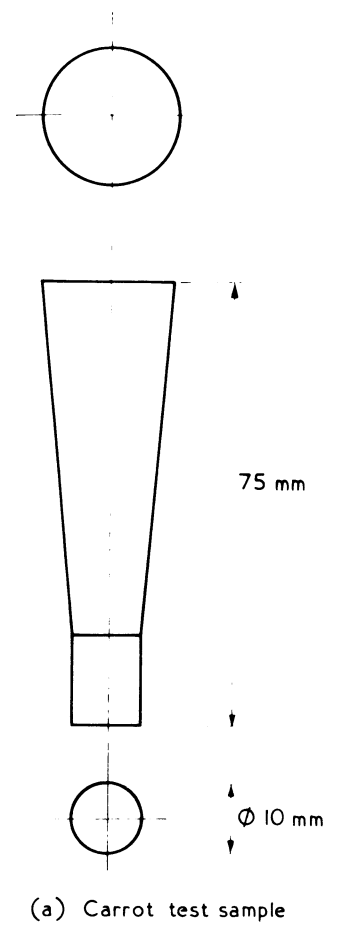
For nitriding steels, at least one test sample shall be included with each nitriding batch. The sample shall have accompanied the castings it represents throughout all the heat treatment processes to which the castings are subject prior to nitriding.

For carburizing steels, at least one test sample shall be carburized with each batch of castings.

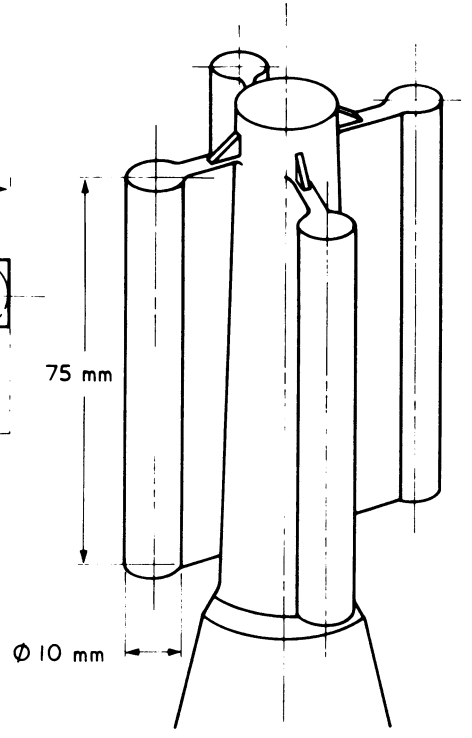
The depth of case of the nitrided or carburized test samples shall comply with drawing requirements, including a stated grinding allowance. At least one hardness test shall be carried out on the hardened case of each test sample. Hardness tests shall be carried out on the hardened case of castings at frequency agreed between the purchaser and the founder.

**1.11.5 Impact test.** The impact test shall comprise of a minimum of two notches and shall be carried out in accordance with the requirements of BS 131-1. Test pieces shall be machined from test samples in the finally heat treated condition.





(b) Keel block test sample  
(Circular or square section)



(c) Clover leaf test sample

NOTE All dimensions given are minimum values

Figure 1 — Types of test sample

## 1.12 Retests

If any test piece fails to comply with the appropriate requirements in Section 2, one of the following procedures shall be adopted by the founder.

- 1) Two additional test pieces shall be used for retests of the material for which failure occurred.
- 2) The casting, together with the test sample, shall be submitted to further heat treatment after which all of the tests shall be repeated.

Should any of the tests in 1) or 2) above fail, the castings represented may, if the founder desires, be reheat treated. Whenever castings are reheat treated, all tests shall be repeated.

In no instance shall the casting be subjected to more than two additional heat treatments other than tempering. Test pieces which contain obvious casting flaws shall not be considered for assessment as above. The castings comply with the requirements of this standard if the retests are satisfactory. If the retests fail to meet these requirements, castings represented by the test pieces which fail do not comply with this standard.

## 1.13 Non-destructive testing

**1.13.1 General.** Non-destructive testing may be applied as agreed between the founder and the purchaser, and, if so required, shall be specified on the enquiry and order. When non-destructive testing is specified, the castings shall be examined in accordance with 1.13.2 and/or 1.13.3 unless other methods are agreed between the founder and the purchaser.

**1.13.2 Radiographic examination.** Castings shall be radiographically examined to the satisfaction of the purchaser; the purchaser shall indicate the frequency and location of any such examination. The radiographic technique and acceptance standard shall be agreed between the founder and the purchaser.

**1.13.3 Magnetic particle or penetrant examination.** Castings shall be examined for freedom from surface defects to the satisfaction of the purchaser. The purchaser shall indicate the frequency of testing, the location and the standard to be met. Flaw detection shall be carried out by the founder unless otherwise agreed by the purchaser. Any casting subjected to additional heat treatment or proof loading and/or correction of distortion after crack testing shall be re-examined.

## 1.14 Rectification of defects

When specified on the order the purchaser shall be consulted before castings are rectified. In such cases, rectification shall be followed by the appropriate heat treatment and non-destructive examination by the method(s) used previously. All rectification by welding should be carried out in accordance with the procedure given in Appendix A.

## 1.15 Identification

**1.15.1** Bars or ingots of remelting stock shall be individually marked with the cast number and any other marking necessary to ensure identification.

**1.15.2** All castings shall be legibly marked for identification purposes, or may be bundled together and labelled to maintain identification, unless otherwise specified by the purchaser.

## 1.16 Manufacturer's certificate

If specified on the enquiry or order, the founder shall supply to the purchaser a certificate giving:

- 1) details of analysis of the batch material to which the mechanical tests results apply;
- 2) the results of the mechanical tests;
- 3) the results of the non-destructive testing (if applicable).

## 1.17 The rounding of numbers rule

Values between the limits of composition shown (*not* dimensional tolerances) are subject to the application of the "rounding" rule in accordance with the requirements of BS 1957. Under this rule the determined values are "rounded" to the last place of figures stated as limits. The following table illustrates the application of the "rounding" rule.

Specification limits		Extreme values which round to the specification limits	
min.	max.	min.	max.
—	0.050	—	0.0505
0.2	0.6	0.15	0.65
6	9	5.5	9.4
6.0	9.0	5.95	9.05
7	10	6.6	10.5
7.5	10.5	7.46	10.54

## 2. Specific requirements for carbon and low alloy steel investment castings

### Type CLA 1: Carbon steel castings

This type includes three grades of carbon steel castings. The purchaser shall state the grade required on the enquiry and order.

*Chemical composition.* The steel shall contain:

Element	Grade A		Grade B		Grade C	
	% min.	% max.	% min.	% max.	% min.	% max.
Carbon	0.15	0.25	0.25	0.35	0.35	0.45
Silicon	0.2	0.6	0.2	0.6	0.2	0.6
Manganese	0.4	1.0	0.4	1.0	0.4	1.0
Nickel <sup>a</sup>	—	0.4	—	0.4	—	0.4
Chromium <sup>a</sup>	—	0.3	—	0.3	—	0.3
Molybdenum <sup>a</sup>	—	0.1	—	0.1	—	0.1
Copper <sup>a</sup>	—	0.3	—	0.3	—	0.3
Sulphur	—	0.035	—	0.035	—	0.035
Phosphorus	—	0.035	—	0.035	—	0.035

<sup>a</sup> Residuals. The total amount of these elements shall not exceed 0.80 %.

*Condition.* The castings shall be supplied in the finally heat treated condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and order.

*Final heat treatment.* The final heat treatment shall consist of normalizing, normalizing and tempering or hardening and tempering at suitable temperatures to give the mechanical properties specified.

*Mechanical properties.* The mechanical properties obtained from the test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	Grade A	Grade B	Grade C
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa) min.	430	500	540
0.2 % proof stress <sup>a</sup> , $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa) min.	195	215	245
Elongation, $A$ , % min.	15	13	11

<sup>a</sup> The 0.2 % proof stress values are for information only.

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be as follows:

- Grade A 121 HB to 174 HB
- Grade B 143 HB to 183 HB
- Grade C 163 HB to 207 HB

**Type CLA 2: 1½ % manganese steel castings**

(pearlitic manganese steel)

*Chemical composition.* The steel shall contain:

Element	% min.	% max.
Carbon	0.18	0.25
Silicon	0.2	0.5
Manganese	1.2	1.7
Nickel <sup>a</sup>	—	0.4
Chromium <sup>a</sup>	—	0.3
Molybdenum <sup>a</sup>	—	0.1
Copper <sup>a</sup>	—	0.3
Sulphur	—	0.035
Phosphorus	—	0.035

<sup>a</sup> Residuals. The total amount of these elements shall not exceed 0.80 %.

*Condition.* The castings shall be supplied in the finally heat treated condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and order.*Final heat treatment.* The final heat treatment shall consist of normalizing, normalizing and tempering or hardening and tempering at suitable temperatures to give the mechanical properties specified.*Mechanical properties* The mechanical properties obtained from the test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.	max.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	550	700
0.2 % proof stress <sup>a</sup> , $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	310	—
Elongation, $A$ , %	13	—
Izod impact strength, ft lbf <sup>b</sup>	30	—

<sup>a</sup> The 0.2 % proof stress values are for information only.  
<sup>b</sup> See Foreword.

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be within the range 152 HB to 201 HB.

**Type CLA 3: 700 N/mm<sup>2</sup> to 850 N/mm<sup>2</sup> alloy steel castings**

This type covers alloy steel castings for structural and engineering purposes.

*Chemical composition.* Unless otherwise specified by the purchaser, the manufacturer shall select the composition to obtain the mechanical properties required: in all cases, however, neither the sulphur nor the phosphorus content shall be more than 0.035 %.*Condition.* The castings shall be supplied in the finally heat treated condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and order.*Final heat treatment.* The heat treatment shall consist of annealing, hardening and tempering unless otherwise agreed between the founder and the purchaser.*Mechanical properties.* The mechanical properties obtained from the test pieces selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.	max.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	700	850
0.2 % proof stress, $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	495	—
Elongation, $A$ , %	11	—
Izod impact strength, ft lbf <sup>a</sup>	25	—

<sup>a</sup> See Foreword.

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be within the range 201 HB to 255 HB.

**Type CLA 4: 850 N/mm<sup>2</sup> to 1 000 N/mm<sup>2</sup> alloy steel castings**

This type covers alloy steel castings for structural and engineering purposes.

*Chemical composition.* Unless otherwise specified by the purchaser, the manufacturer shall select the composition to obtain the mechanical properties required; in all cases, however, neither the sulphur nor the phosphorus content shall be more than 0.035 %.

*Condition.* The castings shall be supplied in the finally heat treated condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and order.

*Final heat treatment.* The final heat treatment shall consist of annealing, hardening and tempering unless otherwise agreed between the founder and the purchaser.

*Mechanical properties.* The mechanical properties obtained from the test pieces selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.	max.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	850	1 000
0.2 % proof stress, $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	585	—
Elongation, A, %	11	—
Izod impact strength, ft lbf <sup>a</sup>	15	—
<sup>a</sup> See Foreword.		

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be within the range 248 HB to 302 HB.

**Type CLA 5: Steel castings having a minimum tensile strength of 1 000 N/mm<sup>2</sup>**

This type includes two grades of material and the purchaser shall state the grade required on the enquiry or order.

*Chemical composition.* Unless otherwise specified by the purchaser, the manufacturer shall select the composition to give the mechanical properties specified after the appropriate heat treatment; in all cases, however, the sulphur content shall be not more than 0.020 % and the phosphorus content not more than 0.025 %.

The chemical composition shall be such as to give the mechanical properties specified after the appropriate heat treatment.

*Condition.* The castings shall be supplied in the finally heat treated condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and order.

*Final heat treatment.* The final heat treatment shall consist of annealing or normalizing followed by hardening and tempering at suitable temperatures to give the mechanical properties specified.

*Mechanical properties.* The mechanical properties obtained from the test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	Grade A	Grade B
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa) min.	1 000	1 160
0.2 % proof stress, $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa) min.	880	1 000
Elongation, A, % min.	9	5
Izod impact strength, ft lbf <sup>a</sup> , min.	30	10
<sup>a</sup> See Foreword.		

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be as follows:

- Grade A 269 HB to 321 HB
- Grade B 341 HB to 388 HB

**Type CLA 7: 3 % chromium-molybdenum steel castings**

This type covers steel castings for engineering purposes. The castings may be used at temperatures up to approximately 400 °C

*Chemical composition.* The steel shall contain:

Element	% min.	% max.
Carbon	0.15	0.25
Silicon	0.3	0.8
Manganese	0.3	0.6
Nickel <sup>a</sup>	—	0.4
Chromium	2.5	3.5
Molybdenum	0.35	0.6
Copper <sup>a</sup>	—	0.3
Sulphur	—	0.035
Phosphorus	—	0.035

<sup>a</sup> Residuals.

*Condition.* The castings shall be supplied in the finally heat treated condition unless otherwise agreed between the founder and the purchaser or stated on the drawing and order.

*Final heat treatment.* The final heat treatment shall consist of annealing, hardening and tempering at suitable temperatures to give the mechanical properties specified.

*Mechanical properties.* The mechanical properties obtained from the test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.	max.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	620	770
0.2 % proof stress, $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	480	—
Elongation, $A$ , %	14	—
Izod impact strength, ft lbf <sup>a</sup>	25	—

<sup>a</sup> See Foreword.

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be within the range 179 HB to 223 HB.

**Type CLA 8: Carbon steel castings for surface hardening**

This material is suitable for surface hardening by a local heating and quenching process.

*Chemical composition.* The steel shall contain:

Element	% min.	% max.
Carbon	0.37	0.45
Silicon	0.2	0.6
Manganese	0.5	0.8
Nickel <sup>a</sup>	—	0.4
Chromium	—	0.3
Molybdenum <sup>a</sup>	—	0.1
Copper <sup>a</sup>	—	0.3
Sulphur	—	0.035
Phosphorus	—	0.035

<sup>a</sup> Residuals. The total amount of these elements shall not exceed 0.80 %.

*Condition.* The castings shall be supplied in the normalized or normalized and tempered condition, carried out at suitable temperatures to give the mechanical properties specified.

*Final heat treatment.* Surface hardening will normally be carried out by the purchaser. When required by the purchaser a hardening test shall be conducted by the founder.

**Hardening test.** A test piece 12 mm in diameter and not less than 75 mm long shall be machined from a test sample representing each melt. The test piece shall be heated to a temperature of 810 °C to 840 °C, allowed to soak and quenched in water.

The hardness of the test piece shall be not less than 500 HV when tested in accordance with BS 427-1.

**Mechanical properties.** The mechanical properties obtained from the test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	540
0.2 % proof stress <sup>a</sup> , $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	245
Elongation, $A$ , %	15

<sup>a</sup> The 0.2 % proof stress value is for information only.

### Type CLA 9: Carbon case hardening steel castings

This material is suitable for hardening by a case carburizing process.

**Chemical composition.** The steel shall contain:

Element	% min.	% max.
Carbon	0.10	0.18
Silicon	0.2	0.6
Manganese	0.6	1.0
Nickel <sup>a</sup>	—	0.4
Chromium <sup>a</sup>	—	0.3
Molybdenum <sup>a</sup>	—	0.1
Copper <sup>a</sup>	—	0.3
Sulphur	—	0.035
Phosphorus	—	0.035

<sup>a</sup> Residuals. The total amount of these elements shall not exceed 0.80 %.

**Condition.** The castings shall be supplied in the as-cast or normalized condition.

Test bars only shall be heat treated as follows:

Blank carburize at a temperature between 880 °C and 930 °C.

Refine at a temperature between 870 °C and 900 °C; cool in air, oil or water.

Harden in water from a temperature between 760 °C and 780 °C.

Where castings are supplied in the normalized condition, test bars treated as specified shall have been previously normalized together with their respective casting heat treatment batch.

By arrangement with the purchaser, tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified.

**Final heat treatment.** The final heat treatment will normally be carried out by the purchaser, but where it has been specified to be carried out by the founder, it shall comply with the conditions specified in Section 1.

**Mechanical properties.** The mechanical properties obtained from the selected test pieces, heat treated as specified and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	495
0.2 % proof stress <sup>a</sup> , $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	215
Elongation, $A$ , %	15
Izod impact strength, ft lbf <sup>b</sup>	20

<sup>a</sup> The 0.2 % proof stress value is for information only.  
<sup>b</sup> See Foreword.

**Type CLA 10: 3 % nickel case hardening steel castings**

This material is suitable for hardening by a case carburizing process.

*Chemical composition.* The steel shall contain:

Element	% min.	% max.
Carbon	0.10	0.18
Silicon	0.2	0.6
Manganese	0.3	0.6
Nickel	2.75	3.5
Chromium <sup>a</sup>	—	0.3
Molybdenum <sup>a</sup>	—	0.1
Copper <sup>a</sup>	—	0.3
Sulphur	—	0.035
Phosphorus	—	0.035
<sup>a</sup> Residuals.		

*Condition.* Castings shall be supplied in the as-cast or normalized condition.

Test bars only shall be heat treated as follows:

Blank carburize at a temperature between 880 °C and 930 °C.

Refine at a temperature between 850 °C and 880 °C; cool in air, oil or water.

Harden in oil or water from a temperature between 760 °C and 780 °C.

Where castings are supplied in the normalized condition test bars treated as specified shall have been previously normalized, together with their respective casting heat treatment batch.

By arrangement with the purchaser tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified.

*Final heat treatment.* The final heat treatment will normally be carried out by the purchaser, but where it has been specified to be carried out by the founder it shall comply with the conditions specified in Section 1.

*Mechanical properties.* The mechanical properties obtained from the selected test pieces, heat treated as specified and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	700
0.2 % proof stress <sup>a</sup> , $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	350
Elongation, $A$ , %	14
Izod impact strength, ft lbf <sup>b</sup>	30
<sup>a</sup> The 0.2 % proof stress value is for information only.	
<sup>b</sup> See Foreword.	

**Type CLA 11: 3 % chromium — molybdenum nitriding steel castings**

*Chemical composition.* The steel shall contain:

Element	% min.	% max.
Carbon	0.20	0.30
Silicon	0.3	0.8
Manganese	0.3	0.6
Nickel <sup>a</sup>	—	0.4
Chromium	2.9	3.5
Molybdenum	0.4	0.7
Vanadium <sup>a</sup>	—	0.02
Copper <sup>a</sup>	—	0.3
Tin <sup>a</sup>	—	0.03
Sulphur	—	0.035
Phosphorus	—	0.035
<sup>a</sup> Residuals.		



*Condition.* Castings shall be supplied in the annealed, hardened and tempered condition.

*Final heat treatment.* The nitriding process will normally be carried out by the purchaser, but where it has been specified to be carried out by the founder it shall comply with the conditions specified in Section 1.

*Mechanical properties.* The mechanical properties obtained from the test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.	max.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	850	1 000
0.2 % proof stress, $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	600	—
Elongation, $A$ , %	8	—
Izod impact strength, ft lbf <sup>a</sup>	15	—
<sup>a</sup> See Foreword.		

The hardness of the castings, if required by the purchaser and stated on the enquiry or order, shall be within the range 248 HB to 302 HB.

### Type CLA 12: 1 % chromium steel castings (abrasion resisting)

This material is used for resistance to wear and abrasion. There are three grades, as follows:

- Grade A and B : carbon — chromium  
 Grade C : carbon — chromium — molybdenum

The purchaser shall state the grade required on the enquiry and order.

*Chemical composition.* The steel shall contain:

Element	Grades A and B		Grade C	
	% min.	% max.	% min.	% max.
Carbon	0.45	0.55	0.55	0.65
Silicon	0.3	0.8	0.3	0.8
Manganese	0.5	1.0	0.5	1.0
Nickel <sup>a</sup>	—	0.4	—	0.4
Chromium	0.8	1.2	0.8	1.5
Molybdenum	—	0.1 <sup>a</sup>	0.2	0.4
Copper <sup>a</sup>	—	0.3	—	0.3
Sulphur	—	0.035	—	0.035
Phosphorus	—	0.035	—	0.035
<sup>a</sup> Residuals.				

*Condition.* Castings shall be supplied in the annealed or finally heat treated condition or as specified by the purchaser.

*Final heat treatment.* The final heat treatment shall consist of annealing followed by either normalizing and tempering or hardening and tempering, at suitable temperatures to give the mechanical properties specified.

*Mechanical properties.* The mechanical properties obtained from the finally heat treated test pieces, selected and tested in accordance with the requirements of Section 1, shall be as follows:

Property	Grade A
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa) min.	700
Elongation, $A$ , % min.	8
Hardness, HB min.	207

The minimum hardness of finally heat treated test pieces of Grades B and C shall be 293 HB and 341 HB respectively.

The hardness of castings supplied in the annealed condition shall be not greater than 255 HB.

The required hardness and the frequency of hardness testing shall be agreed between the founder and the purchaser.

**Type CLA 13: Nickel — molybdenum case hardening steel castings**

This material is suitable for hardening by a case carburizing process.

*Chemical composition.* The steel shall contain:

Element	% min.	% max.
Carbon	0.12	0.20
Silicon	0.2	0.6
Manganese	0.3	0.7
Nickel	1.5	2.0
Molybdenum	0.2	0.3
Chromium <sup>a</sup>	—	0.3
Copper <sup>a</sup>	—	0.3
Sulphur	—	0.035
Phosphorus	—	0.035
<sup>a</sup> Residuals.		

*Condition.* Castings shall be supplied in the as-cast or normalized condition.

Test bars only shall be heat treated as follows:

Blank carburize at a temperature between 880 °C and 930 °C.

Refine at a temperature between 850 °C and 880 °C, cool in air, oil or water.

Harden in oil from a temperature between 760 °C and 780 °C.

Where castings are supplied in the normalized condition test bars, treated as specified, shall have been previously normalized together with their respective casting heat treatment batch.

By arrangement with the purchaser, tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified.

*Final heat treatment.* Carburizing and surface hardening will normally be carried out by the purchaser, but where it has been specified to be carried out by the founder, it shall comply with the conditions specified in Section 1.

*Mechanical properties.* The mechanical properties obtained from test pieces, selected and heat treated as specified and tested in accordance with the requirements of Section 1, shall be as follows:

Property	min.
Tensile strength, $R_m$ , N/mm <sup>2</sup> (= MPa)	700
0.2 % proof stress <sup>a</sup> , $R_{p0.2}$ , N/mm <sup>2</sup> (= MPa)	350
Elongation, $A$ , %	14
Izod impact strength, ft lbf <sup>b</sup>	30
<sup>a</sup> The 0.2 % proof stress value is for information only.	
<sup>b</sup> See Foreword.	

## Appendix A Procedure for repairing castings by welding

### A.1 General

In order to maintain a high standard of workmanship in the practice of welding castings, the following general principles and the information given in BS 4570-1 should be followed, but the precise technique will of necessity vary according to circumstances.

### A.2 Welders

The technical management should be fully satisfied that all the welders are proficient both as regards skill in welding and in the proper use of the mechanical and electrical apparatus they employ.

### A.3 Preparation for welding

In the preparation for the repair of defects it is most important to ensure that the foundation for welding is good and that the exposed metal is sound, clean, free from all foreign matter and of a suitable shape to permit adequate access for welding, otherwise sound repairs cannot be made.

In normal circumstances, mechanical methods should be used for removing metal and defects in preparation for welding.

In order to minimize the risk of cracking, it may be desirable, in the case of complicated castings and those which are likely to contain high residual stresses produced during manufacture, to stress-relieve the whole casting before weld preparation.

### A.4 Heat treatment

Recommendations for pre-heating, and post-weld heat treatment temperatures are given in Table 1.

### A.5 Pre-heating

Pre-heating refers to heat treatment done immediately before welding, i.e. welding should commence when the parent metal in the region of the weld has attained the recommended temperature. During the welding operation the temperature of the parent metal in the region of the weld should not fall below that recommended for pre-heating. Variations in composition, mass, design and the extent of the welding make it impossible to lay down hard and fast rules as to the amount of pre-heat to be applied. The figures given in Table 1, therefore, are only intended as a guide.

### A.6 Post-weld heat treatment

Post-weld heat treatment refers to treatment done after the weld has been deposited. This treatment may be necessary to reduce stresses due to welding or to minimize hardening or both. It is normally applied to the whole casting.

Post-weld heat treatment has to be considered in relation to the general heat treatment to be applied to the casting to provide specific properties and where such general heat treatment has to be applied before welding is done, it may be necessary to repeat the heat treatment after welding.

### A.7 Recommended electrodes

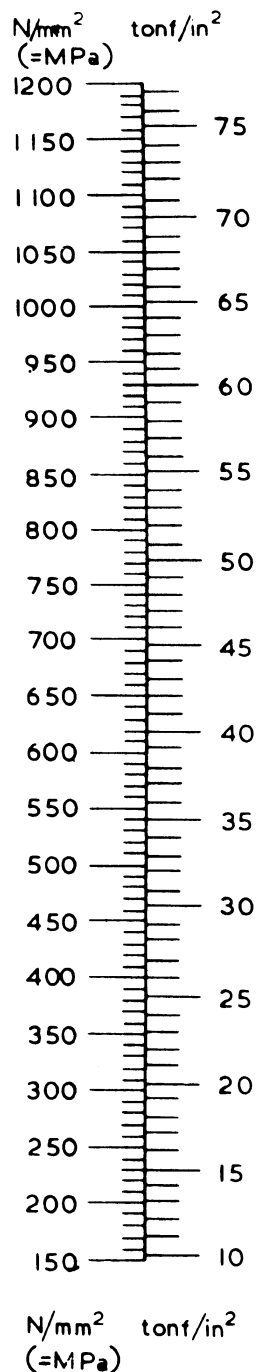
Recommended electrodes are given in Table 1.

**Table 1 — Recommended electrodes, pre-heating and post-weld heat treatment temperatures**

(The information given in Table 1 is for guidance purposes only.)

Type	Grade	Electrodes for manual metal-arc welding (see Note 1)	Pre-heating temperature °C min	Post-weld heat treatment temperature °C
CLA 1	A	BS 639	—	—
CLA 1	B and C	BS 639	150	—
CLA 2	—	BS 2493, Mo B	200	—
CLA 3	—	No suitable	250	600 – 650
CLA 4	—	BS electrode	250	600 – 650
CLA 5	A and B	available	275	500 – 600
CLA 7	—	BS 2493, 2 Cr Mo B or 2 Cr Mo R	275	600 – 650
CLA 8	—	BS 639	150	600 – 650 followed by air cooling
CLA 9	—	No suitable	See Note 2	
CLA 10	—	BS electrode available		
CLA 11	—	BS 2493, 2 Cr Mo B or 2 Cr Mo R	275	600 – 650
CLA 12	A and B	BS 639	250	500 – 600
CLA 12	C	BS 639	300	500 – 600
CLA 13	—	No suitable BS electrode available	See Note 2	
NOTE 1 It is suggested that, in the repair of castings by inert-gas arc welding processes, filler materials of similar composition to the weld metal from manual metal-arc welding electrodes be used.				
NOTE 2 These castings may be welded in areas which are not subjected to wear in service and by agreement between the founder and the purchaser.				

## Appendix B Stress unit conversion



Conversion factor 1 N/mm<sup>2</sup> = 1 MPa = 0.064 75 tonf/in<sup>2</sup>.

For more detailed conversion see BS 350 "Conversion factors and tables".



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## Publications referred to

This standard makes reference to the following British Standards:

BS 18, *Tensile testing of metals.*

BS 18-2, *Steel (general).*

BS 131, *Methods for notched bar tests.*

BS 131-1, *The Izod impact test on metals.*

BS 240, *Method for Brinell hardness test.*

BS 240-1, *Testing of metals.*

BS 427, *Method for Vickers hardness test.*

BS 427-1, *Testing of metals.*

BS 639, *Covered electrodes for the manual metal-arc welding of mild steel and medium tensile steel.*

BS 860, *Tables for comparison of hardness scales.*

BS 1957, *Presentation of numerical values (fineness of expression; rounding of numbers).*

BS 2493, *Low alloy steel electrodes for manual metal-arc welding.*

BS 4570, *Fusion welding of steel castings.*

BS 4570-1, *Production, rectification and repair.*

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