BRITISH STANDARD

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Specification for

Investment castings in metal —

Part 2: Corrosion and heat resisting steels, nickel and cobalt base alloys

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Co-operating organizations

The Iron and Steel and the Non-ferrous Metals Industry Standards Committees, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations.

The Iron and Steel Industry Standards Committee

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

The Non-ferrous Metals Industry Standards Committee

Aluminium Federation
Association of Bronze and Brass Founders*
British Electrical and Allied Manufacturers' Association
British Lead Manufacturers' Association
British Non-ferrous Metals Federation
British Non-ferrous Metals Technology Centre
British Steel Industry*
Copper Development Association
Department of Trade (Marine Division)
Electric Cable Makers' Confederation
Institute of British Foundrymen*
Institution of Mechanical Engineers (Automobile Division)
Institution of Mining and Metallurgy
Institution of Production Engineers
Institution of Structural Engineers
Lead Development Association
Light Metal Founders' Association*
London Metal Exchange
Magnesium Industry Council
Ministry of Defence*
National Brassfoundry Association
Non-ferrous Metal Stockists
Post Office
Royal Institute of British Architects
Society of Motor Manufacturers and Traders Ltd.*
Tin Research Institute
Zinc Development Association

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

British Investment Casters' Technical Association.

This British Standard, having been approved by the Iron and Steel and the Non-ferrous Metals Industry Standards Committees, was published under the authority of the Executive Board on 30 May 1975

The following BSI references relate to the work on this standard:
Committee reference ISM/NFM/6
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Amendments issued since publication

Amd. No.	Date of issue	Comments
4767	March 1985	Indicated by a sideline in the margin

Contents

Foreword

This Part of this British Standard, which has been prepared under the authority of the Iron and Steel and the Non-ferrous Metals Industry Standards Committees, 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.

The scope of the new edition has been enlarged and it is now being published in 4 parts. The other parts which complete the series are as follows:

— *Part 1: Carbon and low alloy steel;*

— *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 are available.

Stress unit conversions are given in Appendix A.

Certification. Attention is drawn to the certification facilities described on the inside back cover of this standard.

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

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 20, 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.

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Section 1. General requirements

1 Scope

This Part of this British Standard specifies requirements for investment castings in corrosion and heat resisting steels and nickel and cobalt base alloys, complying with the general requirements of this section. and with the appropriate requirements of section 2.

2 References

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

3 Definitions

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

3.1
investment casting

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

3.2
remelting stock

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

3.3
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 having been added to the furnace or ladle (when a continuous process is employed) excluding deoxidants

3.4
heat treatment batch

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

the following heat treatment definitions apply

martensitic corrosion and heat resisting stainless steels

3.5
annealing

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

a) inducing softness

b) improving machinability

c) obtaining a desired structure

d) removing stresses

3.6
hardening

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

3.7
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

austenitic and precipitation hardening alloys

3.8
precipitation treatment (ageing)

the heat treatment of alloys to promote precipitation to produce optimum creep, or stress rupture and/or tensile characteristics. It may be accompanied by a change in hardness

3.9
solution treatment

the heat treatment of alloys normally intended for subsequent precipitation treatment, at a suitable temperature for sufficient time to ensure adequate solution of the precipitation phase(s), followed by cooling at a rate sufficient to retain the phase(s) in solution. The term is also associated with material in the softest condition

3.10
softening or annealing heat treatment

the heat treatment designed to give a soft, ductile product and normally associated with recrystallization of the material

NOTE 1 The terms are generally applied to alloys not subjected to precipitation treatment.
NOTE 2 A "softening" treatment is sometimes applied to alloys which are suitable for precipitation treatment in order to eliminate the effect of cold work. This treatment may effect an incomplete solution of the precipitated phase(s).

4 Information to be supplied by the purchaser

The following information should be stated on the enquiry and order. A drawing of the part to be made should be supplied in appropriate cases.

a) The number of this British Standard together with the type number and grade (if applicable) given in section 2, e.g. BS 3146/2 ANC 1/A.

b) The condition in which the castings are to be supplied. (See clause **10** and section 2.)

c) Whether non-destructive testing is required and, if so, the details which have been agreed. (See clause **14**.)

d) Whether consultation is required before castings are rectified. (See clause **15**.)

e) Whether a certificate is required, giving details of analysis, mechanical testing and non-destructive testing, as appropriate. (See clause **17**.)

f) Whether the hardness of the castings is required for type ANC 1, type ANC 2 and type ANC 22.

g) Any special requirements of the purchaser.

5 Method of manufacture

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

6 Freedom from contamination

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

7 Chemical composition

7.1 Remelting stock. The 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 the purpose of 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 the analysis for those elements specified. Care should be taken to prevent contamination of the metal from preceding casts or melts.

7.2 Castings. The chemical composition of the castings shall conform to the appropriate material specification given in section 2. 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. (See also clause **17**.)

8 Tolerances

The castings shall be within the dimensional tolerances as specified on the casting drawing or order.

9 Freedom from defects

Castings shall be free from harmful defects. Notwithstanding previous acceptance as complying with the requirements of this standard, any casting which is later found to contain harmful defects shall be rejected. 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 clause **8**.

10 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 should be taken to prevent excessive oxidation or decarburization during any heat treatment process.

11 Provision and preparation of test samples

Where required, test samples shall be provided as follows:

a) from separately cast test bars from an identical charge and cast under similar conditions;

b) from integrally cast test bars;

c) cut from castings.

In the case of test bars provided as in a) and b) they shall conform to one of the types in Figure 1.

Unless otherwise agreed between the purchaser and the founder where or when castings are supplied in other than the finally heat treated condition, additional test pieces shall be supplied to accompany the castings through the final heat treatment. The number of additional samples required shall be stated on the order.

NOTE In alloys where mass effect becomes a factor during heat treatment, the ruling section of the test piece should be related to the ruling section of the casting.

12 Tests

12.1 General. Tensile, bend and impact test pieces shall be machined from test samples in fully heat treated condition to one of the standard test pieces shown in the appropriate British Standard.

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.

12.2 Tensile test. The tensile test shall be carried out in accordance with BS 18-2.

12.3 Bend test. The bend test shall be carried out in accordance with BS 1639.

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

12.5 Impact test. The impact test shall comprise a minimum of two notches and shall be carried out in accordance with the requirements of BS 131-1.

12.6 Inter crystalline corrosion test. When required by the purchaser a bend test shall be carried out as follows.

Each bend test piece shall be not greater than 13 mm in diameter or thickness and before being bent shall be heated for 30 min at a temperature of 650 °C, and cooled in air. It shah then be immersed either:

a) for 72 h in a boiling solution having the following composition:

111 g of copper sulphate crystals ($CuSO_4.5H_2O$)

98 g of concentrated sulphuric acid (d = 1.84)

made up to 1 litre with distilled water; or

b) for 24 h in a boiling solution of the composition given in a) to which 50 g of copper turnings or filings are added before the test, the test piece being in contact with this copper. The test solution may be used only once.

Precautions shall be taken during boiling to prevent concentration by evaporation. After this preparation each test piece shall be bent without cracking through 90° around a radius equal to three times the diameter or thickness of the test piece.

13 Retests

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

a) Two additional test pieces shall be used for retests of the material for which failure occurred.

b) The casting, together with test sample, shall be submitted to further heat treatment after which all of the 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 the requirements, castings represented by the test pieces which fail do not comply with the requirements of this standard.

14 Non-destructive testing

14.1 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 **14.2** and/or **14.3**.

Flaw detection shall be carried out by the founder unless otherwise agreed by the founder. Any casting subjected to additional heat treatment or proof loading shall be re-examined unless otherwise agreed by the purchaser.

14.2 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.

14.3 Magnetic particle or penetrant testing. 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.

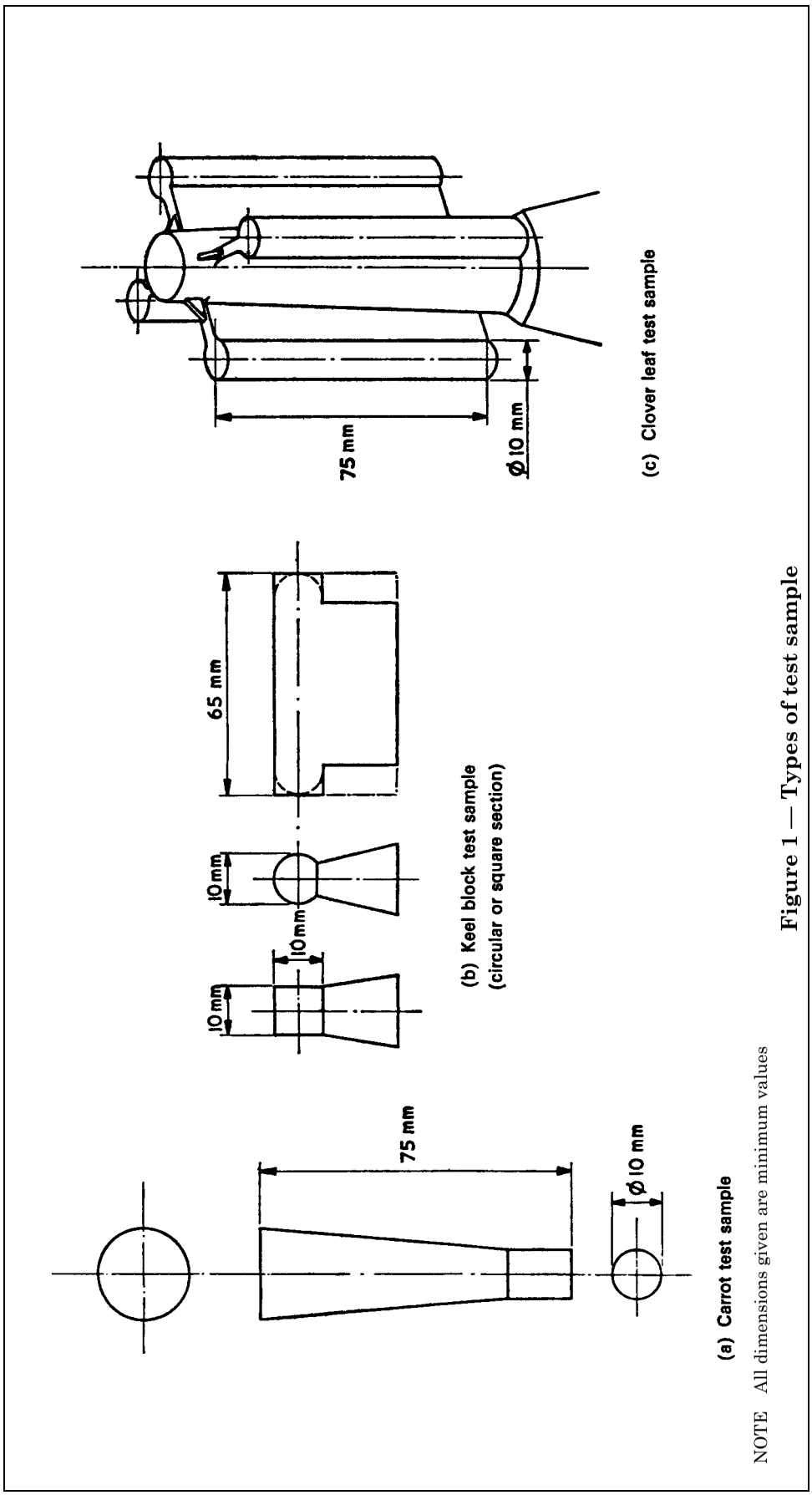


Figure 1 — Types of test sample

NOTE All dimensions given are minimum values

15 Rectification of defects

When specified by the purchaser on the order, he shall be consulted before castings are rectified. In all cases, rectification shall be followed by appropriate heat treatment and non-destructive examination.

16 Identification

16.1 Bars or ingots of remelting stock shall be individually marked with the cast number and/or any other markings necessary to ensure identification.

16.2 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.

17 Manufacturer's certificate

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

a) details of analysis of the batch to which the mechanical tests results apply;

b) the results of the mechanical tests;

c) the results of the non-destructive testing examination (if applicable).

18 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. If the figure following the last significant figure is 5 the nearest even value is used for the last significant figure, i.e. 6.35 rounds to 6.4, 6.45 rounds to 6.4.

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

Section 2. Specific requirements for investment castings in corrosion and heat resisting steels and nickel and cobalt base alloys

Type ANC1: 13 % chromium martensitic steel castings

This type covers the requirements for martensitic corrosion resisting steel castings for general engineering purposes from 540 N/mm^2 to 695 N/mm^2. There are three grades and each grade can also be supplied to a free machining condition. The purchaser shall specify the grade and condition required.

Chemical composition. The steel shall contain;

Element	Grade A		Grade B		Grade C	
	% min.	% max.	% min.	% max.	% min.	% max.
Carbon	—	0.15	0.12	0.20	0.20	0.30
Silicon	0.2	1.2	0.2	1.2	0.2	1.2
Manganese	0.2	1.0	0.2	1.0	0.2	1.0
Phosphorus	—	0.035	—	0.035	—	0.035
Sulphur	—	0.035[a]	—	0.035[a]	—	0.035[a]
Chromium	11.5	13.5	11.5	13.5	11.5	13.5
Nickel	—	1.0	—	1.0	—	1.0

[a] Where a free machining grade is specified the sulphur content may be as high as 0.3 % and/or other suitable elements may be present.

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/or order.

Final heat treatment. The final heat treatment shall consist of hardening by heating to a temperature within the range 950 °C to 1 000 °C followed by quenching in oil, then tempering at a temperature not exceeding 750 °C.

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

Property	Grade A	Grade B	Grade C
Tensile strength, R_m, N/mm^2 (= MPa) min.	540	620	695
0.2 % proof stress, $R_{p0.2}$, N/mm^2 (= MPa) min.	340	415	435
Elongation[b], A, % min.	15	13	11
Angle of bend[b]	120°	90°	—
Radius of bend[b]	$2t$[c]	$2t$[c]	—

[a] The 0.2 % proof stress values are for information only.
[b] Not applicable to free machining grade.
[c] t is the thickness of test piece.

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

Grade A 152 HB to 207 HB
Grade B 183 HB to 229 HB
Grade C 201 HB to 255 HB

By agreement between the purchaser and the founder, grades A, B and C may be supplied in a harder condition than the indicated hardness. In these cases the tensile and bend tests will not apply.

Type ANC 2: 18 % chromium 2 % nickel martensitic steel castings

This type covers the requirements for 850 N/mm^{2}min. martensitic corrosion resisting steel castings for general engineering purposes.

Chemical composition. The steel shall contain:

Element	% min.	% max.
Carbon	0.12	0.25
Silicon	0.2	1.0
Manganese	0.2	1.0
Phosphorus	—	0.035
Sulphur	—	0.035
Chromium	15.5	20.0
Nickel	1.5	3.0

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/or order.

Final heat treatment. The final heat treatment shall consist of hardening by heating to a temperature within the range 950 °C to 1 020 °C followed by quenching in oil or air and tempering within the range 500 °C to 680 °C.

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^2 (= MPa)	850	1 000
0.2 % proof stress[a] $R_{p0.2}$, N/mm^2 (= MPa)	630	—
Elongation, A, %	8	—

[a] The 0.2 % proof stress value is for information only.

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

Type ANC 3: Austenitic 18 % chromium 10 % nickel steel castings

This type covers the requirements for austenitic corrosion resisting steel castings for general engineering purposes. There are two grades which can also be supplied to a free machining condition. The purchaser shall specify the grade and condition required.

Chemical composition. The steel shall contain:

Element	Grade A		Grade B[a]	
	% min.	% max.	% min.	% max.
Carbon	—	0.12	—	0.12
Silicon	0.2	2.0	0.2	2.0
Manganese	0.2	2.0	0.2	2.0
Phosphorus	—	0.035	—	0.035
Sulphur	—	0.035[b]	—	0.035[b]
Chromium	17.0	20.0	17.0	20.0
Nickel	8.0	12.0	8.5	12.0
Niobium	—	—	8 × C[c]	1.1

[a] Suitable for welding without subsequent heat treatment.
[b] Where a free machining grade is specified the sulphur content may be as high as 0.3 % and/or other suitable elements may be present.
[c] C is the carbon content.

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/or order.

Final heat treatment. The final heat treatment shall consist of heating to a temperature within the range 1 000 °C to 1 100 °C followed by oil or water quenching, or cooling rapidly in air.

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, Rm, N/mm^2 (= MPa)	460
0.2 % proof stress, $R_{p0.2}$, N/mm^2 (= MPa)	200
Elongation[a], A, %	20
Angle of bend[a]	120°
Radius of bend[a]	$1\frac{1}{2}t$[b]

[a] Not applicable to free machining grades.
[b] t is the thickness of test piece.

Where free machining grade is specified the elongation shall be 12 % min. In the case of free machining grades the bend test shall not be applied.

Intercrystalline corrosion test. Where specified on the drawing and order the material shall comply with the bend test specified in **12.6**, except that, in the case of grade **A**, the intermediate heat treatment at 650 °C shall be omitted.

Type ANC4: Austenitic 18 % chromium 11 % nickel 3 % molybdenum steel castings

This type covers the requirements for molybdenum — containing austenitic corrosion resisting steel castings for general engineering purposes. There are three grades which can also be supplied to a free machining condition. The purchaser shall Specify the grade and condition required.

Chemical composition. The steel shall contain:

Element	Grade A		Grade B		Grade C	
	% min.	% max.	% min.	% max.	% min.	% max.
Carbon	—	0.08	—	0.08	—	0.12[c]
Silicon	0.2	1.5	0.2	1.5	0.2	1.5
Manganese	0.2	2.0	0.2	2.0	0.2	2.0
Phosphorus	—	0.035	—	0.035	—	0.035
Sulphur	—	0.035[d]	—	0.035[d]	—	0.035[d]
Chromium	18.0	20.0	17.0	20.0	17.0	20.0
Molybdenum	3.0	4.0	2.0	3.0	2.0	3.0
Nickel	11.0	14.0	10.0	—	10.0	—
Niobium	—	—	—	—	8 × C[e]	1.1

NOTE 1 Additional elements may be present as agreed between the purchaser and the founder.
NOTE 2 All three grades are suitable for welding without subsequent heat treatment.
[c] Where a lower carbon content is desired this should be agreed between the purchaser and the founder.
[d] Where a free machining grade is specified the sulphur content may be as high as 0.3 % and/or other suitable elements may be present.
[e] C is the carbon content.

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/or order.

Final heat treatment. The final heat treatment shall consist of heating to a temperature within the range 1 000 °C to 1 150 °C followed by oil or water quenching, or cooling rapidly in air.

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^2 (= MPa)	500
0.2 % proof stress[a], $R_{p0.2}$, N/mm^2 (= MPa)	210
Elongation, A, %	12[b]
Angle of bend	120°
Radius of bend	$2t$[c]

[a] The 0.2 % proof stress value is for information only.
[b] Where a free machining grade is specified the elongation shall be 10 % min.
[c] t is the thickness of test piece.

Intercrystalline corrosion test. Where specified on the drawing and order the material shall comply with the bend test specified in **12.6**.

Type ANC 5: Nickel chromium steel castings

This type covers the requirements for alloy steel castings having resistance to scaling at elevated temperatures. There are three grades and the purchaser shall specify the grade required.
Chemical composition. The steel shall contain:

Element	Grade A		Grade B		Grade C	
	% min.	% max.	% min.	% max.	% min.	% max.
Carbon	—	0.5	—	0.5	—	0.75
Silicon	0.2	3.0	0.2	3.0	0.2	3.0
Manganese	0.2	2.0	0.2	2.0	0.2	2.0
Chromium	22.0	27.0	15.0	25.0	10.0	20.0
Nickel	17.0	22.0	36.0	46.0	55.0	65.0

NOTE Additional elements may be present as agreed between the purchaser and the founder.

Condition. The castings shall be supplied in the "as-cast" condition, unless otherwise agreed between the purchaser and the founder and stated on the drawing and/or order.

Type ANC 6: Chromium nickel steel castings

This type covers the requirements for alloy steel castings possessing good corrosion and heat resisting properties. There are three grades and the purchaser shall specify the grade required.

Chemical composition. The steel shall contain:

Element	Grade A		Grade B		Grade C	
	% min.	% max.	% min.	% max.	% min.	% max.
Carbon	0.1	0.3	0.15	0.3	0.05	0.15
Silicon	0.75	2.0	0.75	2.0	0.75	2.0
Manganese	0.2	1.0	0.2	1.0	0.2	1.0
Phosphorus	—	0.035	—	0.035	—	0.035
Sulphur	—	0.035	—	0.035	—	0.035
Chromium	20.0	25.0	20.0	25.0	20.0	25.0
Nickel	10.0	15.0	10.0	15.0	10.0	18.0
Tungsten	—	—	2.5	3.5	2.5	3.5

Condition. The castings shall be supplied in the "as-cast" condition unless otherwise agreed between the purchaser and the founder and stated on the drawing and/or order.

Ferrite content. If the castings are to be welded it is recommended that the following conditions be observed.

The structure of the castings should contain between 3 % and 12 % ferrite and, in order to obtain this, the following relationship should be observed. If NE equals Nickel Equivalent and CE equals Chromium Equivalent then:

$NE = 30C + Ni + 0.5\ Mn$

$CE = Cr + W + 1.5\ Si$

$CE - NE = 10.5 \pm 2.0$

It is also recommended that castings be stabilized prior to welding at not less than 950 °C. Where resistance to intercrystalline corrosion is desired the intercrystalline corrosion test should be specified and carried out in accordance with **12.6**.

Mechanical properties. When required by the purchaser and stated on the drawing and/or order, mechanical properties obtained from 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^2 (= MPa)	460
Elongation, *A,* %	17

Type ANC 8: Nickel base – 20 % chromium 0.4 % titanium castings

This type covers the requirements for alloy castings having high strength and resistance to oxidation up to 1 100 °C with good welding properties.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.08	0.15
Silicon	0.2	1.0
Manganese	0.2	1.0
Chromium	18.0	22.0
Titanium	0.2	0.6
Aluminium	—	0.3
Iron	—	5.0
Nickel	remainder	

Condition. The castings shall be supplied in the "as-cast" condition unless otherwise agreed between the purchaser and the founder and stated on the drawing and/or order.

If required, stress relieving shall consist of heating to 1 100 °C to 1 130 °C followed by cooling in still air.

Type ANC 9: Nickel base – 20 % chromium 2.5 % titanium 1.2 % aluminium castings

This type covers the requirements for alloy castings having good resistance to creep and oxidation at temperatures up to at least 750 °C.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.04	0.10
Silicon	0.2	1.0
Manganese	0.2	1.0
Chromium	18.0	22.0
Titanium	2.2	3.0
Aluminium	0.8	1.6
Iron	—	2.0
Nickel + Cobalt[a]	remainder	

[a] Cobalt shall not exceed 2.0 %.

Condition. The castings shall be supplied in the "as-cast" or finally heat treated condition as agreed between the founder and the purchaser and stated on the drawing and/or order.

Final heat treatment. The final heat treatment shall consist of solution treatment at 1 080 ± 15 °C for 4 h to 8 h and cooling in air followed by ageing at 700 ± 20 °C for 16 h and cooling in air.

Type ANC 10: Nickel base – 20 % chromium 16.5 % cobalt 2.4 % titanium 1.3 % aluminium castings

This type covers the requirements for alloy castings having good resistance to creep and oxidation up to at least 870 °C.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.05	0.13
Silicon	0.2	1.0
Manganese	0.2	1.0
Chromium	18.0	21.0
Titanium	2.0	2.7
Aluminium	1.0	1.6
Cobalt	15.0	18.0
Iron	—	2.0
Nickel	remainder	

Condition. The castings shall be supplied in the "as-cast" or finally heat treated condition as specified by the purchaser and stated on the drawing and/or order.

Final heat treatment. The final heat treatment shall consist of solution treatment at 1 080 ± 15 °C for 4 h to 8 h and cooling in air followed by ageing at 700 ± 10 °C for 16 h and cooling in air.

Type ANC 11: Nickel base – 21 % chromium 10 % cobalt 10 % molybdenum castings

This type covers the requirements for alloy castings having good resistance to thermal shock and oxidation up to 1 100 °C.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.27	0.40
Silicon	0.2	0.45
Manganese	0.2	0.5
Chromium	18.0	23.0
Molybdenum	9.5	11.0
Titanium[a]	—	0.30
Aluminium[a]	—	0.20
Cobalt	9.0	11.0
Iron[a]	—	1.0
Nickel	remainder	

[a] Residuals.

Condition. The castings shall be supplied in the "as-cast" condition.

Type ANC 13: Cobalt base – 26 % chromium 10 % nickel 7 % tungsten castings

This type covers the requirements for alloy castings having high resistance to creep, oxidation and thermal shock.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.40	0.55
Silicon	0.5	1.0
Manganese	0.5	1.0
Nickel	9.5	11.5
Chromium	24.5	26.5
Tungsten	7.0	8.0
Iron	—	2.0
Cobalt	remainder	

Condition. The castings shall be supplied in the "as-cast" condition.

Type ANC 14: Cobalt base – 27 % chromium 5.5 % molybdenum 2.7 nickel castings

This type covers the requirements for alloy castings having a high resistance to corrosion, wear and thermal shock.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.2	0.3
Silicon	0.2	1.0
Manganese	0.2	1.0
Nickel	1.75	3.75
Chromium	25.0	29.0
Molybdenum	5.0	6.0
Iron	—	3.0
Cobalt	remainder	

Condition. The castings shall be supplied in "as-cast" condition.

Mechanical properties. When specified by the purchaser and stated on the drawing and/or order, mechanical properties obtained from 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^2 (= MPa)	650
0.2 % proof stress, $R_{po.2}$, N/mm^2 (= MPa)	450
Elongation, A, %	6

Type ANC 15: Nickel base – 28 % molybdenum castings

This type covers the requirements for castings having a high resistance to corrosion by hot concentrated hydrochloric and other acids.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.02	0.12
Silicon	0.5	1.2
Manganese	0.5	1.2
Molybdenum	26.0	30.0
Iron	4.0	7.0
Sulphur	—	0.030
Nickel	remainder	

Condition. The castings shall be supplied in the "as-cast" or finally heat treated condition. The purchaser shall state the condition in which the castings are required.

Final heat treatment. The final heat treatment shall consist of annealing at 1 150 °C to 1 180 °C followed by water quenching.

Type ANC 16: Nickel base – 17 % molybdenum 16.5 % chromium 4.5 % tungsten castings

This type covers the requirements for castings having a resistance to corrosion by oxidizing acids.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.05	0.15
Silicon	0.5	1.2
Manganese	0.5	1.2
Chromium	15.5	17.5
Molybdenum	16.0	18.0
Tungsten	3.75	5.25
Iron	4.0	7.0
Sulphur	—	0.030
Nickel	remainder	

Condition. The castings shall be supplied in the "as-cast" condition or finally heat treated condition. The purchaser shall state the condition in which the castings are required.

Final heat treatment. The final heat treatment shall consist of annealing at 1 200 °C to 1 230 °C followed by water quenching.

Type ANC 17: Nickel base – 9 % silicon 3% copper castings

This type covers the requirements for castings having a resistance to corrosion by sulphuric acid.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	0.05	0.12
Silicon	8.5	10.0
Manganese	0.5	1.2
Iron	—	2.0
Copper	2.0	4.0
Sulphur	—	0.030
Nickel	remainder	

Condition. The castings shall be supplied in the "as-cast" condition.

Type ANC 18: Nickel base – 31 % copper, silicon castings

This type covers the requirements for castings having a resistance to corrosion by mineral acid and salt water. There are three grades and the purchaser shall specify the grade required.

Chemical composition. The alloy shall contain:

Element	Grade A		Grade B		Grade C	
	% min.	% max.	% min.	% max.	% min.	% max.
Carbon	0.1	0.3	0.05	0.15	0.05	0.15
Silicon	0.5	1.5	2.5	3.0	3.5	4.5
Manganese	0.5	1.5	0.5	1.5	0.5	1.5
Iron	—	3.0	—	3.0	—	3.0
Copper	28.0	34.0	28.0	34.0	28.0	34.0
Magnesium	0.07	0.13	0.07	0.13	0.07	0.13
Sulphur	—	0.050	—	0.050	—	0.050
Nickel	remainder		remainder		remainder	

Condition. The castings shall be supplied in the "as-cast" condition.

Type ANC 19: Nickel base – 20 % chromium 7 % niobium 6 % molybdenum 3 % iron 3 % tungsten castings

This type covers the requirements for precipitation hardening nickel base chromium, niobium, molybdenum, iron, tungsten alloy castings. It is a high strength alloy resistant to oxidation and thermal shock.

Chemical composition. The alloy shall contain:

Element	% min.	% max.
Carbon	—	0.06
Silicon	0.10	0.4
Manganese	0.10	0.5
Sulphur	—	0.015
Chromium	19.0	21.0
Cobalt	—	2.0
Copper	—	0.2
Iron	2.0	4.0
Molybdenum	5.5	6.5
Niobium + Tantalum	6.2	7.0
Tungsten	2.0	3.0
Nickel	remainder	

Condition. Castings shall be supplied in the "as-cast" condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and/or order.

Final heat treatment. When castings are required in the finally heat treated condition, the heat treatment shall consist of solution treatment at 1 080 °C to 1 100 °C for 8 h and cooling in air, followed by heating to a temperature of 750 ± 10 °C for 4 h and cooling in air.

Type ANC 20: 14 % chromium 5 % nickel 2 % copper 1 % molybdenum steel castings

This type covers the requirements for precipitation hardening chromium, nickel, copper, molybdenum steel castings. There are two grades, grade A 950 N/mm^2 and grade B 1 250 N/mm^2, and the purchaser shall specify on the order which grade is required.

The material offers a combination of high strength combined with corrosion resistance and good welding characteristics.

Chemical composition. The steel shall contain:

Element	% min.	% max.
Carbon	—	0.07
Silicon	0.2	2.0
Manganese	0.2	1.0
Phosphorus	—	0.025
Sulphur	—	0.025
Chromium	12.5	15.5
Molybdenum	0.5	2.5
Nickel	3.0	6.0
Copper	1.0	3.5
Niobium	—	0.5

Condition. 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/or order.

Heat treatment

Grade A

a) *Solution treatment*. Heat at a temperature between 1 020 °C and 1 180 °C for not less than 1 h and cool in air to below 25 °C.

b) *Precipitation treatment*

1) Heat at a temperature between 700 °C and 770 °C for not less than 2 h and cool in air. Hold at room temperature for not less than 2 h before further heat treatment.

2) Heat at a temperature between 520 °C and 620 °C for not less than 2 h and cool in air. Alternatively, the intermediate precipitation treatment of 700 °C to 770 °C may be omitted.

Grade B

a) *Solution treatment*. Heat at a temperature between 1 020 °C and 1 180 °C for not less than 1 h and cool in air to room temperature.

b) *Precipitation treatment*

1) Heat at a temperature between 800 °C and 850 °C for not less than 2 h and cool in air to room temperature. Hold at room temperature for not less than 24 h before further heat treatment.

2) Heat at a temperature between 450 °C and 520 °C for up to 4 h and cool in air to room temperature.

Alternatively, the intermediate precipitation treatment of 800 °C may be omitted.

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^2 (= MPa)	950 to 1 200	1 250 to 1 500
0.2 % proof stress, $R_{p0.2}$, N/mm^2 (= MPa) min.	800	950
Elongation, A, % min.	12	8
Reduction in area, Z, % min.	30	15
Izod impact strength, ft lbf[a] min.	15	8

[a] See foreword.

Type ANC 21: 26 % chromium 5 % nickel 3 % copper 2 % molybdenum steel castings

This type covers the requirements for chromium, nickel, copper, molybdenum steel castings. The material offers a combination of good corrosion resistance and strength.

Chemical composition. The steel shall contain :

Element	% min.	% max.
Carbon	—	0.05
Silicon	—	0.75
Manganese	—	0.75
Phosphorus	—	0.050
Sulphur	—	0.050
Chromium	25.0	27.0
Molybdenum	1.75	2.25
Nickel	4.75	6.00
Copper	2.75	3.25
Nitrogen	—	0.10

Condition. The castings shall be supplied in the "as-cast" condition unless otherwise agreed between the founder and the purchaser and stated on the drawing and/or order.

Mechanical properties. The mechanical properties obtained from 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^2 (= MPa)	700
0.2 % proof stress, $R_{p0.2}$ N/mm^2 (= MPa)	500
Elongation, A, %	18
Izod impact strength, ft lbf[a]	10

[a] See foreword.

Intercrystalline corrosion test. Where specified on the drawing and order the steel shall comply with the bend test specified in **12.6**.

Type ANC 22: 16 % chromium 4 % nickel 3 % copper steel castings

This type covers the requirements for chromium, nickel, copper precipitation hardening steel castings. There are three grades, grade A, grade B and grade C, with different specified mechanical properties and the purchaser shall specify on the order and/or drawing the grade required.

Chemical composition. The steel shall contain:

Element	% min.	% max.
Carbon	—	0.06
Silicon	—	1.0
Manganese	—	0.70
Phosphorus	—	0.035
Sulphur	—	0.030
Chromium	15.5	16.7
Nickel	3.6	4.6
Copper	2.8	3.5
Niobium + Tantalum	0.15	0.40
Nitrogen	—	0.05

Condition. The castings shall be supplied in the fully heat treated condition.

NOTE When requested, final ageing may be carried out by the purchaser, providing that the requirements are clearly stated on the order and/or drawing.

Heat treatment. Full heat treatment shall consist of homogenization, solution treatment and *ageing or* double solution treatment and ageing.

a) *Homogenization*. Homogenize at a temperature of 1 150 ± 15 °C for not less than 90 min, cool in oil, air or inert gas to below 25 °C.

b) *Solution treatment*. Heat at a temperature of 1 040 ± 15 °C for not less than 1 h per 25 mm of section (30 min minimum), cool in oil, air or inert gas to below 25 °C.

NOTE It is advisable to perform stages a) and b) in either inert atmosphere or by heating in vacuum and gas quenching if excessive scaling is to be avoided.

c) *Precipitation treatment (ageing)*. Heat for not less than 1 h and not more than 4 h at the temperature given below for the appropriate grade, cool in air to room temperature.

Grade	A	B	C
Precipitation temperature (°C)	470 to 510	520 to 560	570 to 610

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

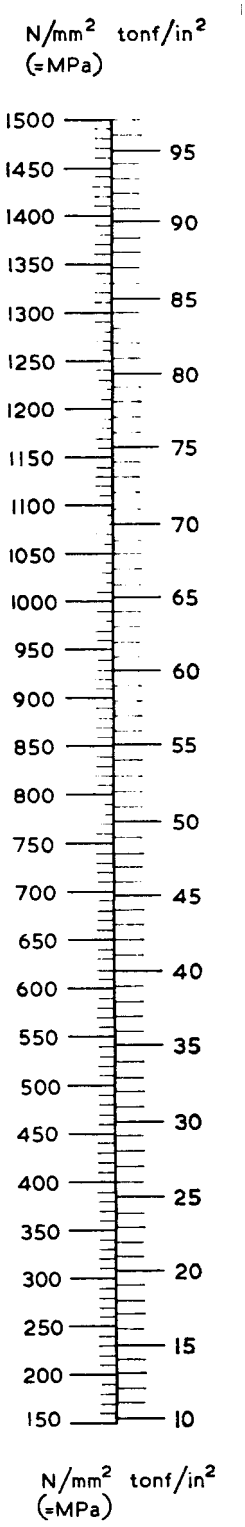
Property	Grade A	Grade B	Grade C
Tensile strength, Rm, N/mm^2, min.	1 230	1 030	900
0.2 % proof stress, $R_{p0.2}$, N/mm^2, min.	1 030	895	830
Elongation, A, %, min.	8	8	8
Reduction in area, Z, %, min.	15	20	20

The hardness of castings, if required by the purchaser and stated on the order and/or drawing, shall be as follows.

Grade	A	B	C
Hardness HB, min.	361	313	294
Hardness HR_c, min.	40	34	32

NOTE The hardness of castings prior to ageing should not be greater than 336 HB or 36 HRc.'

Appendix A Stress unit conversion



Conversion factor 1 N/mm^2 = 1 MPa = 0.064 75 tonf/in^2.
For more detailed conversion see BS 350 “Conversion factors and tables”

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 1860, *Tables for the comparison of hardness scales.*
BS 1639, *Methods for bend testing of metals.*
BS 1957, *Presentation of numerical values (fineness of expression; rounding of numbers).*

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