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Grey cast irons — Classification

Fontes à graphite lamellaire — Classification

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Contents

Page

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 25, *Cast irons and pig irons*.

This third edition cancels and replaces the second edition (ISO 185:2005), which has been technically revised. The main changes compared with the previous edition are as follows:

— terms and definitions have been added for “separately cast sample”, “side-by-side cast sample” and “cast-on sample”;

— Table 1 has been revised to delete the column of anticipated minimum tensile strength values in castings; this information has been moved to Annex C;

— Table 1 has been revised to include side-by-side cast samples with the same tensile strength requirements as separately cast samples;

— Table 1 has been revised to add a maximum tensile strength for each grade for separately cast samples and side-by-side cast samples;

— Table 1 has been revised to revise minimum tensile strength values for some selected grades and relevant wall thicknesses of cast-on samples;

— Annex C has been revised to add Table C.1, which shows anticipated values for tensile strength in grey iron castings based on relevant wall thickness; some values are slightly changed from those in Table 1 of the previous edition;

— information in Annex D has been updated to include corresponding hardness grades from GB/T 9439;

— additional changes have been made for clarity of expression and improved consistency with ISO standards for other types of cast irons.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

This document deals with the classification of grey cast irons, subdivided into two groups:

— materials specified by their tensile strength;

— materials specified by their hardness.

It is also possible to specify grey cast irons by a combination of tensile strength and hardness.

NOTE This document does not cover technical delivery conditions for grey iron castings.

The properties of grey cast iron depend on the form and distribution of the graphite and on the structure of the matrix.

For many applications, tensile strength and hardness are not the only properties of interest to casting designers. Other mechanical or physical properties can be decisive for the use of grey iron. For example:

— the thermal capacity and the thermal diffusivity for disc brakes;

— the damping capacity for engine blocks or machine beds;

— the thermocycle fatigue for exhaust manifolds or ingot moulds.

Therefore, Annex A provides additional information of interest to casting designers.

Furthermore:

— Annex B contains additional information on the relationship between hardness and tensile strength;

— Annex C contains additional information on the relationship between tensile strength, hardness and wall thickness of grey iron castings;

— Annex D provides cross-references of ISO 185 grade designations to other standard grades of grey cast irons.

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Grey cast irons — Classification

1 Scope

This document specifies the properties of unalloyed and low-alloyed grey cast irons used for castings that have been manufactured in sand moulds or in moulds with comparable thermal behaviour.

This document specifies the characterizing properties of grey cast irons by any of the following:

a) the tensile strength of cast samples;

b) if agreed by the manufacturer and the purchaser, the tensile strength of samples cut from a casting;

c) if agreed between the manufacturer and the purchaser, the hardness of the material determined on castings or on a cast-on knob.

If agreed by the manufacturer and the purchaser, the combination of tensile strength from option a) or option b) and plus hardness from option c) can be specified. Information on specifying a combination of tensile strength and hardness is given in Annex B.

This document specifies eight grades of grey cast iron according to tensile strength (see Table 1) and six grades of grey cast iron according to Brinell hardness (see Table 2).

This document does not apply to grey cast irons used for pipes and pipe fittings and continuous cast products.

This document does not cover technical delivery conditions for grey iron castings.

NOTE General information on the engineering properties of grey cast irons is provided in ISO/TR 10809-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 945-1, *Microstructure of cast irons — Part 1: Graphite classification by visual analysis*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

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3.1
grey cast iron
cast material, iron and carbon based, carbon being present mainly in the form of flake (lamellar) graphite particles

Note 1 to entry: Grey cast iron is also known as "flake graphite cast iron" and, less commonly, as "lamellar graphite cast iron".

Note 2 to entry: Graphite form, distribution and size are specified in ISO 945-1.

3.2
relevant wall thickness
section of the casting, agreed between the manufacturer and the purchaser, to which the determined mechanical properties apply

3.3
separately cast sample
sample cast in a separate sand mould under representative manufacturing conditions and material

3.4
side-by-side cast sample
sample cast in the mould alongside the casting, with a connected but separate running system

3.5
cast-on sample
sample attached directly to the casting

4 Designation

The material shall be designated as given in either Table 1 or Table 2. The designation system is given in ISO/TR 15931.

The number in position 3 of the designation in Table 1 is the minimum tensile strength of the grade as determined by test pieces machined from standardized 30 mm test bars or from cast samples of corresponding relevant wall thickness.

The number in position 3 of the designation in Table 2 is the maximum Brinell hardness value of the grade for relevant wall thickness > 40 mm to ≤ 80 mm.

5 Order information

The following information shall be supplied by the purchaser:

a) the complete designation of the material;

b) any special requirements that have to be agreed between the manufacturer and the purchaser.

All agreements between the manufacturer and the purchaser shall be made by the time of acceptance of the order.

6 Manufacture

Unless otherwise specified by the purchaser, the method of manufacture of grey cast irons, including their chemical composition, to obtain the specified mechanical properties shall be left to the discretion of the manufacturer.

The manufacturer shall ensure that the requirements of this document are met for the material grade specified in the order.

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For grey cast irons to be used in special applications, the chemical composition and heat treatment may be the subject of an agreement between the manufacturer and the purchaser.

7 Requirements

7.1 Mechanical properties

The order shall specify, in an unambiguous manner, whether the characterizing property is tensile strength determined on cast samples or Brinell hardness determined on the casting, or both tensile strength and Brinell hardness.

If the order does not specify the characterizing property, then the manufacturer shall characterize the material according to tensile strength.

7.2 Tensile properties

7.2.1 General

The property values apply to grey cast irons cast in sand moulds or in moulds of comparable thermal behaviour. Subject to amendments to be agreed upon in the order, the property values may be applied to castings obtained by alternative methods.

Tensile properties are dependent upon wall thickness as shown in Table 1. For process quality assurance purposes, standardized 30 mm test bars are commonly used.

NOTE Tensile testing requires sound test pieces in order to guarantee pure uniaxial stress during the test.

7.2.2 Test pieces machined from cast samples

The tensile properties of the eight grades of grey cast iron specified by tensile strength, when determined in accordance with 9.1 using test pieces machined from cast samples, shall conform to the requirements specified in Table 1.

7.2.3 Test pieces cut from a casting

If test pieces are to be machined from samples cut from a casting, the manufacturer and the purchaser shall agree on:

— the locations on a casting where the samples shall be taken;

— the minimum value or the allowable range of values for the tensile properties, when determined in accordance with 9.1.

NOTE 1 The properties and the structure of castings are not uniform and depend on the complexity of the castings and their variation in section thickness.

NOTE 2 Tensile properties for test pieces machined from samples cut from a casting are affected not only by material properties (subject of this document) but also by the local casting soundness (not subject of this document).

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Table 1 — Tensile strength of grey cast irons determined on test pieces machined from cast samples

Material designation	Relevant wall thickness t		Tensile strength R_m		
			in separately cast samples or side-by-side cast samples		in cast-on samples
	mm		MPa		MPa
	≥	≤	≥	≤	≥
ISO 185/JL/100	5	40	**100**	200	—
ISO 185/JL/150	2,5	5	**150**	250	—
	5	10			—
	10	20			—
	20	40			125
	40	80			110
	80	150			100
	150	300			90
ISO 185/JL/200	2,5	5	**200**	300	—
	5	10			—
	10	20			—
	20	40			170
	40	80			155
	80	150			140
	150	300			130
ISO 185/JL/225	5	10	**225**	325	—
	10	20			—
	20	40			190
	40	80			170
	80	150			155
	150	300			145
ISO 185/JL/250	5	10	**250**	350	—
	10	20			—
	20	40			210
	40	80			190
	80	150			170
	150	300			160
ISO 185/JL/275	10	20	**275**	375	—
	20	40			230
	40	80			210
	80	150			190
	150	300			180
ISO 185/JL/300	10	20	**300**	400	—
	20	40			250
	40	80			225
	80	150			210
	150	300			190

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Table 1 *(continued)*

Material designation	Relevant wall thickness t		Tensile strength R_m		
			in separately cast samples or side-by-side cast samples		in cast-on samples
	mm		MPa		MPa
	≥	≤	≥	≤	≥
ISO 185/JL/350	10	20	**350**	450	—
	20	40			290
	40	80			260
	80	150			240
	150	300			220

For each grade, the figure in bold indicates the minimum tensile strength to which the material designation of the grade relates, based on separately cast or side-by-side cast 30 mm test samples.

Minimum and maximum tensile strength values are mandatory for separately cast samples and for side-by-side cast samples.

Tensile strength values are mandatory for cast-on samples representing the relevant wall thickness, which shall be agreed by the manufacturer and the purchaser.

For relevant wall thicknesses greater than 300 mm, the manufacturer and the purchaser shall agree on the type and size of the cast sample and on the minimum required tensile strength value.

If a particular type of sample is to be specified, a "/" is added to the designation, followed by a letter indicating the type of sample:

/S = separately cast sample or side-by-side cast sample;

/U = cast-on sample;

/C = sample cut from casting.

If tensile strength is specified as a characterizing property, the type of the sample should be stated in the order. If not stated in the order, the type of sample is left to the discretion of the manufacturer.

For high damping capacity and thermal conductivity, ISO 185/JL/100 is the most suitable material.

For each grade, Brinell hardness decreases with increasing wall thickness.

7.3 Hardness properties

Classification of grey iron castings by hardness is applicable principally where machinability or wear resistance are of importance.

The Brinell hardness values of the six grades of grey cast iron specified by hardness, when determined in accordance with 9.2, shall conform to the requirements specified in Table 2.

NOTE 1 Brinell hardness stated in HBW means under test conditions of 10/3000 unless different test conditions have been specified.

Minimum and maximum Brinell hardness values for the relevant wall thickness specified by the purchaser shall be mandatory for the castings covered by the order.

If a casting is ordered on the basis of hardness, the relevant wall thickness and the position of the test shall be agreed.

NOTE 2 For a relevant wall thickness $t > 80$ mm, grades are not classified by hardness.

If it is not possible to use the Brinell test method in accordance with ISO 6506-1, alternative test methods may be used, which shall have correlated values with Brinell hardness.

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Table 2 — Brinell hardness of castings of grey cast iron

Material designation	Relevant wall thickness t		Brinell hardness	
	mm		HBW	
	>	≤	≥	≤
ISO 185/JL/HBW155	**40**	**80**	**—**	**155**
	20	40		160
	10	20		170
	5	10		185
	2,5	5		210
ISO 185/JL/HBW175	**40**	**80**	**100**	**175**
	20	40	110	185
	10	20	125	205
	5	10	140	225
	2,5	5	170	260
ISO 185/JL/HBW195	**40**	**80**	**120**	**195**
	20	40	135	210
	10	20	150	230
	5	10	170	260
ISO 185/JL/HBW215	**40**	**80**	**145**	**215**
	20	40	160	235
	10	20	180	255
	5	10	200	275
ISO 185/JL/HBW235	**40**	**80**	**165**	**235**
	20	4	180	255
	10	20	200	275
ISO 185/JL/HBW255	**40**	**80**	**185**	**255**
	20	40	200	275

For each grade, the figure in bold indicates the minimum and maximum Brinell hardness to which the material designation of the grade relates and the corresponding relevant wall thickness range limits.

Information on the relationship between Brinell hardness and tensile strength is given in Annex B.

Information on the relationship between tensile strength, Brinell hardness and wall thickness is given in Annex C.

By agreement between the manufacturer and the purchaser, a narrower Brinell hardness range, not less than 40 HBW, may be adopted at the agreed position on the casting. An example of such a circumstance is castings for long-series production.

For each grade, Brinell hardness decreases with increasing wall thickness.

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7.4 Graphite structure

If the graphite structure is agreed upon, the test shall be carried out in accordance with 9.3.

8 Sampling

8.1 General

Samples shall be supplied in order to characterize the grade of the material.

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Samples shall be made from the same material as that used to produce the castings they represent and during the same period as when the castings are made.

If castings are subjected to heat treatment, then the samples shall be heat-treated in the same way as the castings they represent.

All samples shall be adequately marked to guarantee full traceability to the castings they represent.

8.2 Types of samples

Several types of samples (separately cast samples, side-by-side cast samples, cast-on samples, samples cut from castings) can be used, depending on the mass and wall thickness of the casting.

When relevant, the type of sample should be agreed upon between the manufacturer and the purchaser. Unless otherwise agreed, the choice of sample type is left to the discretion of the manufacturer.

When the mass of the casting is > 1 000 kg and its thickness is > 50 mm, cast-on samples should preferably be used. The dimensions and the location of the sample shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

NOTE For process quality assurance purposes, cast samples corresponding to Figure 1, Type II are commonly used.

8.3 Samples for tensile test

8.3.1 Size of cast samples

The size of the cast sample (see Figure 1) should correspond to the relevant wall thickness of the casting. Alternatively, standardized 30 mm test bars corresponding to Figure 1, Type II may be used to characterize the material.

If other sizes are used, the sizes and the minimum tensile value or range of tensile values to be obtained shall be agreed upon between the manufacturer and the purchaser.

8.3.2 Frequency and number of test samples

Samples representative of the material shall be produced at a frequency in accordance with the process quality assurance procedures adopted by the manufacturer or as otherwise agreed with the purchaser.

8.3.3 Separately cast samples

The samples shall meet the requirements of Figure 1. The samples shall be poured vertically.

The moulds used to cast separately cast samples shall have comparable thermal behaviour to the moulding material used to cast the castings. The moulds may be made for casting several samples simultaneously.

The samples shall be removed from the mould at a temperature of < 500 °C. By agreement between the manufacturer and the purchaser, samples may be removed from the mould at a temperature of > 500 °C, provided the castings are also to be removed from the moulds at this higher temperature.

Samples of other dimensions and using other casting procedures may be agreed between the manufacturer and the purchaser for the purpose of representing the properties of particular castings.

NOTE An indication of the likely values of tensile strength is given in Figure C.1.

8.3.4 Side-by-side cast samples

Side-by-side cast samples are representative of the castings concurrently cast and of all other castings of similar relevant wall thickness from the same test unit.

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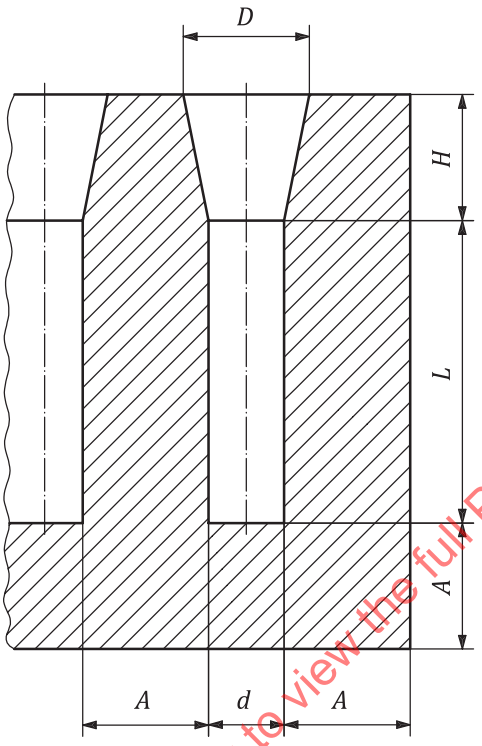
When mechanical properties are required for a series of castings belonging to the same test unit, the side-by-side cast samples shall be produced in the last moulds poured.

The samples shall meet the requirements of Figure 1. The samples shall be poured vertically or horizontally with an adapted feeding system.

Dimensions in mm



Dimension	Type			
	I	II	III	IV
d (+2/-0)	15	30	45	75
L	A function of the test piece length			
D (±5)	40	50	70	105
H	≥ 40	≥ 50	≥ 60	≥ 90
A	≥ 40	≥ 50	≥ 60	≥ 90
Preferred diameter (d) of tensile test piece	10	20	32	32

Figure 1 — Separately cast or side-by-side cast samples

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8.3.5 Cast-on samples

Cast-on samples are representative of the castings to which they are attached and of all other castings of similar relevant wall thickness from the same test unit.

When mechanical properties are required for a series of castings belonging to the same test unit, the cast-on samples shall be produced in the last moulds poured.

The samples shall have a general shape as indicated in either Figure 2 or Figure 3 with corresponding dimensions.

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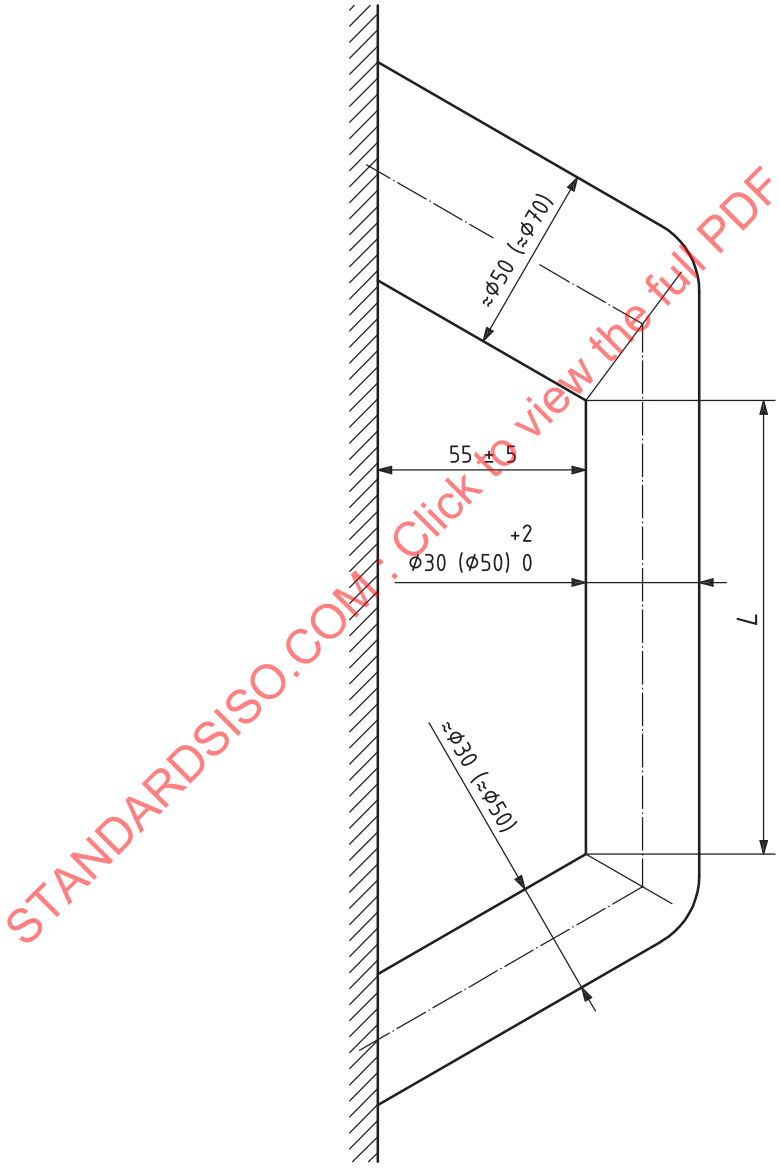
The length L (see Figures 2 and 3) shall be determined according to the length of the test piece and the clamping device.

NOTE Two possible sets of sizes are shown in Figures 2 and 3, with the larger test-piece size option shown in brackets. The small-size set is used for castings of wall thickness < 100 mm, and the large-size set is used for castings of wall thickness ≥ 100 mm.

The type, dimensions and location of the cast-on sample shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order. The sample details shall take into account the shape of the casting and the running system in order to avoid unfavourable effects on the properties of the adjacent material. If there is no such agreement, the manufacturer shall decide on the type of sample, which shall be located at a representative position on the casting.

Cast-on samples should be used only for castings of wall thickness > 20 mm and mass > 200 kg.

Dimensions in mm



NOTE For the significance of figures in brackets, see the NOTE in 8.3.5.

Figure 2 — Cast-on sample — Type 1

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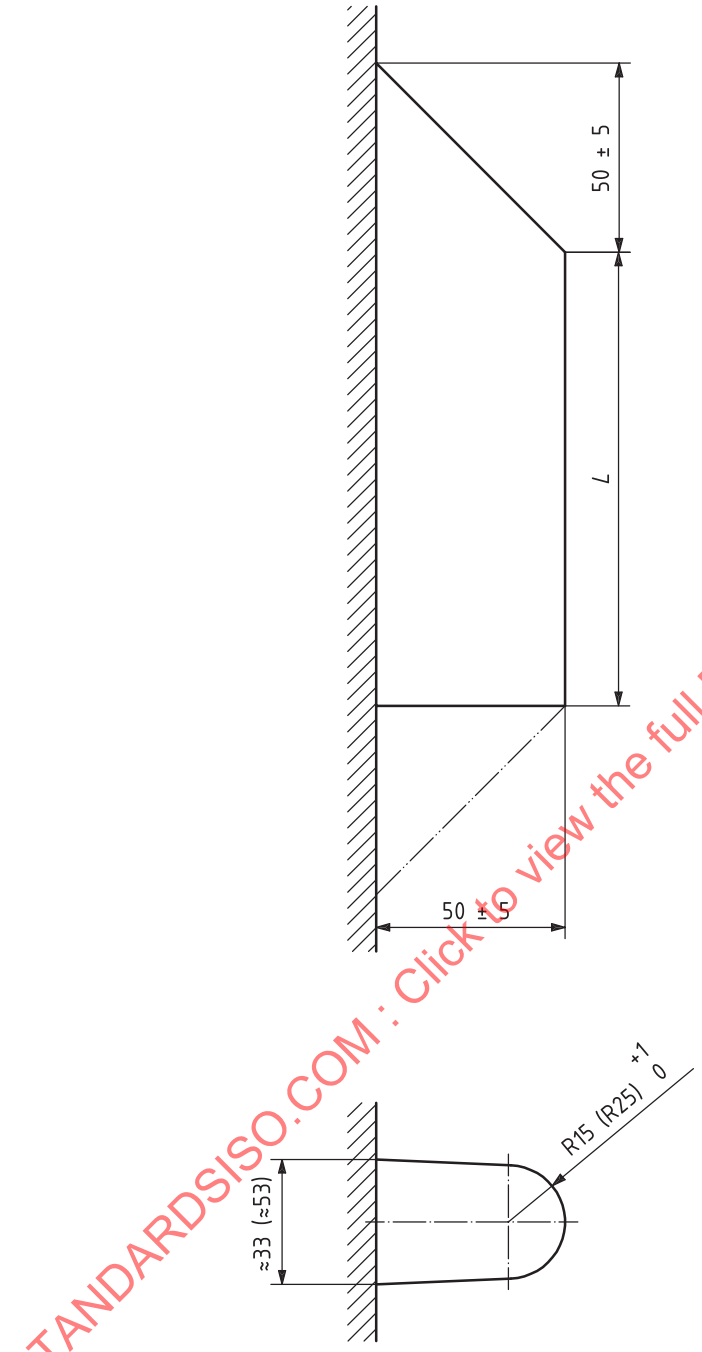
Dimensions in mm



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NOTE For the significance of figures in brackets, see the NOTE in 8.3.5.

Figure 3 — Cast-on sample — Type 2

8.3.6 Samples cut from a casting

In addition to the requirements of the material, the manufacturer and the purchaser may agree on the properties required (if any) at stated locations in the casting. If specified, these properties shall be determined by testing of test pieces machined from samples cut from the casting at the stated locations.

The manufacturer and the purchaser shall agree on the diameter of these test pieces.

In the absence of any directions by the purchaser, the manufacturer may choose the locations from which to cut the samples and the diameter of the test pieces.

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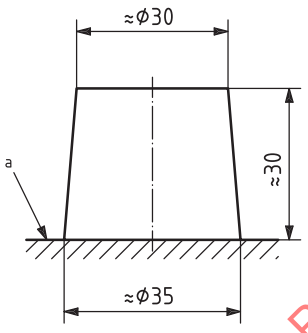
8.4 Samples for hardness test

Hardness tests may be carried out on the separately cast samples described in 8.3.3.

Alternatively, the Brinell hardness test may be carried out, by agreement between the manufacturer and the purchaser, on a test piece ("Brinell knob") that is cast-on to the casting as shown in Figure 4. The position of the Brinell knob, and its size and shape, shall be agreed between the manufacturer and the purchaser.

In order to carry out the Brinell hardness test, the test piece is removed from the casting, ground on the cut surface and then tested on the ground surface.

Dimensions in mm



Key

a surface of casting

Figure 4 — Example of a Brinell knob

If the casting is heat-treated, the Brinell knob shall not be detached from the casting until the heat-treatment process has been concluded.

9 Test methods

9.1 Tensile test

The tensile test shall be carried out in accordance with the requirements of ISO 6892-1, using a test piece that conforms to either Figure 5 or Figure 6.

NOTE For the same material, the results achieved using test piece A can be slightly higher than those achieved by using test piece B.

The dimensions of the test piece shall conform to the dimensions given in Table 3. The gripped parts may be either threaded or plain to suit the clamping device.

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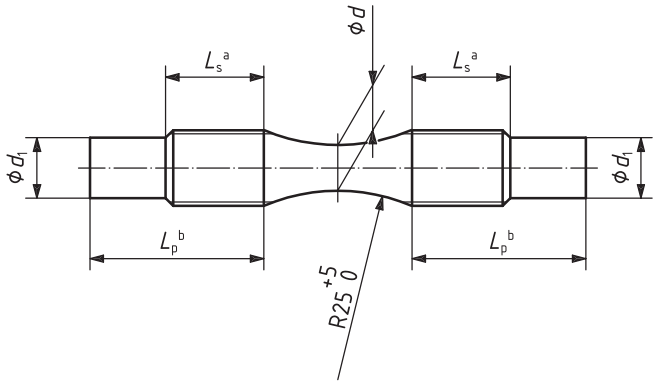
Dimensions in mm



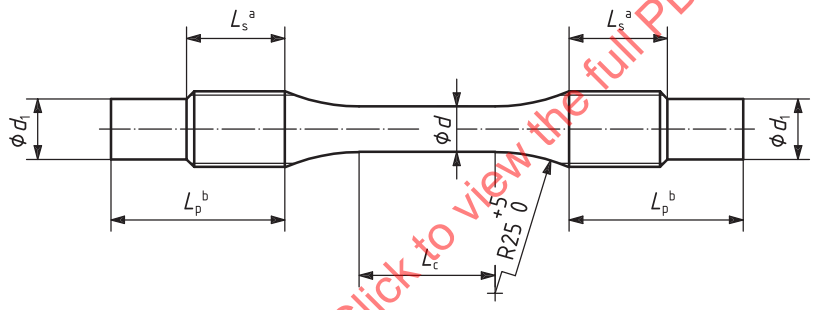
Key

a length of threaded end

b length of plain end

Figure 5 — Test piece A

Dimensions in mm



Key

a length of threaded end

b length of plain end

Figure 6 — Test piece B

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Table 3 — Dimensions of test pieces A and B

Values in millimetres

Diameter of the parallel length d	Thread type for threaded test pieces	Thread length L_S	Diameter d_1 for plain ends	Threaded test piece A, total length	Test piece B, parallel length L_C
6 ± 0,1	M10	13	8	46	18
8 ± 0,1	M12	16	10	53	24
10 ± 0,1	M16	20	12	63	30
12,5 ± 0,1	M20	24	15	73	36,5
16 ± 0,1	M24	30	20	87	48
20 ± 0,1	**M30**	**36**	**23**	**102**	**60**
25 ± 0,1	M36	44	30	119	75
32 ± 0,1	M45	55	40	143	96
$L_P > L_S$, to suit the clamping device. The row in bold indicates the preferred dimensions for the test pieces. The cross-sectional area S_0 shall be calculated.					

9.2 Brinell hardness test

The Brinell hardness test, if required, shall be carried out at an agreed position on the casting, in accordance with the requirements of ISO 6506-1.

If it is not possible to use the Brinell test method in accordance with ISO 6506-1, alternative test methods may be used, which shall have correlated values with Brinell hardness.

9.3 Graphite structure

The graphite structure, if required, shall be determined in accordance with ISO 945-1.

9.4 Alternative test procedures

If agreed between the manufacturer and the purchaser, alternative test procedures, which give equivalent results for tensile strength, Brinell hardness and graphite structure, may be used.

10 Retests

10.1 Need for retests

Retests shall be carried out if a test is not valid (see 10.2).

Retests are permitted if a test result does not meet the mechanical property requirements for the specified grade (see 10.3).

10.2 Test validity

A test is not valid if one or more of the following conditions applies:

a) a faulty mounting of the test piece or defective operation of the test machine;

b) a defective test piece because of incorrect pouring or incorrect machining;

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c) a casting defect in the test piece, evident after fracture.

In the above cases, a new test piece shall be taken from the same sample or from a duplicate sample cast at the same time. The result of the retest shall be substituted for the result of the invalid test.

10.3 Nonconforming test results

If any test gives results which do not conform to the specified requirements, for reasons other than those given in 10.2, the manufacturer shall have the option to conduct retests. If the manufacturer conducts retests, two retests shall be carried out for each failed test.

If the results of both retests meet the specified requirements, the material shall be deemed to conform to this document.

If the results of one or both retests fail to meet the specified requirements, the material shall be deemed not to conform to this document.

10.4 Heat treatment of samples and castings

There shall be no heat treatment of castings that were not ordered with heat treatment specified, unless such heat treatment is agreed by the purchaser prior to the shipment of castings.

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Annex A
(informative)

Information on mechanical and physical properties in addition to that given in Tables 1 and 2

Information on mechanical properties is given in Table A.1.

Information on physical properties is given in Table A.2.

Table A.1 — Mechanical properties in separately cast test pieces with 30 mm as-cast diameter

Characteristic	Symbol	SI-unit	Material designation						
			ISO 185/ JL/150	ISO 185/ JL/200	ISO 185/ JL/225	ISO 185/ JL/250	ISO 185/ JL/275	ISO 185/ JL/300	ISO 185/ JL/350
			Matrix structure						
			ferritic/ pearlitic			pearlitic			
Tensile strength	R_m	MPa	150 to 250	200 to 300	225 to 325	250 to 350	275 to 375	300 to 400	350 to 450
0,1 % proof strength	$R_{p0,1}$	MPa	98 to 165	130 to 195	150 to 210	165 to 228	180 to 245	195 to 260	228 to 285
Compression strength		MPa	600	720	780	840	900	960	1 080
0,1 % compression proof strength		MPa	195	260	290	325	360	390	455
Bending strength		MPa	270 to 455 ($1{,}82 \times R_m$)	345 to 520 ($1{,}73 \times R_m$)	380 to 550 ($1{,}69 \times R_m$)	415 to 580 ($1{,}66 \times R_m$)	450 to 610 ($1{,}63 \times R_m$)	480 to 640 ($1{,}60 \times R_m$)	540 to 690 ($1{,}54 \times R_m$)
Shear strength		MPa	170	230	260	290	320	345	400
Torsional strength		MPa	170	230	260	290	320	345	400
Modulus of elasticity	E	GPa	78 to 103	88 to 113	95 to 115	103 to 118	105 to 128	108 to 137	123 to 143
Poisson's ratio	ν	—	0,26	0,26	0,26	0,26	0,26	0,26	0,26
Bending fatigue strength		MPa	70 to 115 ($0{,}46 \times R_m$)	90 to 140 ($0{,}46 \times R_m$)	105 to 150 ($0{,}46 \times R_m$)	115 to 160 ($0{,}46 \times R_m$)	125 to 170 ($0{,}46 \times R_m$)	140 to 185 ($0{,}46 \times R_m$)	160 to 205 ($0{,}46 \times R_m$)
Fatigue limit under reversed tension-compression stresses		MPa	50 to 85 ($0{,}34 \times R_m$)	70 to 100 ($0{,}34 \times R_m$)	75 to 110 ($0{,}34 \times R_m$)	85 to 120 ($0{,}34 \times R_m$)	95 to 130 ($0{,}34 \times R_m$)	100 to 135 ($0{,}34 \times R_m$)	120 to 155 ($0{,}34 \times R_m$)
Torsional fatigue strength		MPa	55 to 95 ($0{,}38 \times R_m$)	75 to 115 ($0{,}38 \times R_m$)	85 to 125 ($0{,}38 \times R_m$)	95 to 135 ($0{,}38 \times R_m$)	105 to 140 ($0{,}38 \times R_m$)	115 to 150 ($0{,}38 \times R_m$)	135 to 170 ($0{,}38 \times R_m$)
When there are special requirements relating to machinability or magnetic properties, then ISO 185/JL/100 may be used. The required properties can be obtained by means of a structure-changing heat-treatment process. ISO 185/JL/100 is not cited in Table A.1.									

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Table A.2 — Physical properties in separately cast test pieces with 30 mm as-cast diameter

Characteristic	Symbol	SI-unit	Material designation[a]						
			ISO 185/ JL/150	ISO 185/ JL/200	ISO 185/ JL/225	ISO 185/ JL/250	ISO 185/ JL/275	ISO 185/ JL/300	ISO 185/ JL/350
Density	ρ	kg/dm^3	7,10	7,15	7,15	7,20	7,20	7,25	7,30
Specific heat capacity between 20 °C and 200 °C	c	J/(kg·K)	460						
Specific heat capacity between 20 °C and 600 °C	c	J/(kg·K)	535						
Linear expansion coefficient between −100 °C and +20 °C	α	µm/(m·K)	10,0						
Linear expansion coefficient between 20 °C and 200 °C	α	µm/(m·K)	11,7						
Linear expansion coefficient between 20 °C and 400 °C	α	µm/(m·K)	13,0						
Thermal conductivity at 100 °C	λ	W/(m·K)	52,5	50,0	49,0	48,5	48,0	47,5	45,5
Thermal conductivity at 200 °C	λ	W/(m·K)	51,0	49,0	48,0	47,5	47,0	46,0	44,5
Thermal conductivity at 300 °C	λ	W/(m·K)	50,0	48,0	47,0	46,5	46,0	45,0	43,5
Thermal conductivity at 400 °C	λ	W/(m·K)	49,0	47,0	46,0	45,0	44,5	44,0	42,0
Thermal conductivity at 500 °C	λ	W/(m·K)	48,5	46,0	45,0	44,5	43,5	43,0	41,5
Resistivity	ρ	Ω·mm^2/m	0,80	0,77	0,75	0,73	0,72	0,70	0,67
Coercivity	H_c	A/m	560 to 720						
Maximum permeability at room temperature	μ	µH/m	220 to 330						
Hysteresis losses at B = 1 T		J/m^3	2 500 to 3 000						

When there are special requirements relating to machinability or magnetic properties, then ISO 185/JL/100 may be used. The required properties can be obtained by means of a structure-changing heat-treatment process. ISO 185/JL/100 is not cited in Table A.2.

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Annex B
(informative)

Additional information on the relationship between hardness and tensile strength of grey cast irons

B.1 General

Hardness and tensile strength, as well as modulus of elasticity and the modulus of rigidity of grey cast iron of a given grade, are approximately related to each other. In most cases, an increase in the value of one property results in an increase in the values of other properties. Grey cast irons naturally divide into a family or series of grades having different relative hardness (RH) or tensile-strength-to-hardness (T/H) ratios. This annex briefly discusses RH and T/H for grey cast irons.

B.2 Relative hardness

The following empirical relationship between Brinell hardness (HBW) and tensile strength R_m exists:

$$HBW = RH \times (A + B \times R_m)$$

Commonly accepted values for the constants are:

— $A = 100$

— $B = 0{,}44$

where RH is the relative hardness.

RH has been found to vary between 0,8 and 1,2 (see Figure B.1).

The factor RH is influenced mainly by the raw materials, the melting process and the metallurgical working method. Within one foundry, these influences can be maintained nearly constant. Therefore, the manufacturer can indicate both hardness and the corresponding tensile strength.

B.3 Tensile-strength-to-hardness ratio

Tensile-strength-to-hardness (T/H) ratios are regulated by the eutectic graphite content, up to the eutectic composition shown in Figure B.2, with carbon equivalent (CE) as the graphite parameter. Using tensile strength in MPa and Brinell hardness in HBW, the T/H ratios of grey cast irons range from approximately 0,8 to 1,4.

NOTE Brinell hardness in HBW can be converted to MPa by multiplying the HBW value times the gravitational constant: MPa = HBW × 9,806 65. Using hardness in MPa makes T/H ratio truly dimensionless, with the T/H ratios of grey cast irons in a range from approximately 0,082 to 0,143.

T/H ratio continues to decline as CE increases above the eutectic, but at a much smaller and less predictable rate. Constant T/H lines in Figure B.2 are essentially lines of constant graphite effect on mechanical properties. Properties sensitive to both graphite and matrix, such as bulk tensile strength and bulk hardness, vary in constant proportionality to each other and to their matrix counterparts (matrix tensile strength and matrix hardness) along constant T/H lines. Elastic modulus and damping capacity vary mainly with graphite and are, therefore, highly uniform along the constant T/H lines. Because these lines are also lines of constant eutectic graphite and carbon equivalent — the most

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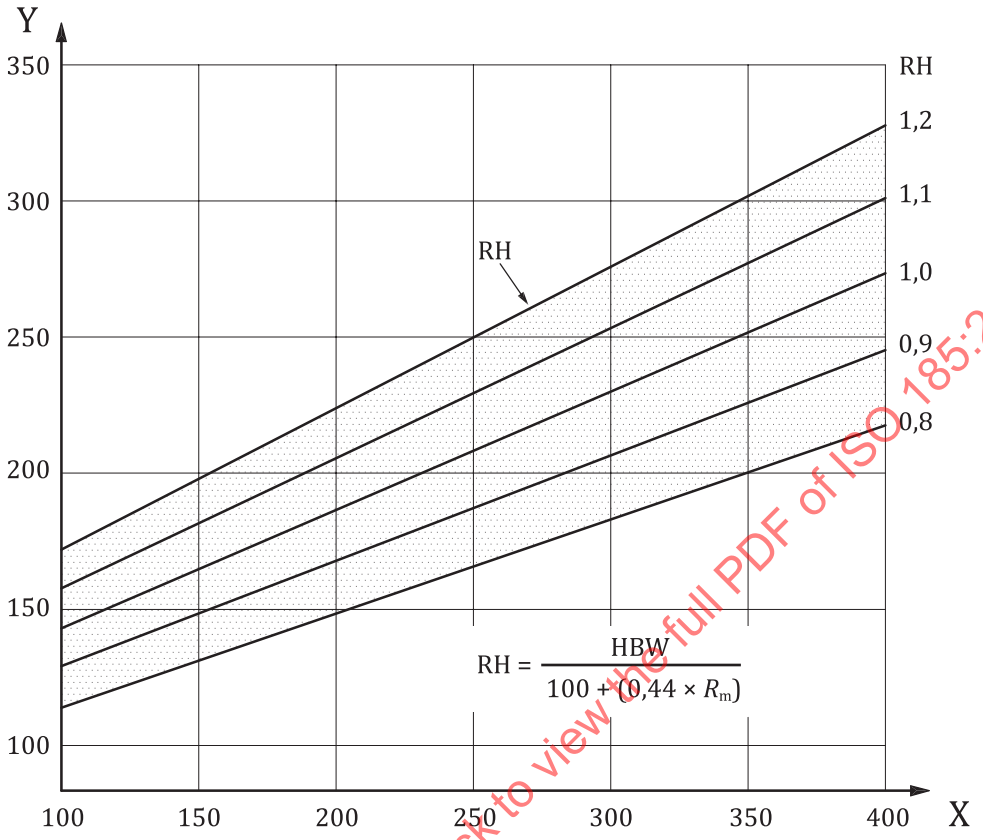
important castability parameters — they are logical grade lines for foundry control as well as for mechanical property control.



Key

X tensile strength, (R_m), in MPa
Y Brinell hardness, HBW
RH relative hardness

Figure B.1 — Relative hardness relationship between Brinell hardness and tensile strength of grey cast irons

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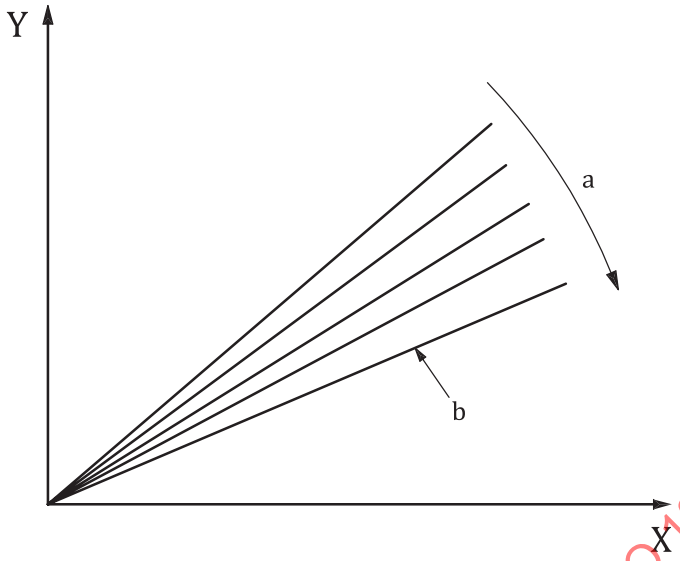

Key

X Brinell hardness

Y tensile strength

[a] Increasing CE, decreasing T/H.

[b] Eutectic.

Figure B.2 — Tensile-strength-to-Brinell hardness relationship (T/H ratio) of grey cast irons

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Annex C
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Additional information on the relationship between tensile strength, hardness and wall thickness of grey iron castings

Table C.1 and Figure C.1 provide additional general information on the expected relationship between the minimum tensile strength and relevant wall thickness of grey iron castings. Figure C.2 provides information on the average Brinell hardness and relevant wall thickness of castings.

Not all castings can be produced in any material hardness grade given in Table 2 for any relevant wall thickness, and this is reflected in Figure C.2. To meet the requirements of any hardness range, more than one material grade can be used, depending on the relevant wall thickness involved.

This illustrates the importance of reaching an agreement between the manufacturer and the purchaser on the specification of the hardness required in castings, and also the location where a hardness test should be carried out.

Table C.1 — Anticipated tensile strength in grey iron castings based on relevant wall thickness

Material designation	Relevant wall thickness t		Tensile strength R_m anticipated values in the casting
	mm		MPa
	>	≤	≥
ISO 185/JL/100	5	40	—
ISO 185/JL/150	2,5	5	165
	5	10	150
	10	20	135
	20	40	115
	40	80	100
	80	150	90
	150	300	—
ISO 185/JL/200	2,5	5	220
	5	10	200
	10	20	180
	20	40	155
	40	80	135
	80	150	120
	150	300	—
ISO 185/JL/225	5	10	—
	10	20	225
	20	40	205
	40	80	175
	80	150	155
	150	300	140

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Table C.1 *(continued)*

Material designation	Relevant wall thickness t		Tensile strength R_m anticipated values in the casting
	mm		MPa
	>	≤	≥
ISO 185/JL/250	5	10	250
	10	20	225
	20	40	195
	40	80	170
	80	150	160
	150	300	155
ISO 185/JL/275	10	20	250
	20	40	215
	40	80	190
	80	150	180
	150	300	170
ISO 185/JL/300	10	20	270
	20	40	235
	40	80	210
	80	150	195
	150	300	185
ISO 185/JL/350	10	20	315
	20	40	275
	40	80	240
	80	150	220
	150	300	210

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