Australian Standard®

Ductile cast iron

STANDARDS
Australia

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The following are represented on Committee MT-001:

- Australian Railway Association
- Australian Building Codes Board
- Australian Foundry Institute
- Australian Industry Group
- Australian Steel Industry
- Bureau of Steel Manufacturers of Australia
- Institute of Materials Engineering Research Association
- New Zealand Heavy Engineering Research Association

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This Standard was issued in draft form for comment as DR 06612.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through public comment period.

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AS 1831—2007

Australian Standard®

Ductile cast iron

Originated as AS G9—1961.
Previous edition AS 1831—2002.
Fourth edition 2007.

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee MT-001, Iron and Steel, to supersede AS 1831—2002, *Ductile cast iron*.

After consultation with stakeholders in both countries, Standard Australia and Standards New Zealand decided to develop this Standard as an Australian, rather than an Australian/New Zealand Standard.

This Standard is identical with, and has been reproduced from ISO 1083:2004, *Spheroidal graphite cast irons—Classification*.

The objective of this Standard is to specify grades of spheroidal graphite cast irons by mechanical properties.

This Standard is one of a series of Standards covering the range of tensile testing methods. The series comprises the following:

AS

1830	Grey cast iron
1831	Ductile cast iron (this Standard)
1832	Malleable cast iron
1833	Austenitic cast iron
1982	Methods for the measurement of case depth in steels
2027	Abrasive-resistant cast irons
2074	Cast steels
4314	Founding—Patterns, pattern equipment and coreboxes for the production of sand moulds and sand cores
4738	Metal castings
4738.1	Part 1: Ferrous sand moulded
5049	Cast iron—Designation of microstructure of graphite
5052	Compacted (vermicular) graphite cast irons—Classification
5054	Ausferritic spheroidal graphite cast irons—Classification
5080	Ferrous materials—Heat treatment—Glossary of terms

As this Standard is reproduced from an international standard, the following applies:

(a)   Its number appears on the cover and title page while the international standard number appears only on the cover.

(b)   In the source text 'this International Standard' should read 'this Australian Standard'.

(c)   A full point substitutes for a comma when referring to a decimal marker.

(d)   Where the ISO Standard number is shown (i.e. ISO 1083) in a ductile cast iron specification, it should be read as 'AS 1831'.

References to International Standards should be replaced by references to Australian Standards, as follows:

| *Reference to International Standard* | | *Australian Standard* | |
ISO		AS	
148	Steel—Charpy impact test (V-notch)	1544	Methods for impact tests on metals
148-1	Part 1: Test method	1544.2	Method 2: Charpy V-notch test
148-2	Part 2: Verification of test macines		
148-3	Part 3: Preparation and characterization of Charpy V reference test pieces for verification of test machines		
945	Cast iron—Designation of microstructure of graphite	5049	Cast iron—Designation of microstructure of graphite
6506	Metallic materials—Brinell hardness test	1816	Metallic materials—Brinell hardness test
6506–1	Part 1: Test method	1816.1	Part 1: Test method (ISO 6506-1:1997, MOD)
6892	Metallic materials—Tensile testing at ambient temperature	1394	Metallic materials—Tensile testing at ambient temperature
TR 15931	Designation systems for cast irons and pig irons	4738	Metal castings
		4738.1	Part 1: Ferrous sand moulded

The terms 'normative' and 'informative' are used to define the application of the annex to which they apply. A normative annex is an integral part of a standard, whereas an informative annex is only for information and guidance.

CONTENTS

INTRODUCTION

The properties of spheroidal graphite cast irons depend on their structure.

The mechanical properties of the material can be evaluated on machined test pieces prepared from:

— separately cast samples;

— samples cast on to either the casting or the running system, hereafter referred to as cast-on sample;

— samples cut from a casting (only when an agreement is made between the manufacturer and the purchaser).

The material grade is defined by mechanical properties measured on machined test pieces prepared from separately cast samples, cast-on samples or samples cut from the casting, by agreement between the manufacturer and the purchaser.

If hardness is a requirement of the purchaser as being important for the application, then Annex E provides means for its determination.

It is well known that tensile properties and hardness of spheroidal graphite cast iron are interrelated. When considered by the purchaser as being important for the application, both tensile and hardness properties may be specified.

Some material grades may be suitable for pressure applications.

Further technical data on spheroidal graphite cast irons is given in Annexes C and G.

vi

NOTES

AUSTRALIAN STANDARD

Ductile cast iron

1 Scope

This International Standard defines the grades and the corresponding requirements for spheroidal graphite cast irons.

This International Standard specifies a classification based on mechanical properties measured on machined test pieces prepared either from:

— separately cast samples;

— cast-on samples;

— samples cut from a casting.

This International standard also specifies a classification as a function of hardness.

This International Standard does not apply to spheroidal graphite cast iron used for pipes, fittings and accessories which are specified in accordance with ISO 2531 and ISO 7186. It does not apply to highly alloyed (austenitic) spheroidal cast irons which are specified in accordance with ISO 2892. This International Standard does not apply to ausferritic cast irons which are specified in accordance with ISO 17804.

2 Normative references

The following referenced documents are indispensable for the application 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 148, *Steel — Charpy impact test (V-notch)*

ISO 945:1975, *Cast iron — Designation of microstructure of graphite*

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

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO/TR 15931, *Designation system for cast irons and pig irons*

3 Terms and definitions

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

3.1
spheroidal graphite cast iron
cast material, iron and carbon-based, the carbon being present mainly in the form of spheroidal graphite particles

NOTE   Spheroidal graphite cast iron is also known as ductile iron, and less commonly as nodular iron.

3.2
graphite spheroidizing treatment
process that brings the liquid iron into contact with a substance to produce graphite in the predominantly spheroidal (nodular) form during solidification

3.3
relevant wall thickness
section of the casting, agreed between the manufacturer and the purchaser, to which the determined mechanical properties shall apply

4 Designation

The material shall be designated in accordance with ISO/TR 15931. The relevant designations are given in Tables 1 to 4.

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 upon between the manufacturer and the purchaser by the time of acceptance of the order.

6 Manufacture

The method of producing spheroidal graphite cast iron, and its chemical composition, shall be left to the discretion of the manufacturer who shall ensure that the requirements of this international Standard are met for the material grade specified in the order.

NOTE   For spheroidal 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.

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

7 Requirements

7.1 Test pieces machined from separately cast samples

7.1.1 General

The mechanical properties of spheroidal graphite cast iron shall be as specified in Table 1 and, if applicable, in accordance with the requirements given in 7.1.2 and Table 2.

The requirements for grade ISO1083/JS/500-10/S shall be as specified in Annex A.

Table 1 — Mechanical properties measured on test pieces machined from separately cast samples

Material designation	Tensile strength R_m N/mm² min.	0,2 % proof stress $R_\mathrm{p0,2}$ N/mm² min.	Elongation A % min.
ISO1083/JS/350-22-LT/S[a]	350	220	22
ISO1083/JS/350-22-RT/S[b]	350	220	22
ISO1083/JS/350-22/S	350	220	22
ISO1083/JS/400-18-LT/S[a]	400	240	18
ISO1083/JS/400-18-RT/S[b]	400	250	18
ISO1083/JS/400-18/S	400	250	18
ISO1083/JS/400-15/S	400	250	15
ISO1083/JS/450-10/S	450	310	10
ISO1083/JS/500-7/S	500	320	7
ISO1083/JS/550-5/S	550	350	5
ISO1083/JS/600-3/S	600	370	3
ISO1083/JS/700-2/S	700	420	2
ISO1083/JS/800-2/S	800	480	2
ISO1083/JS/900-2/S	900	600	2

NOTE 1   The values for these materials apply to castings cast in sand moulds of comparable thermal behaviour. Subject to amendments to be agreed upon in the order, they can apply to castings obtained by alternative methods.

NOTE 2   Whatever the method used for obtaining the castings, the grades are based on the mechanical properties measured on test pieces machined from samples separately cast in a sand mould or a mould of comparable thermal behaviour.

NOTE 3   The mechanical properties of the materials refer to separately cast samples produced in accordance with Figures 1, 2 or 3.

NOTE 4   Elongation values are determined from $L_0 = 5\,d$. For other gauge lengths, see 9.1 and Annex B.

NOTE 5   1 N/mm² = 1 MPa.

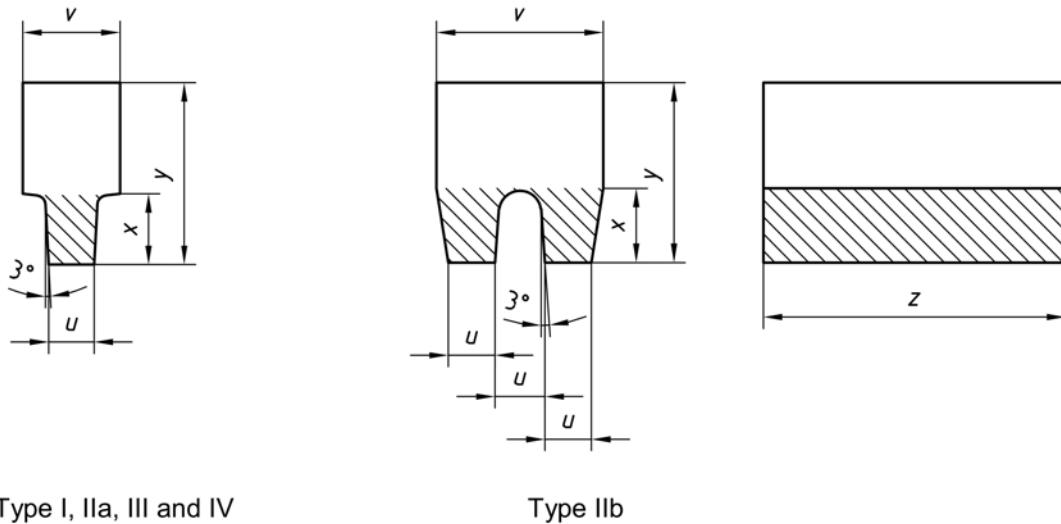[a]   LT for low temperature (− 20 °C or − 40 °C).

[b]   RT for room temperature (23 °C).

7.1.2 Impact test

The particular impact resistance values given in Table 2 for room and low temperature applications, if applicable, shall only be determined if specified by the purchaser by the time of acceptance of the order.

Table 2 — Minimum impact resistance values measured on V-notched test pieces machined from separately cast samples

| Material designation | Minimum impact resistance values J | | | | | |
| | room temperature (23 ± 5) °C | | low temperature (− 20 ± 2) °C | | low temperature (− 40 ± 2) °C | |
	Mean value from 3 tests	Individual value	Mean value from 3 tests	Individual value	Mean value from 3 tests	Individual value
ISO1083/JS/350-22-LT/S[a]	—	—	—	—	12	9
ISO1083/JS/350-22-RT/S[b]	17	14	—	—	—	—
ISO1083/JS/400-18-LT/S[a]	—	—	12	9	—	—
ISO1083/JS/400-18-RT/S[b]	14	11	—	—	—	—
NOTE 1 The impact resistance values for these materials apply to castings cast in sand moulds of comparable thermal behaviour. Subject to amendments to be agreed upon in the order, they can apply to castings obtained by alternative methods.						
NOTE 2 Whatever the method used for obtaining the castings, the grades are based on the mechanical properties measured on test pieces machined from samples separately cast in a sand mould or a mould of comparable thermal behaviour.						
NOTE 3 These material grades may be suitable for some pressure vessel applications. (For fracture toughness, see Annex C.)						
[a] LT for low temperature.						
[b] RT for room temperature.						

Type I, IIa, III and IV   Type IIb

Dimensions in millimetres

Dimension	Type				
	I	IIa	IIb	III	IV
u	12,5	25	25	50	75
v	40	55	90	90	125
x	30	40	40 to 50	60	65
y[a]	80	100	100	150	165
z[b]	A function of the test piece length				

a	For information only.
b	z shall be chosen to allow a test piece of dimensions shown in Figure 4 to be machined from the sample.

The thickness of the sand mould surrounding the samples shall be:

— 40 mm minimum for types I, IIa and IIb;

— 80 mm minimum for types III and IV.

NOTE   For the manufacture of thin-walled castings or castings in metal moulds, the tensile properties may, by agreement between the manufacturer and the purchaser, be determined on test pieces taken from samples of thickness, u, less than 12,5 mm.

Figure 1 — Separately cast samples (option 1)
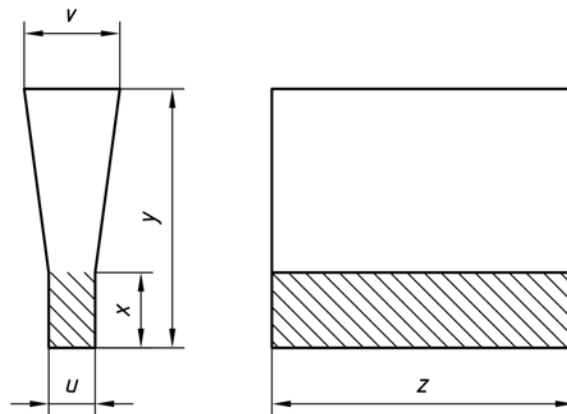
Dimensions in millimetres

Dimension	Type			
	I	II	III	IV
u	12,5	25	50	75
v	40	55	100	125
x	25	40	50	65
y[a]	135	140	150	175
z[b]	A function of the test piece length			

[a] For information only.

[b] z shall be chosen to allow a test piece of dimensions shown in Figure 4 to be machined from the sample.

The thickness of the sand mould surrounding the samples shall be:

— 40 mm minimum for types I and II;

— 80 mm minimum for types III and IV.

NOTE   For the manufacture of thin-walled castings or castings in metal moulds, the tensile properties may, by agreement between the manufacturer and the purchaser, be determined on test pieces taken from samples of thickness, u, less than 12,5 mm.

Figure 2 — Separately cast samples (option 2)

Dimensions in millimetres
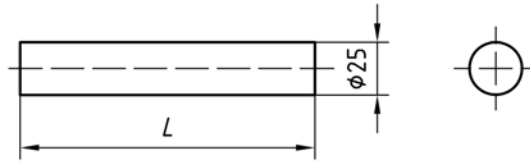
a) Sample — Minimum sample length L = 150 mm
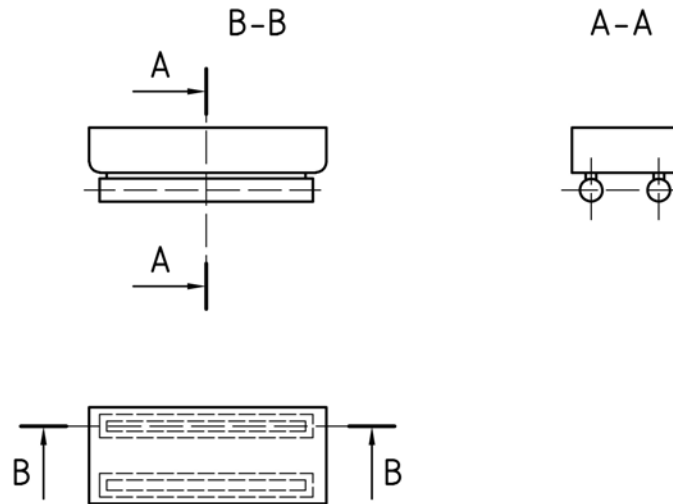
b) Schematic drawing of one type of mould (Lynchburg sample) given as an example

Figure 3 — Separately cast samples (option 3)

7.2 Test pieces machined from cast-on samples

7.2.1 General

The mechanical properties of spheroidal graphite cast iron test pieces shall be as specified in Table 3 and, if applicable, in accordance with the requirements given in 7.2.2 and Table 4.

The requirements for grade ISO1083/JS/500-10/U shall be as specified in Annex A.

Table 3 — Mechanical properties measured on test pieces machined from cast-on samples

Material designation	Relevant wall thickness t mm	Tensile strength R_m N/mm^2 min.	0,2 % proof stress $R_{p0,2}$ N/mm^2 min.	Elongation A % min.
ISO1083/JS/350-22-LT/U[a]	$t \leqslant 30$	350	220	22
	$30 < t \leqslant 60$	330	210	18
	$60 < t \leqslant 200$	320	200	15
ISO1083/JS/350-22-RT/U[b]	$t \leqslant 30$	350	220	22
	$30 < t \leqslant 60$	330	220	18
	$60 < t \leqslant 200$	320	210	15
ISO1083/JS/350-22/U	$t \leqslant 30$	350	220	22
	$30 < t \leqslant 60$	330	220	18
	$60 < t \leqslant 200$	320	210	15
ISO1083/JS/400-18-LT/U[a]	$t \leqslant 30$	380	240	18
	$30 < t \leqslant 60$	370	230	15
	$60 < t \leqslant 200$	360	220	12
ISO1083/JS/400-18-RT/U[b]	$t \leqslant 30$	400	250	18
	$30 < t \leqslant 60$	390	250	15
	$60 < t \leqslant 200$	370	240	12
ISO1083/JS/400-18/U	$t \leqslant 30$	400	250	18
	$30 < t \leqslant 60$	390	250	15
	$60 < t \leqslant 200$	370	240	12
ISO1083/JS/400-15/U	$t \leqslant 30$	400	250	15
	$30 < t \leqslant 60$	390	250	14
	$60 < t \leqslant 200$	370	240	11
ISO1083/JS/450-10/U	$t \leqslant 30$	450	310	10
	$30 < t \leqslant 60$	to be agreed between the manufacturer and the purchaser		
	$60 < t \leqslant 200$	to be agreed between the manufacturer and the purchaser		
ISO1083/JS/500-7/U	$t \leqslant 30$	500	320	7
	$30 < t \leqslant 60$	450	300	7
	$60 < t \leqslant 200$	420	290	5
ISO1083/JS/550-5/U	$t \leqslant 30$	550	350	5
	$30 < t \leqslant 60$	520	330	4
	$60 < t \leqslant 200$	500	320	3
ISO1083/JS/600-3/U	$t \leqslant 30$	600	370	3
	$30 < t \leqslant 60$	600	360	2
	$60 < t \leqslant 200$	550	340	1
ISO1083/JS/700-2/U	$t \leqslant 30$	700	420	2
	$30 < t \leqslant 60$	700	400	2
	$60 < t \leqslant 200$	650	380	1
ISO1083/JS/800-2/U	$t \leqslant 30$	800	480	2
	$30 < t \leqslant 60$	to be agreed upon between the manufacturer and the purchaser		
	$60 < t \leqslant 200$	to be agreed upon between the manufacturer and the purchaser		
ISO1083/JS/900-2/U	$t \leqslant 30$	900	600	2
	$30 < t \leqslant 60$	to be agreed upon between the manufacturer and the purchaser		
	$60 < t \leqslant 200$	to be agreed upon between the manufacturer and the purchaser		

NOTE 1   The mechanical properties of test pieces machined from cast-on samples may not reflect exactly the properties of the casting itself, but may be a better approximation than those obtained from a separately cast sample. Further values for proof stress are given in Annex D for guidance.

NOTE 2   Elongation values are determined from $L_0 = 5\,d$. For other gauge lengths, see 9.1 and Annex B.

NOTE 3   1 N/mm^2 = 1 MPa.

[a]   LT for low temperature.

[b]   RT for room temperature.

7.4   Classification by hardness

The classification by Brinell hardness shall only be specified when agreed between the manufacturer and the purchaser (see Annex E).

7.5   Graphite structure

The graphite structure shall be mainly of form VI and V in accordance with ISO 945:1975. A more precise definition may be agreed between the manufacturer and the purchaser.

This structure shall be confirmed either by metallographic examination or by non-destructive methods. In case of dispute, the result of the microscopic examination shall prevail.

NOTE   Annex F gives more information on nodularity.

7.6   Matrix structure

Information on matrix structure is given in Table G.1.

8   Sampling

8.1   General

Samples shall be provided to represent the casting(s) produced.

Samples shall be made from the same material as that used to produce the casting(s) which they represent (see 8.5).

Several types of sample (separately cast samples, cast-on samples, samples cut from a casting) can be used, depending on the mass and wall thickness of the casting. When the mass of the casting exceeds 2 000 kg and its thickness exceeds 200 mm, cast-on samples or samples cut from a casting should be preferably used.

8.2   Separately cast samples

8.2.1   Frequency and number of tests

Samples representative of the material shall be produced at a frequency in accordance with the in-process quality assurance procedures adopted by the manufacturer.

In the absence of an in-process quality assurance procedure or any other agreement between the manufacturer and the purchaser, a minimum of one tensile test shall be carried out to confirm the material, at a frequency to be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

When impact tests are agreed by the time of acceptance of the order, samples shall be produced at a frequency to be agreed between the manufacturer and the purchaser.

8.2.2   Samples and test pieces

The samples shall be cast separately in sand moulds at the same time as the castings and under representative manufacturing conditions. The moulds used to cast the separately cast samples shall have comparable thermal behaviour to the moulding material used to cast the castings.

It is an option of the manufacturer to use an adequate running system which reproduces conditions similar to those of the castings.

The samples shall meet the requirements of either Figures 1, 2 or 3.

The samples shall be removed from the mould at a temperature similar to that of the castings.

If the graphite spheroidizing treatment is carried out in the mould (in-mould method), the samples shall be:

— either cast alongside with the castings, with a joint running system or

— cast separately using a similar treatment method in the sample mould as the method used to produce the castings.

The samples shall be given the same heat treatment, if any, as the castings which they represent.

The tensile test piece shown in Figure 4 and, if applicable, the impact test piece shown in Figure 5 shall be machined from a sample shown in Figures 1 or 2 (hatched part) or from the sample shown in Figure 3. Unless otherwise agreed, the choice of the option is left to the discretion of the manufacturer.
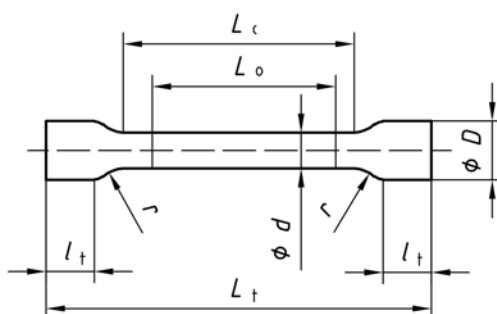
Dimensions in millimetres

d	L_o	L_c [a] min
5	25	30
7	35	42
10	50	60
14 [b]	70	84
20	100	120

[a]   In principle.

[b]   Preferred dimension.

where

L_o is the original gauge length ; i.e. $L_o = 5 \times d$;

d is the diameter of the test piece along the gauge length;

L_c is the parallel length; $L_c > L_o$ (in principle, $L_c - L_o > d$);

L_t is the total length of the test piece, which depends on L_c and l_t.

NOTE   The method of gripping the ends of the test piece, together with their length l_t, may be agreed between the manufacturer and the purchaser.
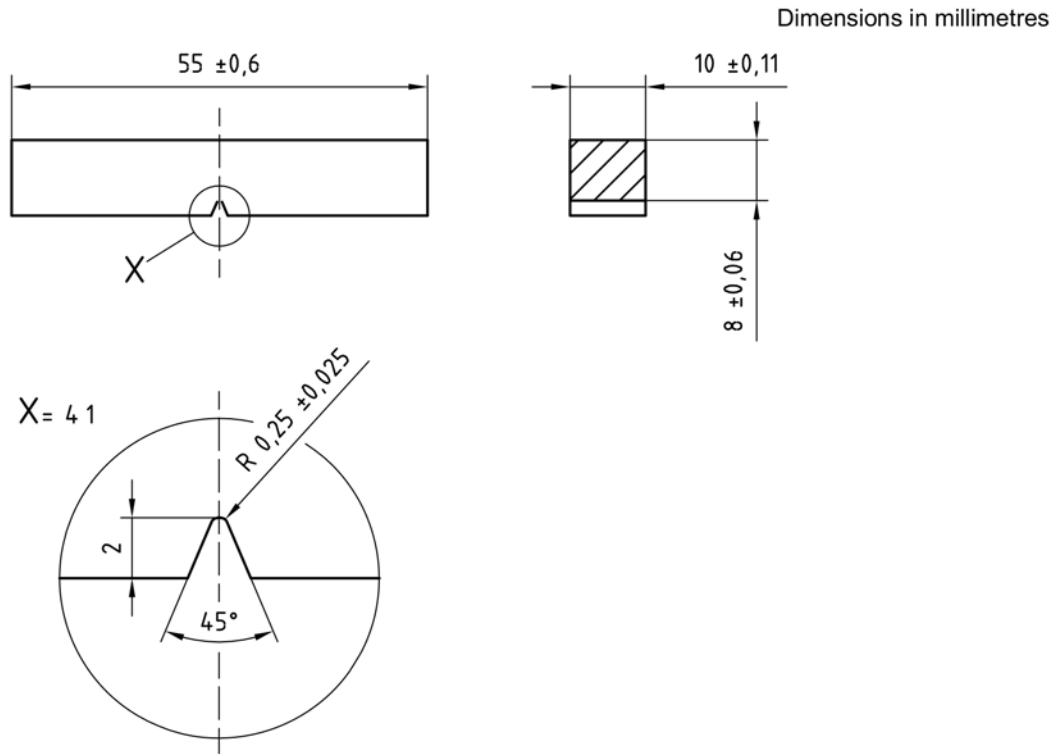
Figure 4 — Tensile test piece

Dimensions in millimetres

Figure 5 — Charpy V-notched impact test piece

8.3 Cast-on samples

8.3.1 Frequency and number of tests

Cast-on samples are representative of the castings to which they are attached and also of all other castings of a similar wall thickness from the same lot, or produced at the same time interval in accordance with the inprocess quality assurance procedure used by the manufacturer.

In the absence of an in-process quality assurance procedure or any other agreement between the manufacturer and the purchaser, a minimum of one tensile test shall be carried out to confirm the material, at a frequency to be agreed between the manufacturer or the purchaser by the time of acceptance of the order.

When impact tests are agreed by the time of acceptance of the order, samples shall be produced at a frequency to be agreed between the manufacturer and the purchaser.

8.3.2 Samples and test pieces

The samples, from which the test pieces for tensile and/or impact testing are taken, shall be cast-on to the castings or to the running system. Cast-on samples may be used for any mass or section of the casting at the discretion of the manufacturer or by agreement with the purchaser when the unit mass of the castings is equal to or greater than 2 000 kg or when the relevant wall thickness varies between 30 mm and 200 mm.

When the mass of the casting exceeds 2 000 kg and its thickness exceeds 200 mm, cast-on samples should preferably be used. In this case, the dimensions of the cast-on sample shall be agreed between the manufacturer and the purchaser.

The location of cast-on samples shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order, taking into account the shape of the casting and the running system, in order to avoid any unfavourable effect on the properties of the adjacent material.

The samples shall have a general shape as indicated in Figure 6 and the dimensions shown therein.

Unless otherwise agreed between the manufacturer and the purchaser, when castings are to be heat treated, the cast-on samples shall not be separated from the castings until after the heat treatment.

The tensile test piece shall be in accordance with Figure 4.

The impact test piece, if applicable, shall be in accordance with Figure 5.
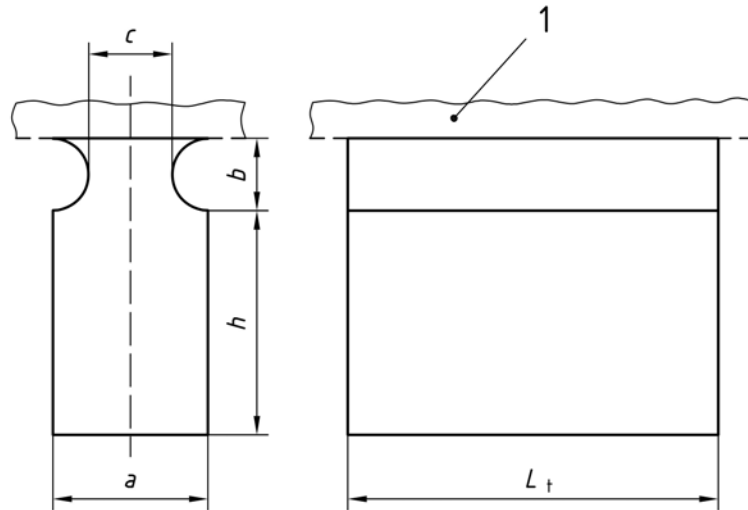
Key

1   casting (or running system)

Dimensions in millimetres

Type	Relevant wall thickness of the casting t	a	b max.	c min	h	L_t
A	$t \leqslant 12,5$	15	11	7,5	20 to 30	a
B	$12,5 < t \leqslant 30$	25	19	12,5	30 to 40	a
C	$30 < t \leqslant 60$	40	30	20	40 to 65	a
D	$60 < t \leqslant 200$	70	52,5	35	65 to 105	a
a L_t shall be chosen to allow a test piece of dimensions show in Figure 4 to be machined from the sample.						

NOTE   If smaller dimensions are agreed upon between the manufacturer and the purchaser, the following relationships apply:

$b = 0,75 \times a$ and $c = \dfrac{a}{2}$

Figure 6 — Cast-on sample

8.4 Samples cut from a casting

8.4.1 General

In addition to agreeing to the requirements of the material, the manufacturer and the purchaser may agree on the properties required at stated locations in the casting. These properties shall be determined by testing test pieces machined from samples cut from the casting at these stated locations. These samples should have a diameter equal to or smaller than 1/3 of the casting wall thickness and should be larger than 1/5 of the casting wall thickness. In the case of large individual castings, samples may be taken at agreed locations in the casting.

8.4.2 Other conditions

The location from which the sample is taken shall be in an area where the casting wall thickness is representative of its average wall thickness.

To determine the required size of the test piece, the purchaser shall, by the time of acceptance of the order, indicate to the manufacturer which are the important sections of the casting. In the absence of any direction by the purchaser, the manufacturer may select the diameter of the test piece.

8.5 Formation of test units and number of tests

8.5.1 Examples of test units

Examples of test units are as follows:

— castings poured from the same ladle – up to 2 000 kg of fettled castings; this may vary, where practicable, by agreement between the manufacturer and the purchaser;

— a single casting, if its mass equals or exceeds 200 kg;

— for continuous pouring of large tonnages of spheroidal graphite cast iron, the maximum size of test unit shall be restricted to the castings produced in a two hour period of pouring;

— when the graphite spheroidizing treatment is carried out on less than 2 000 kg, the test unit to be taken shall be the number of castings produced from that quantity of treated metal.

NOTE   After heat treatment, a test unit will remain the same unless different heat treatments have been applied to distinct parts of the test unit. In such cases, these distinct parts will become separate test units.

8.5.2 Number of tests per test unit

Sampling and testing shall be carried out in accordance with Clauses 8, 9 and 10. Sampling and testing shall be carried out on each test unit unless the in-process quality assurance system makes provision for amalgamation of lots. When the graphite spheroidizing treatment has been carried out in the mould, the formation of test units and the number of tests shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

9 Test methods

9.1 Tensile test

The tensile test shall be carried out in accordance with ISO 6892. The preferred test piece diameter is 14 mm but, either for technical reasons or for test pieces machined from samples cut from the casting, it is permitted to use a test piece of different diameter (see Figure 4). For either of these exceptions the original gauge length of the test piece shall conform to the formula:

$$L_o = 5,65 \times \sqrt{S_o} = 5 \times d$$

where

L_o is the original gauge length;

S_o is the original cross-section area of the test piece;

d is the diameter of the test piece along the gauge length.

If the above formula for L_o is not applicable, then an agreement shall be made between the manufacturer and the purchaser on the dimensions of the test piece to be made.

A test piece with a different gauge length may be agreed upon between the manufacturer and the purchaser. For tensile test pieces with a gauge length $L_o = 4 \times d$, Table B.1 shall be used to convert the elongation value to that for $L_o = 5 \times d$.

9.2 Impact test

The impact test shall be carried out on three Charpy V-notched impact test pieces (see Figure 5) in accordance with ISO 148, using test equipment with an appropriate energy to determine the properties correctly.

9.3 Hardness test

If agreed between the manufacturer and the purchaser, the hardness shall be determined as Brinell hardness in accordance with ISO 6506-1. Alternative hardness tests may also be agreed upon.

The test shall be carried out on the test pieces or at one or several points on the castings after preparation of the testing area in accordance with the agreement between the manufacturer and the purchaser.

If the measuring points are not the subject of an agreement, they shall be chosen by the manufacturer.

Further information on hardness is given in Annex E.

10 Retests

10.1 Need for retests

Retests shall be carried out if a test is not valid.

Retests are permitted to be carried out if a test result does not meet the mechanical property requirements for the specified grade.

10.2 Test validity

A test is not valid if there is:

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;

c)   a fracture of the tensile test piece outside the gauge length;

d)   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.

The result of the retest shall be used.

10.3 Non-conforming 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 both retests give results that meet the specified requirements, the material shall be deemed to conform to this International standard.

If one or both retests give results that fail to meet the specified requirements, the material shall be deemed not to conform to this International standard.

10.4 Heat treatment of samples and castings

Unless otherwise specified, in the case of castings in the as-cast condition with mechanical properties not in conformance with this International standard, a heat treatment may be carried out.

In the case of castings which have undergone a heat treatment and for which the test results are not satisfactory, the manufacturer shall be permitted to re-heat treat the castings and the representative samples. In this event, the samples shall receive the same number of heat treatments as the castings.

If the results of the tests carried out on the test pieces machined from the re-heat treated samples are satisfactory, then the re-heat treated castings shall be regarded as conforming to this International standard.

The number of re-heat treatment cycles shall not exceed two.

Annex A
(normative)

Spheroidal graphite cast irons with high silicon content

NOTE   This annex is only applicable when its requirements have been agreed by the manufacturer and purchaser by the time of acceptance of the order.

A.1 Scope

This annex applies to spheroidal graphite cast iron grades ISO1083/JS/500-10 and ISO1083/JS/HBW200/Z with high silicon content and a minimum R_m = 500 N/mm^2.

Spheroidal graphite cast iron grade ISO1083/JS/500-10 has greatly improved machinability compared to grade ISO1083/JS/500-7 (see A.4.2).

A.2 Material requirements

A.2.1 Mechanical properties

Mechanical properties shall be as specified in Table A.1.

Table A.1 — Mechanical properties

Material designation	Relevant wall thickness t mm	R_m N/mm^2 min.	$R_{p0,2}$ N/mm^2 min.	A % min.
Separately cast sample				
ISO1083/JS/500-10/S	—	500	360	10
Cast-on sample				
ISO1083/JS/500-10/U	$t \leqslant 30$	500	360	10
	$30 < t \leqslant 60$	490	360	9
	$60 < t \leqslant 200$	470	350	7

A.2.2 Classification as a function of hardness

Brinell Hardness shall be as specified in Table A.2.

Table A.2 — Hardness

Material designation	HBW	R_m N/mm^2 min.	$R_{p0,2}$ N/mm^2 min.
ISO1083/JS/HBW/200/Z[a]	185 to 215	500 [b]	360 [b]

[a] Designation ends with "Z" in order to differentiate the Brinell hardness from ISO 1083/JS/HBW200.

[b] For information only.

A.3 Microstructure

Where a microstructure examination is required, it shall be verified that the graphite structure consists mainly of form VI and V graphite in accordance with ISO 945:1975. The matrix must be predominantly ferrite with a maximum pearlite content of 5 %. The amount of free cementite shall not exceed 1 %.

A.4 Supplementary information

A.4.1 Application

Grade ISO1083/JS/500-10 is used for applications where good machinability, high ductility and moderate strength are required.

A.4.2 Machinability

Compared to grade ISO1083/JS/500-7, grade ISO1083/JS/500-10 exhibits considerably less hardness deviation. This reduction in hardness variation results in improved machinability with the same average Brinell hardness value.

A.4.3 Chemical composition

The chemical composition of spheroidal graphite cast irons is not specified by this International standard. Chemical composition will vary, depending on the method of manufacturing (charge materials, casting dimension, etc.). Table A.3 shows one example of the chemical composition of ISO1083/JS/500-10 in order to fulfil the requirements for tensile strength, elongation and hardness.

Table A.3 — Example of chemical composition

C % approx.	Si % approx.	Mn % max.	P % max.	S % max.	Mg % approx.	Cu % max.
3,3	3,7	0,3	0,05	0,02	0,04	0,1

Annex B
(normative)

Relationship between the elongation values obtained when using test pieces with $L_o = 5 \times d$ and $L_o = 4 \times d$

The choice of a test piece with a gauge length of $L_o = 4 \times d$ instead of $5 \times d$ shall be agreed upon between the manufacturer and the purchaser.

If a test piece with a gauge length of $L_o = 4 \times d$ is used, the dimensions of the test piece shown in Figure B.1 shall be used.

Table B.1 gives the relationship between the values for elongation to fracture for both test pieces.

Table B.1 — Relationship between elongation values for $L_o = 5 \times d$ and $L_o = 4 \times d$ test pieces

Elongation $(L_o = 5 \times d)$ %	Elongation $(L_o = 4 \times d)$ %
22	23
18	19
15	16
10	11
7	8
5	6
3	3,5
2	2,5

The values for elongation using a gauge length of $L_o = 4 \times d$ are calculated according to:

$$A\,(L_o = 4 \times d) = A\,(L_o = 5 \times d) \times 1{,}047 + 0{,}39$$

NOTE   Values given in Table B.1 have been calculated from a statistically determined regression using values from separately cast test pieces [10].

Dimensions in millimetres

57,2

50,8 ±0,01

R 9,5

$\phi 12{,}7 \pm 0{,}025$
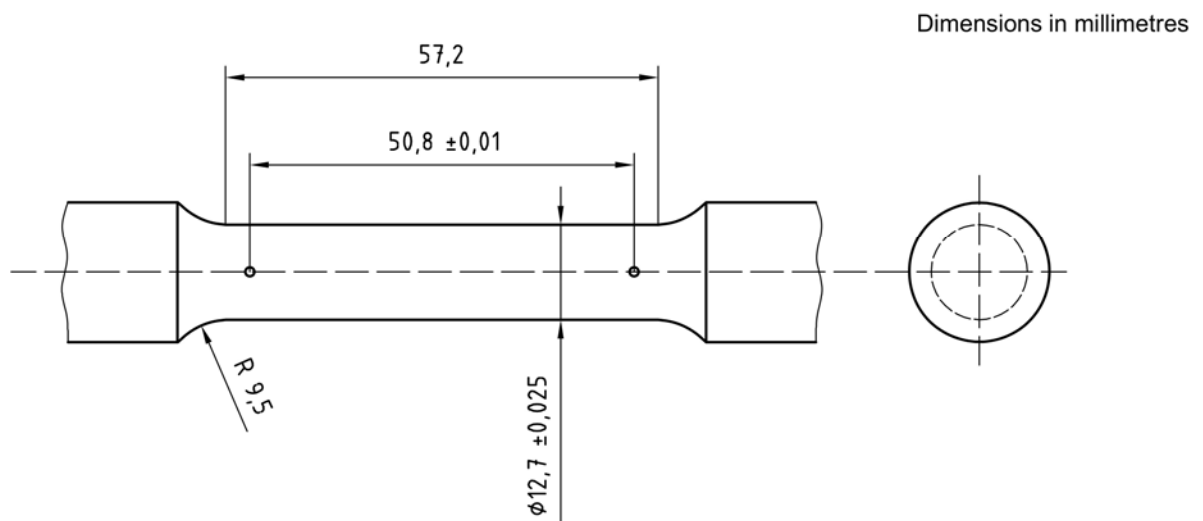
Figure B.1 — Tensile test piece with a gauge length $L_o = 4 \times d$

Annex C
(informative)

Toughness

C.1 General

The use of a ductile material such as ferritic spheroidal graphite cast iron for applications involving tensile loads requires a load-related evaluation of the strength and toughness characteristics in relationship to the operating temperature and the rate of loading with the aim of ensuring safety against fracture under all operating conditions.

Among others, the evaluation criteria for a design are based on the strength calculation and the establishment of the nominal stress. Not only with dynamically-loaded components shall it be ensured that brittle fracture does not lead to their failure but also under conditions that promote brittle fracture it is possible that fracture can be initiated through component stresses lower than the yield strength. This then leads to fracture through unstable crack propagation. It is only with a sufficient and known fracture toughness or ductility that a material can guarantee the well-known "leak-before-fracture" requirement of a component.

C.2 Methods to determine toughness

C.2.1 Impact toughness

The Charpy impact test described in ISO 148, is the usual method of determining resistance to brittle fracture. Here, the absorbed impact energy (or notch toughness or notched bar impact energy) is mostly used as a measure for determining the toughness.

With these methods, as it is not possible to separate the individual constituents of the energy (plastic deformation, crack initiation and crack propagation), use is made of the instrumented notched bar impact test or of other methods of fracture mechanics. The latter method is especially suitable for larger components.

C.2.2 Fracture mechanics

With the fracture mechanics concept, crack size and component stress are quantitatively linked together with a material characteristic, which then characterizes the resistance to crack propagation. The objective is determined to the critical crack size or the stress that leads to unstable crack propagation and to sudden failure of the component.

Linear-elastic fracture mechanics facilitate quantitative acquisition of the failure of crack-afflicted components as a result of unstable crack propagation with static loading or stable crack propagation with cyclic loading. The fracture toughness, K_{IC}, determined by this method, establishes the material's resistance to unstable crack propagation leading to brittle fracture. With ductile materials this concept is only applicable at low temperatures or in the presence of embrittlement effects, e.g. through microstructure or large wall thickness.

Yielding fracture mechanics is used if plastic deformation occurs ahead of the crack tip, i.e. elasto-plastic material behaviour. Determination may be made by means of the CTOD concept (crack tip opening displacement), in which the damage mechanism is controlled by the critical deformation at the crack tip.

With the J-integral concept a line integral is defined around the crack tip. Analogous with the previous concept a material characteristic is obtained that defines resistance to crack initiation.

## C.3 Comparison of the toughness of cast iron materials and cast steels

In view of the above comments it is understandable that evaluating only the notch impact energy of a ferritic spheroidal graphite cast iron does not represent a suitable measure for comparing its toughness or ductility with that of steel, because it is not possible to make any statement regarding the plastic deformability and cracking behaviour of the material.

Ferritic spheroidal graphite cast irons which in the ductile range have a notched impact energy of 12 J to 20 J, have a crack initiation behaviour comparable to unalloyed and low alloyed steels (with a notch impact energy of around 50 J in the higher range). The fracture toughness values of ferritic spheroidal cast iron result in elasto-plastic fracture behaviour even down to − 60 °C, i.e. a tough fracture characteristic, so that the K_{IC} values are on the same level as that of unalloyed and low alloyed steels (see Figures C.1 and C.2).

C.4 Evaluation of the test method

The results of fracture mechanics tests on ferritic spheroidal graphite cast irons show that, by comparison with steel and cast steel, their fracture mechanics properties should be more highly evaluated than would be expected from their relatively low notched bar impact energy.

When selecting a ferritic spheroidal graphite cast iron grade, even for use at low temperatures, the precise type of loading and any potential notch in the casting should be taken into account. For most applications, when the notch impact energy does not have to be guaranteed, the ferritic grades ISO1083/JS/400-18/U and ISO1083/JS/400-15/U are more suitable than ISO1083/JS/400-18-LT/U. The same applies to the different types of ISO1083/JS/350-22.
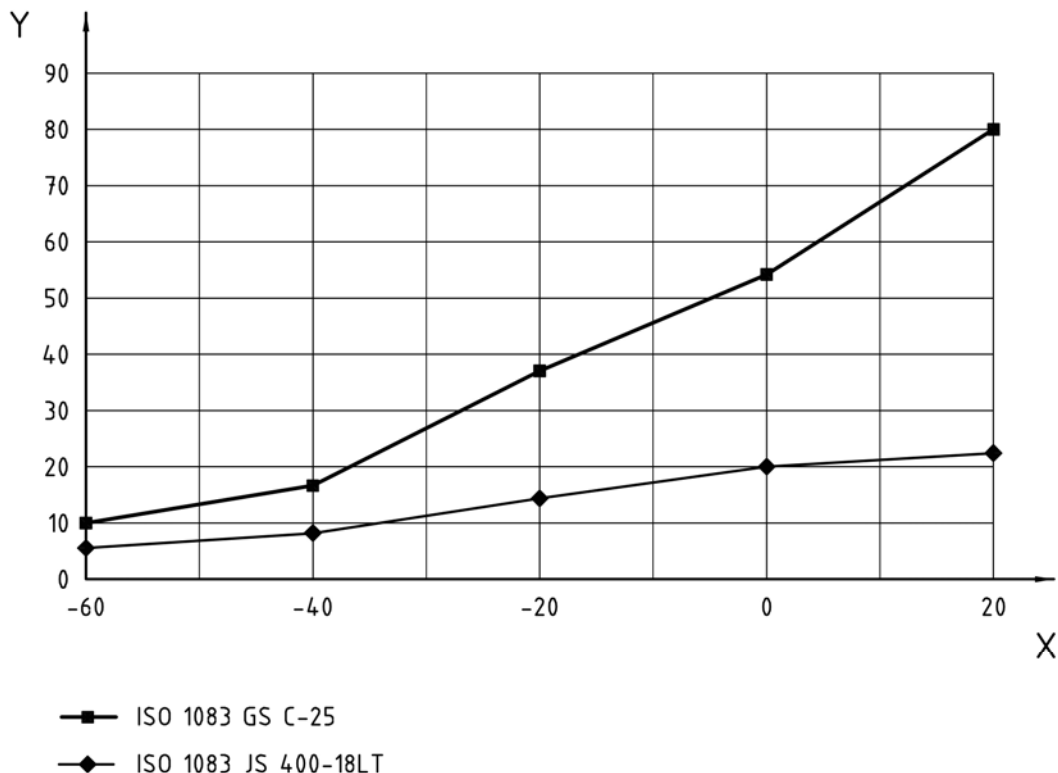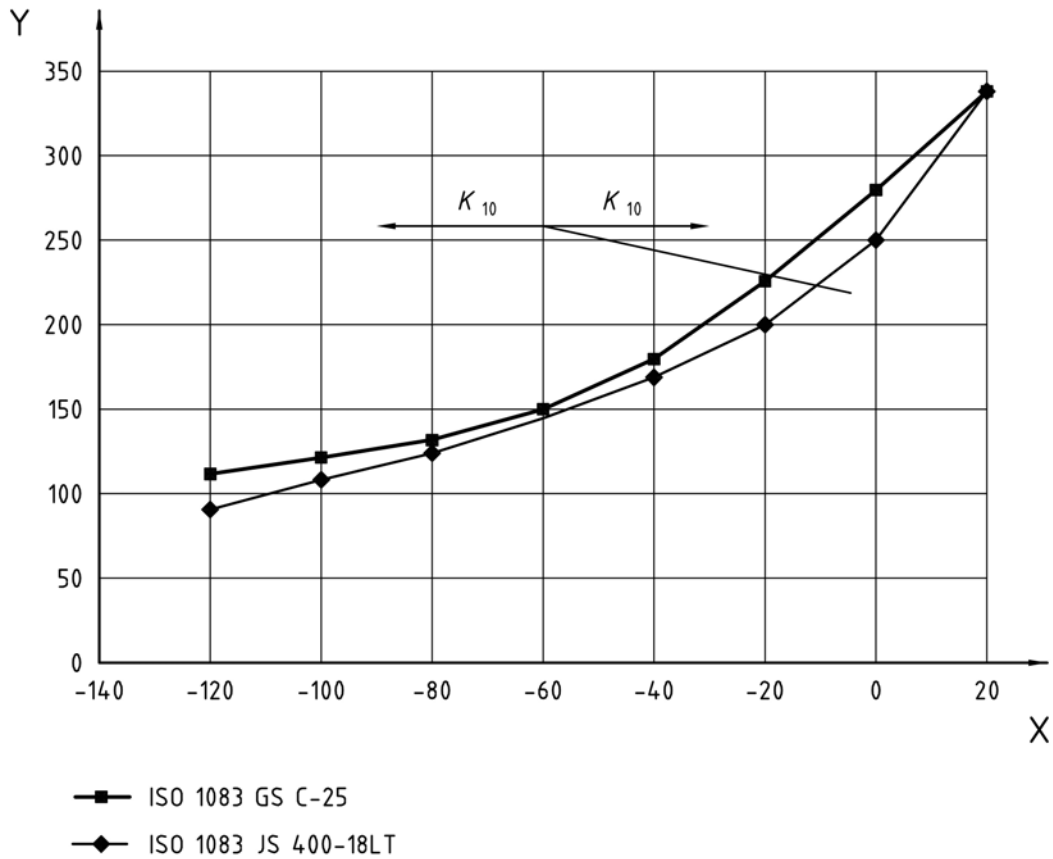

Key

X   Temperature, °C
Y   Impact resistance value, J (ISO-V)

Figure C.1 — Impact strength of ferritic spheroidal graphite cast iron and cast steel

Key

X   Temperature, °C

Y   Fracture toughness, MN/m$^{-3/2}$

Figure C.2 — Lower borderline of the fracture toughness of ferritic spheroidal cast iron and cast steel

Annex D
(informative)

Guidance values for 0,2 % proof stress for test pieces machined from samples cut from the castings

Material designation	0,2 % proof stress, $R_{p0,2}$ N/mm^2 min. for wall thickness t			
	$t \leqslant 50$ mm	50 mm $< t \leqslant 80$ mm	80 mm $< t \leqslant 120$ mm	120 mm $< t \leqslant 200$ mm
ISO1083/JS/400-15/C	250	240	230	230
ISO1083/JS/500-7/C	290	280	270	260
ISO1083/JS/550-5/C	320	310	300	290
ISO1083/JS/600-3/C	360	340	330	320
ISO1083/JS/700-2/C	400	380	370	360

Annex E
(normative)

Classification as a function of hardness

NOTE   This annex shall only be applicable when its requirements have been agreed upon between the manufacturer and the purchaser by the time of acceptance of the order.

E.1 General

When only hardness is required, the Brinell hardness values shall be as specified in Table E.1.

When hardness is required in addition to the tensile properties, the Brinell hardness values shall be as specified in Table E.1 and the procedure given in E.3 is recommended.

E.2 Classification

The hardness classes for the materials shall be as specified in Table E.1.

Table E.1 — Classification as a function of hardness

Material designation	Brinell hardness range HBW	Other properties[a, b] R_m N/mm^2	$R_{p0,2}$ N/mm^2
ISO1083/JS/HBW130	less than 160	350	220
ISO1083/JS/HBW150	130 to 175	400	250
ISO1083/JS/HBW155	135 to 180	400	250
ISO1083/JS/HBW185	160 to 210	450	310
ISO1083/JS/HBW200	170 to 230	500	320
ISO1083/JS/HBW215	180 to 250	550	350
ISO1083/JS/HBW230	190 to 270	600	370
ISO1083/JS/HBW265	225 to 305	700	420
ISO1083/JS/HBW300[c]	245 to 335	800	480
ISO1083/JS/HBW330[c]	270 to 360	900	600

NOTE   1 N/mm^2 = 1 MPa.

[a]   When only hardness is required, these properties are for information.

[b]   When hardness is required in addition to tensile properties, these properties provide an introductory step to the procedure given in E.3.

[c]   ISO1083/JS/HBW300 and ISO1083/JS/HBW330 are not recommended for thick section castings.

By agreement between the manufacturer and the purchaser, a narrower hardness range may be adopted; a tolerance range of between 30 and 40 Brinell hardness units is commonly acceptable. This hardness range may be wider for grades with a ferritic-pearlitic matrix structure.

E.3 Determination of a hardness range capable of meeting the tensile property requirements

This procedure applies mainly to serial production of castings, where it is possible to obtain the required number of samples.

This procedure is used to determine the hardness range of a material grade specified by its tensile properties according to Table 1 and/or Table 3, for a grade designated in Table E.1, for a particular foundry process.

a) Select the hardness grade from Table E.1.

b) Select the corresponding grade in Table 1 and/or Table 3 and the type of sample using the values shown in Table E.1 for tensile strength and yield strength of the specified hardness grade.

c) Retain only those test pieces with a value within the hardness range for the selected grade, see a).

d) Determine tensile strength, yield strength, elongation and Brinell hardness values for each test piece. Round hardness values to the nearest 10 HBW. As agreed between the manufacturer and the purchaser, in order to obtain the desired statistical confidence, conduct as many tests as are necessary to obtain a minimum number of values of tensile strength for each HBW value.

e) Plot histograms of tensile properties, as a function of hardness.

f) For each HBW value, take the minimum value of each tensile property as the process capability indicator.

g) Specify as the minimum HBW value the minimum hardness for which tensile strength and yield strength meet the requirements of the grade specified in Table 1 and Table 3.

h) Specify as the maximum HBW value the maximum hardness for which the elongation meets the requirements of the grade specified in Table 1 or Table 3.

The hardness range lies between the minimum and the maximum HBW values as determined by the above procedure.

E.4 Sampling

Each hardness test shall be carried out either on a casting or on a test piece at locations agreed between the manufacturer and the purchaser. In the absence of an agreement the test shall be carried out at representative locations chosen by the manufacturer.

E.5 Test method

The hardness test shall be carried out in accordance with ISO 6506-1.

If it is not possible to carry out the hardness test on the casting itself, then by agreement between the manufacturer and the purchaser, it may be carried out on a knob cast-on to the casting itself or on a separately cast sample.

If the test is carried out on a knob cast-on to the casting, it shall not be separated, before concluding any required heat treatment.

If the test is carried out on a test piece taken from a separately cast sample, this shall be subjected firstly to any heat treatment required for the castings of which it is representative.

E.6 Number and frequency of hardness tests

The number and frequency of hardness tests can be the subject of an agreement between the manufacturer and the purchaser by the time of acceptance of the order.

E.7 Microstructure

The lowest hardness is achieved with a ferritic matrix. The hardness increases with the amount of pearlite.

Eutectic carbides increase hardness but they are normally undesirable and only likely to be present in minor amounts.

Annex F
(informative)

Nodularity (or spheroidal graphite rate)

The nodularity of spheroidal graphite cast iron is defined as the percentage of graphite particles that are spheroidal or nodular in shape (form VI and V of ISO 945:1975).

This percentage is generally determined at $100 \times$ magnification on a polished, cut section of a sample. It may also be determined by image analysis, at higher magnification, or even, after prior calibration, by measuring the ultrasonic velocity across the material.

The level of nodularity depends not only on the manufacturing process (charge material, residual magnesium content, inoculation mode, etc.) but also on the cooling modulus of the section in question. Moreover, some degeneration of the graphite in contact with the mould is occasionally observed.

It is not possible to fix precisely, a critical level of nodularity with respect to the minimum characteristics appearing in this International standard, even for a specified cooling modulus, because the level varies not only with the measuring method used but also with the grade of cast iron in question (in particular its chemical composition), the pearlite content and, to some extent, the number of graphite particles per unit area.

However, a level of nodularity of 80 % to 85 % or more generally ensures (more than enough for $R_{p0,2}$) the minimum tensile properties specified in this International Standard. Most of the 15 % to 20 % of graphite not in form VI and V is then in form IV and possibly in form III.

For castings subjected to severe loading, in particular under fatigue conditions, a higher nodularity (including requirements for a specific percentage of form VI and V graphite) may be required. Such a requirement should be evaluated by an experimental study, specific to the casting and the material grade.

Annex G
(informative)

Additional information on mechanical and physical properties

Information on mechanical and physical properties is given in Table G.1 (in addition to that given in Tables 1 to 4).

Examples of the relationship between Brinell hardness and tensile strength R_m of spheroidal cast irons are given in Figure G.1.

Table G.1 — Typical properties[a]

Characteristic	Unit	Material designation									
		ISO1083/ JS/350-22	ISO1083/ JS/400-18	ISO1083/ JS/450-10	ISO1083/ JS/500-7	ISO1083/ JS/550-5	ISO1083/ JS/600-3	ISO1083/ JS/700-2	ISO1083 /JS/800-2	ISO1083/ JS/900-2	ISO1083/ JS/500-10
Shear strength	N/mm²	315	360	405	450	500	540	630	720	810	nd[b]
Torsional strength	N/mm²	315	360	405	450	500	540	630	720	810	nd[b]
Modulus of elasticity E (tension and compression)	GN/m²	169	169	169	169	172	174	176	176	176	170
Poisson's ratio ν	—	0,275	0,275	0,275	0,275	0,275	0,275	0,275	0,275	0,275	0,28 to 0,29
Fatigue limit (Wöhler)[c] (rotating bending) unnotched[d] (ϕ 10,6 mm)	N/mm²	180	195	210	224	236	248	280	304	304	225
Fatigue limit (Wöhler)[c] (rotating bending) notched[e] (ϕ 10,6 mm)	N/mm²	114	122	128	134	142	149	168	182	182	140
Compression strength	N/mm²	—	700	700	800	840	870	1 000	1 150	—	nd[b]
Fracture toughness K_{IC}	MPa·$\sqrt{m}$	31	30	28	25	22	20	15	14	14	28
Thermal conductivity at 300 °C	W/(K·m)	36,2	36,2	36,2	35,2	34	32,5	31,1	31,1	31,1	nd[b]
Specific heat capacity 20 °C to 500 °C	J/(kg·K)	515	515	515	515	515	515	515	515	515	nd[b]
Linear expansion coefficient 20 °C to 400 °C	μm/(m·K)	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	nd[b]
Density	kg/dm³	7,1	7,1	7,1	7,1	7,1	7,2	7,2	7,2	7,2	7,1
Maximum permeability	μH/m	2 136	2 136	2 136	1 596	1 200	866	501	501	501	nd[b]
Hysteresis loss (B = 1T)	J/m³	600	600	600	1 345	1 800	2 248	2 700	2 700	2 700	nd[b]
Resistivity	μΩ·m	0,50	0,50	0,50	0,51	0,52	0,53	0,54	0,54	0,54	nd[b]
Predominant structure		ferrite	ferrite	ferrite	ferrite-pearlite	ferrite-pearlite	pearlite-ferrite	pearlite	pearlite or tempered martensite	tempered martensite[f], [g]	ferrite

NOTE 1   The notched test pieces are illustrated in [6] and [7], see bibliography.

NOTE 2   1 N/mm² = 1 MPa.

NOTE 3   Unless otherwise specified, the values given in this Table come from measurements at room temperature.

a   For details, see [5].

b   Not determined.

c   Fatigue limit test pieces.

d   Unnotched – In annealed ferritic spheroidal graphite cast iron the fatigue limit is about 0,5 × tensile strength in spheroidal graphite cast iron with a tensile strength of 370 N/mm². The ratio decreases with increase in tensile strength until, in pearlitic and quenched and tempered spheroidal graphite cast iron, the fatigue limit is approximately 0,4 × tensile strength. The ratio decreases further when tensile strength exceeds 740 N/mm².

e   Notched – For a test piece of 10,6 mm diameter at notch with a circumferential 45° V-notch having a radius of 0,25 mm, the fatigue limit of annealed spheroidal graphite cast iron decreases to a value of about 0,63 × fatigue limit of unnotched test pieces in spheroidal graphite cast iron with a tensile strength of 370 N/mm². This figure decreases as the tensile strength of a ferritic spheroidal graphite cast iron increases. In spheroidal graphite cast iron with intermediate strengths and in pearlitic spheroidal graphite cast iron and quenched and tempered spheroidal graphite cast iron, the fatigue limit of notched test pieces is approximately 0,6 × the fatigue limit of unnotched test pieces.

f   For large castings, it can also be pearlite.

g   Or bainite-ausferrite.
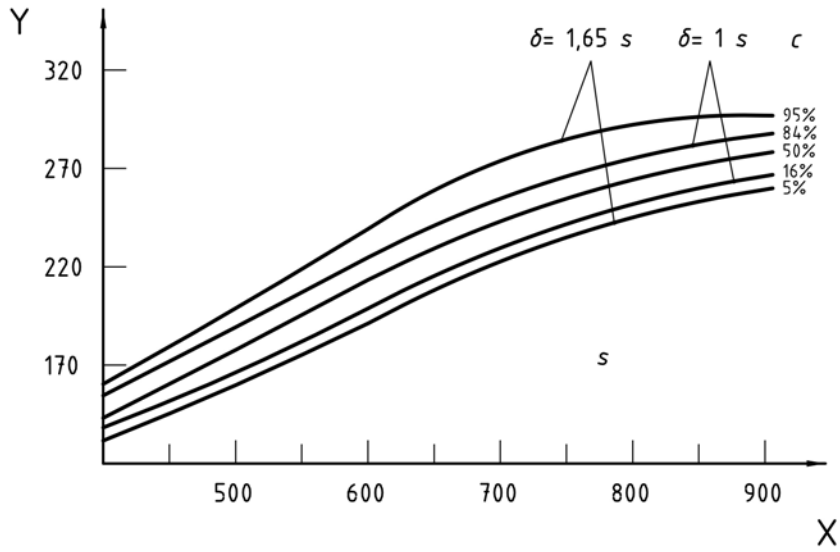
Key

X   Tensile strength R_m, N/mm^2

Y   Brinell hardness, HBW

c   Confidence limit

s   Standard deviation

Figure G.1 — Examples of the relationship between Brinell hardness and tensile strength of spheroidal graphite cast iron, in accordance with [8]

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33

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