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Spheroidal graphite cast irons

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Foundry Society, Inc. (JFSinc)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS G 5502 : 2007**), which has been technically revised.

However, **JIS G 5502 : 2007** may be applied in the **JIS** mark certification based on the relevant provisions of Article 30, paragraph (1), etc. of the Industrial Standardization Act until 19 April 2023.

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Spheroidal graphite cast irons

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 1083** : 2018, Edition 4, by incorporating the part corresponding to this Standard without any modifications of the technical contents, but also adding some **JIS** specification contents that are not given in the said corresponding International Standard.

The vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JC. Annex JA and Annex JB are unique to **JIS** and not given in the corresponding International Standard.

1 Scope

This Standard specifies the requirements for spheroidal graphite cast irons (hereafter referred to as cast irons).

NOTE The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 1083 : 2018 *Spheroidal graphite cast irons — Classification* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 0403 *Castings — System of dimensional tolerances and machining allowances*

JIS G 0201 *Glossary of terms used in iron and steel (Heat treatment)*

JIS G 0320 *Standard test method for heat analysis of steel products*

JIS G 1253 *Iron and steel — Method for spark discharge atomic emission spectrometric analysis*

JIS Z 2241 *Metallic materials — Tensile testing — Method of test at room temperature*

NOTE Normative reference in the corresponding International Standard : ISO 6892-1 *Metallic materials — Tensile testing — Part 1 : Method of test at room temperature*

JIS Z 2242 *Method for Charpy pendulum impact test of metallic materials*

NOTE Normative reference in the corresponding International Standard : ISO 148-1 *Metallic materials — Charpy pendulum impact test — Part 1 : Test method*

JIS Z 2243-1 *Brinell hardness test — Part 1 : Test method*

NOTE Normative reference in the corresponding International Standard : ISO 6506-1 *Metallic materials — Brinell hardness test — Part 1 : Test method*

JIS Z 2350 *Method for measurement of performance characteristics of ultrasonic probes*

JIS Z 2353 *Method for measurement of ultrasonic velocity in solids*

JIS Z 8461 *Linear calibration using reference materials*

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

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS B 0403** and **JIS G 0201**, and the following apply.

3.1

spheroidal graphite cast iron

cast iron in which carbon is being present mainly in the form of spheroidal graphite particles by graphite spherodizing treatment of liquid iron

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

3.2

ferritic to pearlitic spheroidal graphite cast iron, SGI

cast iron with a matrix structure containing ferrite, pearlite or a combination of both

3.3

solid-solution strengthened ferritic spheroidal graphite cast iron, SSSGI

cast iron with a matrix mainly consisting of ferrite, solution strengthened by increasing the amount of silicon (hereafter referred to as Si) compared to SGI

3.4

graphite spherodizing treatment

process that brings the liquid iron into graphite spherodizing form by adding graphite spherodizing agent

NOTE This process is often followed by a second process called inoculation.

3.5

fading

phenomenon in which the effect of graphite spherodizing agents or inoculants added to liquid iron fades over time

3.6**in-mould process**

manufacturing process of cast irons, in which molten metal is reacted with a graphite spherodizing agent in a reaction chamber installed in the sand mould before being poured into the mould cavity

3.7**matrix structure**

portions of microstructure of iron casting, not occupied by graphite particles

3.8**cast sample**

generic term for separately cast sample, side-by-side cast sample and cast-on sample, which are taken by casting

3.9**separately cast sample**

sample cast under the same conditions as the cast iron itself separately from the cast iron itself using the sand mould having the same thermal properties as the sand mould used in the manufacture of the cast iron itself (see Table 6 to Table 8)

3.10**side-by-side cast sample**

sample cast in the mould alongside the cast iron itself, with a joint running system (see Table 6 to Table 8)

3.11**cast-on sample**

sample cast in the mould attached directly to the cast iron itself (see Table 9)

3.12**sample cut from a casting**

sample obtained directly from the cast iron itself

3.13**sample for preparation of regression equation**

sample having different graphite nodularity one another for preparation of the regression equation between sound velocity and graphite nodularity

3.14**cast test piece**

test piece manufactured by machining a cast sample

It is the generic term for separately cast test piece, side-by-side cast test piece and cast-on test piece.

3.15**separately cast test piece**

test piece manufactured by machining a separately cast sample

3.16**side-by-side cast test piece**

test piece manufactured by machining a side-by-side cast sample

3.17**cast-on test piece**

test piece manufactured by machining a cast-on sample

3.18**test piece cut from a casting**

test piece manufactured by machining a sample cut from a casting

3.19**white pig-iron sample**

sample for a chemical analysis in which carbon is crystallized not as graphite particles but as Fe_3C (cementite) by quenching molten metal

3.20**test piece for preparation of regression equation**

test piece manufactured by machining a sample for preparation of regression equation

3.21**test piece for zero point adjustment**

plate test piece used for obtaining a datum point to measure the propagation time of ultrasonic wave

NOTE See Table JB.2.

3.22**flaws**

portions having cavities, inclusions, cracks, poor casting surface, poor surface etc. Flaws are divided into those not detrimental to practical use and those detrimental to practical use.

3.23**defects**

flaws detrimental to practical use in mechanical properties, physical properties, appearance etc. among so-called flaws

3.24**gate**

time-limiting range for extracting only necessary echoes in sound velocity measurement

NOTE See **JB.8** and **JB.9**.

3.25**relevant wall thickness**

wall thickness of cast iron itself to which the determined mechanical properties shall apply

3.26**test unit**

number of pieces or the tonnage of cast irons to be accepted or rejected together, on the basis of the inspection results in accordance with the requirements of the relevant specification, material standard or order

NOTE This term is sometimes referred to as “inspection lot” or “test batch”.

4 Divisions and designations

The divisions and designations of cast irons shall be as given in Table 1.

Table 1 Divisions and designations of cast irons

Division	Designation
SGI	FCD 350-22L ^{a)}
	FCD 350-22R ^{b)}
	FCD 350-22
	FCD 400-18L ^{a)}
	FCD 400-18R ^{b)}
	FCD 400-18
	FCD 400-15
	FCD 450-10
	FCD 500-7
	FCD 550-5
	FCD 600-3
	FCD 700-2
	FCD 800-2
	FCD 900-2

Table 1 (concluded)

Division	Designation
SSSGI	FCD 450-18
	FCD 500-14
	FCD 600-10
“/S” shall be suffixed to the designation for separately cast test pieces. “/U” shall be suffixed to the designation for side-by-side cast test pieces or cast-on test pieces. “/C” shall be suffixed to the designation for test pieces cut from a casting. NOTE Annex I shows cross-references of designations among JIS, ISO Standard and other standards of spheroidal graphite cast irons. Notes a) Cast irons of designation suffixed with “L” are to be used for the evaluation of impact property at low temperature (see 7.3). b) Cast irons of designation suffixed with “R” are to be used for the evaluation of impact property at room temperature (see 7.3).	

5 Order information

The following information shall be supplied by the purchaser :

- the complete designation of cast irons shown in Table 1;
- any requirements specified in Clause 7, as agreed between the purchaser and the manufacturer.

All the order shall be confirmed by the agreements on order information **a)** and **b)** between the purchaser and the manufacturer.

6 Manufacture

The method of producing cast irons and their chemical composition shall be left to the discretion of the manufacturer, unless otherwise specified by the purchaser.

If the cast irons are to be used for special purposes as specified by the purchaser, the chemical composition and the heat treatment shall be as agreed between the purchaser and the manufacturer.

7 Requirements

7.1 General

General requirements for cast irons are as follows.

- For the specified tensile property and impact property, the values of cast test pieces cast in the same sand mould or in the sand mould having the same thermal properties as that used for the cast irons, or of test pieces cut from a casting shall apply. As agreed between the purchaser and the manufacturer, these values may also apply to the cast irons cast in the sand mould having similar thermal properties.
- The designations in Table 2 are expressed in terms of the combination of tensile strength and elongation after fracture of test pieces worked from cast samples cast

with a relevant wall thickness of 30 mm or under. The designation is irrespective of the type of cast sample.

- c) The properties specified in Table 2 and Table 3 obtained according to 11.1 are called “the tensile properties”. The property specified in Table 4 obtained according to 11.2 is called “the impact property”. Other mechanical properties are called “specific mechanical properties” herein.
- d) Where the relevant wall thickness exceeds 200 mm, the requirements for the tensile properties, type of cast sample and dimensions, and microstructures shall be as agreed between the purchaser and the manufacturer.
- e) The tensile properties of cast iron may be substituted by hardness as agreed between the purchaser and the manufacturer (see Annex E).

7.2 Tensile properties

a) Tensile properties of cast test pieces

The tensile properties of cast test pieces shall be as follows.

- 1) The test pieces shall be cut out by the method in accordance with 10.2.1 a) or 10.2.1 c) and prepared in accordance with 10.2.2 a), and tested in accordance with 11.1.
- 2) The tensile properties of SGI shall be as given in Table 2.
- 3) The tensile properties of SSSGI shall be as given in Table 3.

b) Tensile properties of test pieces cut from a casting

The tensile properties of test pieces cut from a casting shall be as follows.

- 1) The test pieces shall be cut out by the method in accordance with 10.2.1 b) or 10.2.1 c) and prepared in accordance with 10.2.2 a), and tested in accordance with 11.1.
- 2) The tensile properties of SGI and SSSGI shall be as agreed between the purchaser and the manufacturer.

Guidance values for tensile properties are shown in Annex D for reference.

NOTE 1 The tensile properties of cast irons can vary depending on the complexity of shape and fluctuations in their section thicknesses and cooling rates.

NOTE 2 The tensile properties of cast irons are also affected by the local “flaws” of cast irons.

Table 2 Tensile properties of cast test pieces of SGI

Designation	Relevant wall thickness t mm	0.2 % proof strength $R_{p0.2}$ MPa	Tensile strength R_m MPa	Elongation after fracture ^{a)} A %
FCD 350-22L/S FCD 350-22L/U	$t \leq 30$	220 min.	350 min.	22 min.
	$30 < t \leq 60$	210 min.	330 min.	18 min.
	$60 < t \leq 200$	200 min.	320 min.	15 min.
FCD 350-22R/S FCD 350-22R/U	$t \leq 30$	220 min.	350 min.	22 min.
	$30 < t \leq 60$	220 min.	330 min.	18 min.
	$60 < t \leq 200$	210 min.	320 min.	15 min.
FCD 350-22/S FCD 350-22/U	$t \leq 30$	220 min.	350 min.	22 min.
	$30 < t \leq 60$	220 min.	330 min.	18 min.
	$60 < t \leq 200$	210 min.	320 min.	15 min.
FCD 400-18L/S FCD 400-18L/U	$t \leq 30$	240 min.	400 min.	18 min.
	$30 < t \leq 60$	230 min.	380 min.	15 min.
	$60 < t \leq 200$	220 min.	360 min.	12 min.
FCD 400-18R/S FCD 400-18R/U	$t \leq 30$	250 min.	400 min.	18 min.
	$30 < t \leq 60$	250 min.	390 min.	15 min.
	$60 < t \leq 200$	240 min.	370 min.	12 min.
FCD 400-18/S FCD 400-18/U	$t \leq 30$	250 min.	400 min.	18 min.
	$30 < t \leq 60$	250 min.	390 min.	15 min.
	$60 < t \leq 200$	240 min.	370 min.	12 min.
FCD 400-15/S FCD 400-15/U	$t \leq 30$	250 min.	400 min.	15 min.
	$30 < t \leq 60$	250 min.	390 min.	15 min.
	$60 < t \leq 200$	240 min.	370 min.	12 min.
FCD 450-10/S FCD 450-10/U	$t \leq 30$	280 min.	450 min.	10 min.
	$30 < t \leq 60$	As agreed between the purchaser and the manufacturer.		
	$60 < t \leq 200$			
FCD 500-7/S FCD 500-7/U	$t \leq 30$	320 min.	500 min.	7 min.
	$30 < t \leq 60$	300 min.	450 min.	7 min.
	$60 < t \leq 200$	290 min.	420 min.	5 min.
FCD 550-5/S FCD 550-5/U	$t \leq 30$	350 min.	550 min.	5 min.
	$30 < t \leq 60$	330 min.	520 min.	4 min.
	$60 < t \leq 200$	320 min.	500 min.	3 min.
FCD 600-3/S FCD 600-3/U	$t \leq 30$	370 min.	600 min.	3 min.
	$30 < t \leq 60$	360 min.	600 min.	2 min.
	$60 < t \leq 200$	340 min.	550 min.	1 min.
FCD 700-2/S FCD 700-2/U	$t \leq 30$	420 min.	700 min.	2 min.
	$30 < t \leq 60$	400 min.	700 min.	2 min.
	$60 < t \leq 200$	380 min.	650 min.	1 min.
FCD 800-2/S FCD 800-2/U	$t \leq 30$	480 min.	800 min.	2 min.
	$30 < t \leq 60$	As agreed between the purchaser and the manufacturer.		
	$60 < t \leq 200$			
FCD 900-2/S FCD 900-2/U	$t \leq 30$	600 min.	900 min.	2 min.
	$30 < t \leq 60$	As agreed between the purchaser and the manufacturer.		
	$60 < t \leq 200$			

Table 2 (concluded)

NOTE	The values of tensile properties of cast test pieces ~~express those of the cast iron corresponding to the relevant wall thickness. However, the wall thickness varies for every portion of cast iron; therefore, the values in this table do not necessarily express the properties of whole cast iron.~~
Note ^{a)}	The elongation after fracture is in accordance with the original gauge length of 10.2.2 a) .

Table 3 Tensile properties of cast test pieces of SSSGI

Designation	Relevant wall thickness t mm	0.2 % proof strength $R_{p0.2}$ MPa	Tensile strength R_m MPa	Elongation after fracture ^{a)} A %
FCD 450-18/S FCD 450-18/U	$t \leq 30$	350 min.	450 min.	18 min.
	$30 < t \leq 60$	340 min.	430 min.	14 min.
	$60 < t$	As agreed between the purchaser and the manufacturer.		
FCD 500-14/S FCD 500-14/U	$t \leq 30$	400 min.	500 min.	14 min.
	$30 < t \leq 60$	390 min.	480 min.	12 min.
	$60 < t$	As agreed between the purchaser and the manufacturer.		
FCD 600-10/S FCD 600-10/U	$t \leq 30$	470 min.	600 min.	10 min.
	$30 < t \leq 60$	450 min.	580 min.	8 min.
	$60 < t$	As agreed between the purchaser and the manufacturer.		
NOTE 1 These designations can be suitable for some pressure vessel applications.				
NOTE 2 The values of tensile properties of cast test pieces <u>express those of the cast iron corresponding to the relevant wall thickness. However, the wall thickness varies for every portion of cast iron; therefore, the values in this table do not necessarily express the properties of whole cast iron.</u>				
Note ^{a)} The elongation after fracture is in accordance with the original gauge length of 10.2.2 a) .				

7.3 Impact property

When the impact property test is requested by the purchaser, the test pieces shall be cut out by the method in accordance with **10.2.1** and prepared in accordance with **10.2.2 b)**, and tested in accordance with **11.2**.

The absorbed energy by the Charpy pendulum impact test shall be as given in Table 4. At the time of order, the designation shall be specified by the purchaser for SGI used at low temperature or room temperature [see Note ^{a)} and Note ^{b)} to Table 1], and the mean value of absorbed energy of the three test pieces and the individual values shall be as given in Table 4.

Table 4 Absorbed energy values measured on V-notched cast test pieces of SGI

Designation	Relevant wall thickness t mm	Absorbed energy (J)					
		Room temperature $23\text{ °C} \pm 5\text{ °C}$		Low temperature $-20\text{ °C} \pm 2\text{ °C}$		Low temperature $-40\text{ °C} \pm 2\text{ °C}$	
		Mean value of three pieces	Individual value	Mean value of three pieces	Individual value	Mean value of three pieces	Individual value
FCD 350-22L/S FCD 350-22L/U	$t \leq 30$	—	—	—	—	12 min.	9 min.
	$30 < t \leq 60$	—	—	—	—	12 min.	9 min.
	$60 < t \leq 200$	—	—	—	—	10 min.	7 min.
FCD 350-22R/S FCD 350-22R/U	$t \leq 30$	17 min.	14 min.	—	—	—	—
	$30 < t \leq 60$	17 min.	14 min.	—	—	—	—
	$60 < t \leq 200$	15 min.	12 min.	—	—	—	—
FCD 400-18L/S FCD 400-18L/U	$t \leq 30$	—	—	12 min.	9 min.	—	—
	$30 < t \leq 60$	—	—	12 min.	9 min.	—	—
	$60 < t \leq 200$	—	—	10 min.	7 min.	—	—
FCD 400-18R/S FCD 400-18R/U	$t \leq 30$	14 min.	11 min.	—	—	—	—
	$30 < t \leq 60$	14 min.	11 min.	—	—	—	—
	$60 < t \leq 200$	12 min.	9 min.	—	—	—	—
NOTE The values of absorbed energy of cast test pieces express those of the cast iron corresponding to the relevant wall thickness. However, the wall thickness varies for every portion of cast iron; therefore, the values in this table does not necessarily express the absorbed energy of whole cast iron.							

7.4 Chemical composition

When requested by the purchaser, the cast irons shall be tested in accordance with 11.3, and the results shall be as agreed between the purchaser and the manufacturer. In this case, for SSSGI, requirements of A.2.1 should be satisfied.

7.5 Hardness

The Brinell hardness (hereafter referred to as the hardness) of cast irons shall be tested in accordance with 11.4, and the results shall be as agreed between the purchaser and the manufacturer. Other hardness may apply as agreed between the purchaser and the manufacturer.

Information concerning the hardness is shown in Annex E.

7.6 Graphite form and microstructure

7.6.1 Graphite form

The graphite form shall be tested in accordance with 11.5.1 and the graphite nodularity shall be as follows.

The graphite nodularity of cast irons obtained in accordance with Annex JA, Annex JB or Annex F shall be at least 80 %. If the graphite nodularity is less than 80 %, the acceptance criteria shall be as agreed between the purchaser and the manufacturer, provided the tensile properties satisfy the requirement.

Such graphite particles as shown in Figure F.1 shall not exist in cast irons except on the surface zone.

NOTE For SSSGI, reference information on graphite form is shown in **A.2.3**.

7.6.2 Microstructure

When requested by the purchaser, the microstructure of cast irons shall be tested in accordance with **11.5.2**, and the results shall be as agreed between the purchaser and the manufacturer. In this case, for the matrix structure of SSSGI, requirements of **A.2.2** should be referred to.

7.7 Specific mechanical properties

When requested by the purchaser, the cast irons shall be tested in accordance with **11.6**, and the results shall be as agreed between the purchaser and the manufacturer.

As a reference, typical values of specific mechanical properties are shown in Table G.1 and the reference values in Table G.2.

7.8 Physical properties

When requested by the purchaser, the cast irons shall be tested in accordance with **11.7**, and the results shall be as agreed between the purchaser and the manufacturer.

As a reference, typical values of physical values are shown in Table G.1.

7.9 Internal soundness

The internal soundness of cast irons shall be tested in accordance with **11.8**, and there shall be no flaws detrimental to practical use. The acceptance criteria for the internal soundness of cast irons shall be as agreed between the purchaser and the manufacturer.

7.10 Shape, dimensions, dimensional tolerances, machining allowances, draft angle and mass

The purchaser or the manufacturer shall specify the dimensions and the shape of cast irons in drawing. The dimensional tolerances, machining allowances and draft angle, unless otherwise specified, shall be in accordance with **JIS B 0403**. The mass of cast irons shall be as agreed between the purchaser and the manufacturer.

7.11 Appearance

The appearance of cast irons shall be tested in accordance with **11.9**, and there shall be no flaws detrimental to practical use. The acceptance criteria for the appearance of cast irons shall be as agreed between the purchaser and the manufacturer.

8 Samples

8.1 Sampling

8.1.1 General

The manufacturer shall prepare samples representative of the cast irons being manufactured, for each test unit (see **10.1.1**) of cast irons. Samples shall be used for tensile

test, impact test, chemical analysis, hardness test, graphite form and microstructure tests, specific mechanical properties tests, and physical properties tests.

- a) The sample used for tensile test, impact test, hardness test, graphite form and microstructure tests, specific mechanical properties tests, and physical properties tests shall be any of the separately cast sample, side-by-side cast sample, cast-on sample or sample cut from a casting according to the relevant wall thickness of cast irons. The selection of sample shall be as agreed between the purchaser and the manufacturer. In the absence of agreement, the decision may be left to the manufacturer.
- b) It is desirable that the sample for chemical analysis is made of white pig-iron regardless of its shape.
- c) When the mass of cast iron exceeds 2 000 kg and the relevant wall thickness exceeds 60 mm, cast-on samples or samples cut from a casting should preferably be used as agreed between the purchaser and the manufacturer. In the absence of agreement, the decision shall be left to the manufacturer.
- d) Side-by-side cast samples and cast-on samples should be produced from the last sand mould filled in the test unit.
- e) Separately cast samples should be produced from a sand mould after the last mould in the test unit has been filled.
- f) The dimensional tolerances for samples shall be as given in Table A.1 of JIS B 0403.
- g) Separately cast samples should not be used for cast irons produced by the in-mould process.
- h) Heat treatment of samples shall be in accordance with Clause 9.
- i) At least one reserve sample should be prepared in case where retests are necessary.
- j) All samples shall be adequately marked to guarantee full traceability to the cast irons which they represent.

8.1.2 Sampling frequency

Sampling shall be performed at a frequency in accordance with in-process quality assurance procedures determined by the manufacturer. The case where the in-process quality assurance procedure is not specified shall be as agreed between the purchaser and the manufacturer.

8.1.3 Sampling methods

8.1.3.1 Sampling method of cast sample

8.1.3.1.1 Separately cast sample

Separately cast samples shall be cast concurrently with cast irons in a separate sand mould using the same manufacturing method as that of the cast irons. These samples

shall be representative of the cast irons concurrently cast.

The sampling method of separately cast sample shall be as follows.

- a) The sand moulds used to cast the samples shall have comparable thermal behaviour to the sand mould used to produce the cast irons.
- b) The samples shall be cast according to an appropriate casting system plan capable of reproducing the conditions used for production of the cast irons.
- c) The sample shape shall be selected from Table 6 to Table 8, and the dimensions, from those provided in the selected table.
- d) The samples shall be removed from the mould at a temperature similar to that of the cast irons, which shall not exceed 500 °C.
- e) The sample shall be subjected to the same heat treatment as cast irons, if necessary.

8.1.3.1.2 Side-by-side cast sample

Side-by-side cast samples shall be cast in the mould alongside the cast iron itself with a joint running system. These samples shall be representative of the cast irons concurrently cast.

The sampling method of side-by-side cast sample shall be as follows.

- a) When the in-mould process is applied, samples shall be cast with the same joint running system as that of the cast irons.
- b) The sample shape shall be selected from Table 6 to Table 8, and the dimensions, from those provided in the selected table.
- c) The sample shall be subjected to the same heat treatment as cast irons, if necessary.

8.1.3.1.3 Cast-on sample

Cast-on samples shall be cast by being directly attached to the cast iron itself. These samples are representative of the cast irons to which they are attached, and also of all other cast irons of a similar relevant wall thickness from the same test unit.

The install position of cast-on sample shall be as agreed between the purchaser and the manufacturer.

The sampling method of cast-on sample shall be as follows.

- a) The sampling position shall be as agreed between the purchaser and the manufacturer.
- b) The shape and dimensions of sample shall be selected from Type A to Type D as shown in Table 9.

8.1.3.2 Cutting method of sample cut from a casting

The sample cut from a casting is a sample cut directly from the cast iron itself and represents the cut cast iron and all the other cast irons with the relevant wall thick-

ness of the same test unit.

The cutting method of sample cut from a casting shall be as follows.

- a) The sample shall be cut from the position where the manufacturer has determined that the properties of the cast iron itself can be evaluated. As agreed between the purchaser and the manufacturer, other positions are permissible.
- b) The shape and dimensions of sample shall be as agreed between the purchaser and the manufacturer.

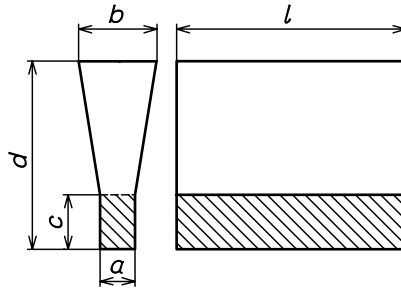
8.1.4 Dimensions of cast samples

The dimensions of cast samples shall correspond to the relevant wall thickness and sample types as shown in Table 5. The case where samples of other dimensions are used shall be as agreed between the purchaser and the manufacturer.

Table 5 Types of cast samples and preferred diameters of parallel part of tensile test pieces in relation to relevant wall thicknesses of cast irons

Relevant wall thickness t mm	Type of sample				Preferred diameter of parallel part of tensile test piece ^{a)} d_0 mm
	Y-shaped sample (See Table 6)	U-shaped sample (See Table 7)	Knock-off-shaped sample (See Table 8)	Cast-on sample (See Table 9)	
$t \leq 12.5$	Type A	Type A	—	Type A	7
	—	—	Type K _b , Type K _c	—	14
$12.5 < t \leq 30$	Type B	Type B1. Type B2	Type K _b , Type K _c	Type B	14
$30 < t \leq 60$	Type C	Type C	—	Type C	14
$60 < t \leq 200$	Type D	Type D	—	Type D	14
Note ^{a)} Other diameter may be used as agreed between the purchaser and the manufacturer.					

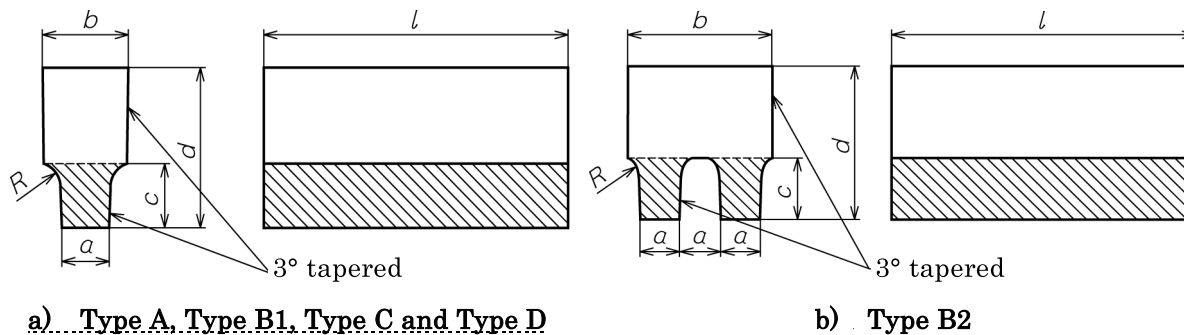
Table 6 Shapes and dimensions of separately cast sample and side-by-side cast sample (Y-shaped sample)



Unit: mm

Dimension	Classification			
	Type A	Type B	Type C	Type D
a	12.5	25	50	75
b ^{a)}	40	55	100	125
c	25	40	50	65
d ^{a)}	135	140	150	175
l ^{b)}	A function of the test piece length to be used.			
The thickness of the sand mould surrounding the samples <u>should</u> be at least 40 mm for Type A and Type B, and at least 80 mm for Type C and Type D. For the manufacture of thin-walled castings or castings in metal moulds, the tensile properties may, as agreed between the purchaser and the manufacturer, be determined on test pieces taken from castings of thickness a of less than 12.5 mm. Notes ^{a)} The <u>dimension b</u> and dimension d are for information only. ^{b)} The dimension l <u>shall be large enough to allow that Test piece No. 14A or Test piece No. 4 specified in JIS Z 2241 can be cut out.</u>				

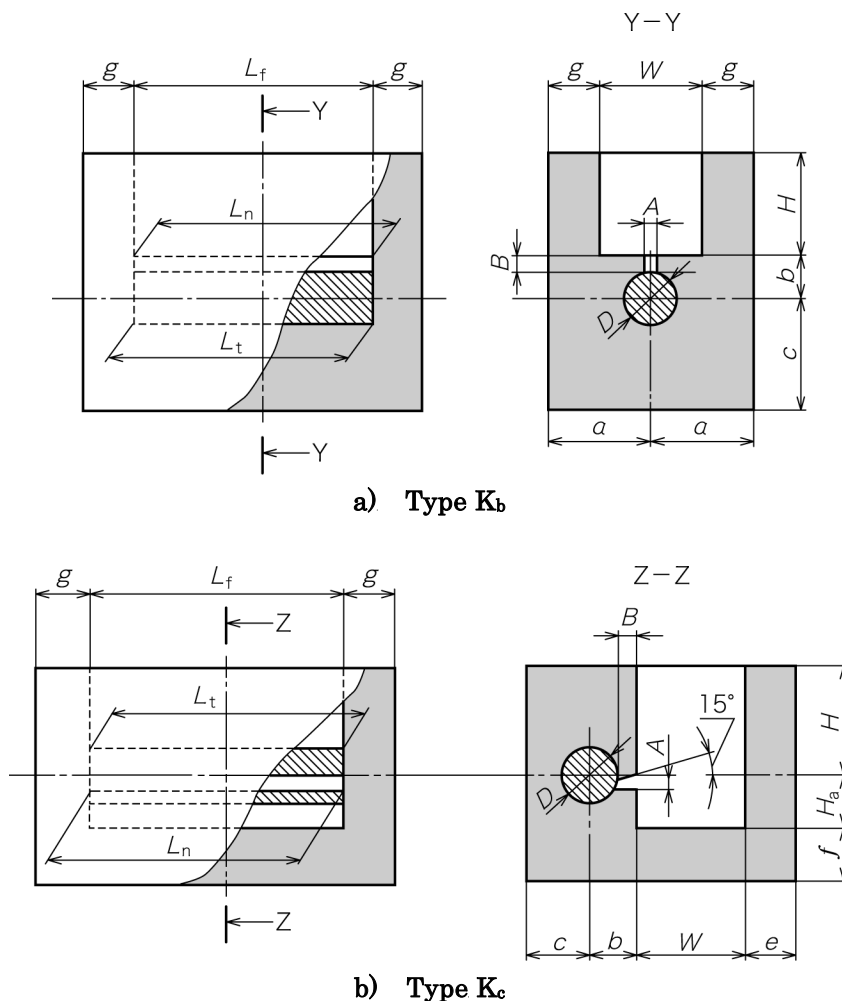
Table 7 Shapes and dimensions of separately cast sample and side-by-side cast sample (U-shaped sample)



Unit: mm

Dimension	Classification				
	Type A	Type B1	Type B2	Type C	Type D
a	12.5	25	25	50	75
b ^{a)}	40	55	90	90	125
c	30	40	40 or 50	60	65
d ^{a)}	80	100	100	150	165
R	5				
l ^{b)}	A function of the test piece length to be used.				
The thickness of the sand mould surrounding the samples should be at least 40 mm.					
Notes ^{a)} The dimension b and dimension d are for information only.					
^{b)} The dimension l shall be large enough to allow that Test piece No. 14A or Test piece No. 4 specified in JIS Z 2241 can be cut out.					

Table 8 Shapes and dimensions of separately cast sample and side-by-side cast sample (knock-off-shaped sample)



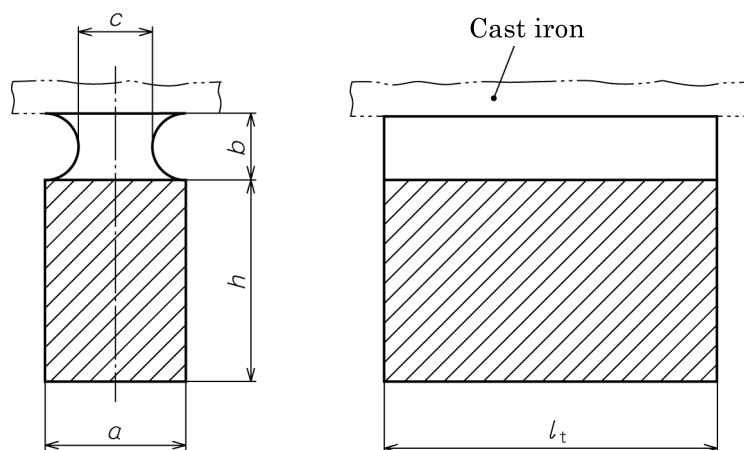
Unit: mm

Dimension	Classification	
	Type K _b	Type K _c
A ^{a)}	6	6
B ^{a)}	7.5	7.5
D	25	25
H ^{a)}	≥50	≥50
H _a ^{a)}	—	25
L _f	— b)	
L _n	— b)	
L _t	— b)	
W ^{a)}	50	50
a ^{a)}	≥50	—
b ^{a)}	20	20
c ^{a)}	≥55	≥20
e ^{a)}	—	≥25
f ^{a)}	—	≥70
g ^{a)}	≥25	≥25

Table 8 (concluded)

Notes	a) The dimensions $A, B, H, H_a, W, a, b, c, e, f$ and g are for information only.
	b) The dimensions L_f, L_n and L_t shall be large enough to allow that Test piece No. 14A or Test piece No. 4 specified in JIS Z 2241 can be cut out.

Table 9 Shapes and dimensions of cast-on sample



Unit: mm

Dimension	Classification			
	Type A	Type B	Type C	Type D
$t^{a)}$	$t \leq 12.5$	$12.5 < t \leq 30$	$30 < t \leq 60$	$60 < t \leq 200$
a	15	25	40	70
$b^{b)}$	$b \leq 11$	$b \leq 19$	$b \leq 30$	$b \leq 52.5$
$c^{b)}$	$7.5 \leq c$	$12.5 \leq c$	$20 \leq c$	$35 \leq c$
h	20 to 30	30 to 40	40 to 65	65 to 105
l_t	c)	c)	c)	c)

The thickness of the sand mould surrounding the samples should be at least 40 mm for Type A and Type B, and at least 80 mm for Type C and Type D.

The case where the sampling in these dimensions is impracticable shall be as agreed between the purchaser and the manufacturer.

Notes a) t indicates the relevant wall thickness of cast iron.

b) The dimensions b and c are for information only.

c) The dimension l_t shall be large enough to allow that Test piece No. 14A or Test piece No. 4 specified in **JIS Z 2241** can be cut out.

8.2 Samples used for tensile test

The samples used for tensile test shall be in accordance with either 8.1.3.1 or 8.1.3.2.

8.3 Samples used for impact test

The samples used for impact test shall be in accordance with either 8.1.3.1 or 8.1.3.2.

8.4 Samples used for chemical analysis

At least one sample used for chemical analysis shall be taken in accordance with 8.1.1 b) for every test unit.

8.5 Samples used for hardness test

The samples used for hardness test shall be in accordance with either 8.1.3.1 or 8.1.3.2. As agreed between the purchaser and the manufacturer, a cast iron itself may be used.

8.6 Samples used for graphite form and microstructure tests

The samples used for graphite form and microstructure tests shall be in accordance with either 8.1.3.1 or 8.1.3.2. As agreed between the purchaser and the manufacturer, a cast iron itself may be used.

8.7 Samples used for specific mechanical properties tests

The samples used for specific mechanical properties tests shall be in accordance with either 8.1.3.1 or 8.1.3.2. If the purchaser and the manufacturer have agreed on a sampling position, samples may be taken from the agreed position.

8.8 Samples used for physical properties tests

The samples used for physical properties tests shall be in accordance with either 8.1.3.1 or 8.1.3.2. If the purchaser and the manufacturer have agreed on a sampling position, samples may be taken from the agreed position.

9 Heat treatment

9.1 General

If requested by the purchaser, the manufacturer shall perform heat treatment on the cast irons. The type of heat treatment and heat treating conditions used shall be as agreed between the purchaser and the manufacturer. In the absence of agreement, the decision shall be left to the manufacturer.

9.2 Heat treatment on samples

Separately cast or side-by-side cast samples shall be heat-treated in the same furnace and at the same time as the cast irons, and for the same number of times as the cast irons.

Cast-on samples should not be detached from the cast iron until the end of heat treatment, unless otherwise agreed between the purchaser and the manufacturer.

Samples cut from a casting shall be obtained after heat treatment of cast iron itself.

10 Test pieces

10.1 Test units and number of tests

10.1.1 Test units

The test unit refers to the cast irons cast from one or more ladles, or as necessary,

the cast irons heat treated one or more times after casting. Unless otherwise agreed between the purchaser and the manufacturer, one sample from every test unit shall represent the mechanical properties of the test unit.

If the in-process quality assurance system defined by the manufacturer specifies the amalgamation of test units and this can guarantee the mechanical properties, two or more test units may be amalgamated as agreed between the purchaser and the manufacturer, and the test may be performed with the representative test unit from among them.

In the absence of agreement, one sample per test unit shall express the mechanical properties of the test unit.

When the in-mould process is applied, the test unit shall be as agreed between the purchaser and the manufacturer.

Examples of test units are as follows :

- when a graphite spheroidizing treatment is performed on portions of less than 2 000 kg in mass of molten metal : the number of cast irons poured from the same ladle;
- a single cast iron of at least 200 kg in mass : one piece of the cast iron;
- when produced from a continuous pouring furnace : the number of cast irons cast with the amount of graphite spheroidizing treated molten metal in each treatment ladle or transfer ladle used to replenish the molten metal to the continuous pouring furnace continuously;
- when different heat treatments are performed on distinct cast irons of the test unit : the number of cast irons undergoing each heat treatment.

10.1.2 Number of tests

At least one cast test piece satisfying the test unit requirement in 10.1.1 shall be prepared, and tested at least once in accordance with Clause 11. Other number of tests may apply as agreed between the purchaser and the manufacturer.

If the in-process quality assurance system does not specify the amalgamation of test units, the number of tests shall be as agreed between the purchaser and the manufacturer.

When the in-mould process is applied, the number of tests shall be as agreed between the purchaser and the manufacturer.

10.2 Cutting method, shapes, dimensions and number of test pieces

10.2.1 Cutting method of test pieces

The cutting method of test pieces shall be in accordance with the following a) to c).

a) Cast test pieces

- 1) Cast test pieces shall be cut from the shaded portion of any of the cast samples shown in Table 6 to Table 9.
- 2) The cutting method of test pieces from the cast samples should refer to Annex H.

b) Test pieces cut from a casting

- 1) Test pieces cut from a casting shall be cut from the sample of **8.1.3.2** as agreed between the purchaser and the manufacturer. In the absence of agreement, the manufacturer shall determine the cutting portion.
 - 2) The cutting portion shall be such that the graphite particles in the sample are representative of those in the cast iron and the surface layer shall not contain abnormal structures or other “flaws,” ensured by agreement between the purchaser and the manufacturer. In the absence of agreement, the decision shall be left to the manufacturer.
 - 3) The dimensions and diameter of test pieces shall be as agreed between the purchaser and the manufacturer. In the absence of agreement, the decision shall be left to the manufacturer.
 - 4) The centreline of test piece should be located at the midpoint between the surface and the centre of the cast iron.
- c) The details of tensile test pieces to be cut from samples with a wall thickness less than 12.5 mm and of tensile test shall be as agreed between the purchaser and the manufacturer.

10.2.2 Shapes and dimensions of test pieces

The shapes and dimensions test pieces shall be as follows.

a) Tensile test piece

- 1) The shapes and dimensions of tensile test piece shall be in accordance with those of Test piece No. 14A specified in **JIS Z 2241**. Test piece No. 4 may be used as agreed between the purchaser and the manufacturer.
- 2) If it is necessary to use a test piece of a different diameter than that of Test piece No. 14A specified in 1), the original gauge length shall be in accordance with Formula (1).

$$L_o = 5.65 \times \sqrt{S_o} \text{ or } L_o = 5 \times d \dots\dots\dots (1)$$

where, L_o : original gauge length (mm)
 S_o : original cross-sectional area of parallel part (mm²)
 d : diameter of parallel part (mm)

If Formula (1) is not applicable to the determination of original gauge length, the size of test piece shall be as agreed between the purchaser and the manufacturer.

b) Impact test piece

- 1) The shapes and dimensions of impact test piece shall be in accordance with **JIS Z 2242**.
- 2) The shape and dimensions of test pieces shall be in accordance with V-notched impact test pieces. Other notched test pieces may be used as agreed between the

purchaser and the manufacturer.

c) Other test pieces

Test pieces of other shapes and dimensions than those of **a)** and **b)** shall be as agreed between the purchaser and the manufacturer. In the absence of agreement, the decision shall be left to the manufacturer.

10.2.3 Number of test pieces

The number of test pieces shall be as follows.

- a) The number of tensile test pieces, except the reserves, shall be one. At least two reserve test pieces should be prepared, considering the retests. The case where two test pieces for retest cannot be cut out shall be as agreed between the purchaser and the manufacturer.
- b) The number of impact test pieces, except the reserves, shall be three. At least six reserve test pieces should be prepared, considering the retests. The case where two test pieces for retest cannot be cut out shall be as agreed between the purchaser and the manufacturer.
- c) The number of test pieces other than those for tensile test and impact test shall be as agreed between the purchaser and the manufacturer. In the absence of agreement, the decision shall be left to the manufacturer.

11 Test methods

11.1 Tensile test

The tensile test shall be in accordance with JIS Z 2241.

11.2 Impact test

The impact test shall be in accordance with **JIS Z 2242**.

11.3 Chemical analysis

The chemical analysis shall be in accordance with **JIS G 0320**. If the chemical analysis is performed in accordance with **JIS G 1253**, the samples shall be taken from white pig-iron samples.

11.4 Hardness test

The hardness test shall be in accordance with **JIS Z 2243-1**.

The hardness of one test piece shall be measured on the test pieces or at one or several positions on the cast irons as agreed between the purchaser and the manufacturer.

If it is impracticable to perform the hardness test on the cast iron, the hardness test may be performed on a knob for hardness test prepared onto the cast iron.

In the absence of agreement for the measurement position, the manufacturer shall select the measurement position.

The hardness range that meets the specified tensile properties shall be in accordance

with Annex E.

11.5 Graphite forms and microstructure tests

11.5.1 Graphite form test

- a) The test shall be in accordance with Annex JA or Annex F, or may be in accordance with Annex JB as agreed between the purchaser and the manufacturer.
- b) If the test results of Annex JB do not conform to **7.6.1**, the test may be invalidated and a retest may be performed in accordance with Annex JA or Annex F.
- c) Test results shall be accompanied by “**JIS** method” if Annex JA is applied, “**ISO** method” if Annex F is applied, and “sound speed method” if Annex JB is applied.

11.5.2 Microstructure test

The test items shall be as agreed between the purchaser and the manufacturer.

The measurement shall be made on the test pieces, or at one or several positions on the cast irons determined as agreed between the purchaser and the manufacturer.

In the absence of agreement for the test items and measurement positions, they shall be selected by the manufacturer.

11.6 Specific mechanical properties tests

The specific mechanical properties tests shall be as agreed between the purchaser and the manufacturer.

11.7 Physical properties tests

The physical properties tests shall be as agreed between the purchaser and the manufacturer.

11.8 Internal soundness test

The internal soundness test shall be in accordance with the nondestructive testing such as liquid penetrant testing, magnetic particle testing, ultrasonic testing and radiographic testing as agreed between the purchaser and the manufacturer.

11.9 Appearance test

The appearance test shall be as agreed between the purchaser and the manufacturer.

12 Retests

12.1 Need for retests

If the results of tensile test according to **11.1** fail to conform to the requirements of **7.2**, the test is regarded as invalid on the grounds as described in **12.2**, and retests may be performed.

Retests shall be performed in accordance with **12.3**, and all the results shall conform to **7.2**.

If the results of impact test according to **11.2** fail to conform to the requirements of

7.3, the test is regarded as invalid on the grounds as described in **12.2**, and retests may be performed.

Retests shall be performed in accordance with **12.3**, and all the results shall conform to **7.3**.

12.2 Test invalid conditions

12.2.1 Tests invalid

A test is invalid if the test falls under any of the following **a)** to **d)** :

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

12.2.2 Partially non-conforming test results

If any results of the test performed according to **11.1** do not conform to the requirements in **7.2** or any results of **11.2** do not conform to **7.3** for reasons other than those given in **12.2.1**, the test shall be regarded as invalid.

12.3 Retests of invalid cast irons

12.3.1 General

The retests of tests invalid according to **12.2.1** shall be made on the reserve test pieces described in **10.2.3** or test pieces machined from the reserve samples described in **8.1.1 i)** once in accordance with **11.1** and/or **11.2**. The result of the retest shall be substituted for the result of the invalid test.

A retest of a partially non-conforming test according to 12.2.2 shall be performed in accordance with 12.3.2 and/or 12.3.3 with a reserve test piece of 10.2.3 or a test piece machined from a reserve sample of 8.1.1 i), and the results of a partially non-conforming test shall be replaced by the results of the retest.

12.3.2 Retest of tensile test

If the results of tensile test do not conform to **7.2**, the manufacturer may perform a retest for the test not conforming to the requirements, using reserve test pieces of the cast iron and the representative sample of **10.2.3 a)**.

The retest, if performed, shall be as follows.

- a) The retest shall be performed twice in accordance with 11.1.
- b) If both of results of two retests conform to **7.2**, the cast iron shall be deemed to conform to this Standard.
- c) If any of the two retest results fails to conform to **7.2**, the cast iron shall be deemed not to conform to this Standard.

12.3.3 Retest of impact test

If the results of impact test do not conform to **7.3**, the manufacturer may perform a retest for the test not conforming to the requirements, using reserve test pieces of the cast iron and the representative sample of **10.2.3 b)**.

The retest, if performed, shall be as follows.

- a) The retest shall be performed twice in accordance with **11.2**.
- b) If both of results of two retests conform to **7.3**, the cast iron shall be deemed to conform to this Standard.
- c) If any of the two retest results fails to conform to **7.3**, the cast iron shall be deemed not to conform to this Standard.

13 Heat treatment of non-conforming cast irons

13.1 General

For cast irons for which test results are not conforming to this Standard, unless disposal in this case is specified, retests may be made according to **13.4** using the reserve samples described in **8.1.1 i)** after heat treatment of **13.2** or **13.3**. The re-heat-treatments and retests are permitted for the following cast irons :

- a) cast irons in as-cast condition whose test result according to **11.1** does not conform to **7.2**, or whose test result according to **11.2** does not conform to **7.3**;
- b) heat-treated cast irons whose test result according to **11.1** does not conform to **7.2** or whose test result according to **11.2** does not conform to **7.3** due to defects in heat treatment.

13.2 Heat-treatment of cast irons as-cast condition

- a) The manufacturer shall perform the heat treatment of Clause **9** on the cast irons and reserve samples described in **8.1.1 i)**.
- b) The number of heat-treatments shall not exceed two.

13.3 Re-heat-treatment of heat-treated cast irons

- a) The manufacturer shall perform the heat treatment of Clause **9** on the cast irons and reserve samples described in **8.1.1 i)**.
- b) The number of re-heat-treatments shall not exceed two.

13.4 Retest of heat-treated cast irons

The cast irons heat-treated according to **13.2** or **13.3** shall be deemed to conform to this Standard if they satisfy **7.2** when tested according to **11.1** or satisfy **7.3** when tested according to **11.2**.

14 Inspections

The inspections of cast irons shall be as follows.

- a) The tensile properties shall conform to **7.2**.

- b) The impact property shall conform to **7.3**.
- c) The chemical composition shall conform to **7.4**.
- d) The hardness shall conform to **7.5**.
- e) The graphite form shall conform to **7.6.1**.
- f) The microstructure shall conform to **7.6.2**.
- g) The specific mechanical properties shall conform to **7.7**.
- h) The physical properties shall conform to **7.8**.
- i) The internal soundness shall conform to **7.9**.
- j) The shape, dimensions, dimensional tolerances, machining allowances, draft angle, and mass shall conform to **7.10**.
- k) The appearance shall conform to **7.11**.

15 Marking

Each product or package of cast irons shall be marked with the following information. Some of the information may be omitted upon approval of the purchaser.

- a) Number of this Standard
- b) Designation
- c) Serial number or its abbreviation
- d) Manufacturer's name or identifying brand

16 Report

If requested by the purchaser, the manufacturer shall submit a report containing the information including: the designation, serial number, manufacturer's name, test results and test methods used.

Annex A (informative)

Additional information on solid solution strengthened ferritic spheroidal graphite cast irons

A.1 General

This Annex applies to SSSGI designations as given in Table 3.

A.2 Material constitution

A.2.1 Chemical composition

In order to fulfil the requirements for the tensile properties, a SSSGI strengthened by Si is recommended (see Table A.1).

Table A.1 Guidance values for Si content in SSSGI

Designation	Si content ^{a) b)} %
<u>FCD 450-18</u>	3.20
<u>FCD 500-14</u>	3.80
<u>FCD 600-10</u>	4.20
Sampling technique and method of chemical analysis for high-Si can have significant effects on the reported silicon content. It is therefore important to establish sampling parameters and to select chemical analysis methods which can be confirmed as giving accurate results.	
Notes ^{a)} Si content may be lower due to other alloying elements or for thick sections.	
^{b)} With increasing Si content, the carbon content should be decreased correspondingly.	

A.2.2 Matrix structure

The matrix should be predominantly ferrite with a maximum pearlite content of 5 %. The amount of free cementite/carbides should be less than 1 %.

A.2.3 Graphite form

The graphite structure should be mainly of Form VI and Form V in accordance with ISO 945-1 (see Figure F.1) or graphite form with a roundness factor of 0.6 or more.

Due to the increased Si content, these SSSGI can show graphite nodularity reduction in thick sections. However, SSSGI ferritic matrix structures are much less sensitive in tensile properties for reduced graphite nodularity, compared to SGI strengthened by substantial amounts of pearlite.

A proportion of Form III graphite can be accepted, provided the remainder is mainly of Form VI and Form V, to fulfil the minimum tensile properties specified in this

Standard.

A.3 Supplementary information

A.3.1 Application

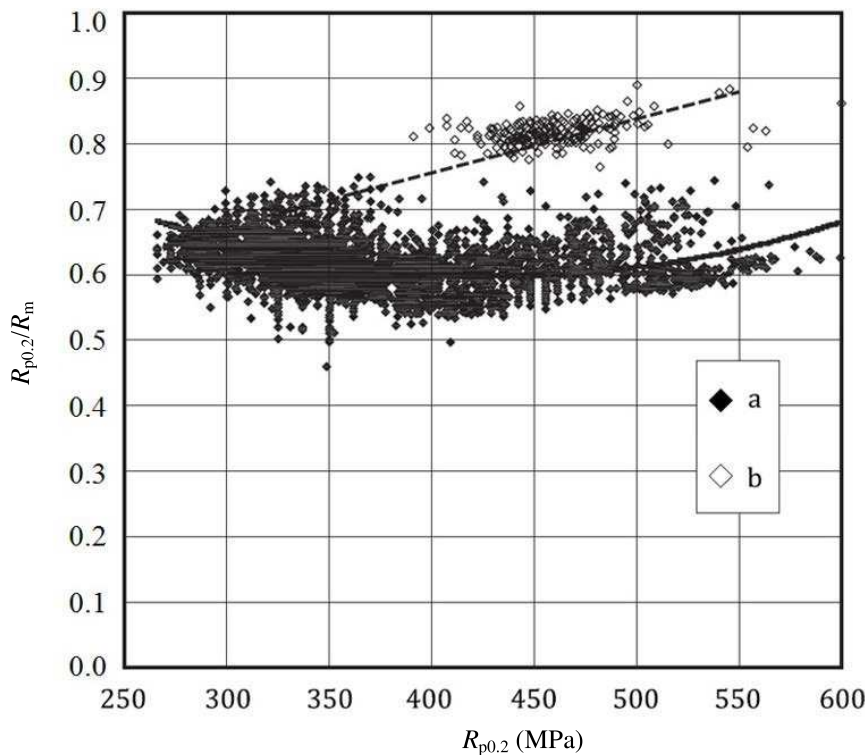
These SSSGI are used for applications where concurrently high ductility, high 0.2 % proof strength and good machinability are required.

A.3.2 Mechanical properties

A.3.2.1 0.2 % proof strength

One of the characteristic properties of SSSGI is the high ratio (0.2 % proof strength/tensile strength) being 0.75 to 0.85 as compared to the lower ratio being 0.55 to 0.65 for SGI (see Figure A.1).

Despite this higher ratio, ductility determined as elongation after fracture values are concurrently considerably higher for SSSGI (compare Table 2 and Table 3).



where, a : SGI
 b : SSSGI
 R_m : tensile strength (MPa)
 $R_{p0.2}$: 0.2 % proof strength (MPa)

Figure A.1 Ratio (0.2 % proof strength/tensile strength) determined at room temperature (cast test piece of 25 mm in wall thickness)