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Spheroidal graphite cast iron — Classification

Fonte à graphite sphéroïdal — Classification

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 1083 was prepared by Technical Committee ISO/TC 25, *Cast iron and pig iron*.

This second edition cancels and replaces the first edition (ISO 1083 : 1976), in which only six grades of spheroidal graphite cast iron were defined.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Spheroidal graphite cast iron — Classification

0 Introduction

Spheroidal graphite, or nodular graphite, cast iron is a casting alloy, iron and carbon based, the latter element being present mainly in the form of spheroidal graphite particles, of form VI as shown in ISO 945.

The properties of spheroidal graphite cast iron depend in particular on the form of the graphite and the structure of the matrix.

This International Standard deals with the classification of spheroidal graphite cast irons in accordance with the mechanical properties of the material.

It includes two distinct classifications :

- mechanical properties measured on test pieces from separately cast test samples;
- mechanical properties measured on test pieces from cast-on test samples.

By agreement between the manufacturer and purchaser, the material properties may also be determined using test pieces taken from samples cut from the casting, the agreement specifying in particular the conditions of sampling and the values to be obtained.

If hardness is recognized by the purchaser and the manufacturer as being essential for the application, and is selected by agreement between them as being the basis for the inspection test, the castings are supplied in conformity with the requirements of the annex.

1 Scope and field of applications

This International Standard defines the grades of spheroidal graphite cast iron and their classification in two distinct categories.

1.1 Classification as a function of the mechanical properties measured on machined test pieces prepared from separately cast test samples

The nine grades of spheroidal graphite cast iron for this category are given in tables 1 and 2.

These grades apply to castings from sand moulds of comparable thermal diffusivity. Subject to amendments to be agreed on the order, they may apply to castings obtained by other methods such as casting in static moulds, or centrifugal casting. They do not apply to castings obtained by continuous casting.

Whatever the method used for obtaining the castings, the grades are based on the mechanical properties measured on samples cast separately in a sand mould or mould of comparable thermal diffusivity.

This International Standard does not apply to spheroidal graphite cast iron used for pipe-lines, which are the subject of ISO 2531 and ISO 7186.

1.2 Classification as a function of mechanical properties measured on machined test pieces prepared from cast-on test samples

The six grades of spheroidal graphite cast iron for this category are given in tables 3 and 4; they normally apply to castings of thickness between 30 and 200 mm, and with a unit mass greater than 2 000 kg.

2 References

ISO 148, *Steel — Charpy impact test (V-notch)*.

ISO 945, *Cast iron — Designation of microstructure of graphite*.

ISO 6506, *Metallic materials — Hardness test — Brinell test*.

ISO 6892, *Metallic materials — Tensile testing*.

3 General requirements

3.1 Production

The method of producing spheroidal graphite cast iron, its composition and any heat treatment are left to the discretion of the manufacturer, who shall ensure that the property requirements specified in this International Standard are complied with for the grade of material specified in the order.

However, for cast iron to be used in special applications, the type of sample, chemical composition and heat treatment may be the subject of an agreement between the purchaser and the manufacturer.

3.2 Properties of the material

3.2.1 Mechanical properties

The properties of materials are given in clause 4 for machined test pieces prepared from separately cast test samples, and in clause 5 for test pieces prepared from cast-on test samples.

3.2.2 Microstructure

Where a microscopic examination is required, it shall be verified that the structure contains a minimum of 80 % of form V or VI graphite in accordance with ISO 945. The number of tests and the sampling conditions shall be defined by agreement between the purchaser and the manufacturer.

Non-destructive methods exist for testing the nodularity of the graphite and the matrix structure, which may be used, if necessary, to limit the number of micrographs to be made.

In cases of dispute, the result of the microscopic examination, which shall be carried out in accordance with an agreement between the purchaser and the manufacturer, shall prevail.

4 Requirements for separately cast test samples

4.1 Formation of batches

4.1.1 Non-continuous production

For non-continuous production, the batches shall be made up of castings made of iron originating from the same treatment ladle and, where necessary, having undergone the same heat treatment. The maximum mass of the batch shall be 2 000 kg of fettled castings. A single casting comprises a batch if its mass is equal to or greater than 2 000 kg.

4.1.2 Continuous production

For continuous production of the same grade, the maximum mass of the batch is limited to the tonnage produced in 2 h.

4.2 Number of tests per batch

4.2.1 A tensile test and, for the grades concerned, an impact test shall be carried out on each batch.

4.2.2 Notwithstanding the requirements of 4.1 and 4.2.1, several batches may be combined for the purpose of acceptance, by agreement between the manufacturer and the pur-

chaser. In this case, other types of continuous inspection shall be carried out during production — metallographic inspections, non-destructive tests, examination of fracture, bend test, etc. — in order to ensure that the successive spheroidizing treatments have been carried out in an identical manner.

4.3 Test samples and test pieces¹⁾

The test samples cast separately in sand moulds, for tensile or impact test, shall be made from the same cast iron as the items in the batch, in conformity with the procedure to be agreed upon for the sampling (see 4.1 and 4.2). They shall be cast at the end of the casting operation.

The shape of test sample shall be selected from those shown in figures 1, 2 and 3, in such a way that the cooling rate is as close as possible to that of the castings they represent. The test pieces shall be machined from the hatched part in figures 1 and 2 or from the round bars in figure 3.

The test samples shall be stripped from the mould at a temperature not exceeding 500 °C and, if necessary, they shall be subjected to the same heat treatment as the castings which they represent and at the same time.

If the spheroidizing treatment is carried out in the mould (in-mould method) the test samples conforming to figure 1, 2 or 3 may be

- either cast side-by-side with the castings, with a joint feeder system;
- or cast separately, with a treatment device in the mould which shall resemble that of the casting as closely as possible.

4.4 Mechanical properties

4.4.1 Tensile strength, proof stress, elongation and additional information

The verification of the 0,2 % proof stress values shall be determined only if specified by the purchaser at the time of ordering.

When measured on machined test pieces prepared from separately cast test samples, the mechanical properties of spheroidal graphite cast iron shall be as specified in table 1 or 2.

4.4.2 Impact test

The specified impact values given in table 2 apply only to grades 400-18 and 350-22.

At the request of the purchaser on ordering, the impact test need not be carried out.

The letter "L" indicates that the corresponding grade shall have the specified impact strength at low temperature as given in table 2.

1) The requirements of this sub-clause may be amended for castings obtained by methods other than sand casting.

5 Requirements for cast-on test samples

5.1 Formation of batches

A single casting constitutes a batch (see 1.2 and 4.1.1).

5.2 Number of tests per batch

A tensile test and, for the grades concerned, an impact test shall be carried out on each batch.

5.3 Test samples and test pieces

The test samples from which the test pieces for tensile and/or impact test are taken are cast-on to the castings.

Cast-on test samples may be selected in preference to separately cast test samples when the unit mass of the castings is equal to or greater than 2 000 kg and when the reference thickness may vary between 30 and 200 mm.

The positioning of the cast-on samples shall be agreed between the parties concerned, taking into account the form of the casting and the system of pouring, in order to avoid any unfavourable effect on the properties of the adjacent metal.

Where castings are to be heat treated, the cast-on test samples shall not be separated from the castings until after the heat treatment.

Unless specially agreed, the test samples shall have the shape and dimensions indicated in figure 4.

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

Grade	Minimum tensile strength ¹⁾ R_m N/mm ²	Minimum 0,2 % proof stress ¹⁾ $R_{p0,2}$ N/mm ²	Minimum elongation ²⁾ A %	For information only	
				Brinell hardness HBS	Predominant constituent of structure
900-2	900	600	2	280 to 360	Bainite or tempered martensite
800-2	800	480	2	245 to 335	Pearlite or tempered structure
700-2	700	420	2	225 to 305	Pearlite
600-3	600	370	3	190 to 270	Pearlite + ferrite
500-7	500	320	7	170 to 230	Ferrite + pearlite
450-10	450	310	10	160 to 210	Ferrite
400-15	400	250	15	130 to 180	Ferrite
400-18	400	250	18	130 to 180	Ferrite
350-22	350	220	22	≤ 150	Ferrite

1) 1 N/mm² = 1 MPa

2) Elongation is measured on an initial gauge length $L_0 = 5d$, where d is the diameter of the gauge length of the test piece.

Table 2 — Minimum impact values measured on test pieces from separately cast test samples

Grade	Minimum impact values in joules, on V-notch test pieces					
	At ambient temperature 23 ± 5 °C		At -20 ± 2 °C		At -40 ± 2 °C	
	Mean value from 3 tests	Individual value	Mean value from 3 tests	Individual value	Mean value from 3 tests	Individual value
400-18	14	11				
400-18 L			12	9		
350-22	17	14				
350-22 L					12	9

5.4 Mechanical properties

5.4.1 Tensile strength, proof stress, elongation and additional information

The verification of the 0,2 % proof stress values shall be determined only if specified by the purchaser at the time of ordering.

When measured on machined test pieces prepared from cast-on test samples, the mechanical properties of spheroidal graphite cast iron shall be as specified in table 3 or 4.

NOTE — These properties cannot reflect exactly the properties of the castings themselves, but may be better approximations than those obtained on separately cast test pieces.

5.4.2 Impact test

The specified impact values given in table 4 apply only to grades 400-18 A and 350-22 A.

At the request of the purchaser on ordering, the impact test need not be carried out.

The letter "L" indicates that the corresponding grade shall have the specified impact strength at low temperature as given in table 4.

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

Grade ¹⁾	Reference thickness e mm	Minimum tensile strength ²⁾ R_m N/mm ²	Minimum 0,2 % proof stress ²⁾ $R_{p0,2}$ N/mm ²	Minimum elongation ³⁾ A %	For information only	
					Brinell hardness HBS	Predominant constituent of structure
700-2 A	$30 < e \leq 60$	700	400	2	220 to 320	Pearlite
	$60 < e \leq 200$	650	380	1		
600-3 A	$30 < e \leq 60$	600	360	2	180 to 270	Pearlite + ferrite
	$60 < e \leq 200$	550	340	1		
500-7 A	$30 < e \leq 60$	450	300	7	170 to 240	Ferrite + pearlite
	$60 < e \leq 200$	420	290	5		
400-15 A ⁴⁾	$30 < e \leq 60$	390	250	15	130 to 180	Ferrite
	$60 < e \leq 200$	370	240	12		
400-18 A ⁴⁾	$30 < e \leq 60$	390	250	15	130 to 180	Ferrite
	$60 < e \leq 200$	370	240	12		
350-22 A	$30 < e \leq 60$	330	220	18	≤ 150	Ferrite
	$60 < e \leq 200$	320	210	15		

1) The letter "A" after the designation of the grade indicates that the properties are obtained on cast-on test samples, to distinguish them from those obtained on separately cast test samples, shown in table 1.

2) $1 \text{ N/mm}^2 = 1 \text{ MPa}$

3) The elongation is measured on an initial gauge length $L_0 = 5d$, where d is the diameter of the gauge length of the test piece.

4) The grades 400-18 A and 400-15 A are distinguished by the guaranteed impact strength values for grade 400-18 A (see table 4).

Table 4 — Minimum impact values measured on test pieces from cast-on test samples

Grade ¹⁾	Reference thickness <i>e</i> mm	Minimum impact values in joules, on V-notch test pieces					
		At ambient temperature 23 ± 5 °C		At -20 ± 2 °C		At -40 ± 2 °C	
		Mean value from 3 tests	Individual value	Mean value from 3 tests	Individual value	Mean value from 3 tests	Individual value
400-18 A	30 < <i>e</i> ≤ 60	14	11				
	60 < <i>e</i> ≤ 200	12	9				
400-18 AL	30 < <i>e</i> ≤ 60			12	9		
	60 < <i>e</i> ≤ 200			10	7		
350-22 A	30 < <i>e</i> ≤ 60	17	14				
	60 < <i>e</i> ≤ 200	15	12				
350-22 AL	30 < <i>e</i> ≤ 60					12	9
	60 < <i>e</i> ≤ 200					10	7

1) The letter "A" after the designation of the grade indicates that the properties are obtained on cast-on test samples, to distinguish them from those obtained on separately cast test samples, shown in table 2.

6 Methods of mechanical testing

6.1 Tensile test

The tensile test shall be carried out on a 14 mm diameter proportional test piece (figure 5) in accordance with ISO 6892.

If it is necessary, for technical reasons, to use a test piece of different diameter, this shall still comply with the formula :

$$L_0 = 5,65 \sqrt{S_0} = 5 d$$

where

L_0 is the original gauge length;

S_0 is the original cross-sectional area of the test piece;

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

The values given in tables 1 and 3 are mandatory. However, the 0,2 % proof stress values shall be determined only if specified by the purchaser at the time of ordering. It shall be measured on the same test pieces as those used for the tensile test.

6.2 Impact test

The impact test is applicable only to the grades listed in tables 2 and 4.

This test shall be carried out in accordance with ISO 148 (Charpy V-notch test piece), using machines with available energy compatible with the properties of the spheroidal graphite cast iron.

The material supplied shall comply with the values given in tables 2 and 4. However, the tests need not be carried out if so requested by the purchaser on ordering.

6.3 Brinell hardness test

When specified by the purchaser, the Brinell hardness test shall be carried out in accordance with ISO 6506.

The test shall be carried out on the test samples or at one or several points on the castings, in accordance with the agreement made by the manufacturer and the purchaser.

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

NOTE — Where hardness is used as the basis for the classification, refer to the annex.

6.4 Inspection requirements

NOTE — This clause is valid only until an International Standard on inspection requirements for cast iron castings is published.

6.4.1 Validity of tests

A test may be disregarded if poor results are obtained and they are not due to the quality of the cast iron itself, but are due to any of the following reasons :

- faulty mounting of the test piece or defective operation of the test machine;
- defective casting or machining of the test piece;
- fracture of the tensile test piece beyond the gauge mark;
- casting defects in the test piece, evident after fracture.

In the above cases, a new test piece shall be taken from the same test sample and the results obtained substituted for those of the defective test piece.

6.4.2 Re-tests

If any test gives results which do not conform to the specified requirements — for reasons other than those given in 6.4 — two re-tests shall be carried out for each failed test.

The batch shall be regarded as conforming to the specified requirements if the two re-tests give satisfactory results as indicated in 4.4 or 5.4.

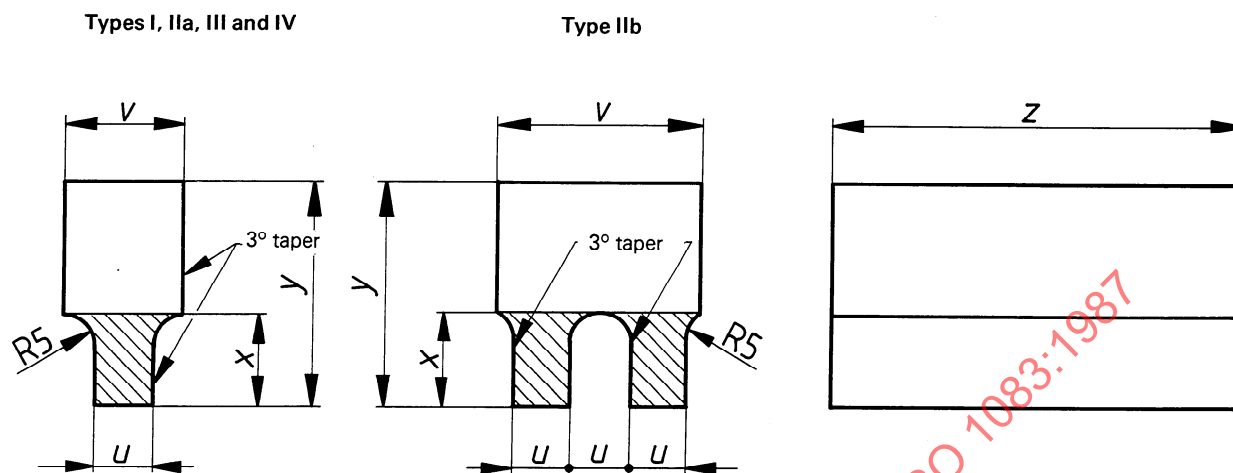
However, the batch shall be rejected if one of the re-tests is not satisfactory.

In the case of castings supplied in the as-cast condition, the manufacturer, by agreement with the purchaser, has the right to heat-treat the castings, together with the representative test samples, and re-submit them for acceptance.

In the case of a batch of castings which have undergone heat treatment, the manufacturer has the right to re-heat-treat the batch, together with the representative test samples, and re-submit them for acceptance. The number of heat treatments for retesting is restricted to two.

In cases where insufficient test material is available smaller tensile test pieces than indicated in 6.1 may be used, provided the ratio $L_0 = 5,65 \sqrt{S_0}$ is maintained.

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Dimension	Dimensions in millimetres for type				
	I	IIa	IIb	III	IV
<i>u</i>	12,5	25	25	50	75
<i>v</i>	40	55	90	90	125
<i>x</i>	30	40	40	60	65
<i>y</i> ¹⁾	80	100	100	150	165
<i>z</i>	A function of the test piece length				

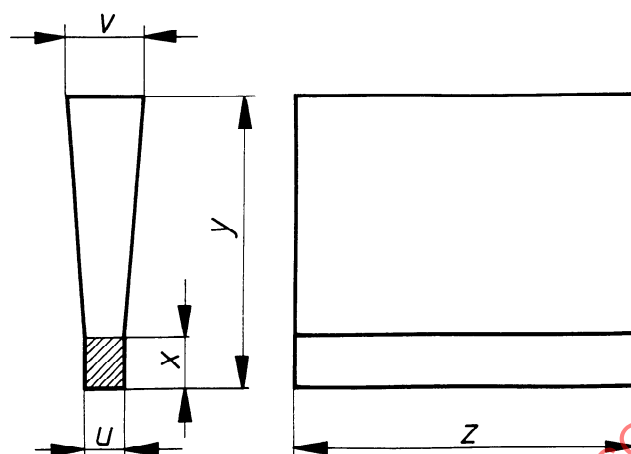
1) For information only.

The thickness of the sand mould surrounding the test sample 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 castings or castings in static moulds, the tensile properties may, by agreement between the purchaser and the manufacturer, be determined on test pieces taken from test samples of thickness less than 12,5 mm.

Figure 1 — U-shaped separately cast test sample



Dimension	Dimensions in millimetres for type			
	I	II	III	IV
<i>u</i>	12,5	25	50	75
<i>v</i>	40	55	100	125
<i>x</i>	25	40	50	65
<i>y</i> ¹⁾	135	140	150	175
<i>z</i>	A function of the test piece length			

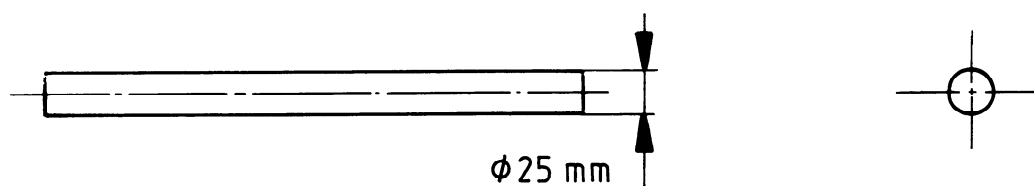
1) For information only.

The thickness of the sand mould surrounding the test sample shall be

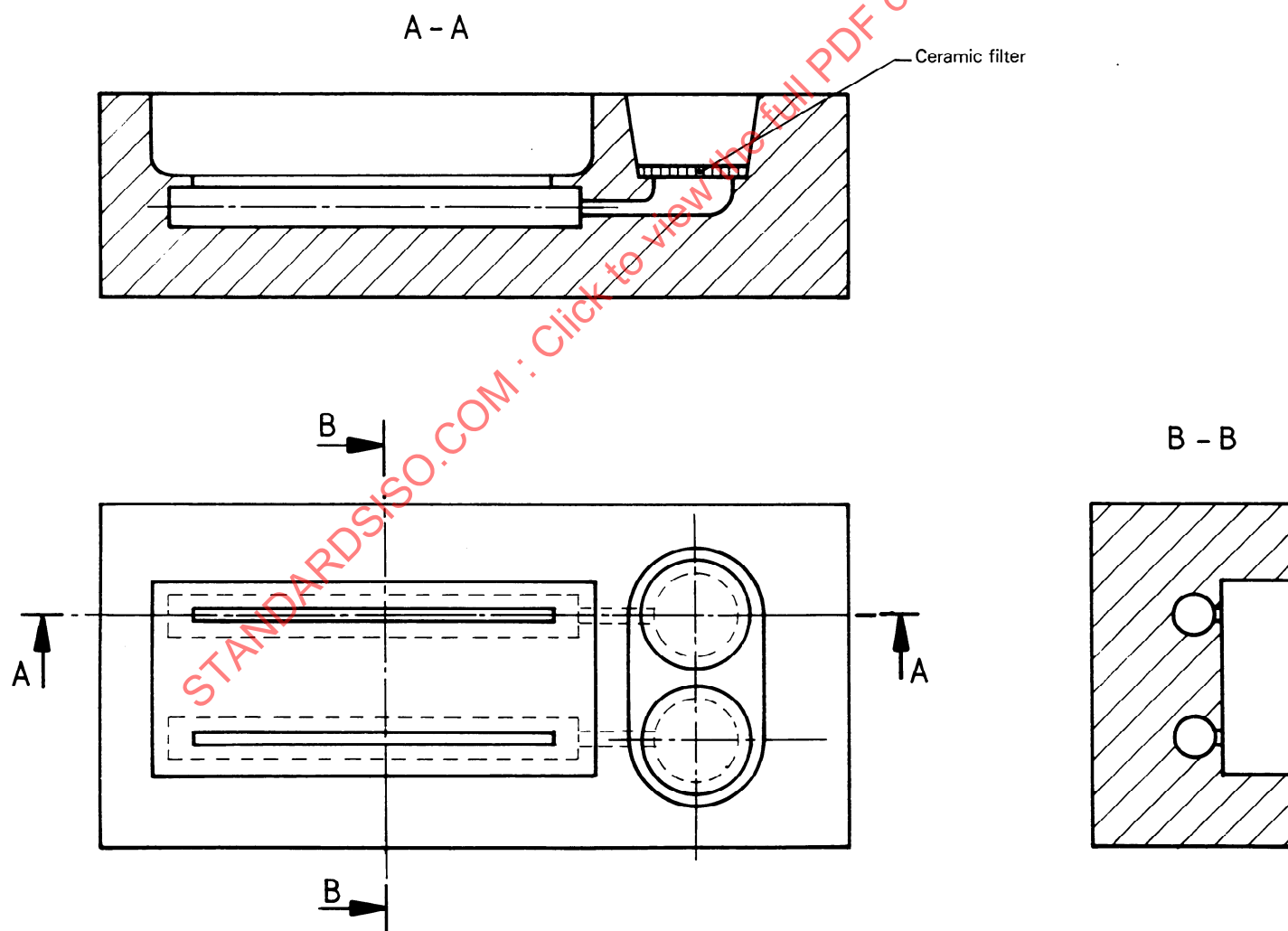
- 40 mm minimum for types I and II;
- 80 mm minimum for types III and IV.

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

Figure 2 — Y-shaped separately cast test sample

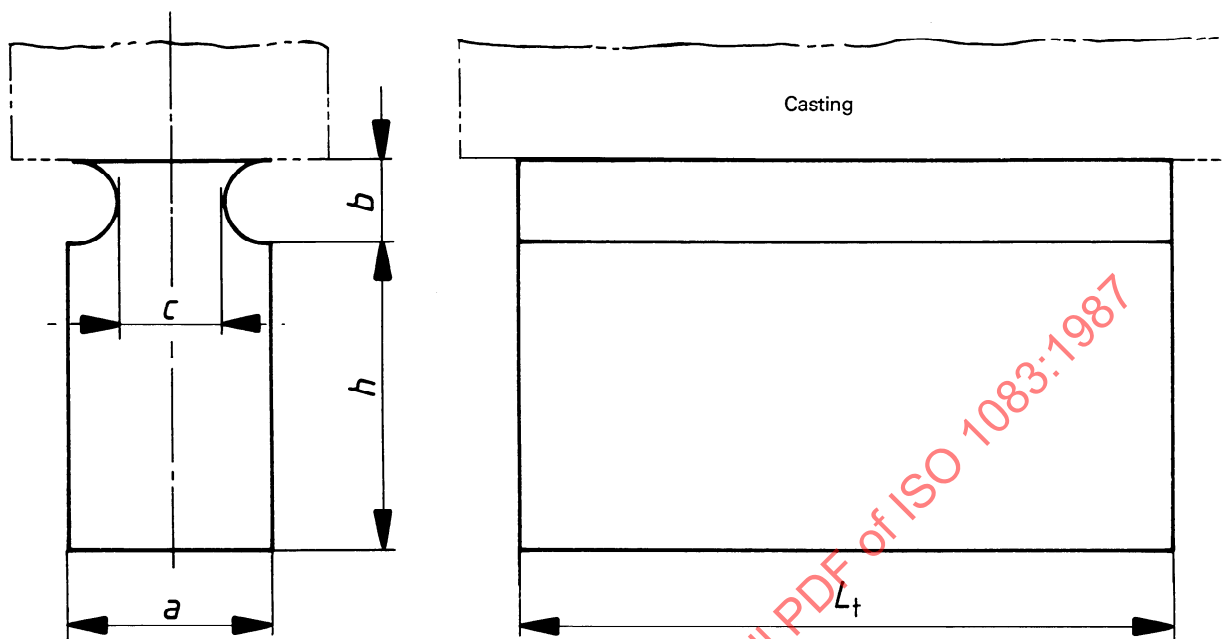


3a) — Round bar



3b) — Schematic drawing of mould, given as an example

Figure 3 — Round-bar-shaped separately cast test sample



Reference thickness of castings e	Dimensions in millimetres				
	a	b min.	c min.	h	L_t
$30 < e \leq 60$	40	30	20	40 to 60	180 ¹⁾
$60 < e \leq 200$	70	52,5	35	70 to 105	180 ¹⁾

1) The recommended total length L_t is 180 mm. In very special cases, it may be reduced, but not to less than 155 mm.

NOTE — If smaller dimensions are agreed upon, the following relationships shall be adhered to :

$$b = 0,75 a \quad \text{and} \quad c = \frac{a}{2}$$

Figure 4 — Cast-on sample block