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Microstructure of cast irons —

Part 1: Graphite classification by visual analysis

Microstructure des fontes —

Partie 1: Classification du graphite par analyse visuelle

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Foreword

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

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

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

This second edition cancels and replaces the first edition (ISO 945-1:2008), which has been technically revised. It also incorporates the Technical Corrigendum ISO 945-1:2008/Cor.1:2010. Figures 3, 4 and 5 have been corrected to a diameter of 120 mm to allow a direct comparison with the microscope display screen.

A list of all the parts in the ISO 945 series can be found on the ISO website.

Introduction

Microstructure designation is a useful feature that provides a means of classifying the graphite form, distribution and size in cast irons.

Graphite classification by visual analysis is a well-established method which is well recognized within the foundry industry as a means of quickly determining the overall graphite microstructure of a cast iron casting.

Microstructure of cast irons —

Part 1:
Graphite classification by visual analysis

1 Scope

This document specifies a method of classifying the microstructure of graphite in cast irons by comparative visual analysis.

The purpose of this document is to provide information about the method of graphite classification. It is not intended to give information on the suitability of cast-iron types and grades for any particular application.

The particular material grades are specified mainly by mechanical properties and, in the case of austenitic and abrasion resistant cast irons, by their chemical composition. The interpretation of graphite form and size does not allow a statistically valid statement on the fulfilment of the requirements specified in the relevant material standard.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 General

4.1 Designation system for classifying graphite in cast irons

When cast iron materials are examined under a microscope in accordance with this document, the graphite shall be classified by the following:

a) its form, designated by Roman numbers I to VI (see Figure 1 and Annex A);

b) its distribution, designated by capital letters A to E (see Figure 2 and Annex B); the graphite distribution designation is only specified for grey cast irons (form I);

c) its size, designated by numbers 1 to 8 (see Figures 3, 4 and 5 and Table 1).

NOTE Figures 1 to 5 show only the outlines and not the structure of the graphite.

4.2 Form

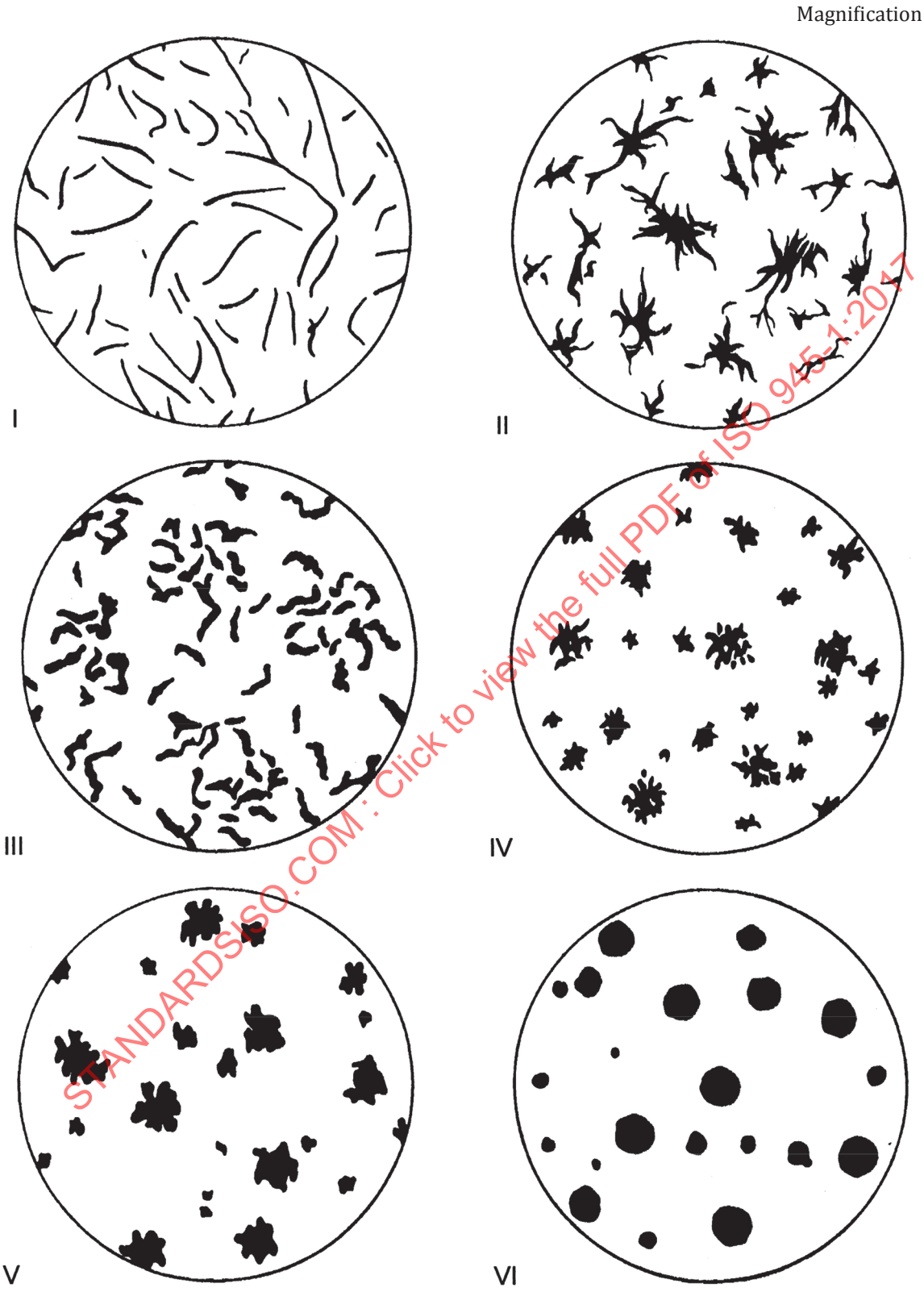


Figure 1 — Reference images for principal graphite forms in cast irons

4.3 Distribution

Magnification ×100

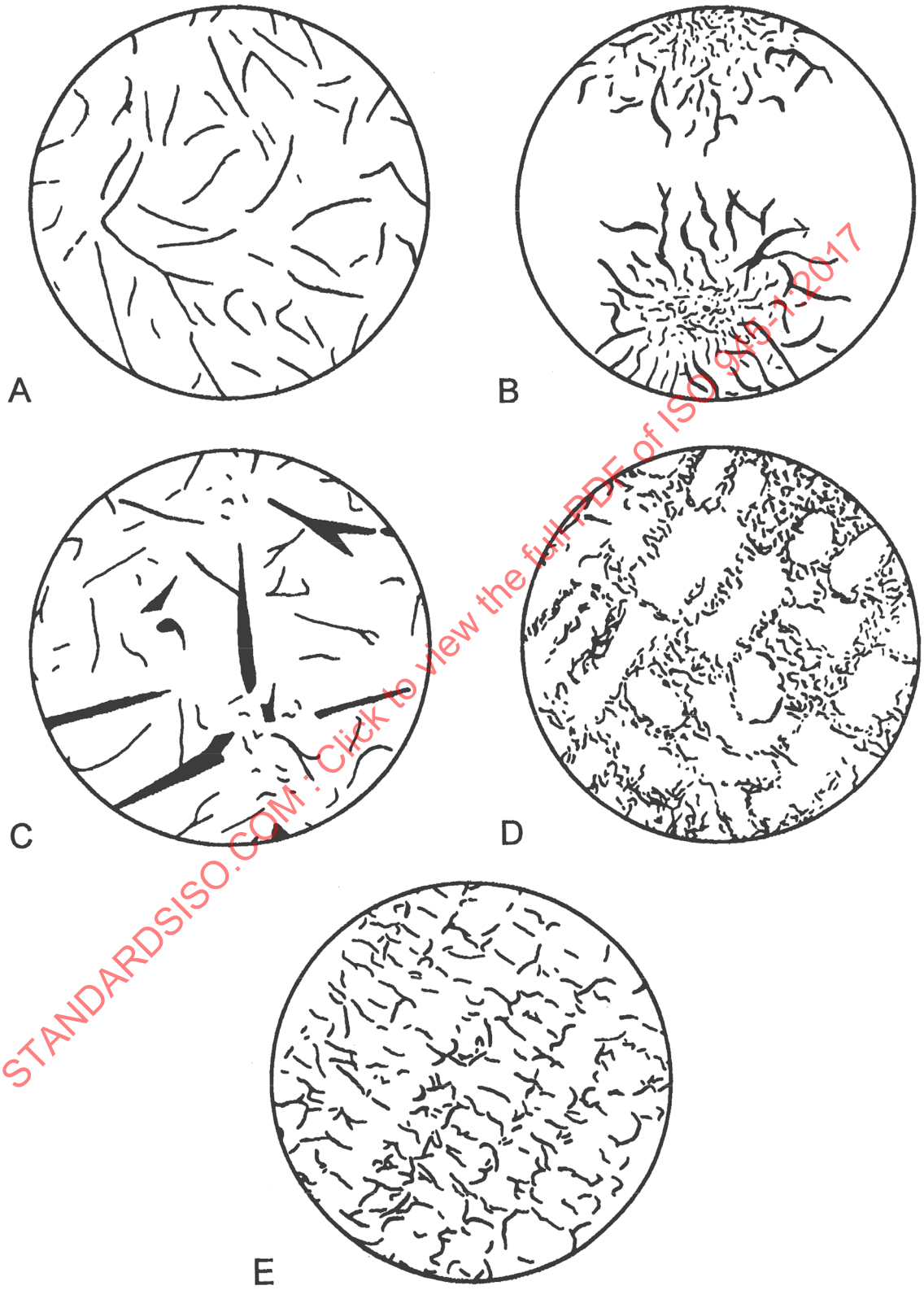
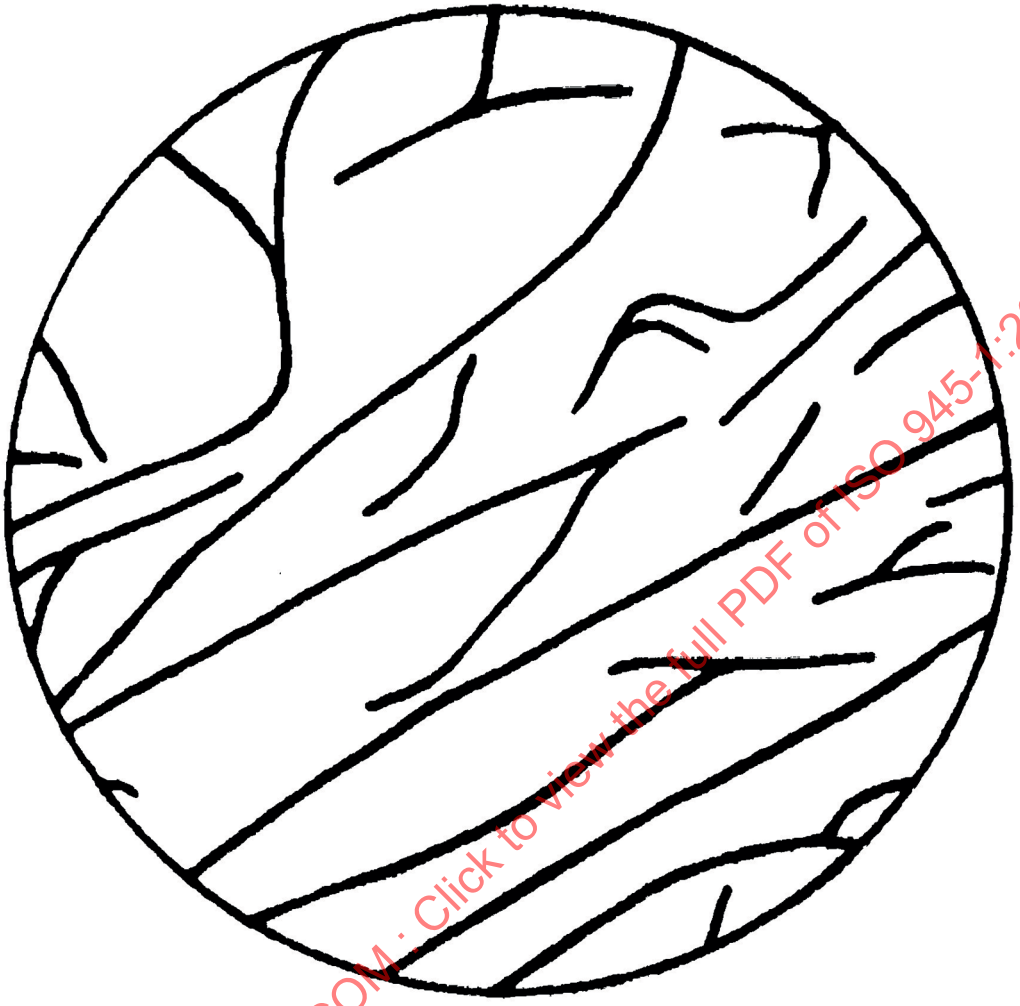


Figure 2 — Reference images for graphite distribution (form I)

4.4 Size

Magnification ×100



1

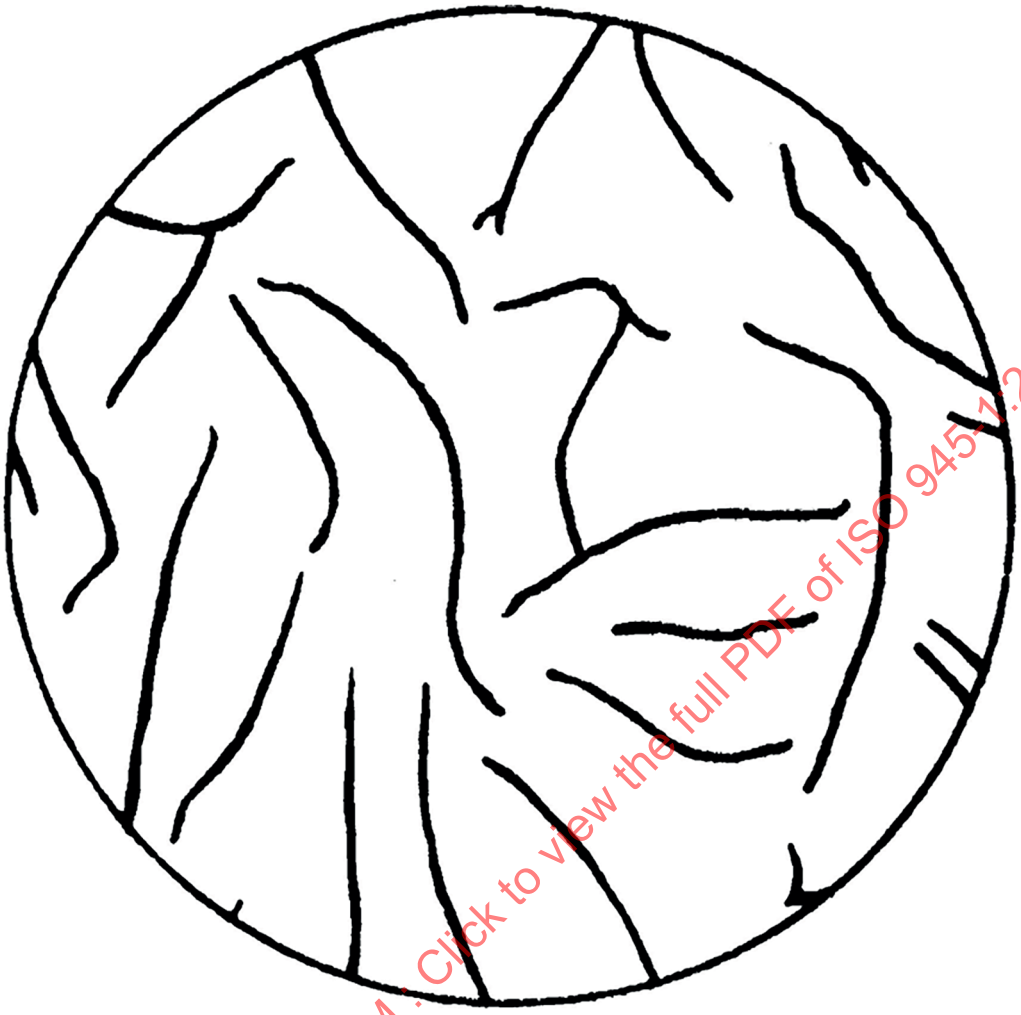
100 µm

a) Reference image for graphite size 1: ≥ 1 mm (form I)

Magnification ×100

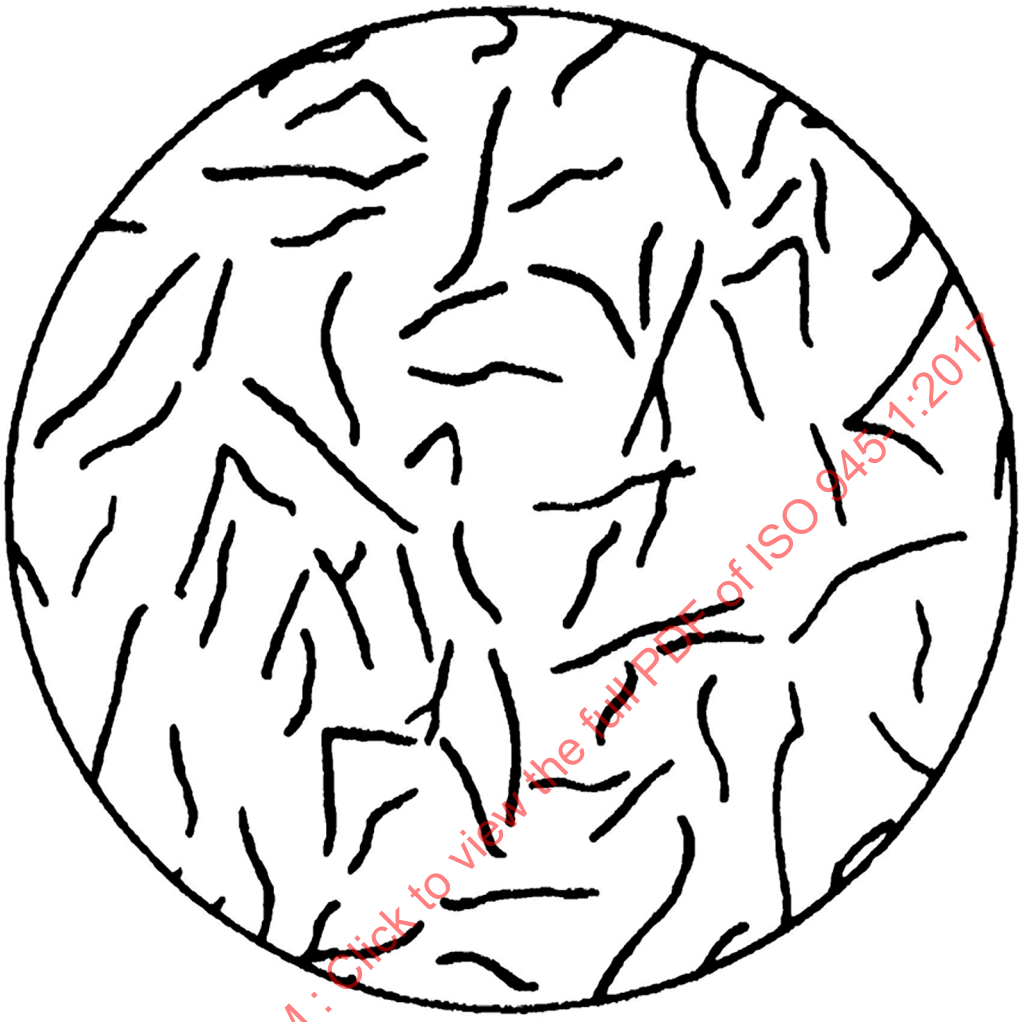
b) Reference image for graphite size 2: 0,5 mm to < 1 mm (form I)

Magnification ×100



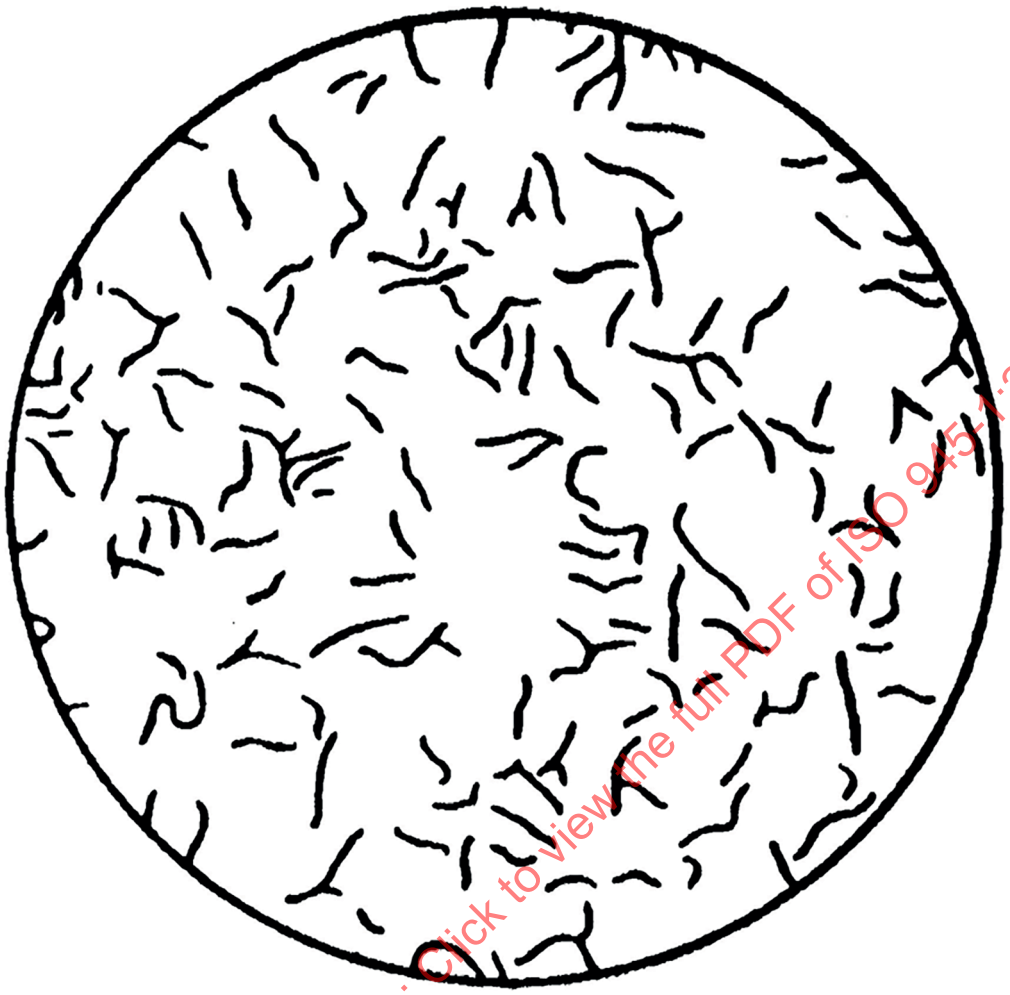
c) Reference image for graphite size 3: 0,25 mm to < 0,5 mm (form I)

Magnification ×100



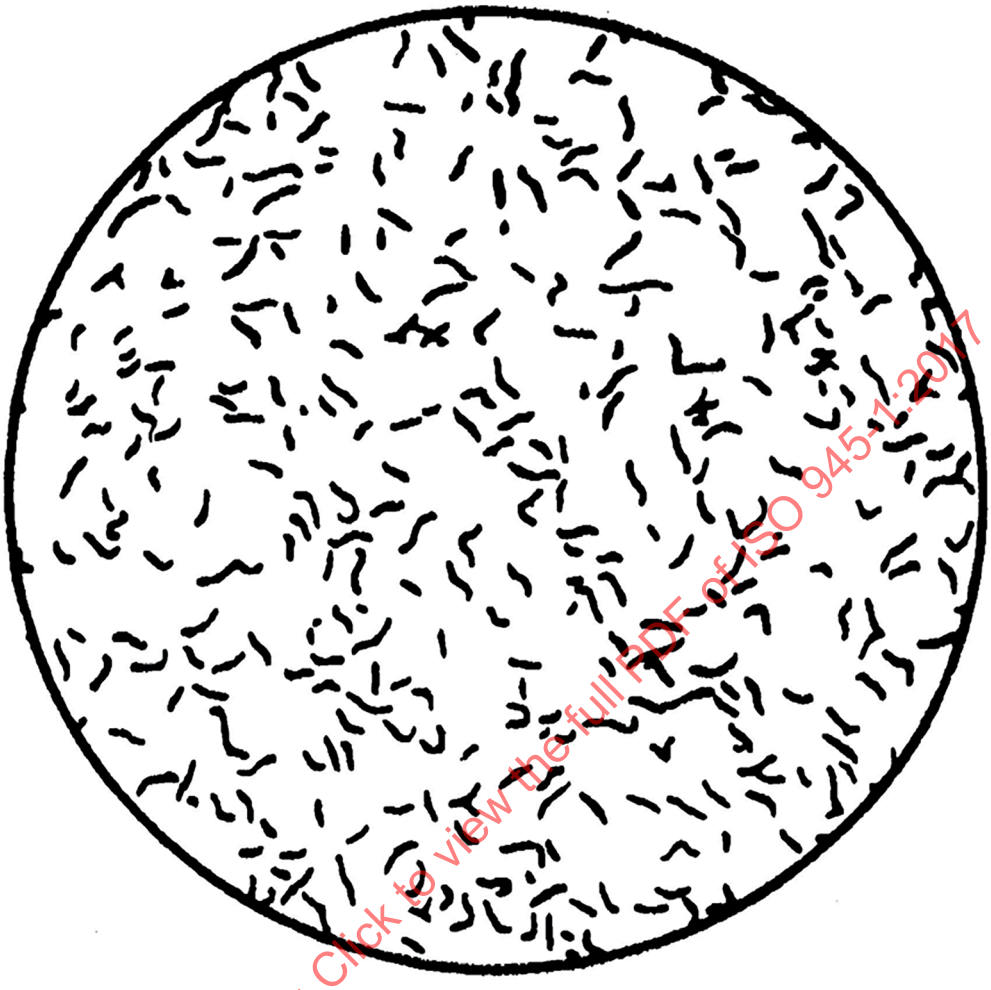
d) Reference image for graphite size 4: 0,12 mm to < 0,25 mm (form I)

Magnification ×100



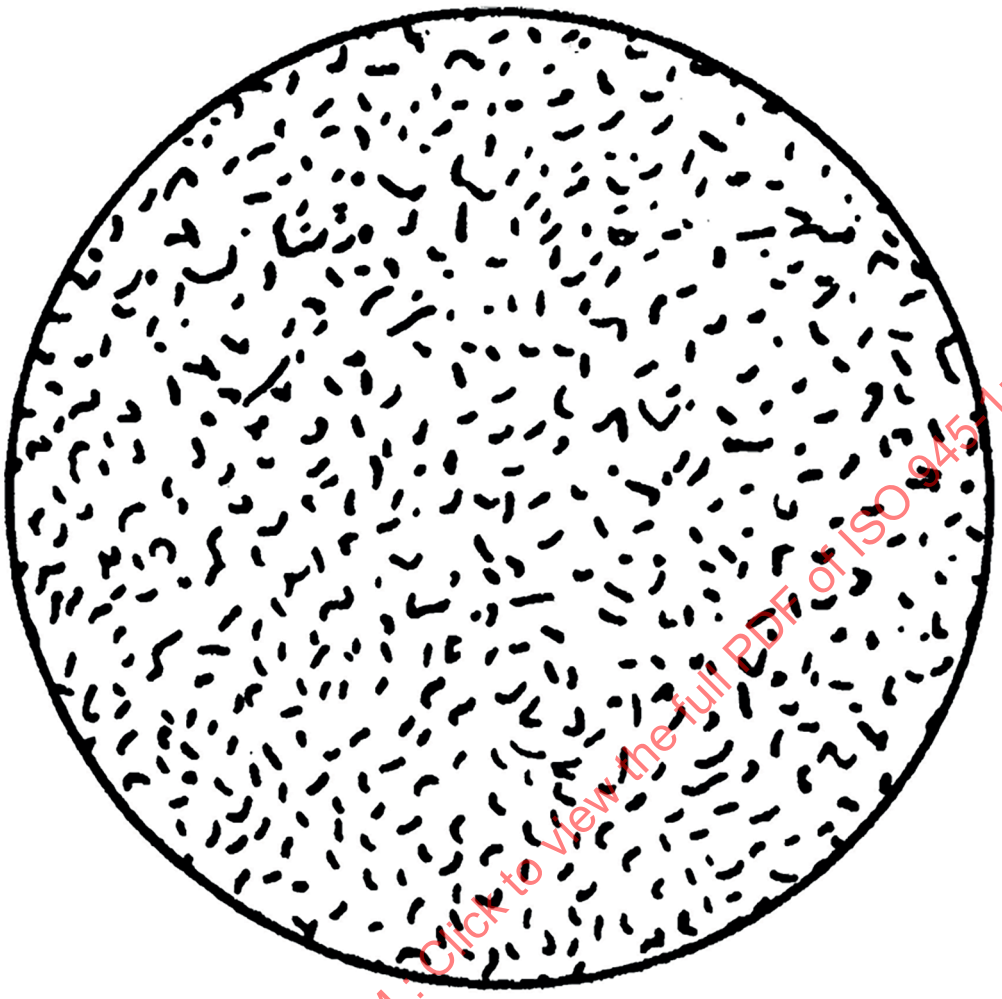
e) Reference image for graphite size 5: 0,06 mm to < 0,12 mm (form I)

Magnification ×100



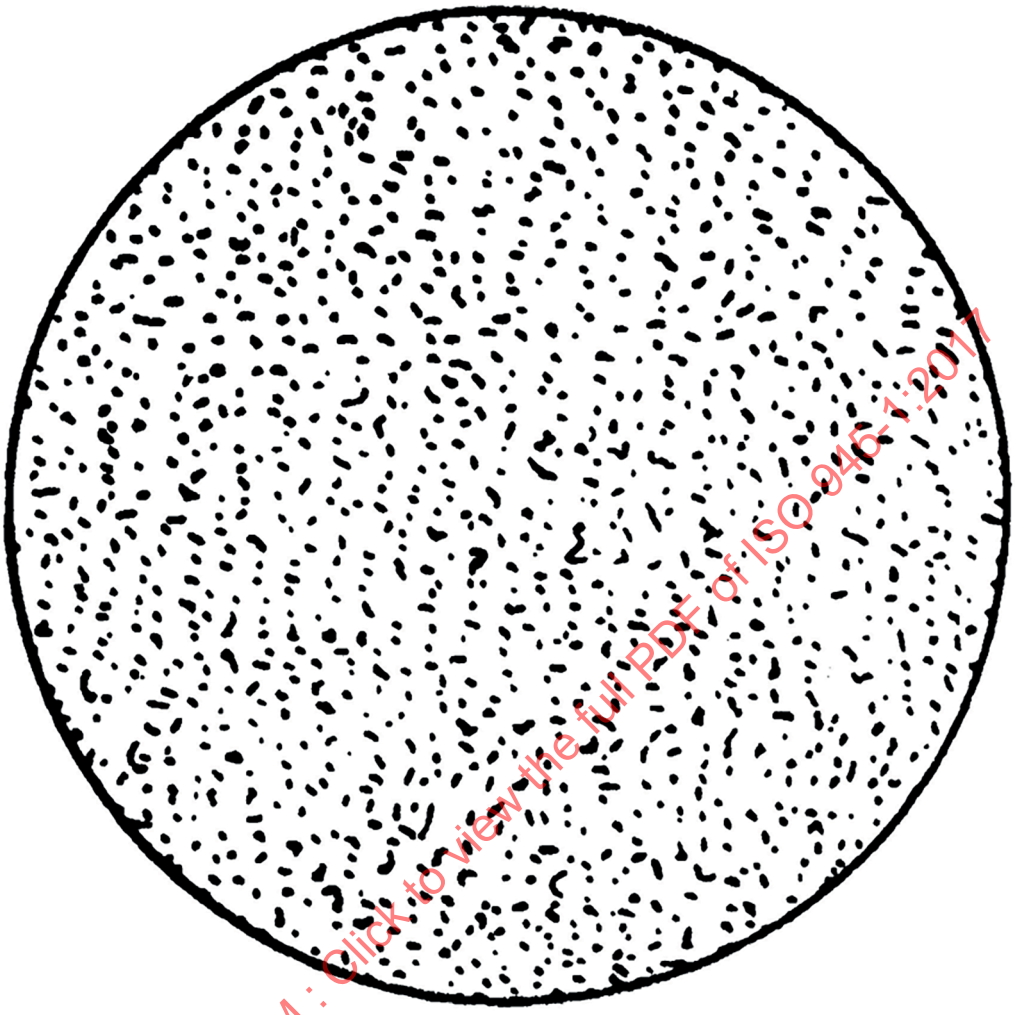
f) Reference image for graphite size 6: 0,03 mm to < 0,06 mm (form I)

Magnification ×100



g) Reference image for graphite size 7: 0,015 mm to < 0,03 mm (form I)

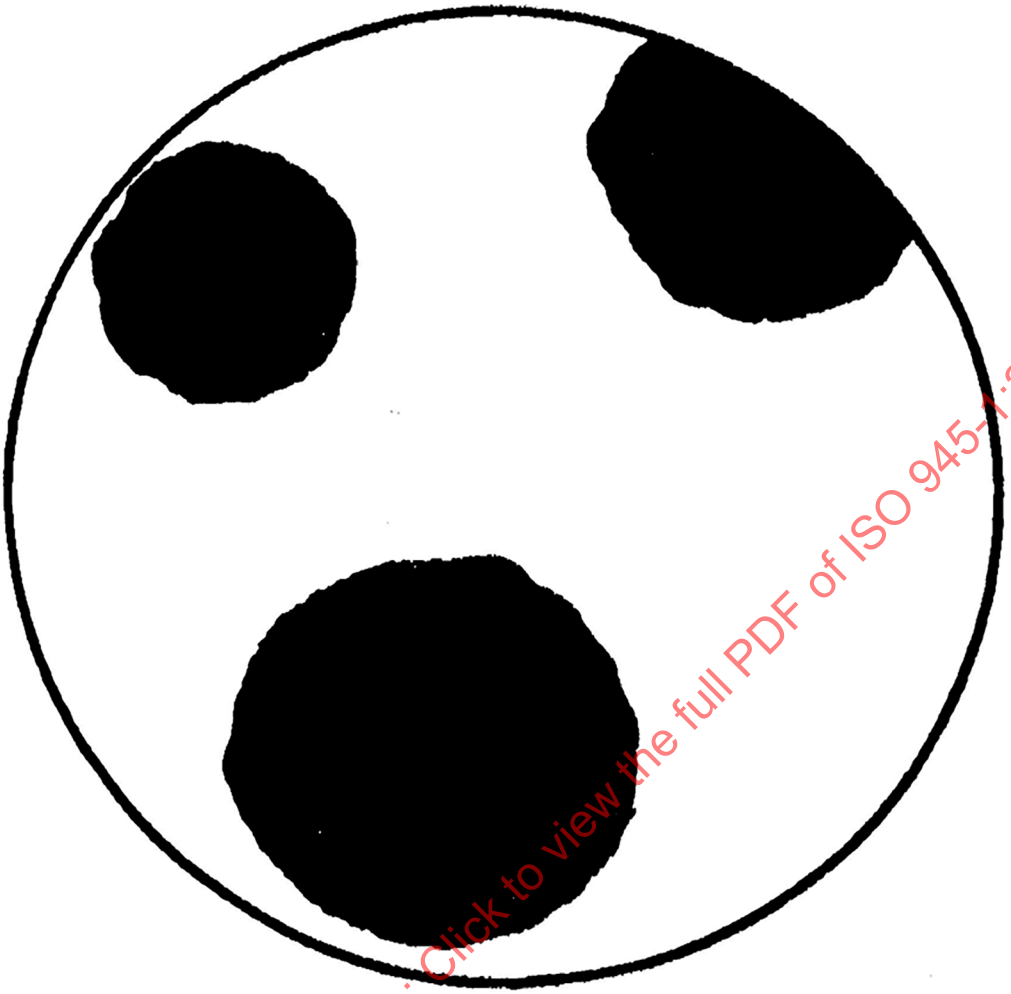
Magnification ×100



h) Reference image for graphite size 8: < 0,015 mm (form I)

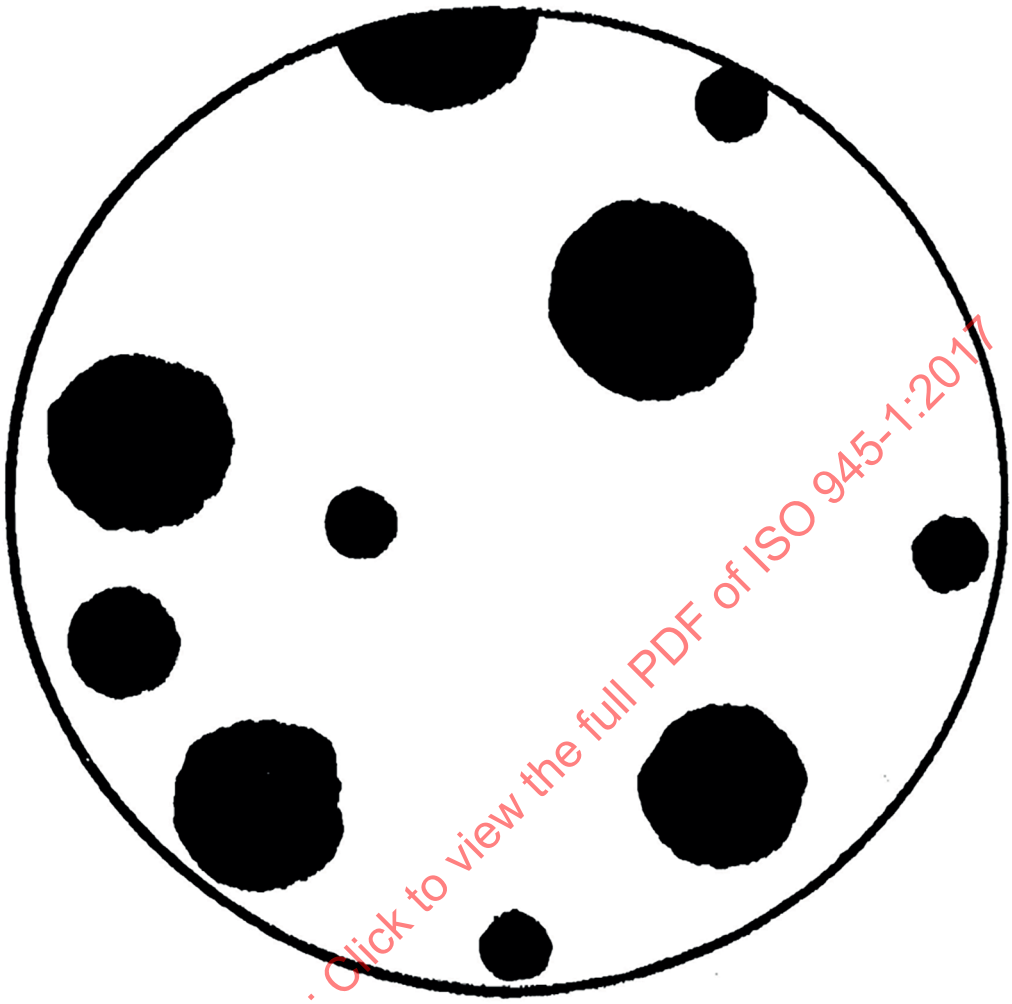
Figure 3 — Reference images for graphite sizes for form I

Magnification ×100



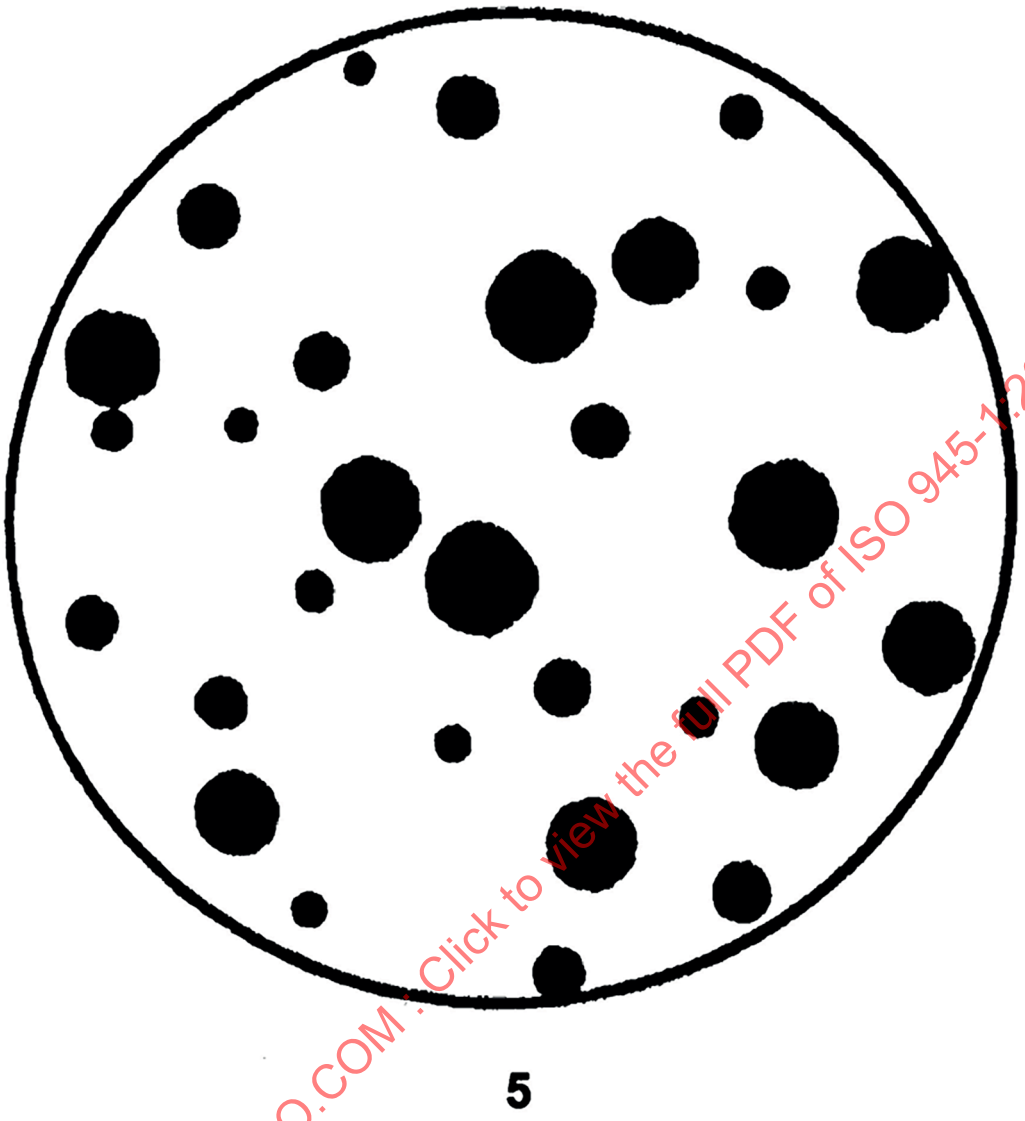
a) Reference image for graphite size 3: 0,25 mm to < 0,5 mm (forms IV to VI)

Magnification ×100



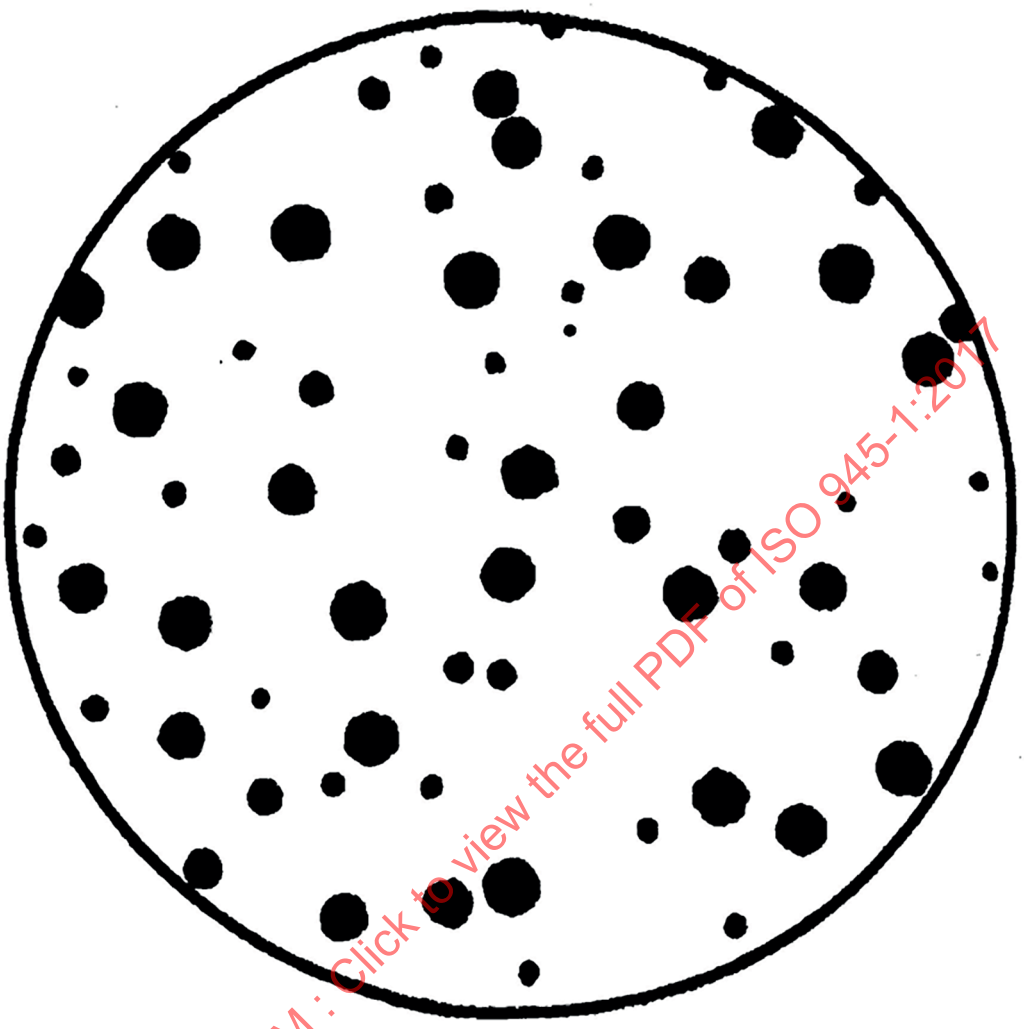
b) Reference image for graphite size 4: 0,12 mm to < 0,25 mm (forms IV to VI)

Magnification ×100



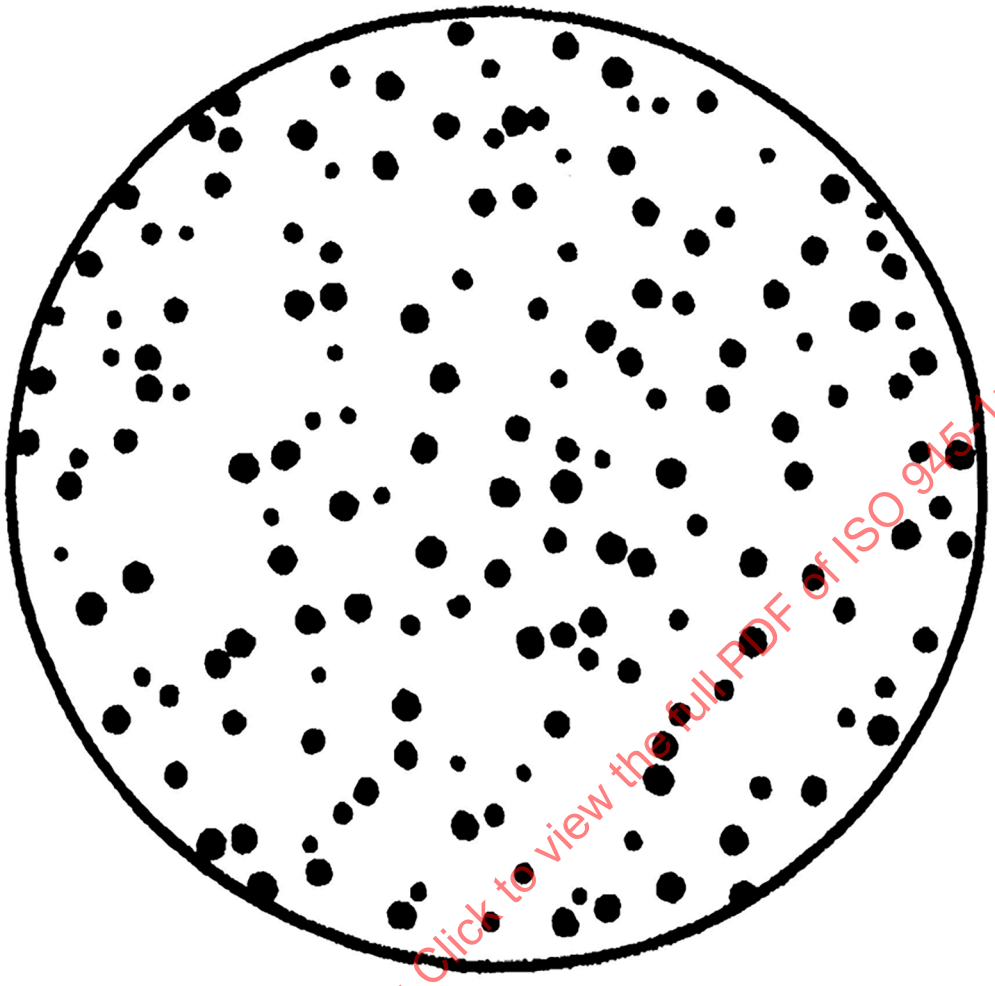
c) Reference image for graphite size 5: 0,06 mm to < 0,12 mm (forms IV to VI)

Magnification ×100



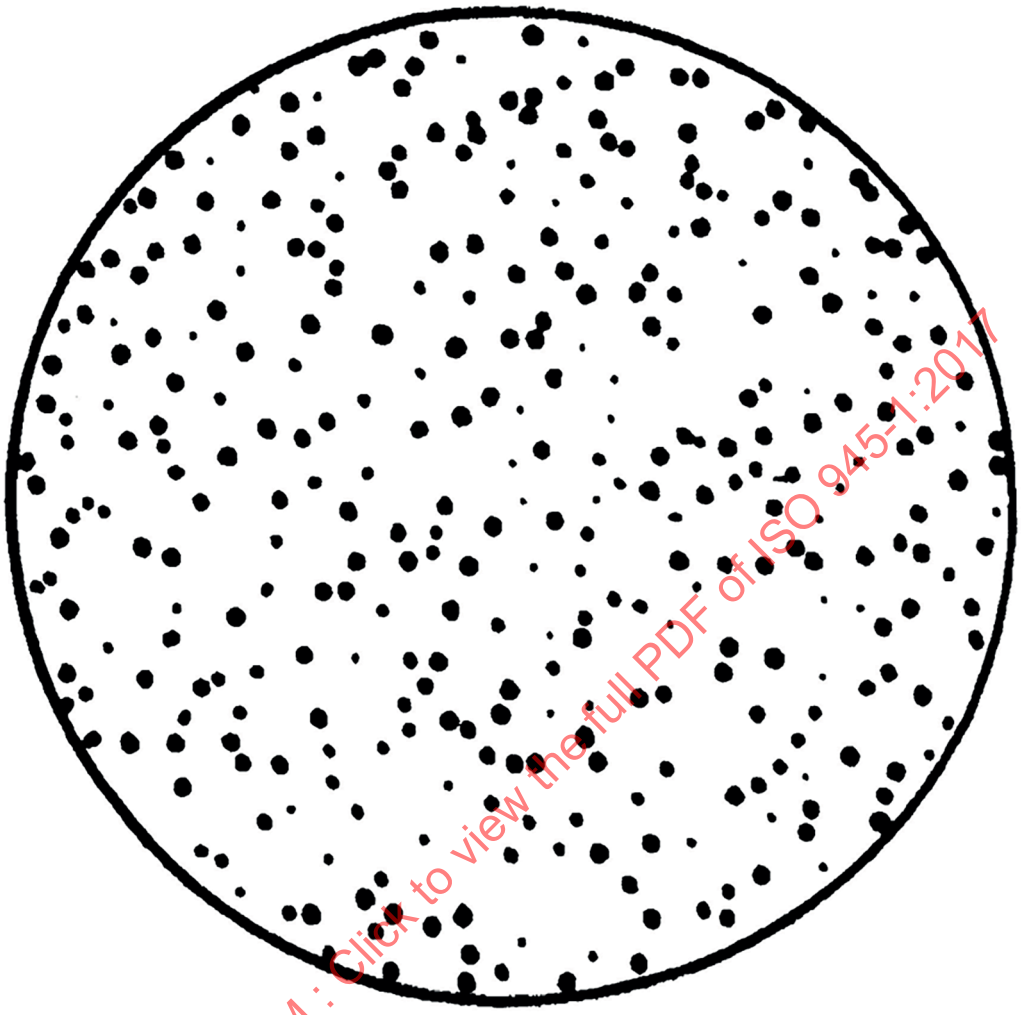
d) Reference image for graphite size 6: 0,03 mm to < 0,06 mm (forms IV to VI)

Magnification ×100



e) Reference image for graphite size 7: 0,015 mm to < 0,03 mm (forms IV to VI)

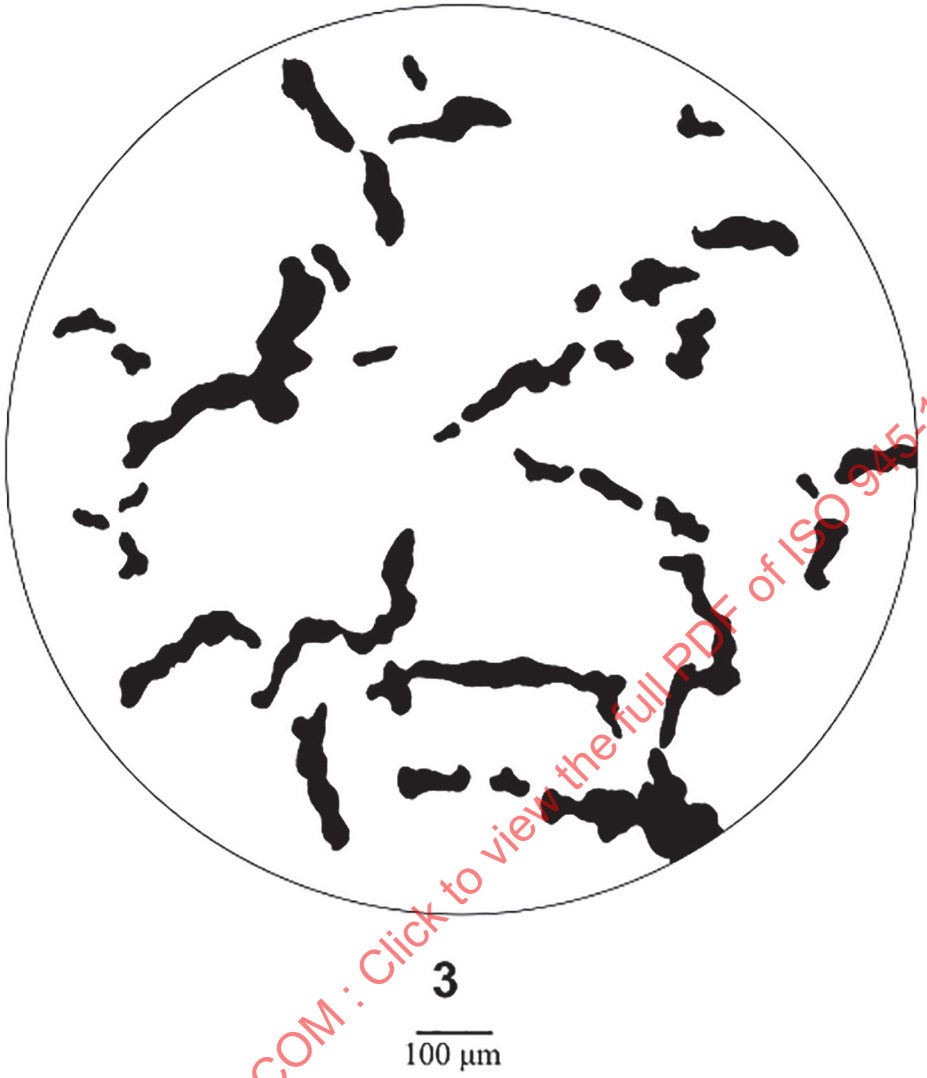
Magnification ×100



f) Reference image for graphite size 8: < 0,015 mm (forms IV to VI)

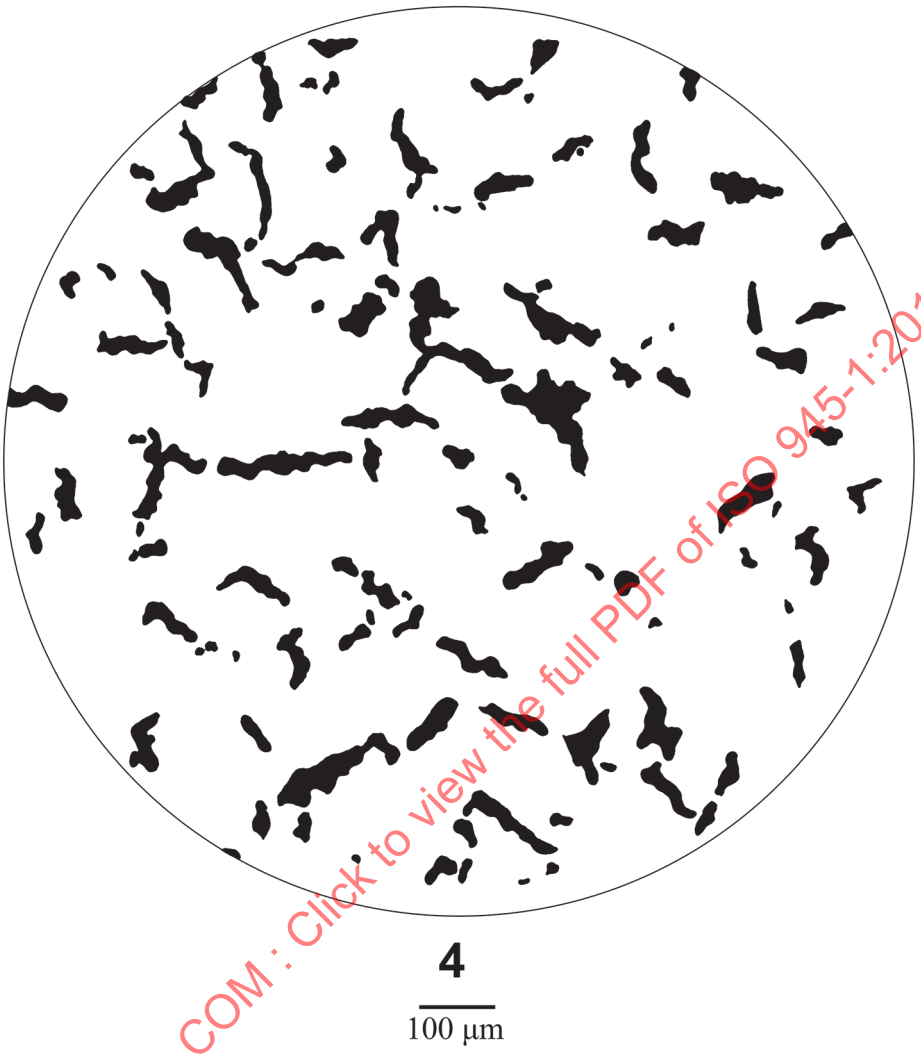
Figure 4 — Reference images for graphite sizes for forms IV to VI

Magnification ×100



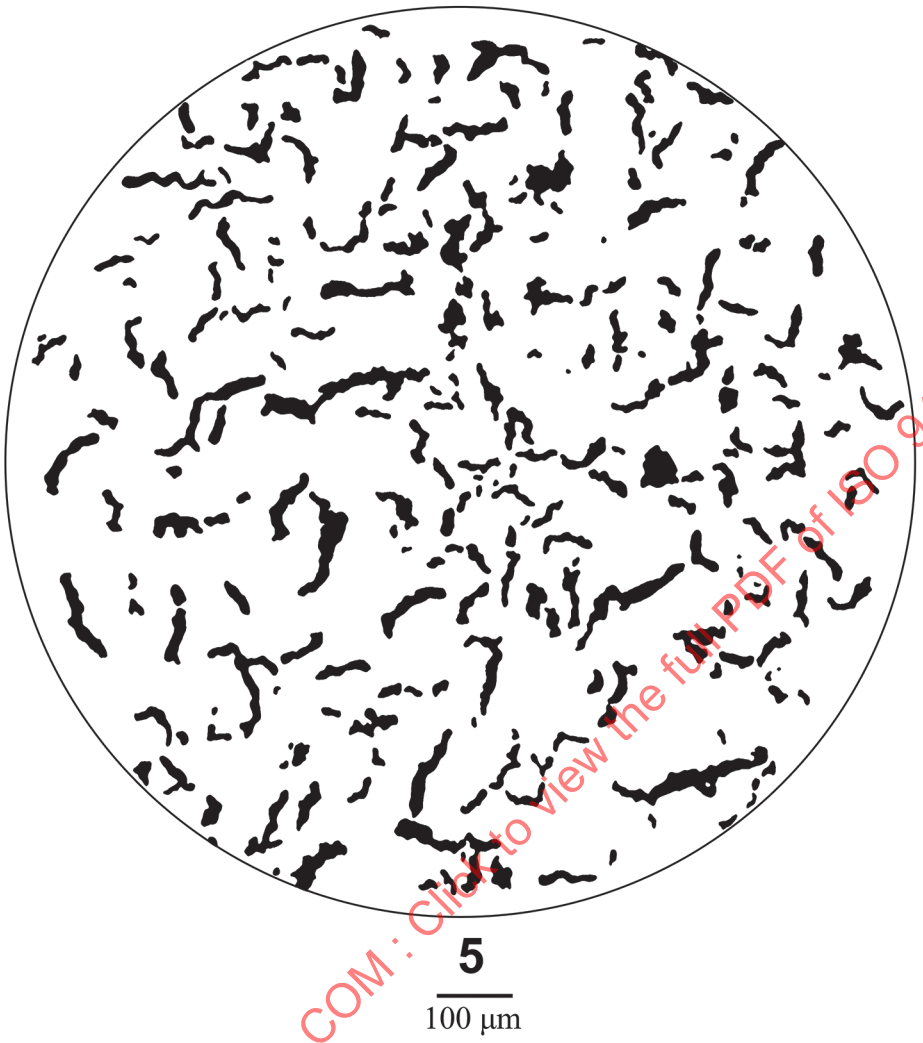
a) Reference image for graphite size 3: 0,25 mm to < 0,5 mm (form III)

Magnification ×100



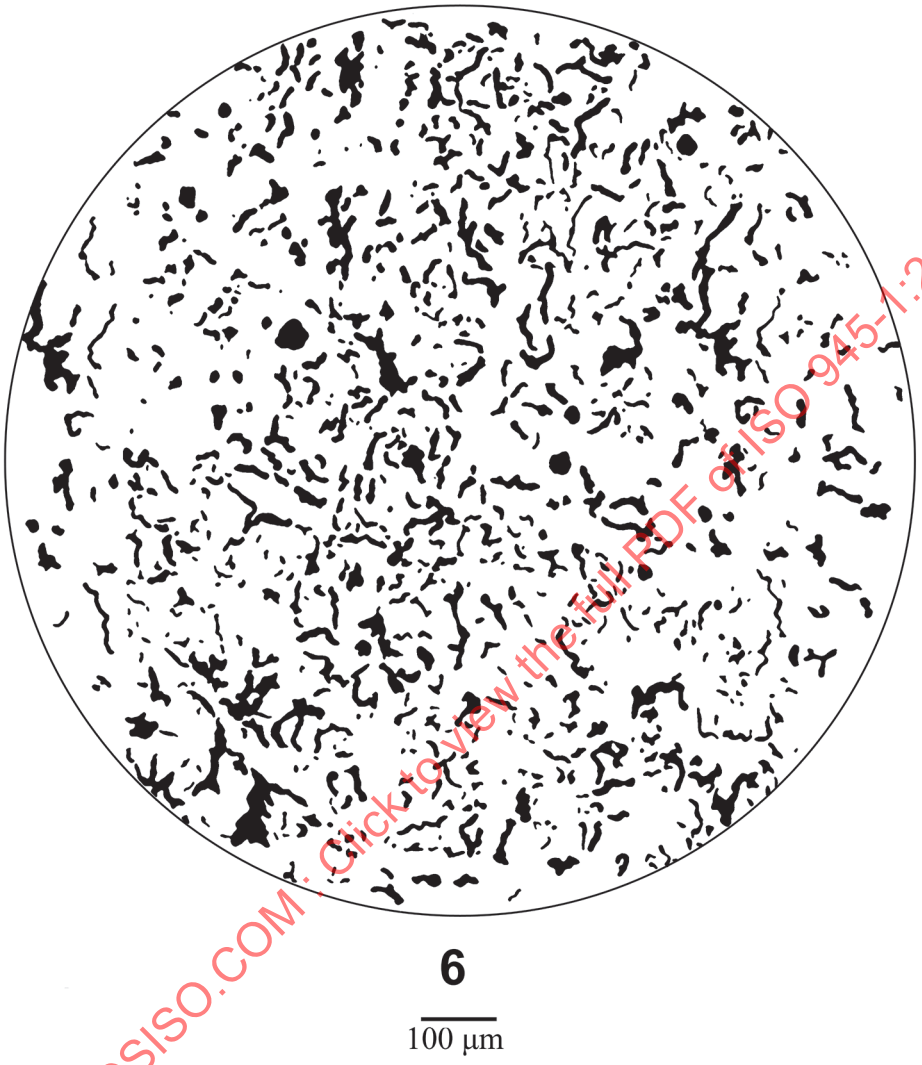
b) Reference image for graphite size 4: 0,12 mm to < 0,25 mm (form III)

Magnification ×100



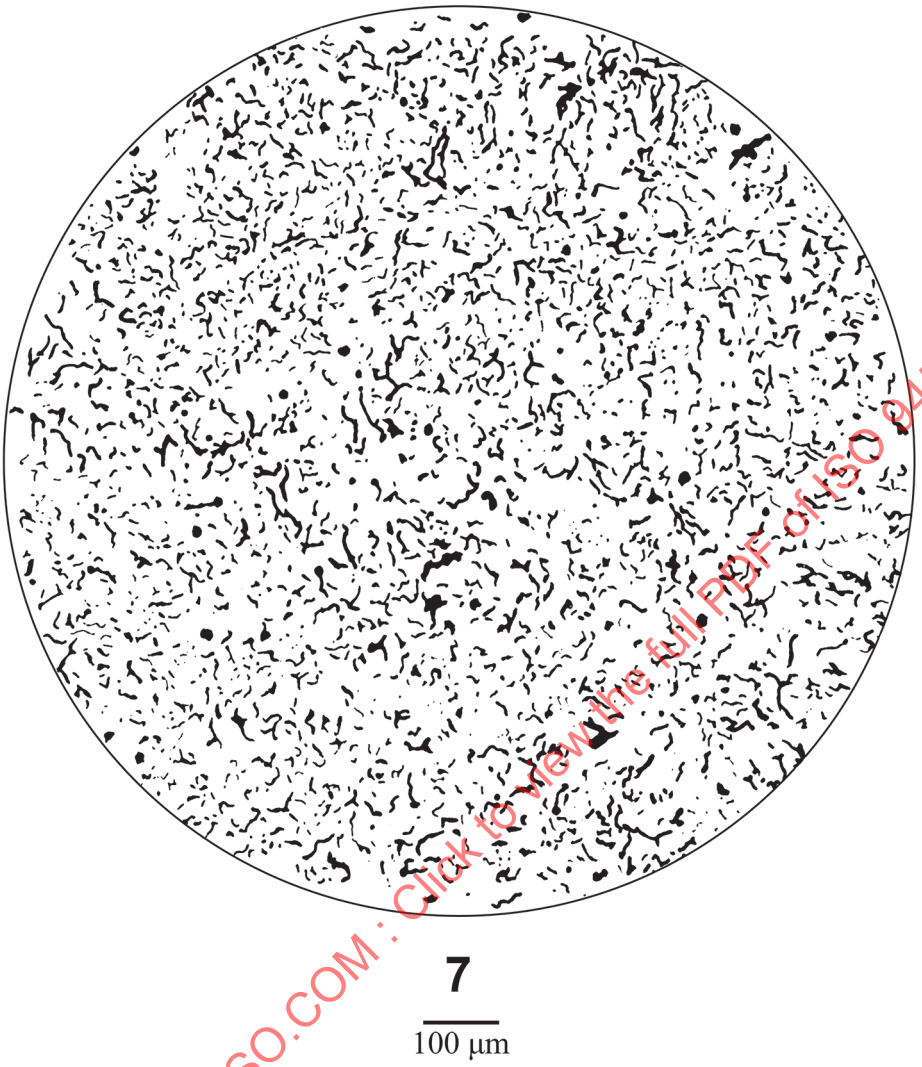
c) Reference image for graphite size 5: 0,06 mm to < 0,12 mm (form III)

Magnification ×100



d) Reference image for graphite size 6: 0,03 mm to < 0,06 mm (form III)

Magnification ×100



e) Reference image for graphite size 7: 0,015 mm to < 0,03 mm (form III)

Figure 5 — Reference images for graphite sizes for form III

4.5 Visual classification of graphite

The reference images given in Figures 1, 2, 3, 4 and 5 provide a basis for classifying graphite forms, distribution and size. The characteristic features of the graphite which occur are designated by letters and numbers. For this purpose, microstructures of graphite are arranged in a series of reference images consisting of schematic microstructures of cast irons. The form, distribution and size of the graphite observed are determined by comparison with the reference images. The classification is allocated as the same as that of the images that resemble them most closely at the same magnification.

NOTE The comparison of actual microstructures with schematic images or photomicrographs depends on the subjective impression of the metallographer.

5 Sampling and sample preparation

5.1 Samples taken from a casting

When taking samples from a casting, it is essential that attention be paid to the location, to the wall thickness, to the distance from the surface and to the presence of chills. The location of the sample in the casting shall be recorded in a report.

If more than one casting is examined, the samples shall be taken from the same location in each casting for the purpose of comparability.

The location of the metallographic specimen shall be agreed between the manufacturer and the purchaser.

5.2 Sample preparation

The area of the polished surface to be examined shall be sufficient to give a true representation of the graphite structure. Attention shall be paid to the careful grinding and polishing of the samples, so that the graphite particles appear in their original form, size and distribution. Inappropriate grinding and polishing can cause an unacceptable alteration of the microstructure. If necessary, the method of polishing may be agreed between the manufacturer and the purchaser.

The examination of the graphite under the microscope is usually carried out on the unetched polished section.

6 Procedure for graphite classification

6.1 Procedure for visual classification of graphite

The polished samples shall be scanned under a microscope in such a manner that a representative area is examined. To examine the graphite form and distribution, a ×100 magnification should preferably be chosen. If necessary, the magnification may be adapted in relation with the wall thickness so that the form and distribution of graphite can be determined by using the reference images given in Figures 1 and 2 (see also Annexes A, B and C). Adjust the microscope magnification to match as closely as possible the corresponding images in Figures 1 and 2 before classifying the graphite form and its distribution, if appropriate. The graphite size is determined by reference to Figures 3, 4 and 5 and Table 1, preferably at ×100 magnification. Other magnifications are permitted (see Table 1, Notes 1 and 2, as well as 7.4).

Examination under the microscope is carried out by direct observation in the microscope or by projection on the ground glass of the microscope or on a visual display screen. The area of view should preferably have approximately the same size as the reference images (about 120 mm diameter). The measurement of the graphite particles can be facilitated by the use of suitably calibrated eye-pieces.

Form and distribution of graphite shall be determined by using the reference images, given in Figures 1 and 2 (see also Annexes A, B and C). Adjust the microscope magnification to match as closely as possible

the corresponding images in Figures 1 and 2 before classifying the graphite form and its distribution, if appropriate.

If the microstructure is visualized on a visual display screen, the combined magnification of both microscope and screen (depending on its size) shall be taken into account.

6.2 Evaluation of the analysis results

The evaluation of the analysis results shall be carried out by an operator trained in this metallographic technique.

7 Reference images

7.1 General

A series of reference images (see Figures 1 to 5) showing schematic microstructures and photomicrographs is provided for the classification of the form, distribution and size of the graphite in cast irons.

In addition to reference images, the photomicrographs show actual graphite microstructures (see Annexes A and B).

7.2 Reference images for graphite form

The reference images for the graphite form (see Figure 1) show six characteristic forms which are designated by the Roman numbers I to VI (see also Annex A). These represent the principal types of graphite observed in cast iron materials. Annex C gives the common terminology and the occurrence of these types of graphite.

The graphite forms are specified in the relevant material standards. Percentages of these graphite forms may also be specified by these standards, e.g. in the case of compacted (vermicular) graphite cast irons.

NOTE ASTM A247 defines seven graphite types designated in the reverse order compared to the six forms defined in this document.

7.3 Reference images for the distribution of graphite (form I)

The reference images for the graphite distribution (see Figure 2) show characteristic graphite distributions designated by the letters A to E.

In addition to reference images, the photomicrographs show actual graphite microstructures (see Annex B).

A variant of distribution C, designated C′, is included in Annex B. This distribution corresponds to thin-walled castings.

7.4 Reference images for graphite size

Figures 3, 4 and 5 shall be used in conjunction with Table 1 to evaluate the graphite size. For ×100 magnification, sizes are indicated ranging from a maximum size of the particle of > 100 mm (size 1) down to < 1,5 mm (size 8). When using Table 1, alternative magnifications may be used (see Table 1, Notes 1 and 2).

NOTE 1 Sizes 1 and 2 have no practical application for graphite forms III to VI. Therefore, they have not been included in Figures 4 and 5.

NOTE 2 The reference images given in Figure 3, 4, and 5 do not represent all the graphite particle sizes present in each of the graphite particle size ranges given in Table 1.

NOTE 3 The schematics show some graphite particles smaller than the minimum size graphite particles for that size range. The schematics represent what can be seen when viewing a two dimensional sectioned view of a three dimensional structure where a normal sized particle is sectioned not through its centreline appears smaller than its actual size.

8 Designation of graphite by form, distribution and size

8.1 Designation system

To characterize the graphite observed, indications are generally necessary on the form, distribution and size of the graphite particles. For this purpose, the following symbols shall be used at different positions of the designation:

— the Roman numbers given in Figure 1 are used for the graphite form at position 1;

— for form I, the capital letters given in Figure 2 are used for the distribution at position 2;

— the Arabic numbers given in Figures 3, 4, and 5 and Table 1 are used for the graphite size at position 3.

EXAMPLE 1 For a grey cast iron with flake (lamellar) shaped graphite particles of form I, distribution A, and size 4, the following designation is used to describe that structure:

I A 4

EXAMPLE 2 For a cast iron with spheroidal graphite particles of form VI and size 4, the following designation is used to describe that structure:

VI 4

Table 1 — Dimensions of graphite particle forms I to VI

Dimensions in millimetres

Size range reference number	Indication of the particle size observed at ×100 magnification	Actual dimension
1	≥ 100	≥ 1
2	50 to < 100	0,5 to < 1
3	25 to < 50	0,25 to < 0,5
4	12 to < 25	0,12 to < 0,25
5	6 to < 12	0,06 to < 0,12
6	3 to < 6	0,03 to < 0,06
7	1,5 to < 3	0,015 to < 0,03
8	< 1,5	< 0,015

NOTE 1 When determining size ranges 1 and 2, a lower magnification (×25 or ×50) may be used.

NOTE 2 When determining size ranges 6 to 8, a higher magnification (×200 or ×500) may be used.

NOTE 3 For determining size ranges, the largest visible graphite particle size is used.

8.2 Designation of different graphite sizes within a casting

If the graphite observed in different areas of view covers two sizes, reference to both is possible.

EXAMPLE 1 3/4

In addition, the predominant size may be emphasized by underlining.

EXAMPLE 2 3/4

8.3 Designation of mixed graphite forms, distributions and sizes

More complex microstructures containing different types of graphite can be defined by estimating the percentage proportions of the different types of graphite.

EXAMPLE 1 For a cast iron with a graphite area comprising 60 % flake (lamellar) shaped graphite particles of form I, distribution A and size 4 and 40 % flake (lamellar) shaped graphite particles of form I, distribution D and size 7, the following designation is used to describe the structure:

60 % I A 4 + 40 % I D 7

EXAMPLE 2 For a cast iron with a graphite area comprising 85 % spheroidal graphite particles of form VI and size 4 and 15 % vermicular graphite particles of form III and covering sizes 3 and 4, the following designation is used to describe the structure:

85 % VI 4 + 15 % III 3/4

8.4 Designation of unclassified graphite forms

If graphite particles are not identifiable to the graphite forms in this document, these should be reported as unclassified graphite forms in accordance with this document.

8.5 Nodule count

The graphite nodule count n_F is determined by using the planimetric method, as shown by Formula (1) (see ISO 643). Nodules are particles normally classified as form VI or V (or even form IV).

$$n_F = \frac{N}{A} \times F^2 \tag{1}$$

where

n_F is the number of particles per unit surface area of the sample;

N is the number of nodules counted;

A is the magnified area;

F is the linear magnification factor.

EXAMPLE At a magnification of ×100, a circle measuring 79,8 mm in diameter (= 5 000 mm^2) is superimposed over a micrograph. At the preferred magnification of ×100, the circular area should preferably contain at least 50 graphite particles in order to minimize the counting error associated with a circular test pattern. Two counts are made:

n_1 is the number of graphite particles completely within the test circle;

n_2 is the number of graphite particles intersected by the test circle.

The total number of graphite particles in this circle of 5 000 mm^2 is shown by Formula (2):

$$n_{100} = n_1 + \frac{n_2}{2} \tag{2}$$

In this case, to express the nodule count as nodules/mm^2, the result given by Formula (2) has to be multiplied by 2, as shown by Formula (3):

$$\frac{F^2}{A} = \frac{100^2}{5\,000} \tag{3}$$

This operation is repeated on other fields.