International Standard 643

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Steels — Micrographic determination of the ferritic or austenitic grain size

Aciers — Détermination micrographique de la grosseur du grain ferritique ou austénitique des aciers

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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.

International Standard ISO 643 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in December 1981.

It has been approved by the member bodies of the following countries :

Australia	Germany, F.R.	Norway
Austria	Hungary	South Africa, Rep. of
Belgium	India	Spain
Brazil	Ireland	Sri Lanka
Bulgaria	Italy	Sweden
Canada	Japan	Switzerland
China	Korea, Dem. P. Rep. of	Turkey
Czechoslovakia	Korea, Rep. of	USA
Egypt, Arab Rep. of	Netherlands	USSR
France	New Zealand	Venezuela

The member body of the following country expressed disapproval of the document on technical grounds :

United Kingdom

This International Standard cancels and replaces ISO Recommendation R 643-1967, of which it constitutes a technical revision.

Steels — Micrographic determination of the ferritic or austenitic grain size

1 Scope and field of application

This International Standard specifies the micrographic method of determining ferritic or austenitic grain sizes of steels. It describes the methods for revealing the grain and for estimating the mean size of the grain revealed.

2 Definitions

2.1 grain : A closed polygonal shape with more or less curved sides which can be revealed within the network of a flat cross-section of the sample, polished and prepared for micrographic examination.

A distinction is made between

2.1.1 austenitic grain : Either the grain of steels showing a single-phase or two-phase austenitic structure (ferrite islands δ) at the ambient temperature,
or the grain formed during heat treatment involving austenitization at a given temperature and time.

2.1.2 ferritic grain : Grain observed in the single-phase or two-phase structure (pearlite islands), generally resulting from transformation $\gamma \rightarrow \alpha$ (with the exception of ferritic-delta steels)[1].

2.2 index : The positive, zero or possibly negative number G which is derived from the mean number m of grains counted in an area of 1 mm^2 of the section of the sample. By definition, $G = 1$ where $m = 16$; the other indices are obtained by the formula

$$m = 8 \times 2^G$$

2.3 intersected segment : The segment of the measurement line across the grain. If $\bar{N}$ is the mean number of grains intersected by a measuring line of length L, the mean value of the intersected segment is

$$\bar{L} = \frac{L}{\bar{N}}$$

2.4 intercept : The point on the grain boundary where the measurement line crosses the grain.

1) Ferritic grain size is generally estimated for non-alloy steels with a carbon content of 0,25 % or less. If pearlite islands of identical dimensions to those of the ferrite grains are present, the islands are then counted as ferrite grains.

3 Symbols and abbreviations

The symbols used are given in table 1.

4 Methods

4.1 Principle

4.1.1 The grain size is revealed by micrographic examination of a polished section of the sample prepared by an appropriate method for the type of steel and for the information sought.

NOTE — If the order or the International Standard defining the product does not stipulate the method of revealing the grain, the choice of this method is left to the manufacturer.

This average size is characterized

a) either by an index obtained

— usually by comparison with standard charts for the measurement of grain size,

— or by counting to determine the average number of grains per unit of area;

b) or by the mean value of the intersected segment.

If an International Standard defines the product, the grain size is expressed either by an upper or lower limit, or by a scale indicating the permissible variations in a given reference condition.

Table 1 — Symbols

Symbols	Definition	Value
g	Linear magnification (to be noted as a reference) of the microscopic image	In principle 100
D	Diameter of the circle on the ground glass screen of the microscope or on a photomicrograph enclosing the image of the reference surface of the test piece	79,8 mm (area = 5 000 mm^2)
n_1	Number of grains completely inside the circle of diameter D	
n_2	Number of grains intersected by the circle of diameter D	
n_{100}	Total equivalent number of grains examined on the image of diameter D (with magnification × 100)	$n_{100} = n_1 + \frac{n_2}{2}$
n_g	Total equivalent number of grains examined on the image of diameter D (with a magnification × g)	
K	Conversion factor from linear magnification g to linear magnification 100	$K = \frac{g}{100}$
m	Number of grains per square millimetre of test piece surface in the area examined	$m = 2\, n_{100}$ (magnification × 100) $m = 2\, K^2 n_g$ (magnification × g)
G	Equivalent index of grain size	
d_m	Mean grain diameter in millimetres	$d_m = \frac{1}{\sqrt{m}}$
a	Mean area of grain in square millimetres	$a = \frac{1}{m}$
L	Length of the measuring line on the surface of the test piece in millimetres	
$\bar{N}$	Mean number of intercepts through the measurement line of length L	
$\bar{N}_L$	Mean number of intercepts through the measuring line per unit of length	$\bar{N}_L = \frac{\bar{N}}{L}$
$\bar{L}$	Mean intersected segment in millimetres	$\bar{L} = \frac{L}{\bar{N}}$ $\bar{L} = \frac{1}{\bar{N}_L}$
N_x	Number of intercepts per millimetre in the longitudinal direction[1]	
N_y	Number of intercepts per millimetre in the transverse direction[1]	
N_z	Number of intercepts per millimetre in the perpendicular direction[1]	

1) The method for designating the direction conforms with ISO 3785, *Steel — Designation of test piece axes.*

5 Selection and preparation of the sample

5.1 Selection

If the order or the International Standard defining the product does not specify the number of samples and the point at which they are to be taken from the product, these are left to the manufacturer. The sample shall be polished in accordance with the usual methods.

5.2 Revealing the ferritic grain

The ferritic grains shall be revealed by etching either with nital (nitric acid ethanol solution), or with picral (picric acid ethanol solution), or with an appropriate reagent.

5.3 Revealing austenitic grain

In the case of steels having a single-phase or two-phase austenitic structure (ferrite islands δ) at ambient temperature, the grain shall be revealed directly by an appropriate micrographic examination.

For other steels, one or other of the methods specified below shall be used depending on the information required, i.e.

— Bechet-Beaujard method by etching with picric acid aqueous satured solution (see 5.3.1);

— Kohn method by controlled oxidation (see 5.3.2);

— McQuaid Ehn method by carburization (see 5.3.3);

— or, if need be, other methods specially agreed upon when ordering.

It should be noted that, if comparative tests are carried out for the different methods, it is indispensable to obtain the same heat treatment conditions and that the results may vary considerably from one method to the other.

5.3.1 Bechet-Beaujard method by etching with picric acid aqueous saturated solution

5.3.1.1 Field of application

This method reveals austenitic grain formed during heat treatment of the sample. It is applicable to samples which have a fine martensitic or bainitic structure.

5.3.1.2 Preparation

Normally, no subsequent heat treatment is generally necessary if the sample has a fine martensitic or bainitic structure. If this is not the case, heat treatment is necessary.

If the conditions for treating the test piece are not provided for by the International Standard defining the product and there is no specification to the contrary, the following conditions shall be applied in the case of heat-treated structural carbon steels and low-alloy steels :

— 1 1/2 h at 850 ± 10 °C for steels whose carbon content is greater than 0,35 %;

— 1 1/2 h at 880 ± 10 °C for steels whose carbon content is less than or equal to 0,35 %.

After this treatment, the test piece should generally be quenched into water or oil.

5.3.1.3 Polishing and etching

A flat surface of the sample shall be polished for micrographic examination. It shall be etched for an adequate period of time by means of an aqueous solution saturated with picric acid together with at least 0,5 % sodium alkylsulfonate or another appropriate wetting agent.

NOTE — The period of etching may vary from a few minutes to more than one hour. Slight re-heating of the solution to 60 °C, for example, may improve the etching action and reduce the period of etching.

Several successive etching and polishing operations are sometimes necessary to ensure a sufficient contrast between the grain boundaries and the general base of the sample. In the case of through-hardened steel, tempering may be carried out before selecting the sample.

5.3.1.4 Result

The boundaries of austenite grains appear at the austenitizing temperature directly in the micrographic examination.

5.3.2 Kohn method by controlled oxidation

5.3.2.1 Field of application

This method shows up the austenitic grain pattern formed by preferential oxidation of the boundaries during austenization at the temperature of a given heat treatment.

5.3.2.2 Preparation

One surface of the sample shall be polished. The rest of its surface shall not show any traces of oxide. The sample shall be placed in a laboratory tube in which either a vacuum of 1 Pa is obtained or an inert gas is circulated (for example purified argon). It shall be austenitized in the heat cycle conditions (heating rate, temperature, holding time) specially agreed or, if this is not the case, in the conditions laid down by the International Standard defining the product.

At the end of this specified heating period, air shall be introduced into the tube for a period of 10 to 15 s.

The sample shall then be water-quenched. The sample can usually be directly examined through the microscope.

NOTE — If there is heavy oxidation of the sample, the oxide adhering to the previously polished surface should be removed by light polishing with a fine abrasive, taking care that the oxide network which has formed on the grain boundaries is retained; then the polishing should be completed by the usual methods. The sample should then be etched using Vilella's reagent :

picric acid (crystallized)	1 g
hydrochloric acid (ϱ_{20} = 1,19 g/ml)	5 ml
ethanol	100 ml

or Benedicks reagent :

metanitrobenzene sulfonic acid	5 ml
ethanol	100 ml.

5.3.2.3 Result

The preferential oxidation of the boundaries shows up the pattern of austenitic grains.

If the preparation is effected correctly, no oxide globules should appear at the grain boundaries.

It may be necessary to use oblique illumination, in certain cases, to show up the boundaries in better relief.

5.3.3 McQuaid Ehn method by carburization at 925 °C

5.3.3.1 Field of application

This is a method specifically for carburizing steels and shows up austenitic grain boundaries formed during carburization of these steels. It is not usually suitable for determining grains actually formed during other heat treatment.

5.3.3.2 Preparation

The samples shall be free from any trace of decarburization or of surface oxidation. Any prior treatment, either cold, hot, mechanical, etc., may have an effect on the shape of the grain obtained; the product specification shall state the treatments to be carried out before determination in cases where it is advisable to take into account these considerations.

In general, the samples shall be conveniently spaced in a carburizing chamber with a lid and filled with dry and active carburizing compound. The carburizing compound usually consists of 60 % of charcoal in grains and 40 % (m/m) of barium carbonate ($BaCO_3$). The volume of carburizing compound used shall be at least 30 times the volume of the the samples to be carburized.

Carburization shall be achieved by maintaining the sample at 925 ± 10 °C for 6 h. This is generally done by keeping the carburizing chamber at 925 ± 10 °C for 8 h. In most cases, a carburized layer of approximately 1 mm is obtained. Cooling down the sample to a temperature lower than the critical temperature shall be at a sufficiently slow rate in order to ensure that the cementite is precipitated at the grain boundaries of the hypereutectoid zone of the carburized layer.

New carburizing compound shall be used each time.

5.3.3.3 Polishing and etching

The carburized sample shall be sectioned normally on its surface. One of the sections should be polished for micrographic examination. It shall be etched :

a) either by means of the le Chatelier and Igevski reagent :

picric acid (crystallized)	2 g
sodium hydroxide (caustic soda)	25 g
water	100 ml

in the boiling state

or by means of electrolytic etching 6 V — 60 s

b) or by nital :

nitric acid (ϱ_{20} = 1,33 g/ml)	2 to 5 ml
ethanol	to make up to 100 ml.

Other reagents may be used as long as the same results are obtained.

5.3.3.4 Result

The grain boundaries of the carburized layer which is approximately 1 mm thick should be revealed as a network of proeutectoid cementite.

5.3.4 Other methods of revealing austenitic grain

For certain steels, after simple heat treatment (annealing or normalizing, quenching and tempering, etc.) the pattern of the austenitic grains may appear in the following forms under micrographic examination : a network of proeutectoid ferrite surrounding pearlite grains, a network of troostite surrounding martensite grains, etc. The austenitic grain may also be revealed by thermal etching under vacuum (not necessarily followed by oxidation). The product specification shall mention these simplified methods[1] in these cases).

6 Characterization of grain size

6.1 Characterization by an index

The index is defined in sub-clause 2.2 by the formula :

$$m = 8 \times 2^G \qquad \ldots (1)$$

This formula may be stated as

$$G = \frac{\log m}{\log 2} - 3 \qquad \ldots (2)$$

or

$$G = \frac{\log m}{0{,}301} - 3 \qquad \ldots (2b)$$

1) Amongst these methods are the following :

— precipitation on the grain boundaries during cooling;

— gradient quenching method, etc.

6.1.1 Assessment by comparison with standard grain size charts

The image examined on the ground glass screen (or on a photomicrograph) is compared with a series of standard charts[1]. These standard charts at a magnification of 100 are numbered from I to VIII so that their number is equal to the index G [see plates A to D (annex B) or E to G (annex C)].

The standard chart with the grain size closest to that of the sample can then be determined.

Where the magnification g of the chart examined is not 100, the index G shall be equal to the number M of the closest standard chart, modified as a function of the ratio of the magnifications :

$$G = M + 6{,}64 \log \frac{g}{100} \qquad \ldots (3)$$

Table 2 gives the relationship between the indices for the usual magnifications.

Table 2 — Relationship between indices for the usual magnifications

Magnification of the image	Index of metal grain for an image identified on a standard chart No							
	I	II	III	IV	V	VI	VII	VIII
25	−3	−2	−1	0	1	2	3	4
50	−1	0	1	2	3	4	5	6
100	1	2	3	4	5	6	7	8
200	3	4	5	6	7	8	9	10
400	5	6	7	8	9	10	11	12
800	7	8	9	10	11	12	13	14

6.1.2 Count

The counting method is defined in annex A.

6.1.3 Estimation of the index

Whether the estimate is carried out by comparison or by count, the accuracy obtained is rarely greater than a half-unit. The index shown shall be rounded to a whole number.

6.2 Characterization by the intersected segment

The number of grains crossed by the measurement line shall be counted on the ground glass screen of the microscope or on the photomicrograph of a representative field. The number of intercepts can also be counted as both methods give the same result.

The measuring line may be straight or circular. The measuring grid in figure 1 shows the types of measuring line to be used.

The grid shall be applied only once to the field examined. It is applied at random to an adequate number of fields to have a valid count.

6.2.1 Linear intersected segment method

The measuring line consists of four straight parts with a total length of 500 mm arranged as shown in figure 1. This arrangement allows the effect of grain anisotrophy to be reduced. The vertical and horizontal lines are used for measuring the grain size in the different directions. One of the two lines is oriented in the desired direction.

The magnification shall be selected so that at least 50 intercepts are obtained in any one measurement.

The following rules shall be followed :

6.2.1.1 In the case where the intersected segments are counted

When the measurement line terminates inside a grain, the segment intersected by this grain is counted as one half.

6.2.1.2 In the case where the intercepts are counted

— the end of the measuring line is counted as 1/2 only when it exactly touches a grain boundary;

— when the line is tangential to the grain boundary, one intercept is also counted;

— when the intercept coincides with a triple point (junction of 3 grains) it is counted as 1,5 intercepts;

— in the case of grains of irregular shape when the line bisects the same grain at two different points, the two intercepts shall be counted.

NOTE — The Snyder-Graff method, described in annex A, represents a linear intersected segment method for tool steel (high-speed steels).

6.2.2 Circular intersected segment method

The measuring line consists either of a set of three concentric circles shown in figure 1 or one single circle.

The total length of the three circles of the grid shown in figure 1 is 500 mm. The magnification shall be selected so that there are at least 50 intercepts when the measurement grid is superposed on the field examined.

In the case of a single circle, the largest circle with a circumference of 250 mm is used. In this case, the magnification to be used shall enable at least 25 intercepts to be counted.

1) These standard charts are either those defined in Euronorm 103-71 [(plates A to D) (annex B)] or those defined in ASTM E 112-77 [(plates E to G (annex C)]. The standard charts selected should be adhered to throughout the whole of the examination.

The circular intersected segment method tends to give slightly high intersected segment values and thus a slightly low number of intercepts. In order to compensate for this, the intercepts caused by a triple point shall be counted as two intercepts instead of 1,5 as is the case with the linear intersected segment method.

6.2.3 Assessment of results

By repeating the measurements of the number of intercepts on different fields several times, it is possible to arrive at the mean value of the number of intercepts $\bar{N}$.

If L is the length of the measurement line, then

$$\bar{N}_L = \frac{\bar{N}}{L} \quad \ldots (4)$$

The mean value of the intersected segment is given by the formula

$$\bar{L} = \frac{1}{\bar{N}_L} \quad \ldots (5)$$

In the case of non-equiaxial structures, it is possible to determine the number of intercepts on three sections respectively :

— 1 longitudinal section;

— 1 transverse section;

— 1 perpendicular section.

The mean number of intercepts per millimetre, $\bar{N}_L$, is then determined by the formula

$$\bar{N}_L = \frac{1}{3}(\bar{N}_x + \bar{N}_y + \bar{N}_z) \quad \ldots (6)$$

where

$\bar{N}_x$ is the mean number of intercepts per millimetre on the longitudinal section;

$\bar{N}_y$ is the mean number of intercepts per millimetre on the transverse section;

$\bar{N}_z$ is the mean number of intercepts per millimetre on the perpendicular section.

NOTES

1 Grains of different size indices

In certain cases, the surface examined may include grains belonging to two or more different systems of size indices. This can be recognized by the presence of several grains of greatly different dimensions from those of the whole, for example. This may then lead to making counts by dimensions and to determining two or several indices with a possible mention of their frequency or their position.

2 Twin grains

Unless otherwise specified, these are counted as a single grain (see figure 2).

3 Non-equiaxed grains

The designation of the grain size may be completed by determining the ratio of their dimensions obtained by measuring on two suitably selected rectangular axes, one of which may be that of the rolled product, the length intersected by a similar number of grains and taking the ratio of these lengths.

7 Test report

The test report shall state :

a) the grade of the steel examined;

b) the type of grain determined (ferritic or austenitic);

c) the method used and the operating conditions;

d) the grain size index or the value of the mean segment.

Annex A

Counting method

(Forms part of the Standard.)

A.1 Principle

The linear magnification g of the image shall be such that at least 50 grains can be counted in an area enclosed by a 79,8 mm diameter circle (area 5 000 mm^2) traced on the ground glass screen of the microscope (or on the photomicrograph).

In principle, the linear magnification is 100. In this case, the actual surface area on the sample is 0,5 mm^2 (see figure 3).

The number of grains n_1 completely inside the circle and the number of grains n_2 intersected by the circumference shall be determined.[1)]

The total number of equivalent grains is

$$n_{100} = n_1 + \frac{n_2}{2} \qquad \ldots (7)$$

The number of grains per square millimetre of the surface of the sample is

$$m = 2\,n_{100} \qquad \ldots (8)$$

or in the case of any magnification g

$$m = 2\left(\frac{g}{100}\right)^2 n_g \qquad \ldots (9)$$

or

$$m = 2K^2 n_g \qquad \ldots (10)$$

where

$$K = \frac{g}{100} \qquad \ldots (11)$$

The mean diameter in millimetres of the actual size grain is

$$d_m = \frac{1}{\sqrt{m}} \qquad \ldots (12)$$

The mean area in square millimetres of the actual size grain is

$$a = \frac{1}{m} \qquad \ldots (13)$$

A nominal value of m corresponds to each value of G. The values of m calculated by formula (8) or (9) within the limits given in table 3 are given to a whole value of G.

A.2 Information on special structures

A.2.1 In the case of steels with a higher carbon content where the pearlite islands are partly surrounded by a border of ferrite or cementite delineating a continuous network, reference should be made to 5.3.4 (in the intersected segment method, the middle of this border should be taken as the grain boundary). In the case where the network is poorly defined, however, the measurement method shall be specially agreed upon.

A.2.2 The metal grains have an irregular polyhedral shape but their mean size can be measured simply. The established practice is to designate as "grains" the geometric figures enclosing the sections of these polyhedrons on the flat surface of the sample. However, it should not be overlooked that under these conditions estimating the mean grain size of a steel cannot be accurate. Indeed, even if the steel consisted of equal polyhedrons, the areas of the polygons observed on any flat surface could take in all the values between a maximum value and zero (the statistical distribution of the values of these areas can be calculated if the shape of the polyhedral structure is known).

A.3 Snyder-Graff method[2)]

A.3.1 Field of application

This method is used for determining the austenitic grain size of hardened and tempered high-speed steels by means of the linear intersected segment method.

A.3.2 Preparation

The sample taken from the product which is usually in the hardened and tempered state shall not receive any supplementary heat treatment.

After being polished, the sample shall be etched by the reagent which contains up to 10 % (V/V) of hydrochloric acid and

1) The count may also be carried out in the same way on a surface enclosed by a square with 70,7 mm sides (area equal to 5 000 mm^2) or by a rectangle of the same area, for example 80,0 mm × 62,5 mm.

2) Snyder, R.W. and Graff, H.F. : Study of grain size in hardened high-speed steel. *Metal Progress* (1938) April, pp. 377-80.

Table 3 — Evaluation of number of grains as a function of various parameters

Grain size indices G	Number of grains m per square millimetre			Mean quadratic diameter d_m of grain mm	Mean quadratic area a of grain mm^2	Mean intersected segment $\bar{L}$ mm	Mean number of intercepts on the measuring line per millimetre
	Nominal value	Limit values from (excl.)	Limit values to (incl.)				
−7	0,062 5	0,046	0,092	4	16	3,577	0,279
−6	0,125	0,092	0,185	2,828	8	2,529	0,395
−5	0,25	0,185	0,37	2	4	1,788	0,559
−4	0,50	0,37	0,75	1,414	2	1,265	0,790
−3	1	0,75	1,5	1	1	0,894	1,118
−2	2	1,5	3	0,707	0,5	0,632	1,582
−1	4	3	6	0,500	0,25	0,447	2,237
0	8	6	12	0,354	0,125	0,320	3,125
1	16	12	24	0,250	0,062 5	0,226	4,42
2	32	24	48	0,177	0,031 2	0,160	6,25
3	64	48	96	0,125	0,015 6	0,113	8,84
4	128	96	192	0,088 4	0,007 81	0,080	12,5
5	256	192	384	0,062 5	0,003 90	0,056 6	17,7
6	512	384	768	0,044 2	0,001 95	0,040 0	25,0
7	1 024	768	1 536	0,031 2	0,000 98	0,028 3	35,4
8	2 048	1 536	3 072	0,022 1	0,000 49	0,020 0	50,0
9	4 096	3 072	6 144	0,015 6	0,000 244	0,014 1	70,7
10	8 192	6 144	12 288	0,011 0	0,000 122	0,010 0	100
11	16 384	12 288	24 576	0,007 8	0,000 061	0,007 07	141
12	32 768	24 576	49 152	0,005 5	0,000 030	0,005 00	200
13	65 536	49 152	98 304	0,003 9	0,000 015	0,003 54	283
14	131 072	98 304	196 608	0,002 8	0,000 007 5	0,002 50	400
15	262 144	196 608	393 216	0,002 0	0,000 003 7	0,001 70	588
16	524 288	393 216	786 432	0,001 4	0,000 001 9	0,001 20	833
17	1 048 576	786 432	1 572 864	0,001 0	0,000 000 95	0,000 87	1 149

NOTE — This table gives for information only the values between the different parameters and is only valid for equiaxed grains.

3 % (V/V) of nitric acid in methyl alcohol. The period of attack shall be from 2 to 10 min. Several successive attacks and polishings are sometimes necessary. The surface of the sample is more or less coloured depending on the type of heat treatment undergone by the product.

A.3.3 Measuring

Under a magnification of 1 000, the number of grains intersected by a measuring line 125 mm long shall be counted. Five counts are carried out in different directions in fields selected at random.

A.3.4 Result

Unless specified to the contrary, the arithmetic mean of the number of grains intersected in five counts characterizes the grain size. The mean intersected segment may be determined from this value.

A.4 Other system of grain size definition

A.4.1 In addition to the grain size definition system described in this International Standard, there is one other system, the American one.

This system defines the grain size by an index G, known as ASTM (E 112-80), which corresponds to the two following definitions :

A.4.1.1 Mean intersected segment method

Index G (ASTM) = 0 corresponds to a mean, intersected segment of 32,0 mm measured at a magnification of 100.

The equation giving the other indices as a function

— of the mean intersected segment is :

$$G\,(\text{ASTM}) = 10{,}000 - 6{,}643\,9 \log_{10} \bar{L} \qquad \ldots (14)$$

— of the mean number of intercepts per unit length (mm) is

$$G\,(\text{ASTM}) = -3{,}287\,7 + 6{,}643\,9 \log_{10} \bar{N}_L \qquad \ldots (15)$$

A.4.1.2 Count method

By definition, index G (ASTM) = 1 corresponds to 15,500 grains per unit area (square millimetre).

The equation giving the other indices as a function of the number of grains per unit area (square millimetre) is

$$G\,(\text{ASTM}) = -2{,}954\,2 + 3{,}321\,9 \log_{10} m \qquad \ldots (16)$$

A.4.2 Numerical ratios between the various grain size indices in the case of regular structures

Equation (2) given in 6.1 may be written as

$$G = -3 + 3{,}321\,9 \log_{10} m \qquad \ldots (17)$$

Comparing this formula with formula (16) shows that

$$G\,(\text{ASTM}) - G = 0{,}045\,8.$$

The ASTM index gives a grain size slightly larger than the one defined by this International Standard, but the difference does not reach one twentieth of an index unit. This is negligible as the estimation of grain size can not generally be accurate to more than one half a unit under the most variable conditions.

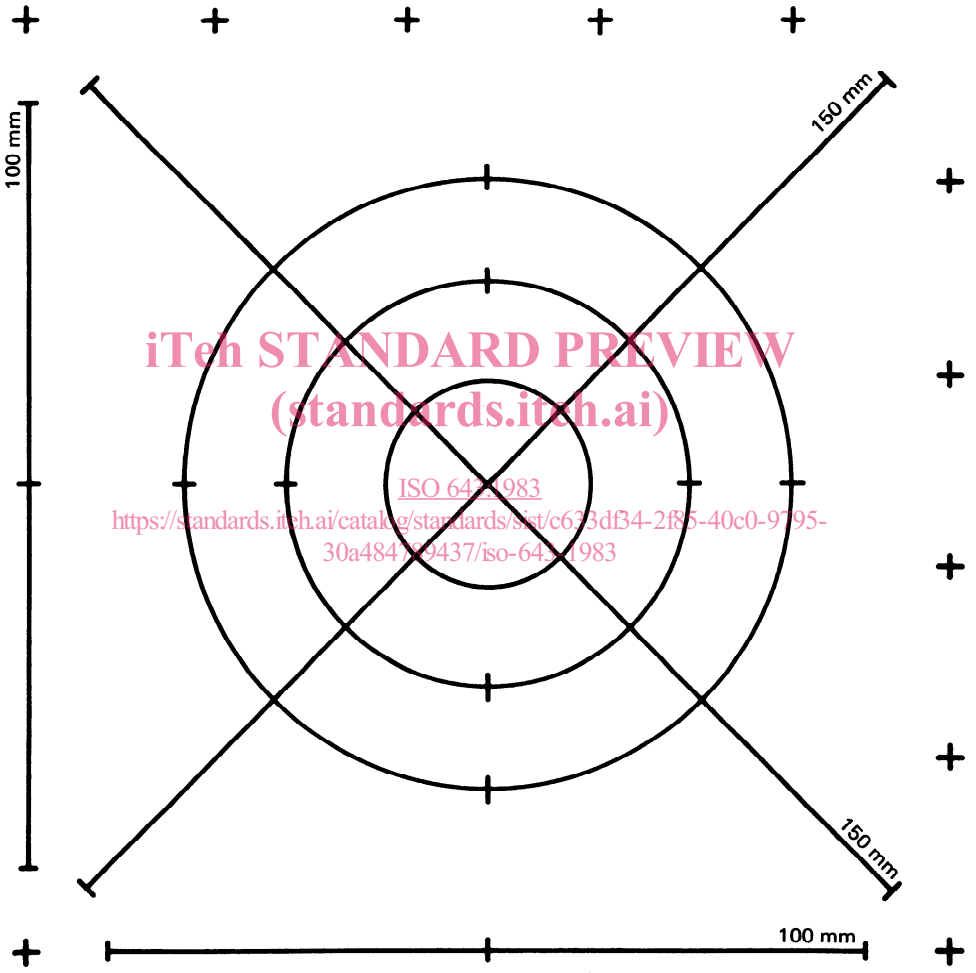

Figure 1 — Measurement grid for the intersected segment method

The dimensions in millimetres of the three circles are

Diameter	Circumference
79,58	250,0
53,05	166,7
26,53	83,3
	Total 500,0

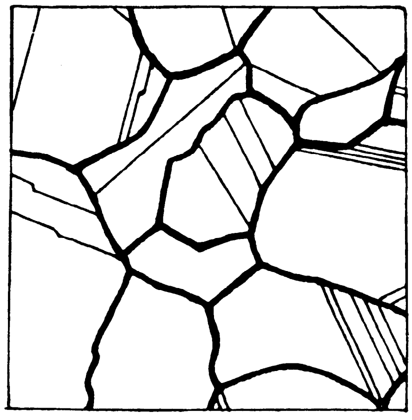

Figure 2 — Evaluation of number of grains (twin grains)

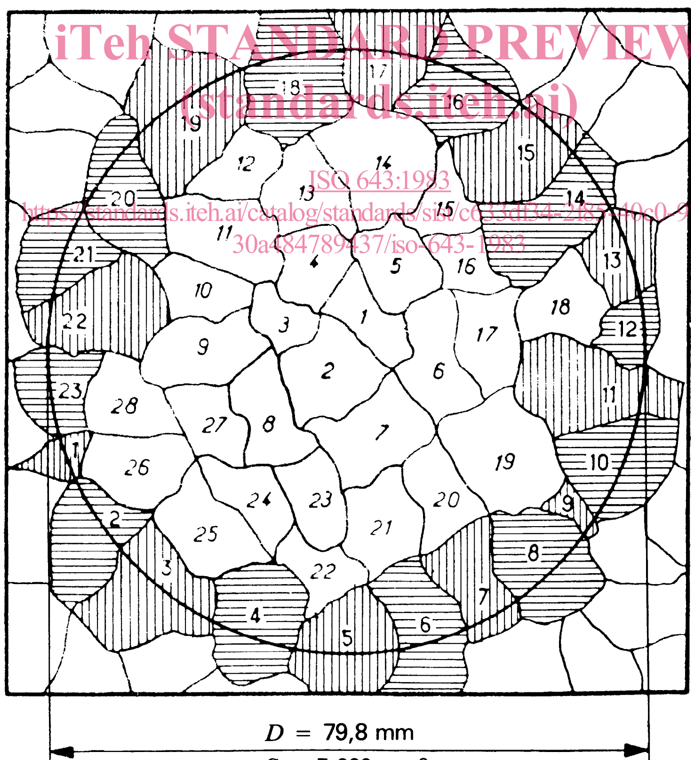

Figure 3 — Evaluation of number of grains in an area enclosed by a circle

Annex B

Determination of grain size — Standard charts — Taken from AFNOR Standard NF A 04-102

(Forms part of the Standard.)

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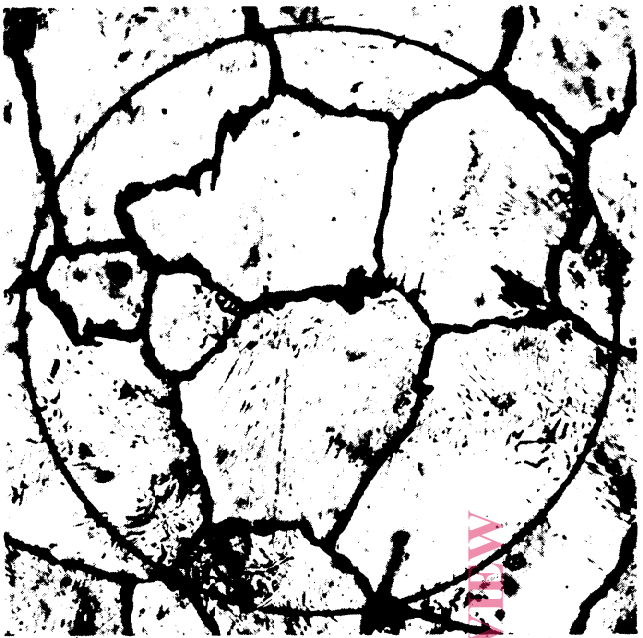
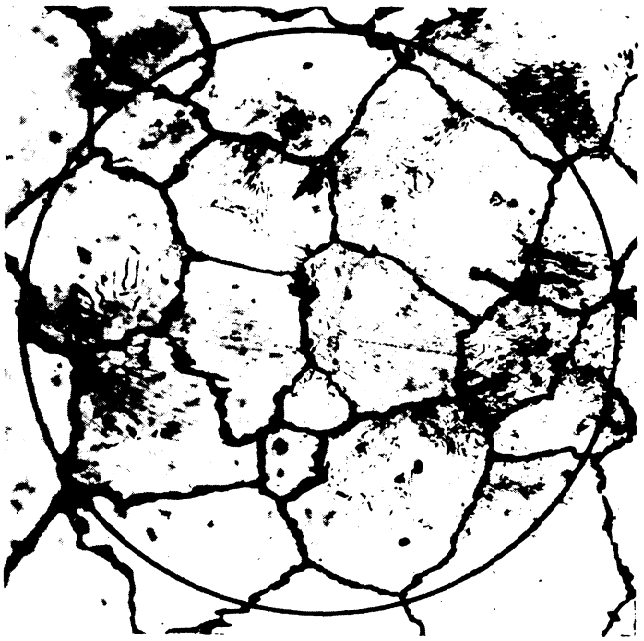
Standard chart I



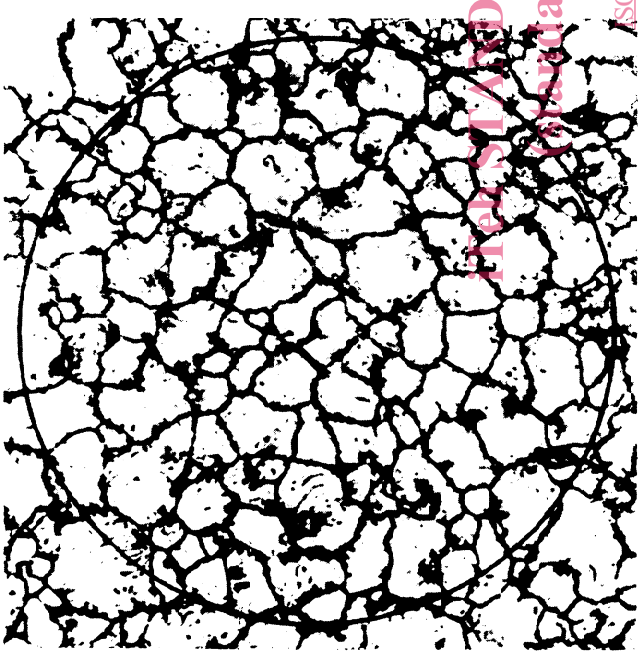
Grain index for a magnification of	−3	−1	**1**	3	5	7
	25	50	**100**	200	400	800

Standard chart II



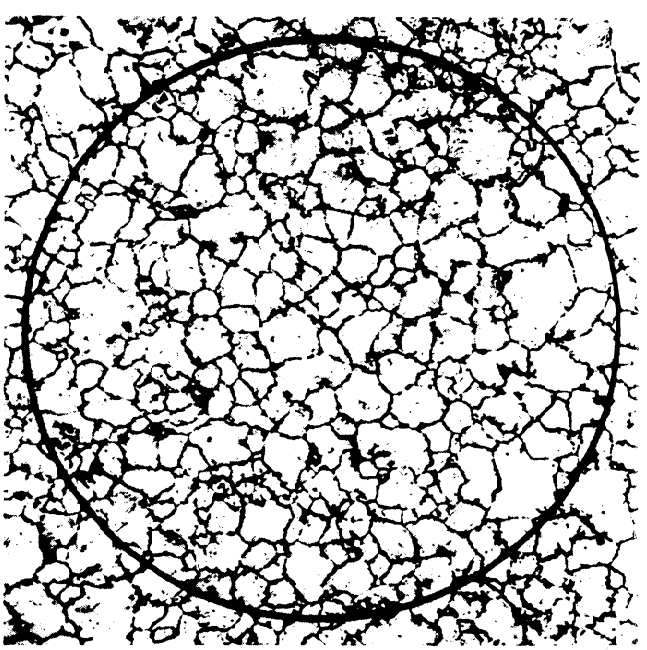
Grain index for a magnification of	−2	0	**2**	4	6	8
	25	50	**100**	200	400	800

Standard chart V



Grain index for a magnification of	1	3	**5**	7	9	11
	25	50	**100**	200	400	800

Standard chart VI



Grain index for a magnification of	2	4	**6**	8	10	12
	25	50	**100**	200	400	800

NOTE — In the case of 100 × magnification, the standard index of G of the grain size is equal to the standard chart number.
In the case of magnification other than 100, the index is different. The table below each standard chart gives the relationship between the grain size