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Metallographic examination

Microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions

DIN 50 602

Metallographische Prüfverfahren; mikroskopische Prüfung von Edelstählen auf nichtmetallische Einschlüsse mit Bildreihen

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Contents

1 Scope and field of application

1.1 This standard describes the examination of special steels for non-metallic inclusions of sulfidic and oxidic nature. Both macroscopic and microscopic methods are used for this purpose. Microscopic examination can be carried out using a metallurgical microscope and automatic devices. It has not been possible to standardize instrumentation for automatic evaluation of micrographs because development of such instruments is not yet complete. This standard specifies a method to be applied for microscopic examination using a metallurgical microscope and a set of standard diagrams arranged in a systematic sequence, which enables the micrograph to be described on the basis of the type and size of inclusion (length and width or diameter) and the frequency (standard diagram plate 1). An index proportional to the content of inclusions from a specified limit size upwards can be calculated separately for the oxide and sulfide components or as a total value. There is also provision for determining maximum sizes.

1.2 By agreement, the standard may also be applied to other steels.

In the case of low-carbon steels and stainless steels with no transformation, it is necessary to take into account the special properties of such steels (see subclause 5.4).

1.3 The standard applies to the steel sections listed in table 1 and figure 1. In the case of flat products in the form of sheet and strip and other products of small thickness and also forgings in which the fibres do not run in a straight line, special features need to be taken into account and agreements reached with regard to sampling and evaluation.

1.4 For steels influenced by the form of sulfide inclusions, a *Stahl-Eisen-Prüfblatt* (Iron and steel test sheet) is currently being prepared, which will take into account the length/width ratio of the inclusions.

1.5 *Stahl-Eisen-Prüfblatt* 1572 *Mikroskopische Prüfung von Automatenstählen auf sulfidische, nicht metallische Einschlüsse mit Bildreihen* [1] (Microscopic examination of free-cutting steels using standard diagrams to assess the content of non-metallic sulfide inclusions) shall be used for examination of "free-cutting steels" on the basis of the shape, size and distribution of the non-metallic inclusions.

1.6 It is not within the scope of this standard to specify maximum permissible contents or evaluation of non-metallic inclusions with a view to determining the serviceability of components. This is covered in material standards or technical delivery conditions.

[1] Obtainable from *Verlag Stahleisen mbH*, Postfach 8229, D-4000 Düsseldorf.

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2 Concepts

2.1 Non-metallic inclusions

Non-metallic inclusions to be assessed on the basis of this standard are constituents, typically found in steel, of sulfidic or oxidic nature originating from contact of the melt with the non-metallic lining of furnaces, ladles or casting channels, from oxidation by air or by slag covers, or resulting from the deoxidation process and the intentional addition of sulfur.

The type, size, shape and quantity of non-metallic inclusions depend on the steel grade, the steelmaking and casting processes, the method of deoxidation, the size of the ingot or continuously cast bar and the degree of deformation of the material. Their distribution is never uniform even in products made from one cast.

2.2 Microscopic inclusions

Microscopic inclusions are understood to mean inclusions which have a maximum area on the polished surface of 0,03 mm². This limit value corresponds to a size of inclusion of 100 mm × 3 mm in a microscope with a 100 × magnification, or to a different length (see clause 6) in the case of inclusions of the same area but, due to different degrees of deformation, involving a different length/width ratio.

2.3 Macroscopic inclusions

Macroscopic inclusions are understood to mean inclusions exceeding the limit value of area of microscopic inclusions. The standard diagram plate in this standard shows some macroscopic inclusions from line 8 onwards, and thus it permits a value to be given for the total degree of purity when an index is calculated.

2.4 Degree of purity

For the purposes of this standard, the degree of purity is a value indicating the content of non-metallic inclusions in the form of sulfides and oxides on the basis of one of the following methods of determination.

a) Method M: determination of maximum size rating values for different types of inclusion.

b) Method K: determination of index of percentage area of non-metallic inclusions in the structure, i.e. the sum obtained by counting inclusions weighted according to their area, starting from a specified size of inclusion upwards, and referred to an area of 1000 mm². This index is a value indicating the content of such inclusions in the product.

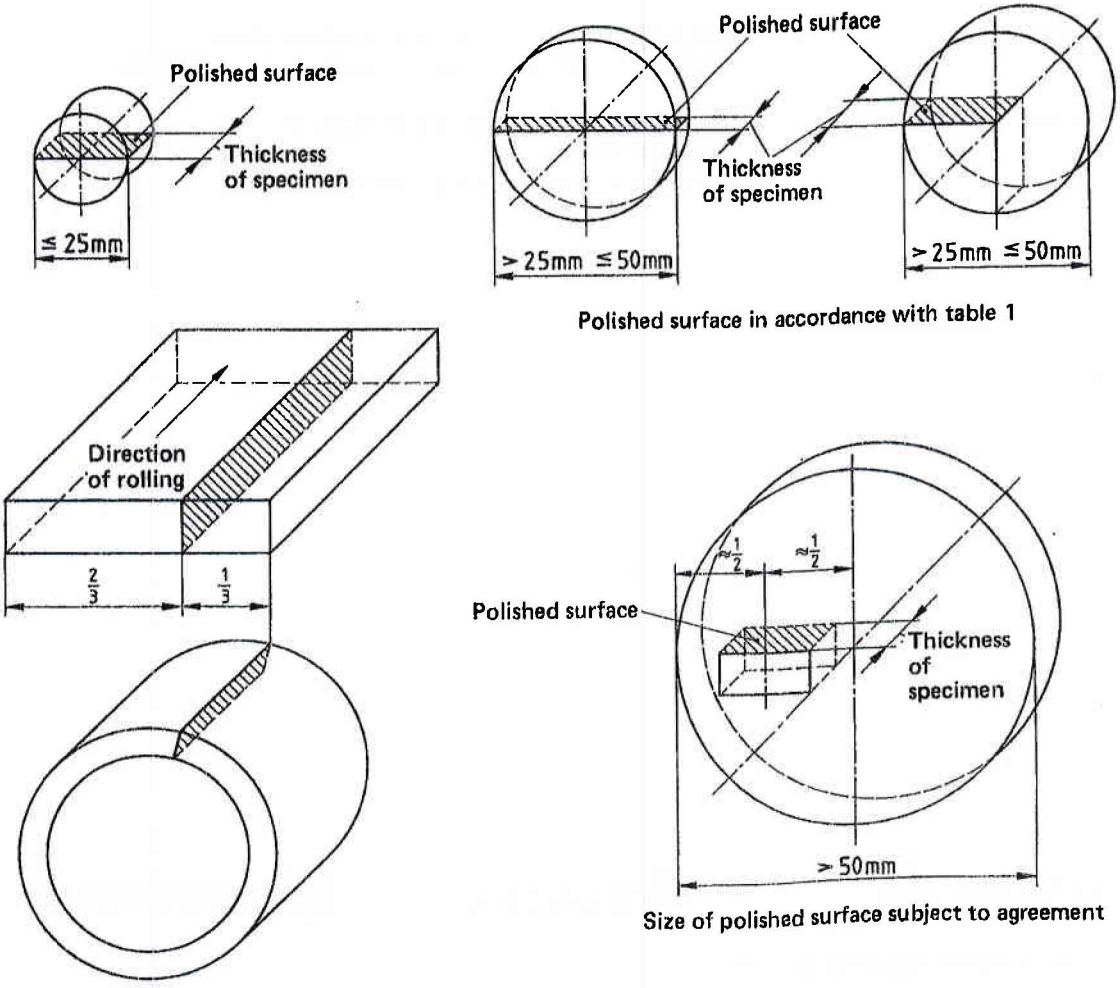

Figure 1. Sampling from products of different sizes

Table 1. **Position of polished surface of the specimen for various specimen sizes**

Size (diameter, length of short side or wall thickness)	Position of polished surface in the specimen
Up to 25 mm	Across the whole cross section of the specimen
Over 25 mm up to 50 mm	Across the whole cross section of the specimen or extending from the outer edge to the longitudinal axis
Over 50 mm	In the middle of the specimen between the outer edge and the longitudinal axis, or by agreement
In the case of wide flats, the polished surface of the specimens shall lie perpendicular to the larger surface and shall be cut adjacent to the first third of the product width, in the direction of rolling, and in the case of tubes, in the direction of the wall thickness and the direction of rolling or in the axial direction (see figure 1). In the case of forgings in which the fibres do not run in a straight line, an agreement shall be made at the time of ordering.	

2.5 Standard diagram plate No. 1

For the purposes of this standard, standard diagram plate No. 1 is a set of diagrams constructed line by line on the basis of a 2^n geometrical series for the area of non-metallic inclusions, containing forms of inclusion typical for steel, the inclusion area doubling from one diagram to the next in each column. Inclusions of equal area but differing in length × width or frequency, are shown on the same line next to the basic column for each type of inclusion.

3 Designation of method

Designation of the examination for non-metallic inclusions as specified in this standard, method K, count of inclusions from rating number 4:

Test DIN 50 602 — K 4

4 Scope of test

4.1 Single specimens do not provide a representative index of the degree of purity of a cast or a batch so that the test is to be carried out on a number of specimens. In general, the degree of purity shall be tested on not less than six specimens.

4.2 For each order, a check shall be made whether the circumstances allow a reduction in the number of specimens to less than 6, for which purpose it is necessary to take into account the quantity supplied and, if required, the extent of any forming the material has undergone and the position of the specimen in the product. The delivery conditions may specify a different number of specimens.

4.3 If the quantity of material submitted for testing exhibits special features, for example that the specimens do not originate from the same cast or the sizes of the various specimens differ substantially from one another, these special features shall be taken into account when agreeing the scope of test (see subclause 4.2).

5 Sampling and preparation of specimens

5.1 The specimens shall be taken in such a manner that the polished surface to be evaluated is if possible parallel to the direction of forming (e.g. rolling), and in the case of rotationally symmetrical cross sections, that it lies in the plane through the axis of the product, this providing satisfactory conditions for comparison of non-metallic inclusions with regard to their length.

5.2 Table 1 and figure 1 give specifications relating to the arrangement (sampling points) of the specimens in round and square steel tubes and wide flats with a small width-to-thickness ratio.

5.3 The size of the polished surface of the specimens of a quantity of material submitted for testing (cast or batch) depends on various circumstances, such as the type and cross-sectional dimensions of the product or the method of evaluation (see the relevant notes given in subclauses 8.2.1 and 8.2.2). In addition, the amount of work involved in sampling and testing should also be taken into account when determining the size. For this reason, on the basis of figure 1, in the case of products exceeding 50 mm in diameter or width, the size of the polished surface may be, for example 12 mm × 18 mm, corresponding to 1/2″ × 3/4″ in ASTM E 45, or the section may extend from the outer edge to the longitudinal axis. As far as possible, the polished surface of the specimens of one test unit should have the same dimensions.

5.4 In polishing the specimens, the inclusions shall not be torn out or be changed in their form and no particles of grinding or polishing agent shall be pressed into the polished surface. If necessary, the surface of the section is to be hardened. For this reason, the specimens are to be carefully ground and then polished for as short a time as possible.

6 Structure and use of standard diagram plates

6.1 Diagram plate No. 1

6.1.1 Diagram plate No. 1 includes four basic columns giving the most commonly observed shapes of inclusions designated by numbers 1, 3, 6 and 8, each consisting of nine diagrams with inclusion rating numbers 0 to 8. The scale of reproduction of the diagrams in plate No. 1 is 100 : 1. The following types of inclusion are distinguished:

inclusion type SS: sulfide inclusions of elongated type;
inclusion type OA: oxide inclusions of fragmented type (aluminium oxides);
inclusion type OS: oxide inclusions of elongated type (silicates);
inclusion type OG: oxide inclusions of globular type.

The derived columns 0, 2, 4, 5, 7 and 9 are described in subclauses 6.1.2 and 6.1.3.

The nine diagrams of a column with the rating numbers 0 to 8 show under rating number 0 the smallest microscopic inclusion that can be evaluated at a magnification of × 100, and under rating number 8 in some cases inclusions that are already in the macroscopic range for the type of inclusion concerned. The area of

the inclusions shown doubles from one diagram to the next, forming a 2^n geometric series where n is the rating number.

The length of the inclusion to be considered increases from diagram to diagram by a factor of 1,5 with a simultaneous increase in the average inclusion width, thus conforming to the basic formula for the increase in area of the inclusions. The length, and in column 6 also the width, are marked on the diagrams in plate No. 1 in order to facilitate measurement. The length of an oxidic inclusion in the case of OA inclusions is greater than that for OS inclusions of the same width, because for a given rating number, the area would otherwise be different. Rating number 9 is reserved for macroscopic inclusions, which are not shown in diagrammatic form, because they would extend beyond the limits of the image field.

6.1.2 If, in the case of a single inclusion, for the same length, the width is only half that in the equivalent diagram of column 1, 3 or 6, the area of the inclusion is also halved so that the rating number is therefore reduced by 1. This is represented by columns 0, 2 and 5, each on the left of a basic column. Similar considerations apply for the evaluation of thicker inclusions with twice the area. In such cases, the rating number is to be increased by 1.

6.1.3 If other non-metallic inclusions up to two rating numbers smaller are visible in the field under observation, the area of the inclusions within the circular sub-field again increases and the rating number is increased by 1 as in columns 4 and 7, on the right of basic columns. Sulfides mostly occur in clusters so that it was not

Table 2. System for assigning narrow elongated non-metallic inclusions to the lines in diagram plate No. 1 (i.e. to the rating numbers) as a function of their width and length

Line number (n): rating number	Average true width (b) of the non-metallic inclusions, in µm 0,5 [2] | 1 | 2 | 3 | 5 | 7 | 10 Average true length (l), in mm							Area (A) [1] (magnification: x 100), in mm²
0	0,20	0,10	0,05 [3,0]	0,03 [6,0]	0,02	0,014	0,01	1
1	0,40	0,20	0,10	0,06 [3,1]	0,04 [6,1]	0,028	0,02	2
2	0,80	0,40	0,20	0,12 [3,2]	0,08 [6,2]	0,056	0,04	4
3	1,60	0,80	0,40	0,25	0,16 [3,3]	0,11 [6,3]	0,08	8
4	3,20	1,60	0,80	0,50	0,32	0,22 [3,4]	0,16 [6,4]	16
5	6,40	3,20	1,60	1,00	0,64	0,44	0,32 [3,5]	32
6		6,40	3,20	2,00	1,28	0,88	0,64	64
7			6,40	4,00	2,56	1,76	1,28	128
8				8,00	5,12	3,52	2,56	256

The pairs of numbers in the boxes give examples of the appropriate diagrams in diagram plate No. 1.

[1] Here again, $A = 2^n$.

[2] Because this is approaching the limit of resolution of the microscope, it is no longer meaningful here to give a precise indication of the true width of the inclusions in this size range.

Table 3. Ranges of average lengths of non-metallic inclusions as specified in table 2

Line number (n): rating number	Mean true width (b) of non-metallic inclusions, in µm 0,5 [1] | 1 | 2 | 3 | 5 | 7 | 10 Range of average length (l), in mm													
	Over	Up to	Over	Up to	Over	Up to	Over	Up to	Over	Up to	Over	Up to	Over	Up to
0	0,15	0,29	0,065	0,15	0,033	0,065	0,022	0,045	0,015	0,03	0,010	0,02	0,0065	0,015
1	0,29	0,56	0,15	0,29	0,065	0,15	0,045	0,09	0,03	0,06	0,02	0,04	0,015	0,029
2	0,56	1,10	0,29	0,56	0,15	0,29	0,09	0,15	0,06	0,12	0,04	0,08	0,029	0,051
3	1,10	2,20	0,56	1,10	0,29	0,56	0,15	0,35	0,12	0,22	0,08	0,16	0,051	0,11
4	2,20	4,40	1,10	2,20	0,56	1,10	0,35	0,66	0,22	0,44	0,16	0,32	0,11	0,22
5	4,40	8,80	2,20	4,40	1,10	2,20	0,66	1,40	0,44	0,88	0,32	0,60	0,22	0,44
6			4,40	8,80	2,20	4,40	1,40	2,80	0,88	1,66	0,60	1,20	0,44	0,88
7					4,40	8,80	2,80	5,60	1,66	3,32	1,20	2,40	0,88	1,66
8							5,60	11,20	3,32	6,64	2,40	4,80	1,66	3,32

[1] Because this is approaching the limit of resolution of the microscope, it is no longer meaningful here to give a precise indication of the true width of the inclusions in this size range.

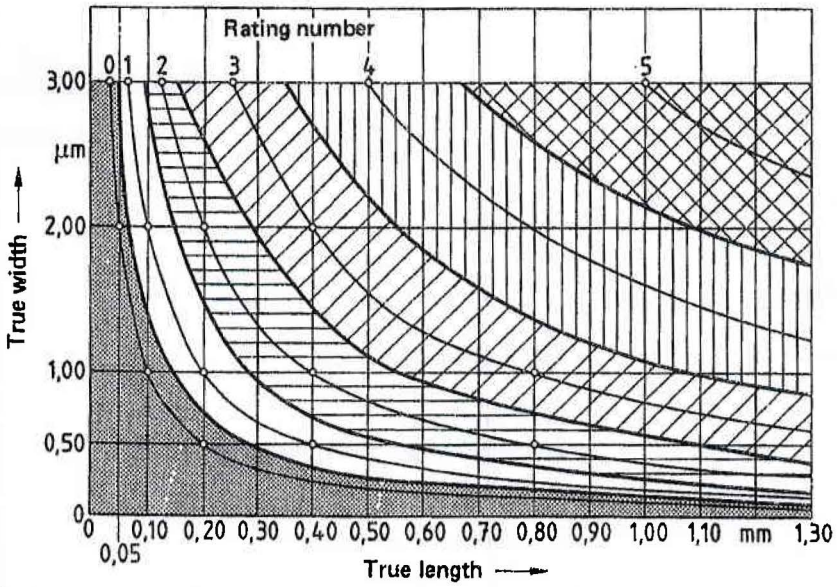

Figure 2. Relationship between true width, true length and size rating number for the inclusions referred to in tables 2 and 3

considered necessary to represent individual sulfidic inclusions. If sulfidic inclusions occur individually, the dimensions of the longest inclusion in the SS columns shall be used as a basis for estimating the length or area and the rating number reduced by 1.

6.2 Diagram plates Nos. 2 and 3

6.2.1 The principle of identical rating numbers for identical areas of inclusions applies also to thinner, more elongated inclusions and those with a greater degree of fragmentation than shown in diagram plate No. 1. Since such inclusions usually extend beyond the limits of the field visible in the microscope (sub-field) these are described in tables 2 and 3 by specifying the appropriate rating number for various combinations of inclusion length and width.

These numerical relationships are shown in a graph in figure 2. This figure can be used especially for simple reading of interpolated values of inclusion length and width.

Diagram plates Nos. 2 and 3, which supplement diagram plate No. 1, are intended to serve as an aid for classifying under a smaller or larger rating number, types of inclusion that are thinner and more fragmented or more tightly grouped than would correspond to the diagrams of the basic series. The principle of assigning the rating number according to the area of the inclusions also applies for thicker inclusions, the classification of which by length has been made in accordance with the basic series of diagram plate No. 1.

When using diagram plates Nos. 2 and 3, it is important to bear in mind the scale of reproduction (200 : 1) when comparing them to the basic series shown in plate No. 1 (100 : 1).

6.2.2 Diagram plate No. 2 including two series (OA and OS and SS) provides a visual aid for determining the width of such inclusions. The length is not given here and therefore is to be measured and then classified under a rating number of the basis of the data given in tables 2 and 3 or figure 2.

6.2.3 Diagram plate No. 3 gives in the left-hand column, type OA inclusions with different degrees of fragmentation. The relevant numbers indicate the amount by which the rating number assigned to the total length, is to be reduced because of the greater degree of fragmentation (see subclause 7.2.3, and also subclause 7.2.4). The width of the inclusion is to be assessed in accordance with diagram plate No. 2.

The right-hand column of diagram plate No. 3 is to be used for classifying clustered inclusions, for classifying which in comparison with an individual inclusion of the basic series, it is necessary to take into account not only the quantity and the distance between the inclusions but also the area of all non-metallic inclusions, i.e. their total extension. The associated numbers show the amount by which the rating number is to be increased, with increasing frequency.

6.2.4 For a classification of globular inclusions, insofar as they are not represented in diagram plate No. 1, i.e. in the case of very small, very large or clustered inclusions, the principle of classification according to the total area of the inclusions is again used as a basis.

6.3 To ensure greater clarity and reduce the work involved, once the user is sufficiently practised, it is possible to use for the test just columns 1, 3, 6 and 8 as shown in diagram plate No. 1, together with plates Nos. 2 and 3 for smaller thicknesses of inclusion, greater degree of fragmentation and greater frequency, because columns 0, 2, 4, 5, 7 and 9 merely show examples of evaluation deviating, for one length of inclusion, only by one rating number from the respective basic column.

7 Test procedure

7.1 The polished surface of the specimens shall be observed using a microscope with a magnification of

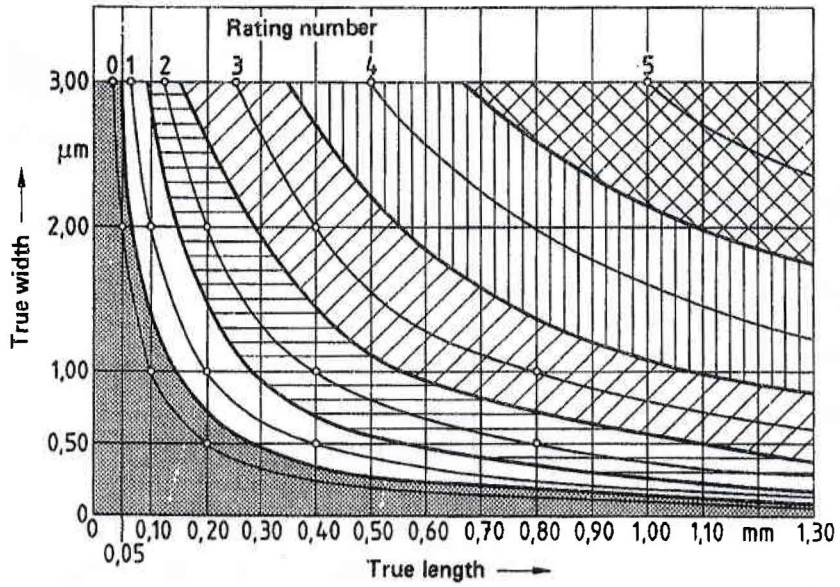

Figure 2. Relationship between true width, true length and size rating number for the inclusions referred to in tables 2 and 3

considered necessary to represent individual sulfidic inclusions. If sulfidic inclusions occur individually, the dimensions of the longest inclusion in the SS columns shall be used as a basis for estimating the length or area and the rating number reduced by 1.

6.2 Diagram plates Nos. 2 and 3

6.2.1 The principle of identical rating numbers for identical areas of inclusions applies also to thinner, more elongated inclusions and those with a greater degree of fragmentation than shown in diagram plate No. 1. Since such inclusions usually extend beyond the limits of the field visible in the microscope (sub-field) these are described in tables 2 and 3 by specifying the appropriate rating number for various combinations of inclusion length and width.

These numerical relationships are shown in a graph in figure 2. This figure can be used especially for simple reading of interpolated values of inclusion length and width.

Diagram plates Nos. 2 and 3, which supplement diagram plate No. 1, are intended to serve as an aid for classifying under a smaller or larger rating number, types of inclusion that are thinner and more fragmented or more tightly grouped than would correspond to the diagrams of the basic series. The principle of assigning the rating number according to the area of the inclusions also applies for thicker inclusions, the classification of which by length has been made in accordance with the basic series of diagram plate No. 1.

When using diagram plates Nos. 2 and 3, it is important to bear in mind the scale of reproduction (200 : 1) when comparing them to the basic series shown in plate No. 1 (100 : 1).

6.2.2 Diagram plate No. 2 including two series (OA and OS and SS) provides a visual aid for determining the width of such inclusions. The length is not given here and therefore is to be measured and then classified under a rating number of the basis of the data given in tables 2 and 3 or figure 2.

6.2.3 Diagram plate No. 3 gives in the left-hand column, type OA inclusions with different degrees of fragmentation. The relevant numbers indicate the amount by which the rating number assigned to the total length, is to be reduced because of the greater degree of fragmentation (see subclause 7.2.3, and also subclause 7.2.4). The width of the inclusion is to be assessed in accordance with diagram plate No. 2.

The right-hand column of diagram plate No. 3 is to be used for classifying clustered inclusions, for classifying which in comparison with an individual inclusion of the basic series, it is necessary to take into account not only the quantity and the distance between the inclusions but also the area of all non-metallic inclusions, i.e. their total extension. The associated numbers show the amount by which the rating number is to be increased, with increasing frequency.

6.2.4 For a classification of globular inclusions, insofar as they are not represented in diagram plate No. 1, i.e. in the case of very small, very large or clustered inclusions, the principle of classification according to the total area of the inclusions is again used as a basis.

6.3 To ensure greater clarity and reduce the work involved, once the user is sufficiently practised, it is possible to use for the test just columns 1, 3, 6 and 8 as shown in diagram plate No. 1, together with plates Nos. 2 and 3 for smaller thicknesses of inclusion, greater degree of fragmentation and greater frequency, because columns 0, 2, 4, 5, 7 and 9 merely show examples of evaluation deviating, for one length of inclusion, only by one rating number from the respective basic column.

7 Test procedure

7.1 The polished surface of the specimens shall be observed using a microscope with a magnification of

× 100. This magnification is the same as the scale of reproduction of the diagrams in plate No. 1 [2]).

The specimen can be observed either through the eyepiece or on a projection on a ground glass screen. The field under observation shall be of the same size as the reference diagrams of plate No. 1 (if possible, 80 mm in diameter; fields with a diameter between 75 and 80 mm are however permitted). It is advisable to limit the field under observation to this size by having a circular mark in the eyepiece or on the ground glass screen. For observation of very thin inclusions, it is advisable to use a magnification of × 200. Such a magnification is equal to the scale on which diagram plate Nos. 2 and 3 are reproduced.

7.2 For rating non-metallic inclusions in a field under observation it is necessary to determine the diagram in plate No. 1 corresponding to that observed, where necessary supplemented by the appropriate diagram from plate Nos. 2 and 3. For this purpose, it is advisable to start from the measurement or estimate of length of the inclusion to be considered.

7.2.1 For an evaluation on the basis of diagram plate No. 1 it is particularly important to note that for rating numbers 6, 7 and 8 of columns 0 to 6 there are some fields in which the length of the non-metallic inclusion to be considered extends beyond the diameter of the circular field to a certain extent. Non-metallic inclusions observed in such cases are to be rated on the basis of the inclusion length given below each diagram. Unless otherwise agreed, even larger inclusions (of the same or of greater thickness) than those shown are all to be classified under rating number 9.

7.2.2 If inclusions of different types and shapes, as shown in the series of diagrams, can be clearly distinguished from each other within one field under observation, these shall be treated as though they had occurred separately in different fields.

7.2.3 Inclusions of types SS, OS and, at a lower degree of fragmentation, OA, lying one behind another on one line shall be regarded as continuous if the distance between two inclusions is less than the length of the smaller of the two inclusions. Isolated point-shaped inclusions are not to be taken into account when determining the total length.

7.2.4 For inclusion type OA, diagram plate No. 3 (left-hand column) provides a basis for assessing the degree of fragmentation to assign to the area the correct rating number. If the average distance between the particles of a string of inclusions of this type is larger than the largest distance between the point-shaped inclusions represented in the top left-hand diagram of plate No. 3, the evaluation shall be made on the basis of inclusion type OG. The reproduction is intended to show that loosely grouped strings are to be assigned lower rating numbers corresponding to the area of oxides contained. These numbers are then generally in ranges which, for example in the case of method K 4, are not recorded, but still are to be taken into account for method K 1.

7.3 In general, the complete area of the polished surface of the specimens shall be examined. Any exceptions to this, which only arise in the case of method K (see subclause 8.2.2.3), shall be specially agreed and specified in the relevant delivery condition.

8 Evaluation using methods M and K

8.1 General

8.1.1 The non-metallic inclusions observed shall be designated (in the sequence indicated below and separated from each other by a point) in each case with the number of the diagram column concerned (type and shape of inclusion) and with the rating number as in diagram plate No. 1, determined in accordance with the procedure described in clauses 6 and 7, e.g. 1.2, 5.3, 6.5.

It is not permitted to give fractions to indicate the inclusion rating (e.g. 2,5; 4 1/2).

8.1.2 Printed forms should preferably be used for recording the test results and their evaluation (e.g. as shown in tables 4, 7 and 8).

8.2 Method of evaluation

Two different methods of evaluation are described in subclauses 8.2.1 and 8.2.2. Which of the two methods is to be used, shall be specified in the relevant delivery condition.

8.2.1 Method M

8.2.1.1 This method serves to determine which of the maximum-size [3]) inclusions of the various types and, where applicable shapes, occur in the quantity of material submitted for testing.

The specimens shall be taken in accordance with the specifications given in subclauses 5.2 and 5.3. The polished section to be evaluated shall be about 200 mm^2, if a size of 12 mm × 18 mm has been agreed.

This method of evaluation is adequate for most industrial purposes and is, for example, used for special structural steels.

8.2.1.2 The complete polished section of each specimen to be evaluated shall first be examined and then for each column of diagram plate No. 1 (if necessary, additionally using plate Nos. 2 and 3), the highest rating number of non-metallic inclusions occurring shall be noted and recorded. From the rating numbers determined for each column for the microsections examined, in each case the arithmetic mean shall be calculated. These values serves as indices for the "degree of purity" of the quantity of material submitted for testing under the conditions existing. The frequency of occurrence of non-metallic inclusions is not assessed in this method. This method therefore also does not provide a comparative value of the content of non-metallic inclusions.

8.2.1.3 Table 4 gives an example for recording the test results obtained in an evaluation in which the values of

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[2]) Diagram plate No. 1 shows the diagrams on a reduced scale of about one third of that of the original plate. It can therefore only give an approximate indication of the original plate. For the evaluation proper, the full scale diagram plate should be used; this can be obtained from *Beuth Verlag GmbH*, Burggrafenstraße 4–6, D-1000 Berlin 30.

[3]) See subclause 2.4.

Table 4. **Example of representing test results when evaluating on the basis of maximum rating numbers, using method M** (see subclause 8.2.1.3)

Number of polished section No.	Maximum rating number determined for each section and for each column in the diagram plate used			
	SS	OA	OS	OG
1	4	5	3	3
2	5	4	4	2
3	3	4	4	2
4	4	3	3	3
5	4	4	2	1
6	3	4	4	3
7	4	3	3	4
8	5	4	3	3
9	3	5	4	2
Mean	3,9	4,0	3,3	2,6

the derived columns of diagram plate No. 1 have been collated for the four types of inclusion with the values of columns 1, 3, 6 and 8, in accordance with the procedure described in subclause 6.3. Inclusions of the same area, whether thin or clustered, are given the same rating number and can thus be grouped together under one type of inclusion.

8.2.1.4 In the case of method M, for a test for sulfidic inclusions assigned to rating number 3 below, a general method for determining the degree of purity e.g. the use of comparative diagrams that give only rough idea of the inclusion content, may be agreed additionally at the time of ordering.

8.2.2 Method K

8.2.2.1 In some cases it may be desirable to record all non-metallic inclusions from a specified size upwards and to give the degree of purity of a cast or a batch by means of a comprehensive index, K [4]), characterizing the area of the inclusions. With this method, the area of the polished section of the specimen to be evaluated shall be at least 100 mm^2. With regard to the sampling points for the samples and the area of the polished section, the notes given in subclauses 5.2 and 5.3 shall apply.

8.2.2.2 It is necessary to decide in each case from which rating number on inclusions are to be evaluated. This (lowest) rating number depends mainly on the manufacturing process (particularly the steelmaking process), and on the intended application of the material concerned and the dimensions of the product.

On the basis of experience the rules given in table 5 for guidance have been drawn up, which should as far as possible be used as a basis when agreeing on the method of evaluation.

8.2.2.3 Unless otherwise agreed, in each case, the whole area of the polished section shall be examined. The sulfidic and oxidic inclusions shall be counted separately and recorded using the examples given in tables 7 and 8. Where only separate, predetermined measurement fields or parts of measurement field within the polished section are to be examined (which is only advisable in exceptional cases), the size and distribution of these fields or parts of measurement fields shall comply with the conditions for a statistical test.

8.2.2.4 Calculation procedure for evaluation using method K

The calculation procedure for obtaining the total index is, for simplicity, based on the method of assigning the factor 1 to the most frequently determined rating number 4. The factors obtained on the basis of the 2^{n-4} geometric series for the other rating numbers are to be rounded so that, in the calculation, it is only necessary to double or halve the numbers. The resulting deviation in the calculation lies within the dispersion arising from the fact that non-metallic inclusions are not uniformly distributed in steel. With this procedure, the larger inclusions are more accurately evaluated.

Table 6 gives the factors to be used in the calculations.

For calculation of the total indices the procedure is as follows (see also examples given in tables 7 and 8): the number of non-metallic inclusions of each inclusion type (SS, OA, OS, OG) and each rating number observed shall be multiplied by the appropriate factor (f'_g, see table 6) and the products added, normally separately for sulfides and for total oxides. The "first subtotals" obtained in

[4]) See subclause 2.4.

Table 5. **Guidance evaluation procedure using method K**

Type of material and steelmaking process	Range of rating numbers to be used in the evaluation	Symbol *)	For example of evaluation, see
Air melted special steels, e.g. steel for ball and roller bearings, structural steels and tool steels with special quality requirements for product sizes not less than 30 mm	≥ 4	K 4	table 7
Vacuum melted or vacuum remelted special steels or alloys or remelted by the electroslag process	≥ 1	K 1	table 8

*) The number following code letter K indicates the smallest rating number from diagram plate No. 1 included in the evaluation (see clause 3).

Table 6. **Values of factor f_g to be used for the evaluation using method K**

Rating number (n)	0	1	2	3	4	5	6	7	8	(9) **)
Factor $F = 2^{n-4}$	1/16	1/8	1/4	1/2	1	2	4	8	16	32
Factor f_g *) to be used for the evaluation	0,05	0,1	0,2	0,5	1	2	5	10	20	50

*) g means rounded.
**) See subclause 7.2.1.

this manner for each individual polished section are then to be added for all specimens in the test unit, thus producing a "second subtotal" (in mm^2) for all specimens. This result is then to be converted to a section area of 1000 mm^2, using the following formula:

$$\frac{\text{second subtotal} \times 1000}{\text{total area of polished section of specimens (in mm}^2\text{)}} = \text{total index}$$

The "total indices" calculated separately in this manner for sulfides (S) and oxides (O) may, by agreement, be added to produce an "overall total index".

The two total indices or the overall total index represent the degree of purity of the test unit examined. The values obtained in the two cases should if possible be integers and for this reason should be rounded, if necessary.

The index denoting the degree of purity is in each case to be given the letter K and, in combination with it, the rating number for the smallest inclusions covered by the evaluation and if necessary, the code letters designating the types of inclusion, so as to avoid confusion and the possibility of comparing results with a different information content.

The method of writing the index is (as shown in table 7):
K 4 = 66 (S: 26; O: 40).

Tables 7 and 8 each give an example of evaluation including a complete description of the evaluation conditions.

9 Test report

The test report shall refer to this standard and give the following information:

a) steel grade and symbol identifying the steelmaking process;
b) form and dimensions of product from which the specimens have been taken;
c) method used as described in subclause 2.4, together with any special features;
d) result of the evaluation, including by agreement
- for method M,
  either the subtotals (see table 3 for example) or only the final results (mean for each column of diagrams considered)
- for method K,
  statement of the smallest rating number included in the evaluation, either by specifying the subtotals (see tables 7 and 8 for examples) or only the final results (total indices for S and O or overall total indices) as described in subclause 8.2.2.4.

Table 7. Example of evaluation using method K 4 as described in subclause 8.2.2 (see table 5) (for air melted 100 mm square special steel billets)

Specimen No.	Area of polished section evaluated, in mm^2	Types of inclusion as in diagram plate No. 1	Number of inclusions classified by rating number									Multiplication and first subtotal	
			0	1	2	3	4	5	6	7	8		
			Factor f_g										
			0,05	0,1	0,2	0,5	1	2	5	10	20	S *)	O *)
1	450	SS					3	1	1	–	–	10	
		OA					5	1	–	–	–		10
		OS					2	–	–	–	–		
		OG					1	–	–	–	–		
2	400	SS					4	2	–	–	–	8	
		OA					3	1	1	–	–		21
		OS					2	1	–	–	–		
		OG					2	–	1	–	–		
3	350	SS					2	1	–	1	–	14	
		OA					4	2	–	–	–		12
		OS					1	1	–	–	–		
		OG					1	–	–	–	–		
4	600	SS					5	–	–	–	–	5	
		OA					8	1	–	–	–		15
		OS					1	1	–	–	–		
		OG					–	1	–	–	–		
5	250	SS					1	1	1	–	–	8	
		OA					3	1	–	–	–		14
		OS					1	–	1	–	–		
		OG					1	1	–	–	–		
6	300	SS					4	1	–	1	–	16	
		OA					2	2	1	–	–		21
		OS					2	–	1	–	–		
		OG					1	1	–	–	–		
Total	2350						Second subtotal					S:61	O:93
							Total index K 4 **)					S:26	O:40
							Overall total index K 4					66	

*) S = sulfides;
O = oxides.

**) Converted to a polished section area of 1000 mm^2 and rounded to the nearest whole numbers.

Table 8. **Example of evaluation using method K 1 as described in subclause 8.2.2 (see table 5) (using vacuum remelted 120 mm square special steel billets)**

Specimen No.	Area of polished section evaluated, in mm^2	Types of inclusion as in diagram plate No. 1	Number of inclusions classified by rating number									Multiplication and first subtotal	
			0	1	2	3	4	5	6	7	8		
			Factor f_g										
			0,05	0,1	0,2	0,5	1	2	5	10	20	S *)	O *)
1	560	SS		6	1	–	–	–	–	–	–	0,8	
		OA		–	–	–	–	–	–	–	–		
		OS		1	–	–	–	–	–	–	–		0,1
		OG		–	–	–	–	–	–	–	–		
2	530	SS		5	2	–	–	–	–	–	–	0,9	
		OA		–	–	–	–	–	–	–	–		
		OS		–	–	–	–	–	–	–	–		0
		OG		–	–	–	–	–	–	–	–		
3	570	SS		7	1	–	–	–	–	–	–	0,9	
		OA		2	–	–	–	–	–	–	–		
		OS		–	–	–	–	–	–	–	–		0,2
		OG		–	–	–	–	–	–	–	–		
4	600	SS		6	3	–	–	–	–	–	–	1,2	
		OA		–	–	–	–	–	–	–	–		
		OS		–	–	–	–	–	–	–	–		0
		OG		–	–	–	–	–	–	–	–		
5	520	SS		4	–	–	–	–	–	–	–	0,4	
		OA		–	–	–	–	–	–	–	–		
		OS		–	–	–	–	–	–	–	–		0
		OG		–	–	–	–	–	–	–	–		
6	540	SS		7	1	–	–	–	–	–	–	0,9	
		OA		–	1	–	–	–	–	–	–		
		OS		–	–	–	–	–	–	–	–		0,2
		OG		–	–	–	–	–	–	–	–		
Total	3320						Second subtotal					S : 5,1	O : 0,5
							Total index K 1 **)					S : 1,54	O : 0,15
							Overall total index K 1 ***)					1,7	

*) S = sulfides;
O = oxides.

**) Converted to a polished section area of 1000 mm^2.

***) Rounded from 1,69 to 1,7.

Standards and other documents referred to

ASTM E 45-85	Standard practice for determining the inclusion content of steel [5]
Stahl-Eisen-Prüfblatt 1572	*Mikroskopische Prüfung von Automatenstählen auf sulfidische, nichtmetallische Einflüsse mit Bildreihen* [1]

Other relevant standards

DIN 50 600	Testing of metallic materials; metallographic micrographs; image scales and formats

Explanatory notes

This standard has been prepared by Joint Committee NMP 131/FES *Metallografische Prüfungen* of the *Normenausschuß Materialprüfung (NMP)* (Materials Testing Standards Committee) and the *Normenausschuß Eisen und Stahl (FES)* (Iron and Steel Standards Committee) in conjunction with the *Verein Deutscher Eisenhüttenleute (VDEh)* (Society of German Ferrous Metallurgy Engineers). It has been developed from *Stahl-Eisen-Prüfblatt* 1570-71 *Mikroskopische Prüfung von Edelstählen auf nichtmetallische Einschlüsse mit Bildreihen* (Microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions) and from Supplement 1 to this specification, *Mikroskopische Prüfung von Edelstählen auf schmale langgestreckte nichtmetallische Einschlüsse* (Microscopic examination of special steels for fine, elongated non-metallic inclusions).

International Standard ISO 4967, Steel; determination of content of non-metallic inclusions; micrographic method using standard diagrams [6] has been issued by the International Organization for Standardization (ISO).

This International standard has not been adopted by the Federal Republic of Germany, mainly because it gives standard diagrams that are not used in Germany and which are not intended to be introduced in Germany. Instead, the present standard, which has been developed from *Stahl-Eisen-Prüfblatt* 1570 (1971) and its Supplement 1 (1977) has been prepared.

International Patent Classification

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[1] See page 1.

[5] Obtainable from the *Auslandsnormenvermittlung* of *DIN*, Burggrafenstraße 6, D-1000 Berlin 30.

[6] Obtainable from *Beuth Verlag GmbH*, Burggrafenstraße 6, D-1000 Berlin 30.