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Steel Metallographic Methods for the Determination of Non-metallic Inclusions.

NOTE :- DO NOT SCRIBLE IN THE SPECIFICATION.

39

					GOST 1778-70	
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S T E E L

Metallographic methods for the determination of nonmetallic inclusions. GOST 1778-70.

This standard pertains to steel and alloys and establishes the metallographic methods for determining their contamination caused by non-metallic inclusions.

1 CLASSIFICATION.

1.1. Non-metallic inclusions are determined by following methods:

method Ш (variants Ш1- Ш14) - by comparing with standard scales; the method is used for testing deformed metal;

method К (variants K1-K2) - by count ing the number of inclusions;

the method is used for testing the deformed and cast metal;

method П (variants П1- П4) - by counting the number and volume percentage of inclusions; the method is used for testing the deformed and case metal; method Л (variants Л1 -Л2) - by linear counting of inclusions; the method is used for testing the casting.

1.2. Use of the methods and their variants for testing the metals, as well as the norms for steel and alloy contamination caused by non metallic inclusions are given in the standards or the Specifications approved in the established order for specific metal product.

Recommendation on choice of methods are specified in appendix 1.

2. Selection of test-pieces making of micro-sections.

2.1. The number of test-pieces to determine the contamination caused by non-metallic inclusions is given in standards for the product and technical documents approved in the established order and should be minimum 6 from each melting. Number of test-pieces depends on the required accuracy of determination.

2.2. Following is the procedure to select the test-pieces from deformed metal.

a) During the check on 6 micro sections-The samples are chosen from 6 bars, bundles, pipes, sheets, strips.

b) during check on more than 6 micro-sections-the samples are chosen per 1, 2, 3, 4 and soon from each of 6 or more of bars, bundles, pipes, sheets, strips.

NOTES: 1. Upon agreement between the supplier and the customer, established may be the place for selecting the test pieces from bars along the ingot height. Test-pieces of bars may be selected from one or a number of ingots during casting of the metal.

2. During check of deformed metal with diameter or thickness exceeding 150mm, test-pieces may be chosen from two bars.

3. During check of drilled or intended for drilling round billet with diameter of upto 600mm and wall thickness not exceeding 250mm the test-pieces are chosen from two billets.

4. During check of sheets with thickness exceeding 1000mm, the test-pieces are chosen from two sheets.

2.3. Test-pieces of deformed bars with diameter or thickness not exceeding 120mm are cut out from the bars of supplied dimension while the samples of bars with diameter or thickness exceeding 120mm are cut out from the specimens reforged or rerolled in to round or square section with diameter or thickness of 80 to 120mm.

NOTE: Upon agreement between the supplier and the customer, it is permitted to cut out test-pieces from bars with diameter or thickness from 120 upto 270mm and also from round billet (drilled or intended for drilling) with diameter of up to 600mm without forging or rolling.

2.4. Test-pieces from cast metal are chosen: a) from one or more ingots or from specimen of one melt.

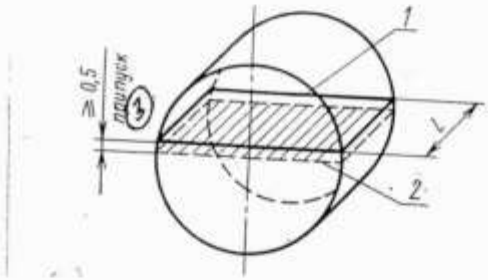
b) for castings - from one or more cast test bar, from one or more cast blank of tensile test samples or from one test cast-on bar of the given melting.

Test bars and blanks of cast tensile test samples are established with the help of the corresponding standards, and arrangement of the cast-on test bars are established upon agreement of the supplier and the customer.

2.5. Test-pieces from deformed metal for making sections with longitudinal grain flow are cut out.

a) from round and square bars with diameter or thickness of up to 40mm inclusive-from edge to edge through centre of the bar drawing 1).

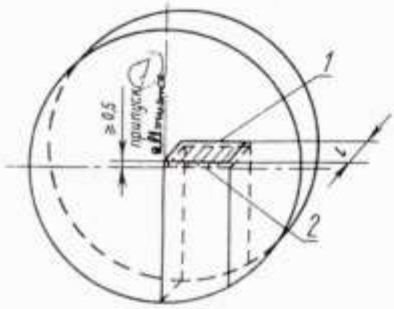
b) from round and square bars with diameter or thicknesss from 40 up to 80mm inclusive-from centre of the bar up to its edge.



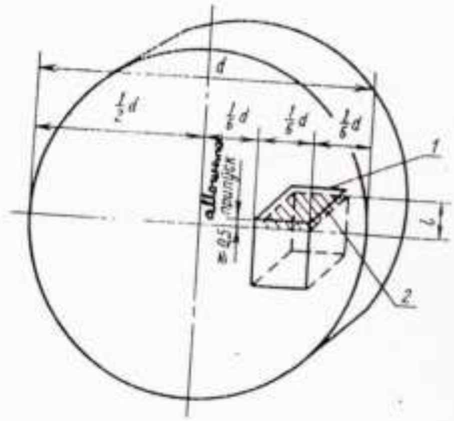
1. Cutting plane; 2. plane of the section. 3. allowance
Drawing - 1.

1. Cutting plane; 2. plant of the section. 3. allowance.
Drawing - 2.

c) from round and square bars with diameter as thickness from 80 upto 120mm inclusive-from centre to ¼th of diameter or thickness (drawing 3) or from centre to the edge (drawing 2).



1. Cutting plane; 2. plant of the section.
Drawing - 3.

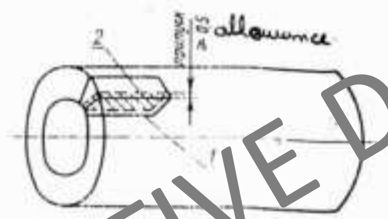


1. Cutting plant; 2. plant of the section.
Drawing - 4.

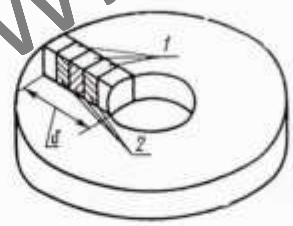
d) from round and square bars with diameter or thickness exceeding 120mm. - at a distance of 1/6 of diameter or thickness off the centre and the edge (drawing 4) so that the centre of section coincides with the centre of the radius or one fourth of the thickness.

e) from pipes-over the whole wall thickness (drawing 5).

f) from round billet, drilled or intended for drilling, with diameter ofupto 600mm, wall thickness, δ to 250mm - in conformity with drawing 6, moreover, dimension of each sample in the radial direction should constitude 1/5 of the billet wall thickness.



1. Cutting plant; 2. plane of section
Drawing-5.

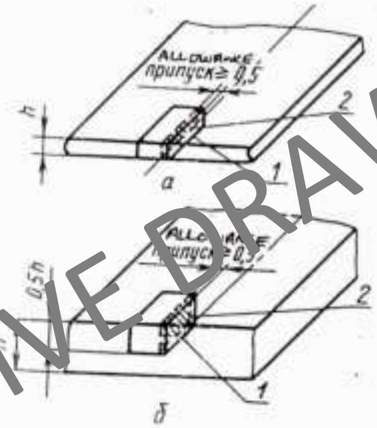


1. Cutting plant; 2. Plane of section.
Drawing - 6.

g) from sheet and strip with thickness of upto 40mm inclusive- over the entire thickness (drg. 7a) and for those with thick- ness above 40mm - upto half of the thickness (drg. 7δ) from the width centre of sheets and strips. Length of the test-piece l is chosen so that the area of the section is of $400 \pm 50mm^2$.

NOTES: 1. Test pieces from symmetric shaped bars (triangular, hexagonal, rhombic and others) are cut out according to drawings for test-pieces from round or plate rolled stock and those from non-symmetric shaped bars are cut out according to drawings approved in an established order.

2. Before making the sections test-pieces of big length may be cut in to a number of parts, considering these pieces



Drawing – 7

1. Cutting Plane
2. Plane of section.

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as one section and if the length of the test-pieces is small, then the required area is gathered from a number of test-pieces considering those as one section.

3. Thin profiles with diameter or thickness less than 10mm may be checked on the reduced area of section minimum $200 \pm 50mm^2$.

4. Inclusions may be checked on sections with area of $500 \pm 100mm^2$.

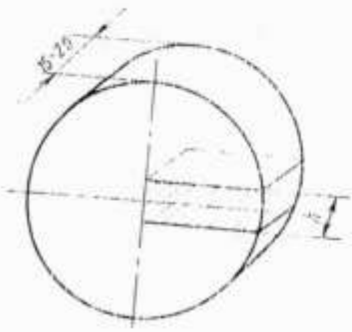
2.6. Test-pieces from deformed metal for making sections with transversal grain flow are cut out:

a) from round and square bars with diameter or thickness of upto 20mm inclusive-the pieces are cut out in the form of corss-washers 15-20mm high (drawing 8).

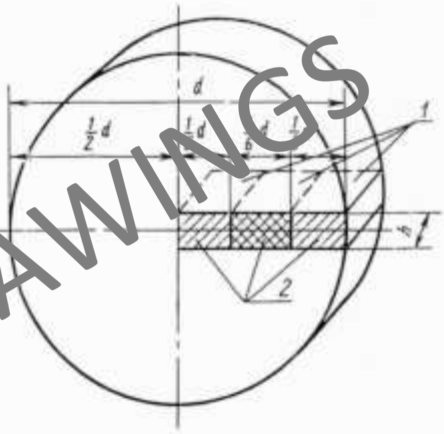
b) from round and squared bars with diameter or thickness from 20 to 40mm, inclusive, the pieces are cut out from edge to edge of bar through centre (drawing 9).

d) from round and square bars with diameter or thickness from 120 to 270mm, inclusive, the piece is cut out in conformity with drawing 11.

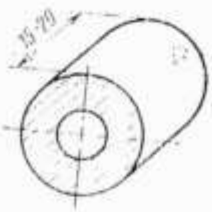
e) from pipes-along the entire circular section of the pipe, from the half, one-fourth or a section of it (drawing 12-15).



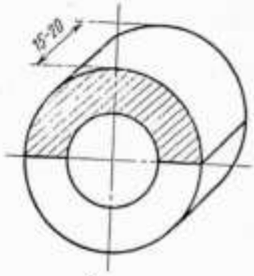
Drawing – 10



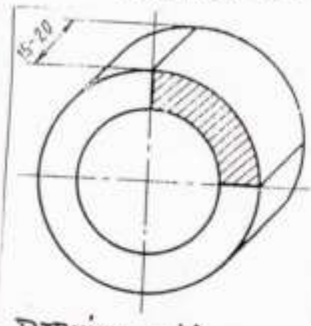
Drawing – 11
1. Test Pieces, 2. Planes of the sections.



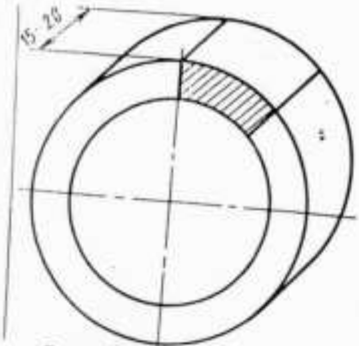
Drawing-12.



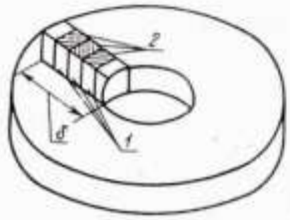
Drawing-13.



Drawing – 14



Drawing – 15



Drawing – 16
1. Test Pieces.
2. Planes of the sections.

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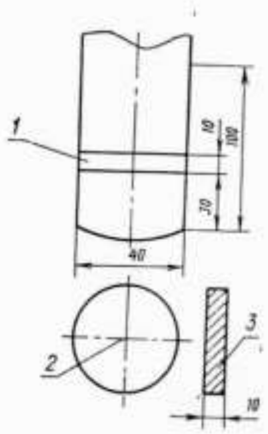
f) from drilled, round billet with wall thickness (δ) of up to 250mm-the piece should be cut out in the radial direction (drawing 16).

g) from sheet and strip with thickness of upto 40mm inclusive-the piece should be cutout over the entire thickness (drawing 17a), if the thickness is morethan 40mm, them the piece is cut out upto half of the thickness from the width centre of sheets and strips (drawing 17б)

Drawing-17.



1. washer 2. Cutting Plane
3. Plane of section.

Drawing - 18.

Area of the sections should be minimum 200mm^2.

NOTE: It is allowed to make the required area from a number of sections.

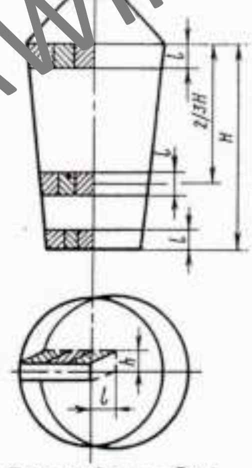
2.7. Test-pieces should be cut out with allowance ensuring the removal of unevennesses, left after cutting and oxidation during heat-treatment, from the plane of the section.

2.8. Test pieces for making the sections from cast metal are cut out as follows:

a) from specimen - in the form of 10 to 15mm thick washers at a distance of 2/3 of the specimen height (drg. 18).

b) from ingot-at three or more horizontal planes along the ingot height (H) and from three cross sections (at the edge from the middle and centre of ingot or along the entire cross-section from edge upto the axis of ingot (drawings 19, 20).

Drawing - 19.

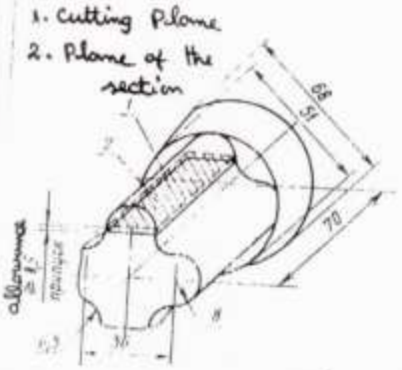


Drawing – 20

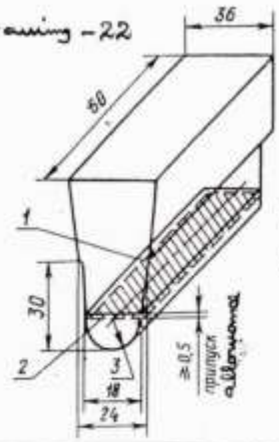
c) from wobbler lebes-from edge to edge of the labe through centre (drawing 21),

d) from wedge specimen-from edge to edge along the diameter plane (drawing 22).

Drawing — 21.
1. Cutting Plane
2. Plane of the section

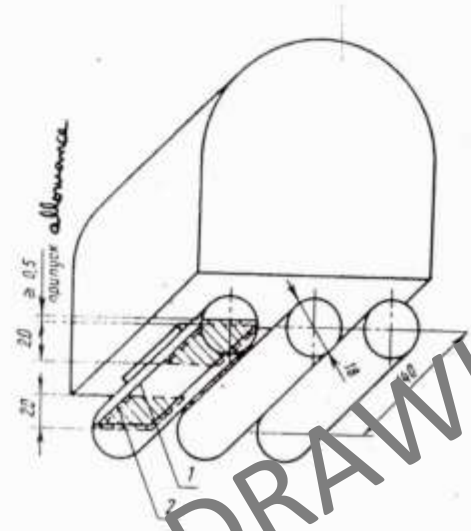


Drawing – 22



1. Cutting Plane
2. Plane of the section

e) from, blanks for tensile test-pieces - in conformity with drawing 23.



=1. Cutting plane; 2. plane of section.

Drawing -23.

2.9. Test-pieces should be cut out by cold mechanical method or by any other method which does not change the structure of the metal.

2.10. Micro sections of the cut-out test-pieces are made on the planes shown by shading in drawing 1-23.

Micro sections may be made on two mutually perpendicular planes of the test-piece cut-out in the form of quadrant of a circle or a square. Each plane of the micro section is considered as a separate test-piece.

2.11. In order to raise the hardness, the test-pieces, before making sections, may be subjected to heat treatment.

Modes of the heat treatment should be specified in the corresponding standards or technical documents approved in an established order.

After heat treatment, the metal layer equal to the allowance is removed by means of an abrasive wheel or by other method.

3. TEST METHODS.

3.1. Method Ш

3.1.1. Non-metallic inclusions of deformed metal having diameter or thickness not less than 6mm are evaluated under a microscope by comparing with standard scales during the inspection of the whole area of unpickled micro sections with longitudinal grain flow.

NOTES: 1. Contamination of the deformed metal with diameter or thickness of less than 6mm is determined by method Ш in intermediate profile or blank.

2. Upon agreement between the supplier and the customer, the non-metallic inclusions may be checked by method Ш in the deformed metal having thickness or diameter from 1.4 to 6.0mm.

3.1.2. The five-point scale classifies the following types of non-metallic inclusions (refer the inserts).

line oxides	- OC
point oxides	- OT
brittle silicates	- CK
plastic silicates	- CП
non-deformable silicates.	- CH
sulphides	- C
line nitrides and carbonitrides	- HC
point nitrides and carbonitrides	- HT
Aluminium nitrides	- HA

Other types of inclusions also can be evaluated by the scale, if their dimensions, shape and arrangement correspond to the given photo-patterns. Characteristics of individual types of inclusions are given in appendix 2.

Types of inclusions which are to be estimated are specified in the standards for the product or in the technical documents approved in an established order.

If the shape and dimensions of the inclusions can not be estimated by one of two neighbouring scale points, then it is permitted to estimate those in 0.5; 1.5; 2.5 points and so on.

Inclusions above point 5 are estimated by point 5 with the sign « greater than » (> 5).

Mark « zero » is given in the case if inclusions of any type are absent and also when inclusions are more than twice less as compared against point 1.

3.[illegible]. If inclusions of a member of types are found in one field of view, then estimation is made for each type of inclusions separately.

Exception is the case, when in one field of view found are:

a) line inclusions of oxides, brittle and plastic silicates and nitrides;

b) point inclusions of oxides and nitrides.

The estimation in one or the other case is made jointly, and the results are written down in the graph of the predominant type of inclusions.

Notes: 1. Upon agreement between the supplier and the customer, the line inclusions may be estimated as the maximum of points obtained during estimation of line oxides, brittle and plastic silicates.

…2. During estimation of metal contamination caused by the inclusions of line nitrides and carbo-nitrides, individual point inclusions are not taken in to account.

3.1.4. Variants of method Ш used for estimating contamination of micro sections and melting caused by non-metallic inclusions are given in table-1.

Table-1.

Vari-ants of method Ш	Magni-ficat-ion	Diameter of field of view, mm.	Criteria for estimating contamination caused by non-metallic inclusions	
			Micro Section	Melting
Ш1	$90-100^{X}$	0.75–0.85	At the maximum contaminated place of the section (maximum point).	Mean point calculated as the arithmatic mean of the maximum estimates of each test-piece for each type of inclusions.
Ш2	$90-110^{X}$	0.75–0.85	At the maximum contaminated place of the section (maximum point).	Mean and maximum points and number of test pieces with a point higher than the maximum one expresed in percent age of total number of test pieces.
Ш3	$90-110^{X}$	0.75–0.85	At the maximum contaminated place of the micro sect-ion (maximum point)	Mean and maximum points and number of test-pie-ces with maximum point.
Ш4	$90-110^{X}$	1.1–1.3	At the maximum contaminated place of the micro sect-ion (maximum point)	Mean point calculated as the arithmatic mean of the maximum estima-tes of each test-piece for each type of inclu-sions.
Ш5	$90-110^{X}$	1.1–1.3	At the maximum contaminated place of the micro sect-ion (maximum point)	Mean and maximum points and number of test-pie-ces with point higher than the maximum one expressed in percentage of the total number of test-pieces.
Ш6	$90-110^{X}$	1.1–1.3	At the maximum contaminated place of the section (maximum point).	Mean and maximum points and the number of test-pieces with maximum point.

Continuation of table-1.

Vari- ants of me- thod.	Mag- nifi- cat- ion	Diameter of field of view, mm.	Criteria for estimating contamination caused by non-metallic inclusions. Micro	Melting
Ш7	90–110x	0.75–0.85	Number of fields of view with point 2 and more by each type of inclusions.	Number of fields of view with point 2 and more, separately for oxide, sulphide and nitride inclusions referred to an area of 10cm2.
Ш8	90–110x	1.1–1.3	Number of fields of view with point 2 and more by each type of inclusions.	Number of fields of view with point 2 and more, separately for oxide, sulphide and nitride inclusions referred to an area of 10cm2.
Ш9.	170–210x	0.38–0.48	At the maximum contaminated place (maximum point)	Mean point, calculated as the arithmatic mean of maximum estimates of each test-piece for each type of inclusions.
Ш10.	170–210x	0.38–0.48	At the maximum contaminated place (maximum point).	Mean and maximum points and the number of test-pieces with maximum point.
Ш11	170–210x	0.6–0.8	At the maximum contaminated place of the section (maximum point).	Mean point calculated as the arithmatic mean of maximum estimates of each test-piece for each type of inclusions.
Ш12	170–210x	0.6–0.8	At the maximum contaminated place of the section (maximum point).	Mean and maximum points and the number of test-pieces with maximum point.
Ш13.	170–210x	0.38–0.48	Number of fields of view with points 2 and more	Number of fields of view with point 2 and more separately for oxide, sulphide and nitride inclusions referred to an area of 10cm2

INDICATIVE DRAWINGS

Variants of method.	Magnification.	Diameter of field of view, mm.	Criteria for estimating contamination caused by non-metallic inclusions.	
			Micro	Melting
Ш14	170-210^{X}	0.6-0.8	Number of fields of view with points 2 and more.	Number of fields of view with point 2 and more separately for oxide, sulphide and nitride inclusion referred to an area of 10 cm².

NOTES: 1. Diameter of field of view of the microscope used in methods Ш1; Ш2; Ш3; Ш7; Ш9; Ш10; Ш13 corresponds to the diameter of the photo pattern (80mm) divided by the magnification.

2. During calculation of arithmatic mean of the points, the point above 5 is taken as equal to 5.

3. The micro section in methods Ш7; Ш8; Ш13 and Ш14 may be estimated by the number of fields of view with points 1, 2, 3, 4, 5 and more than 5. Criterion for estimation of melt is the number of fields of view with point 1, 2, 3, 4, 5, and more than 5 separately for oxide, sulphide and nitride inclusions referred to an area of 10 cm^{2}.

Refults of estimation of the micro sections and melt are written up in conformity with appendices, 3 and 4.

3.1.5. Data of checking contamination of the melt caused by non-metallic inclusions available in the first determination may differ from the results obtained in the second determination by the amount of error depending on the degree of metal contamination and number of test-pieces taken for check.

Maximum errors occuring during determination of the mean points of inclusions and the formula for counting those are given in appendix 5).

3.2. Method K.

3.2.1. The number of inclusions having dimensions more than the estabilished one is counted on unpickled sections under a microscope.

For estimating the contamination of deformed metal used are micro sections with longitudinal grain flow.

3.2.2. The whole area of the micro section is viewed at 170 to 180 power manification and division of the eye-piece scale of 0.007 ± 0.0005 mm. The number of oxide, sulphide and nitride inclusions are determined by groups separately.

Ist group - inclusions are from 1 to 2 divisions of the eye-piece scale, inclusive;

2nd group - inclusions are from 2 to 3 divisions of the eye-piece scale, inclusive;

3rd group - inclusions are from 3 to 4 divisions of the eye-piece scale, inclusive;

4th group - inclusions from 4 to 5 divisions of the eye-piece scale, inclusive;

5th group - inclusions are from 5 to 6 divisions of the eye-piece scale, inclusive.

Number of groups may be increased depending on the maximum Size of inclusions in the metal. By means of the eye-piece scale measured are the diameter or thickness of the inclusions of circular or square shape respectively or minimum and maximum sizes of inclusions of other shape. If, the ratio of maximum and minimum sizes of the inclusion does not exceed two, then the size of the inclusion is to be determined as their arithmatic mean value. Sizes of the stretched inclusions (ratio of length to thickness being more than two, are determined, if their thickness is not less than ¼ of the eye-piece scale division.

The mean linear dimensions of the stretched inclusion (ℓ) is calculated by formula:

$$\ell = \frac{1 + a_o \ell_o}{2}$$

Where,

a_o and ℓ_o – the measured values of thickness and length of inclusions respectively.

The type of inclusions to be estimated is specified in the standards or the technical documents for product approved in an established order.

3.2.3. Variants of method for estimating the sections and melt are given in table-2.

TABLE – 2.

Variants of method K	Criterion for estimating contamination of non-metallic inclusion of the given type.	
	Micro section	Melt
K1	Number of inclusions belonging to 1 to 5th groups.	Number of inclusions of each group over an area of 24 cm^2.*
K2	Number of inclusions belonging to 2 to 5th groups.	Number of inclusions belonging to 2 to 5th groups over an area of 24 cm^2.

*Area of six micro-sections assuming that area of each section is of 4 cm^2.

Results of counting the number of inclusions on micro sections and in melt are recorded in conformity with appendix-6.

NOTES: 1. Inclusions may be estimated in deformed metal of thickness or diameter less than 6mm over an area of 6 cm^2 per one melt.

2. Inclusions may be estimated over an area of 12cm^2 per melt, in the case, if more than 75 inclusions of Ist group are found in one micro section.

3.2.4. The estimation of Ist determination of inclusion belonging to different groups may differ from that of 2nd determination by the amount of error which depends upon degree of metal contamination and nummber of test pieces taken for check.

Example of calculating the error occuring in determination of non-metallic inclusions is given in appendix-7.

3.3. Method П

3.3.1. Inclusions of specific sizes are conted on unpickled sections under a microscope.

For estimation of deformed metal used are micro sections with cross grain flow. Sections with longitudial grain flow may be also used.

3.3.2. Size of micro sections

of the eye-piece scale, by groups given in table-3.

TABLE-3.

Groups of inclusions.	Average Significance for groups in relation to the area of inclusions.	Size of inclusions expressed in divisions of the eye-piece scale. Along the diameter	Along the side of square	Eye-piece scale divisions expressing the are of inclusion occurring in a square.
1	¼	From 0.5 upto 0.7 inclusive.	From 0.4 upto 0.6 inclusive.	From 0.18 upto 0.35 inclusive.
2	½	From 0.7 " 0.9	From 0.6 " 0.8 "	From 0.35 " 0.7
3	1	" 0.9 " 1.3	" 0.8 " 1.2 "	From 0.7 " 1.4
4	2	" 1.3 " 1.9	" 1.2 " 1.7 "	" 1.4 " 2.8
5	4	" 1.9 " 2.7	" 1.7 " 2.4 "	" 2.8 " 5.6
6	8	" 2.7 " 3.8	" 2.4 " 3.4 "	" 5.6 " 11.3
7	16	" 3.8 " 5.4	" 3.4 " 4.8 "	" 11.3 " 22.6
8	32	" 5.4 " 7.6	" 4.8 " 6.7 "	" 22.6 " 45.1
9	64	" 7.6 " 10.7	" 6.7 " 9.5 "	" 45.1 " 90.2
10	128	" 10.7 " 15.2	" 9.5 " 13.4 "	" 90.2 " 180.5
11	256	" 15.2 " 21.4	" 13.4 " 19.0 "	"180.5 " 361.0
12	512	" 21.4 " 30.3	" 19.0 " 26.9 "	"361.0 " 722.0
13	1024	" 30.3 " 42.9	" 26.9 " 38.0	"722.0 "1444.0

NOTE: Groups are made on the priciple of increase of the area of inclusions in geometric pre- gression with 2 as its common ratis.

3.3.3. Variants of method П for estimating contamination of micro sections and melt caused by non- metalic inclusions are given in table 4.

TABLE-4.

Variants of method П	Magnification	Criteria of estimating contamination due to non-metallic inclusions.	
		Micro section	melt
П1. П2. П3. П4.	$300^X(280-300^X)$ $400^X(400-420^X)$ $500^X(500-520^X)$ $600^X(600-630^X)$	Value of the volume percentage and number of inclusions of specific size.	Arithmatic mean of the values of volume percentage of each micro section and the number of inclusions of specific groups per 100mm2 of area.

NOTE: Specified in the brackets are the limits of the magnification used.

3.3.4. Dimensions of all or several types of inclusions depending on the aim of analysis are determined in each field of view.

3.3.5. Before examination, the section is divided from edge to centre in to 5 equal zones (drawing 24). Fields of view in the zones on each micro section are set up in compliance with requirements of table 5.

Drawing 24.

TABLE-5.

Magnification.	Minimum number of fields of view in the tones.					Total number of fields of view on micro section. n
	1	2	3	4	5	
300^X and 400^X	5	15	25	35	45	125
500^X and 600^X	15	45	75	105	135	375

The fields of view in each zone of the section set up along the straight lines on the micro section which are perpendicular to the axis of ingot or rolled stock.

For improving the accuracy of estimating the contamination of the micro sections, the number of fields of view in the zones may be respectively increased by 2, 3, 4 times and so on.

3.3.6. Diameter or side of the square for circular or square inclusions respectively fare considred as the dimension of the inclusions.

For determining the size of inclusions of oval or irregular shape, calculated is the arithmatic mean of the minimum and maximum dimensions, taking this dimension as the diameter of the inclusion.

For determining the size of inclusion of rectangular, rhombic or similar shapes counted is the arithmatic mean of the minimum and maximum dimensions taking this dimension as the side of the square. If the difference between the maximum and minimum dimensions of inclusions is more than twice the group is determined on the basis of area of the inclusion. The total area of inclusions of complex shape may be determined by adding areas of individual sections.

3.3.7. Inclusions are noted as per groups specified in table 3. Results of measuring the inclusions are noted down in conformity with appendix 8.

3.3.8. For calculating the area occupied by inclusions in the micro section, the number of inclusions of each group is to be multiplied by the average area value of inclusions of the given group and the products thus obtained for all the groups are added together.

The average area of inclusions (fav) in one field of view is calculated by formula:

$$fav = f/n.$$

Where; f - total area of inclusions.

n - number of fields of view.

3.3.9. Inclusions content (V) expressed in volume percents is calculated by formula:

$$V = fav\ K,$$

Where; $K = \frac{100}{F}$ - Co-efficient.

$F = \frac{\pi D^2}{4}$ - area of the field of view on the micro section with the established magnification in eye-piece scale divisions in square;

D - diameter of field of view expressed in divisions of eye-piece scale determined by dividing the diameter of the field of view (in mm) one assured with the aid of object-micrometer by the value of the eye-piece scale division of the given microscope;

F, D and K - constant values of the given microscope and the magnification.

3.3.10. Content of non-metallic inclusions expressed in volume percents for melt is calculated as the arithmatic mean of determinations of all test-pieces.

3.3.11. The volume percent is calculated with an accuracy of up to 0,0001. The volume percent and the number of inclusions per 100 sq.mm. of area are calculated in compliance with appendixes 8and 9.

3.3.12. Estimation of inclusions resulting from the first determination may differ from that resulting from the second determination by an amount of error which depends on the metal contamination and the number of fields of view used for the melt under analysis.

Example of counting an error occuring in determination of inclusions in volume percent is given in appendix 10.

3.4. Method П

3.4.1. Contamination of steel caused by inclusions is estimated on unpicked micro sections under microscope.

Variants of method П for determining contamination of melt by non-metallic inclusions are given in table-6.

TABLE - 6.

Variants of method П	Magnification	Criteria for estimating contamination caused by non-metallic inclusions.	
		Micro section	Melt
П1	$300^X(280-300^X)$	Contamination caused by inclusions of specific size.	Contamination to inclusions over a total counting length of 10 cm.
П2	$500^X(500-520^X)$	Contamination caused by inclusions of specific size.	Contamination to inclusions over a total counting length of 10 cm.

NOTE: Specified in brackets are the limits of magnification used.

3.4.2. The micro section is divided with parallel lines in arbitrary direction so, that the length chosen for counting is not less than 3 cm and covers the boundary and the central zones of the cast specimens.

3.4.3. With the aid of -metric screws, mounted at the stage of the microscope, the section is moved in one direction along the marked lines. The maximum size of the inclusions a (see drawing 25) falling in the cross-thread of the eye-piece are measured and noted in conformity with the groups specified in table-7.

Drawing 25.

TABLE-7.

Groups of inclusions	Dimensions of inclusions expressed in eye-piece scale divisions.	Mean value of inclusion size expressed in eye-piece scale divisions,	Group of inclusions.	Dimensions of inclusions expressed in eye-piece scale divisions.	Mean value of inclusion size expressed in eye-piece scale divisions.
1	0 - 2	1	9	16.1-18.0	17
2	2.1 - 4.0	3	10	18.1-20.0	19
3	4.1— 6.0	5	11	20.1-22.0	21
4	6.1 - 8.0	7	12	22.1-24.0	23
5	8.1 - 10.0	9	13	24.1-26.0	25
6	10.1 - 12.0	11	14	26.1-28.0	27
7	12.1 - 14.0	13	15	28.1-30.0	29
8	14.1 - 16.0	15			

3.4.4. Contamination of the micro sections is estimated individually for oxide, sulphide and nitride inclusions or jointly for all types of inclusions to be estimated depend upon the purpose of analysis.

3.4.5. Contamination of the melt (И) caused by inclusions is calculated by formula:

$$И = \frac{b \sum a_i \cdot m_i}{l},$$

Where; b - value of an eye-piece scale division at given magnification, in μm;

ai - mean value of inclusions size expressed in eye-piece scale divisions;

mi - number of inclusions belonging to the given group;

l - counting length, in μm

Example of calculating the contamination is given in appendix 11.

3.4.6. Estimation of contamination resulting from the first determination may vary from that of second determination by the amount of error which depends on the degree of the metal contamination and the total counting length per melt.

The manimum errors occuring in determining the contamination caused by inclusions are given in appendix 12.

Appendix 1. to
GOST 1778-70.
Recommended.

Variants of methods used foe determining the metal contamination caused by non-metallic inclusions of various production process and steel groups.

Variants of methods	Types of tests	Priority use of methods depending on	
		Production process of metal	Groups of steel
1	2	4	5
Ш1, Ш2 Ш4 Ш5	Routine tests.	Melting in electric arc and induction furnaces and in individual cases in open hearth furnaces and converters: Electroslag remelting.	Ball and roller bearing steels, structural steels of special purpose, high-strength steels (having an ultimate strength limit higher than 180 Kgf/mm^2 in the heat-treated condition), tool steels for manufacturing measuring standards and articles of high precision, corrsion resistant steels for vital vacuum-tight articles and vital articles which are to be polished.
Ш3, Ш6, Ш10, Ш12	Routine tests.	Electroslag and vacuum-are remelting.	High strength structural steels of special purpose.

Continuation.

1	2	3	4
Ш1, Ш2, Ш4, Ш5, Ш7, Ш8	Research.	Melting in electric arc, induction, open-hearth furnaces and converters.	Steels and alloys of all grades.
Ш9, Ш11	Routine tests.	Vacuum induction melting, refining remelting (electro slag, vacuum arc etc.)	Ball and roller bearing steel for precision bearings, high strength steels (having an ultimate strength higher than 180Kgf/mm² in heat-treated conditions.
Ш13, Ш14	Research tests.	Vacuum-induction melting, refining remelting (electro slag, vacuum arc, etc.)	Steels and alloys of all grades.
K1	Routine tests	Vacuum induction melting, refining remelting (electro-slag vacuum-arc and etc.)	Ball and roller bearing steels for precision bearings, blanks out of corrosion.steels for special thin-walled tubes.
K2	Routine tests.	Vacuum-induction melting, refining remelting (electro-slag, vacuum-arc and etc.)	Structural steels of special purpose or for manufacturing articles of high-class accuracy and surface finish; tool steels for measuring standards and articles of high-class of ...

1	2	3	4
			accuracy and surface finish; corrosion-resistant steels for polished articles of high-class of surface-finish for vacuum-tight apparatus. Precision alloys supplied in blanks for micro wire.
K1, K2	Research tests.	Vacuum-induction melting refining remelting (electro-slag, vacuum-arc and etc.)	Steels and alloys of all grades.
П1, П2 П3, П4	Research tests	Vacuum - induction melting, refining remelting, (electric-slag, vacuum-arc and (etc).	Steels and alloys of all grades.
П1 П2	Research tests.	Melting in oper hearth, electric-arc and induction furnaces, converters.	Casting from carbon and alloyed structural structural steels.

NOTE: Methods П1, П2, П3, П4 may be used for research tests of the metal melted in open-health, electric arc furnaces and converters in this case. The number of fields of view under examination, should be increased by 3 or more times.

Characteristic of the types of Non-metallic Inclusions.

1. Belonging to oxides are:

inclusions of individual small grains, frequently of corrundum, and spined in the form of lines;

point inclusions, mainly of simple or complex crystals of oxides in the form of individual particles or separate groups dispersed all over the plane of the micro section.

2. Belonging to silicates are:

brittle silicates or soda-lime glasses damaged due to deformation and stretched in to full lines, at times together with oxide inclusions;

silicate or soda-lime glass inclusions undergoing plastic deformation and stretched along the grain flow, differing from sulphides by a darker colour and transparence in a dark field of view;

non-deformable (globular), single or group inclusions of silicates and glass-lime glasses of circular or irregular shape, big particles of oxide inclusions, frequently corrumdum.

Inclusions enumerated in sub-paras 1, 2 belong to oxide inclusions.

3. Belonging to sulphides are, plastic, opaque in dark field of view, stretched along the grain flow individual inclusions or groups of inclusions, usually di-sulphide of iron and manganese.

4. Belonging to nitrides are:

lines and yellow-pink crystals of nitrides and carbo-nitrides of titanium, chiefly of regular shape dispersed all over the field of view;

lines and pale-pink inclusions of nitrides and carbonitrides of niobiums of irregular and circular shape dispersed all over the field of view;

dark crystals of aluminium nitrides, mainly of regular shape and anisotropic.

APPENDIX-3 to
GOST 1778-70
Reference.

Example of recording the results of estimating contamination of the melt due to inclusions.

Methods Ш1 – Ш6, Ш9 – Ш12.

Melt No.	No. of test-piece	Number expressed in points									
		Line oxides OC	Point oxides OT	Brittle silicates CX	Plastic silicates CП	Non-deforming silicates CH	Maximum point from line inclusions (OC, CX, and CП)*	Sulphides, C	Line nitrides and carbonitrides HC.	Point nitrides and carbonitrides	Aluminium nitrides, HA.
25	1	4.0	0	0	0	4.0	4.0	1.0	0	0	0
	2	2.5	0	0	0	2.0	2.5	1.0	0	0	0
	3	1.0	0	2.0	0	0	2.0	0.5	0	0	0
	4	2.0	0	0	0	1.0	2.0	2.0	0	0	0
	5	1.5	0	1.5	0	3.5	1.5	1.5	0	0	0
	6	3.0	0	0	0	1.0	3.0	2.5	0	0	0
Mean point		2.3	0.0	0.6	0.0	1.9	2.5	1.3	0.0	0.0	0.

Number of test-pieces with point higher than the maximum one (X) expressed in percents is determined by formula:

$$X = \frac{m.100}{n},$$

Where;

m - number of test-pieces with point higher than the maximum one;

n - total number of test-pieces.

Example of calculating X for non-deformable silicates when the maximum point established is 3.0.

$$X = \frac{2.100}{6} = 33\%$$

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* The graph is filled in, if upon agreement between the supplier and the customer, it is permitted that the number of line inclusions is maximum out of points obtained during estimation of line oxides, brittle and plastic silicates.

APPENDIX 4 to
GOST 1778-70.
Reference.

Example of recording the results of estimating contamination of the melt caused by inclusions.

Methods Ш7 and Ш8, Ш13 and Ш14

No.of test piece	Area of sections, cm^2	Number of fields of view with points 2 and more in the determination of																												
		Linear oxides OC					Point oxides OT					Brittle silicates CX					Plastic silicates, CП					Non-deformable silicates, CH					Total numb… of oxide i… clusions.			
		Points																												
		2	3	4	5and more	to-tal	2	3	4	5and more	To-tal	2	3	4	5and more	To-tal	2	3	4	5and more	To-tal	2	3	4	5and more	To-tal	2	3	4	5an… mor…
1	3.8	10	-	-	-	10	2	-	-	-	2	-	-	1	-	1	-	1	-	-	1	4	1	-	-	5	16	2	1	-
2	4.2	5	-	1	-	6	3	-	-	-	3	-	2	-	-	2	1	-	-	-	1	5	-	1	-	6	14	2	2	-
3	4.1	30	3	-	-	33	1	-	-	-	1	-	-	2	-	2	-	-	-	-	-	2	2	-	1	5	33	5	2	1
4	3.9	1	-	-	-	1	4	-	-	-	4	-	1	-	-	1	-	1	-	-	1	8	-	-	-	8	13	2	-	-
5	3.7	8	2	-	-	10	5	-	-	-	5	-	-	1	-	1	-	-	1	-	1	10	3	-	-	13	23	5	2	-
6	4.3	2	-	-	-	2	1	-	-	-	1	1	-	-	-	1	-	-	-	-	-	3	-	1	-	4	7	-	1	-
Total	24	56	5	1	-	62	16	-	-	-	16	1	3	4	-	8	1	2	1	-	4	32	6	2	1	41	106	16	8	1

Continuation

No. of test piece	Area of sections, cm²	Number of fields of view with points 2 and more in the determination of: Sulphide, C					Point nitrides HT					Aluminium nitrides HA					Total number of nitri inclusions.				
		Points																			
		2	3	4	5 and more	Total	2	3	4	5 and more	Total	2	3	4	5 and more	Total	2	3	4	5 and more	Tot
1	3.8	30	5	1	-	36	12	10	5	-	27	-	-	-	-	-	12	10	5	-	27
2	4.2	42	22	-	-	64	5	11	10	-	26	-	-	-	-	-	5	11	10	-	26
3	4.1	26	3	-	-	29	13	16	8	-	37	-	-	-	-	-	13	16	8	-	37
4	3.9	15	6	1	-	22	18	8	10	-	36	-	-	-	-	-	18	8	10	-	36
5	3.7	17	4	-	-	21	7	12	4	-	23	-	-	-	-	-	7	12	4	-	23
6	4.3	10	1	1	-	12	11	17	2	-	30	-	-	-	-	-	11	17	2	-	30
Total	24	140	41	3	-	184	66	74	39	-	179	-	-	-	-	-	66	74	39	-	179

Number of fields of view with oxide inclusions of point 2 and more on an area of 10 cm² isequal. to $\frac{131.10}{24}$

Number of fields of view with sulphide inclusions of point 2 and more on an area of 10cm² isequal to $\frac{181.10}{24}$

Number of fields of view with nitride inclusions of point 2 and more on an area of 10cm² is equal to $\frac{179.10}{24}$

Calculation of maximum error in the determination of mean point of non-metallic inclusions by method inclusions by method Ш Example.

Number of test-pieces	Maximum error expressed in points.			
	For alloyed and carbon steels of high quality with dimensions in mm.		For bearing steel with dimensions in mm.	
	Less than 40	40 and more	Less than 40	40 and more
	Line oxides			
6	0.4	0.6	0.3	0.5
9	0.3	0.5	0.2	0.4
12	0.3	0.4	0.2	0.3
n	$\frac{1.0}{\sqrt{n}}$	$\frac{1.5}{\sqrt{n}}$	$\frac{0.7}{\sqrt{n}}$	$\frac{1.2}{\sqrt{n}}$
	Brittle plastic silicates			
6	0.6	0.8	0.4	0.6
9	0.5	0.7	0.3	0.5
12	0.4	0.6	0.3	0.4
n	$\frac{1.5}{\sqrt{n}}$	$\frac{2.0}{\sqrt{n}}$	$\frac{1.0}{\sqrt{n}}$	$\frac{1.5}{\sqrt{n}}$
	Non-deformable plastics			
6	0.5	0.7	0.2	0.4
9	0.4	0.6	0.2	0.3
12	0.3	0.5	0.1	0.3
n	$\frac{1.2}{\sqrt{n}}$	$\frac{1.7}{\sqrt{n}}$	$\frac{0.5}{\sqrt{n}}$	$\frac{1.0}{\sqrt{n}}$
	Sulphides			
6	0.5	0.6	0.3	0.4
9	0.4	0.5	0.2	0.3
12	0.3	0.4	0.2	0.3
n	$\frac{1.2}{\sqrt{n}}$	$\frac{1.5}{\sqrt{n}}$	$\frac{0.7}{\sqrt{n}}$	$\frac{1.0}{\sqrt{n}}$

Number of test-pieces	Maximum error expressed in points			
	For alloyed and carbon steels of high quality with dimensions in mm.		For bearing steel with dimensions in mm.	
	Less than 40	40 and more	Less than 40	40 and more
	Nitrides (for steels containing titanium).			
6	0.4	0.7	-	-
9	0.3	0.6	-	-
12	0.3	0.5	-	-
n	$\frac{1.0}{\sqrt{n}}$	$\frac{1.7}{\sqrt{n}}$	-	-

Mean point of melt estimation ($\overline{X}$) is calculated by formula:

$$\overline{X} = \frac{\Sigma x_i}{n}$$

Where;

Σx_i - total of maximum points of all test-pieces

n - number of test-pieces.

Maximum error ($\delta_0 \overline{x}$) occurring in the determination of mean point is calculated by the formula:

$$\delta_0 \overline{x} = \pm \frac{\delta_0 \cdot 1.65}{\sqrt{n}}$$

Where; δ_0 - root-mean-square deviation calculated from the distribution of estimates of at least 200 test pieces.

1.65- the constant factor for probability of 0.9;

n - number of test-pieces.

APPENDIX 6 to
GOST 1778-70.
Reference.

Example of recording the results during estimation of metal melted by method K1.

Melt. No.	Mark of test piece	Area of the micro section, cm^2.	Number of inclusions for groups				
			1	2	3	4	5
421384	1A	4.1	27	0	0	0	0
	1H	3.9	29	2	0	0	0
	2A	4.2	[illegible]	0	0	0	0
	2H	[illegible]	36	0	0	0	0
	3A	[illegible]	49	1	0	0	0
	[illegible]	4.4	27	0	0	0	0
Total		24	200	3	0	0	0

APPENDIX-7 to
GOST 1778-80
Reference.

Calculation of error occurring in the determination of non-metallic inclusions belonging to Ist group by method K1. Example.

Test-piece No.	Area of the test-piece, cm^2.	Number of inclusions of Ist group on test-piece x_i	Deviation from the mean value of a	a^2
1	3.7	6	-5	25
2	4.2	7	-4	16
3	4.3	9	-2	4

Test-piece No.	Area of the test-piece, cm2.	Number of inclusions of Ist group on test-piece x_i	Deviation from the mean value of a	a^2
4	3.8	10	-1	1
5	3.9	12	1	1
6	4.1	22	11	121
Total	24	66		168

Arithmatic mean value of the number of inclusions $(\overline{X})$ appearing in one test-piece is calculated by the formula:

$$\overline{X} = \frac{\Sigma x_i}{n}$$

Where; Σx_i - total number of inclusions of given group

n - number of test-pieces.

The error $(\delta_{o\bar{x}})$ occurring in counting of inclusions is calculated by formula:

$$\delta_{o\bar{x}} = \pm \frac{\sigma}{\sqrt{n}}$$

Where; σ - standard deviation.

$$\sigma = \sqrt{\frac{\Sigma a^2}{n-1}}$$

Where; Σa^2 - sum of squares of the deviations from mean value of the number of inclusions.

$$\overline{X} = \frac{66}{6} = 11.$$

$$\sigma = \sqrt{\frac{168}{5}} = 5.3.$$

$$\delta_{o\bar{x}} = \frac{5.3}{\sqrt{6}} = \pm 2.2$$

Appendix 8 to
GOST 1778-70.
Reference.

Example of recording and calculating the results of estimating the oxides by the microscope MИM-8

under 290-times magnification.

Groups of inclusions	Number of inclusions in fields of views										Total number of inclusions in 125 fields of view.	Mean value for groups as per area of inclusions.	Area of inclusions raised to square and expressed in eye piece scale divisions
	1	2	3	4	5	6	7	8	9	10*			
1	-	-	-	-	-	-	-	-	-	-	67	$\frac{1}{4}$	16.75
2	-	1	2	-	-	2	-	-	-	-	64	$\frac{1}{2}$	32
3	-	1	-	-	-	-	-	-	-	3	49	1	49
4	2	-	-	-	-	-	2	-	-	-	34	2	68
5	-	-	-	-	-	-	2	1	-	-	34	4	136
6	-	-	-	-	-	1	1	-	-	1	45	8	360
7	1	-	-	-	-	-	1	1	-	-	14	16	224
8	-	1	-	-	-	-	-	-	-	-	13	32	416
Total													1291.75

$$f_{mean} = \frac{1291.75}{125} = 10.33$$

$$v = \frac{10,33.100}{10200} = 10,33.0,0.0098 = 0,1012\%$$

$$K = \frac{100}{10200} = 0.0098.$$

* The graphs for fields of view 11.......125 are field in similarly.

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Example of counting the number of oxides on the micro section having an area of 100 mm^2.

Groups of inclusions.	Area of the fields of view, examined, mm2.	Number of inclusions, group wise, at an area of 21.625 mm2.	Number of inclusions at an area of 100mm2.
1		67	315
2		64	296
3		49	227
4	21.625	34	157
5		34	157
6		45	208
7		14	65
8		13	60
Total	21.625	320	1485

NOTES: 1. Data given in appendix 8 have been used for calculation.

2. Area of the fields of view, examined (21.625) is equal to an area of one field of view (0.173mm^2) multiplied by the number of fields of view examined (125).

3. Arithmatic mean value of estimates of individual test-pieces over an area of 100mm^2 is taken as the number of inclusions in the melt.

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Appendix 10 to
GOST 1778-70.
Reference.

Example of calculating the error occurring in determining the oxide inclusions expressed in volume percents by method П

Number of test-pieces.	Oxide inclusions expressed in volume percents, %. x_i	Deviation from arithmatic mean value	a^2
1	0.0096	+0.0036	0.00001296
2	0.0052	-0.0008	0.00000064
3	0.0045	-0.0015	0.00000225
4	0.0070	+0.0010	0.00000100
5	0.0055	-0.0005	0.00000025
6	0.0042	-0.0018	0.00000324
Total	0.0360	0.0000	0.00002034

Arithmatic mean of the number of inclusions $(\bar{X})$ expressed in volume percents is calculated by formula:

$$\bar{X} = \frac{\Sigma x_i}{n},$$

Where; Σx_i - total content of inclusions expressed in volume percents %;

n - number of test-pieces.

Error $(\delta o\bar{x})$ occurring in the calculation of inclusion content expressed in volume percents is calculated by formula:

$$\delta o\bar{x} = \pm \sqrt{\frac{\delta}{n}}$$

Where; σ - root-mean-square deviation;

$$\sigma \sqrt{\frac{\Sigma a^2}{n-1}}$$

Where; Σa^2 - sum of deviation squares from the mean volue of number of inclusions expressed in volume percents, %.

$$\overline{X} = \frac{0.0360}{6} = 0.0060 \%$$

$$\sigma = \sqrt{\frac{0.00002034}{5}} = 0.0018$$

$$\sigma_{\overline{x}} = \pm \frac{0.0018}{6} = \pm 0.00075.$$

Relative error is equal to

$$\frac{0.00075.100}{0.0060} = 12.5\%$$

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Example of counting the contamination of the melt of steel, grade 35Л by method Л

Inclusions group.	Size of inclusions expressed in eye-piece scale divisions	Mean value of inclusion sizes expressed in eye-piece scale divisions a_i	Oxides: Number of inclusions of the given group, m_i.	Oxides: $a_i\ m_i$	Sulphides: Number of inclusions of the given group m_i.	Sulphides: $a_i\ m_i$
1	0-2	1	25	25	29	29
2	2.1-4.0	3	4	12	69	207
3	4.1-6.0	5	2	10	22	110
4	6.1-8.0	7	-	-	8	56
5	8.1-10.0	9	-	-	1	9
6	10.1-12.0	11	-	-	2	22
7	12.1-14.0	13	-	-	1	13
8	14.1-16.0	15	-	-	-	-
Total				47		446

$l = 180000\ \mu m$

$b = 4\ \mu m$

Magnification 300^{x}

ν sulphides $= \dfrac{4.446}{180000} = 9.91.10^{-3}$

ν Oxides $= \dfrac{4.47}{180000} = 1.04.10^{-3}$.

ν total $= \nu$ oxides $+ \nu$ sulphides.

ν total $= 1.04.10^{-3} + 9.91.10^{-3}$
$= 10.95.10^{-3}$.

Appendix 12 to
GOST 1778-70
Reference.

Example of calculating the maximum error occurring in determination of non-metallic inclusions by method Л depending on the length chosen for calculation.

Length chosen for calculation, cm.	Maximum error $\sigma_{\bar{ox}}$ 10^{-3}	Length chosen for calculation, cm.	Maximum error $\sigma_{\bar{ox}}$ 10^{-3}
1	1.30	18	0.308
3	0.75	21	0.283
6	0.53	24	0.266
9	0.43	l	$\frac{1.3}{\sqrt{l}}$
12	0.38		
15	0.33		

Maximum error ($\sigma_{\bar{ox}}$) of contamination is calculated by formula:

$$\sigma_{\bar{ox}} = \pm \frac{\sigma \cdot 1.65}{\sqrt{l}}$$

Where σ rood-mean-square deviation of distribution per 25cm of calculation length;

1.65 -constant factor for probability of 0.9.

l -calculation length, chosen cm.

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