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Coal sizing equipment — Performance evaluation

Équipement pour la granulométrie du charbon — Évaluation de l'aptitude à l'emploi

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Foreword

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

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

This document was prepared by Technical Committee ISO/TC 27 *Solid mineral fuels*, Subcommittee SC 1, *Coal preparation. Terminology and performance*.

This second edition cancels and replaces the first edition (ISO 10752:1994), of which it constitutes a minor revision.

The main changes compared to the previous edition are as follows:

— editorial corrections throughout the document.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A standard expression of performance is required to define the accuracy of separation of a particular item, to assist in the comparison of the performance of different items of coal sizing equipment and in the prediction of separation results.

Coal sizing equipment — Performance evaluation

1 Scope

This document describes the principles and methods for the expression of results of performance tests on sizing equipment used in coal preparation, and includes methods for the evaluation of performance parameters. Performance test procedures and size measurement techniques are recommended.

This document applies to all types of sizing equipment, categorized as follows:

a) screens;

b) classifiers;

c) others.

The procedure described in this document applies to two-product separations. Performance assessment of multiproduct separations can be achieved by consideration of a series of two-product separations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1213-1, *Solid mineral fuels — Vocabulary — Part 1: Terms relating to coal preparation*

ISO 13909, *Hard coal and coke — Mechanical sampling*

ISO 18283, *Hard coal and coke — Manual sampling*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1213-1 and the following apply.

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

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

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

3.1 General

3.1.1
actual feed
F
material fed to the sizing equipment during the test period and including any recirculated material

3.1.2
coarser material
material that is coarser than the reference size

3.1.3
finer material
material that is finer than the reference size

3.1.4
product
material discharged from the sizing equipment prior to any further treatment or recirculation

3.1.5
coarser product
c
product of size separation that contains a greater proportion of coarser material than does the feed

3.1.6
finer product
f
product of size separation that contains a greater proportion of finer material than does the feed

3.1.7
sharpness of separation
E_{pm}
assessment of the deviation from a perfect separation, usually expressed in terms of mean probable error

3.2 Performance parameters

3.2.1
theoretical yield (sizing)
maximum yield of a product at a reference size, as determined from the size distribution curve for the reconstituted feed

3.2.2
coarser material placement efficiency
E_c
percentage of coarser material in the reconstituted feed that reports to the coarser product

3.2.3
finer material placement efficiency
E_f
percentage of finer material in the reconstituted feed that reports to the finer product

3.2.4
overall separation index
sum of the coarser material placement efficiency and the finer material placement efficiency minus 100

4 Performance criteria

The following criteria should be determined where applicable:

a) feed rate;

b) reference size of separation;

c) sharpness of separation;

d) misplaced material;

e) material placement efficiencies;

f) the degree of difficulty of separation;

g) material characteristics.

NOTE 1 The above criteria will be influenced by test conditions which should therefore be fully reported.

NOTE 2 It is essential that prediction of separation results takes into account the influence of test conditions.

NOTE 3 It is essential that test conditions are made compatible to ensure valid comparisons.

NOTE 4 Conditions should be kept uniform during a test.

5 Performance parameters

For the standard expression of performance of a separation, the criteria given in Clause 4 should be determined by the following parameters:

a) the feed rate, expressed on mass and/or volume bases;

b) the reference size, preferably expressed as both partition size and equal errors size;

NOTE It is recognized that partition size is not always obtainable from the results of a size separation and that an alternative reference size therefore has to be employed. To allow comprehensive comparison of performance, it is recommended that parameters based on equal errors size as the reference be included, in addition to those based on partition size.

c) the sharpness of separation, expressed in terms of probable error;

d) the distribution of misplaced material in each product, presented graphically with respect to size, and the particular values of misplaced material in each product on both feed and product bases, each determined at the reference size of separation;

e) the material placement efficiencies expressed as:

1) coarser material placement efficiency, E_c;

2) finer material placement efficiency, E_f;

3) overall separation index derived from 1) and 2);

f) the degree of difficulty of separation, expressed in terms of near-size material;

g) other relevant characteristics of the feed material.

6 Performance test procedures

The equipment to be tested, the actual feed composition, and the means of handling the feed and products vary widely. A single standard procedure is not applicable. The following general recommendations are made.

a) The average feed rate and/or product flow rates should be determined by the most accurate method possible in the particular circumstances. Typical procedures that may be used are:

1) direct assessment of the mass and/or volume of the whole of the feed or product during the test;

2) continuous assessment by means of a calibrated belt weigher or flowmeter and integration during the test;

3) weighing timed increments taken at regular intervals during the test.

b) Samples should be taken from the actual feed and from each of the products. Sampling techniques, initial number of increments and minimum mass of each increment should be chosen so that all samples taken are representative. Sampling techniques, initial number of increments and minimum mass of increment for solids being conveyed by a fluid should comply with existing document, if available; for solids under other conditions, ISO 13909-1 to ISO 13909-4 and ISO 18283 shall apply as appropriate.

NOTE Representative samples should be taken from all relevant streams to and from the equipment to be tested, to facilitate checking of results and assessment of the effects of degradation.

c) It is essential to determine the feed rate and the actual yield of each product on a dry basis in accordance with ISO 1170. This should be achieved in accordance with one of the following procedures.

   1) The mass of each product should be determined by one or more of the following methods:

      i) direct weighing of the whole of each product collected over the duration of the test or through continuous weighing and integration over the duration of the test;

      ii) taking regular timed increments over the duration of the test;

      iii) weighing each product collected simultaneously over a selected timed period during the test.

      NOTE 1 The methods given in 1) are listed in order of reliability.

      NOTE 2 If it is feasible to measure both the mass of the feed (by belt weigher, weigh hopper, flowmeter, etc.) and the mass of the products, this provides a check.

      NOTE 3 If the mass of one of the products cannot be measured, it can be obtained from a mass balance between the feed and products.

      NOTE 4 Where the solids are conveyed by a fluid, it can be more convenient to make volumetric measurements.

      Representative samples should be taken from relevant streams to determine moisture contents or concentrations of solids as appropriate, so that the results can be reported on a dry basis.

   2) In circumstances that prevent the weighing of sufficient streams, size analyses of feed and products can be used to determine the percentage yield of each product, as described in Annex A.

      In all circumstances, the method used to determine the actual yield of each product should be reported with each respective value in Table 3.

7 Analytical procedures

The method and procedure of size analysis should be selected, as far as possible, to be in agreement with the principle of the equipment under test, to produce results in compatible terms. For example, the results of size analysis by sieving would be compatible with vibrating screens, and the results of size analysis by a series of small cyclones would be compatible with cyclone separators. Size analysis by sieving should be carried out in accordance with ISO 1953. The method and apparatus used, and the basis of the percentages (by mass or volume), shall be stated in the data sheet and in Table 1.

The feed sample and each of the product samples should be subjected to size analyses in which the ratio of the upper and lower size limits does not exceed 2:1 for each size fraction. It is recommended that this ratio for size limits be reduced to $\sqrt{2:1}$ for a minimum of two fractions, both above and below the reference size.

NOTE 1 In some circumstances, a ratio of size limits closer than $\sqrt{2:1}$ may be necessary in the region of the reference size, to ensure that each of the size fractions contains not more than 10 % of the sample.

NOTE 2 Size distribution curves for the products can be used for:

a) providing data for additional partition coefficients;

b) averaging analytically determined values to improve the derived partition curve.

8 Evaluation and presentation of performance characteristics

8.1 General

All data shall be evaluated and presented in one data sheet, three tables and three figures as follows:

a) data sheet — test and equipment data;

b) Table 1 — size distribution of feed and products;

c) Table 2 — partition coefficients and misplaced material data;

d) Table 3 — statement of sizing equipment performance;

e) Figure 1 — partition curve;

f) Figure 2 — size distribution curve for the reconstituted feed;

g) Figure 3 — misplaced material curves.

The presentation of the test data may be accomplished by the procedure described below. The specified tabular and graphical formats are given in Clause 9. Specific worked examples are included in Annexes B, C and D.

NOTE 1 Primary calculation procedures are shown in tables 1 and 2. A column number in parentheses denotes a respective value taken from that column.

NOTE 2 The origins of plotted values are shown in Figures 1 and 2 by reference to table and column numbers.

NOTE 3 Reference to definitions of performance parameters in Clause 3 supports the brief explanation of their derivation given in relevant subclauses and in Tables 1 and 2.

8.2 Basic data

The data obtained from a performance test comprise the size analyses of the actual feed and the coarser and finer products and the proportion of material reporting to each product. These basic data are compiled in table 1, columns 1 to 8, and calculated on a reconstituted feed basis in columns 9 to 12.

8.3 Reconstituted feed size distribution

The size distribution curve for the reconstituted feed is constructed as shown in Figure 2, by plotting the cumulative percent less than the upper size limit (column 12 of Table 1) against the upper size limit (column 1 of Table 1).

NOTE It is convenient to use a logarithmic scale for particle size when plotting size distribution curves, to cover a wide range of sizes and to cater for size limits that are in geometric progression.

8.4 Partition curve

The partition curve is constructed as shown in Figure 1, by plotting the value of each partition coefficient against the corresponding mean size. It is recommended that each size fraction be represented by its geometric mean size. Geometric mean sizes and partition coefficients are calculated in Table 2, columns 13 and 14. The recommended scales are:

— size: $\log_{10}$ 1 cycle = 50 mm;

— partition coefficient: 1 % = 2 mm.

NOTE 1 As an alternative to geometric mean size, each size fraction may be represented by its mid-mass particle size, derived from a known functional relationship or estimated from the reconstituted feed curve.

NOTE 2 As an alternative method of construction, partition coefficients can be plotted as a histogram on a reconstituted feed base, producing an area representative of mass. An intermediate curve is then drawn by equalizing areas within each size fraction. Performance parameters are derived by applying values obtained from the intermediate curve to the size distribution curve for the reconstituted feed.

8.5 Partition size

The partition size, S_{50}, is obtained directly from the partition curve and is entered as a performance parameter in the statement of sizing equipment performance in Table 3.

NOTE The partition size can be determined from the misplaced material curves (see Figure 3) at the minimum value of total misplaced material.

8.6 Sharpness of separation

The 25 %, S_{25}, and 75 %, S_{75}, intercepts are each read from the partition curve (see Figure 1) and are entered as primary parameters in the statement of sizing equipment performance in table 3. For symmetrical partition curves, the sharpness of separation may be expressed in terms of the mean probable error (E_{pm}) as follows:

$$E_{pm} = \frac{S_{75} - S_{25}}{2} \tag{1}$$

In the more common case of skewed partition curves, the sharpness of separation may be expressed in terms of the upper and lower probable errors as follows.

— Upper probable error = $S_{75} - S_{50}$

— Lower probable error = $S_{50} - S_{25}$

The upper probable error and lower probable error parameters may be used separately if one of the intercepts is undefined.

8.7 Misplaced material curves

The misplaced materials in the coarser and finer products are calculated, as a percentage of the reconstituted feed, in Table 2, columns 15 and 16. Corresponding values are summed to give total misplaced material tabulated in column 17 of Table 2. The misplaced material curves are constructed, as shown in Figure 3, by plotting values for coarser products (column 15 of Table 2), finer products (column 16 of Table 2) and total misplaced materials (column 17 of Table 2), each against the corresponding upper size limit S1 (column 1 of Table 1). The recommended scales are:

— size: $\log_{10}$ 1 cycle = 50 mm;

— misplaced material: 1 % = 5 mm.

If it is necessary to use an alternative scale, this should be a simple multiple of the recommended scale; for an example see Figure C.3.

8.8 Misplaced material

The misplaced material is read from each respective curve at the reference size, or sizes (see NOTE 1), and the values are inserted into the statement of sizing equipment performance in Table 3. The value of misplaced material for each respective product is converted to a percentage of that product (see NOTE 2), and the converted values are inserted into the statement in Table 3.

NOTE 1 It is convenient to construct an ordinate on the curves, at the reference size, or sizes, being considered (e.g. S_d, S_{50}, S_e), to assist in reading the three intercepting misplaced values.

NOTE 2 All values of misplaced material obtained from the curves are in terms of percentages of the reconstituted feed. Conversion to percentage of the respective product can be obtained by multiplying the corresponding curve by 100 and dividing by the yield value of the product under consideration (i.e. Y_c or Y_f).

NOTE 3 The procedure can be repeated for any other reference size.

8.9 Equal errors size

The equal errors size, S_e, is determined by reading the size that corresponds to the point of intersection of the misplaced material curves for coarser and finer products. Alternatively, the equal errors size can be determined from the size distribution curve for the reconstituted feed, as the size corresponding to the yield of the finer product. The equal errors size is inserted into the statement of sizing equipment performance in Table 3.

8.10 Theoretical yield

The theoretical yield value at the reference size, or sizes, is determined, for each of the products, from the size distribution curve for the reconstituted feed. Alternatively, each respective theoretical yield value can be determined by subtracting the misplaced material in the product under consideration from the actual yield (Y_c or Y_f) and adding the misplaced material in the complementary product.

EXAMPLE

$$Y_{c,t} = Y_c - M_c + M_f \qquad (2)$$

where

- $Y_{c,t}$ is the theoretical yield of the coarser product;
- Y_c is the yield value of the coarser product;
- M_c is the misplaced material in the coarser product;
- M_f is the misplaced material in the finer product.

Theoretical yield values are inserted into the statement of sizing equipment performance in Table 3.

NOTE 1 Misplaced material values are in terms of percentages of reconstituted feed.

NOTE 2 The theoretical yield of the complementary product can be obtained by difference from 100 %.

8.11 Material placement efficiency

Material placement efficiencies are evaluated and inserted into the statement of sizing equipment performance in Table 3. The calculations are as follows.

a) Coarser material placement efficiency, E_c:

$$E_c = \frac{Y_c - M_c}{Y_{c,t}} \times 100 \qquad (3)$$

where Y_c, M_c and $Y_{c,t}$ are as defined in 8.10.

b) Finer material placement efficiency, E_f:

$$E_f = \frac{Y_f - M_f}{Y_{f,t}} \times 100 \qquad (4)$$

where

Y_f is the yield value of the finer product;

$Y_{f,t}$ is the theoretical yield of the finer product;

M_f is defined in 8.10.

c) Overall separation index (S_i)

$$S_i = E_f + E_c - 100 \quad (5)$$

NOTE 1 Misplaced material values are in terms of percentage of reconstituted feed.

NOTE 2 Alternative methods are available for the evaluation of the material placement efficiencies.

8.12 Near-size material

The near-size material, i.e. material within ±25 % of the reference size or sizes, is determined from the size distribution curve for the reconstituted feed in Figure 2 and is inserted into the statement of sizing equipment performance in Table 3.

Other relevant characteristics of the feed material that influence the degree of difficulty of separation are inserted into the test and equipment data sheet, which varies according to the type of equipment under consideration. Examples of data sheets are given in Annexes B, C and D.

8.13 Test and equipment data

The presentation of the results of performance tests on coal sizing equipment shall include a report of the equipment details, test conditions and characteristics of the feed material, particularly those that influence the degree of difficulty involved in the separation. This information is inserted into the test and equipment data sheet. Since the parameters involved will vary for different categories of equipment, a specimen of the data sheet is not included in the general illustration, but models are presented in the specific worked examples given in Annexes B, C and D.

9 Tabular and graphical presentation

Blank tables and specimen figures are given. The use of these is illustrated in Annexes B, C and D. The order of presentation shall be as follows:

a) data sheet — test and equipment data (see 8.13);

b) Table 1 — size distribution of feed and products;

c) Table 2 — partition coefficients and misplaced material data;

d) Figure 1 — partition curve;

e) Figure 2 — size distribution curve for the reconstituted feed;

f) Figure 3 — misplaced material curves;

g) Table 3 — statement of sizing equipment performance.

Table 1 — Size distribution of feed and products

1	2	3	4	5	6	7	8	9	10	11	12
Method of analysis (see Clause 7)		**Analyses of feed and products**						**Percentage of reconstituted feed**		**Reconstituted feed**	
		Actual feed		**Coarser product**		**Finer product**		**Coarser product**	**Finer product**		
Size limits, mm		**Size fraction**	**Cumulative percent less than** S_1	**Size fraction**	**Cumulative percent less than** S_1	**Size fraction**	**Cumulative percent less than** S_1	**Actual yield**, Y_c %	**Actual yield**, Y_f %	**Size fraction**	**Cumulative percent less than** S_1
Upper	**Lower**	%		%		%		**Size fraction %**	**Size fraction %**	%	
S_1	S_2		Σ (3) ↑		Σ (5) ↑		Σ (7) ↑	$(5)\times\frac{Y_c}{100}$	$(7)\times\frac{Y_f}{100}$	(9)+(10)	Σ (11) ↑
Totals											

NOTE A column number in parentheses denotes a respective value taken from that column.

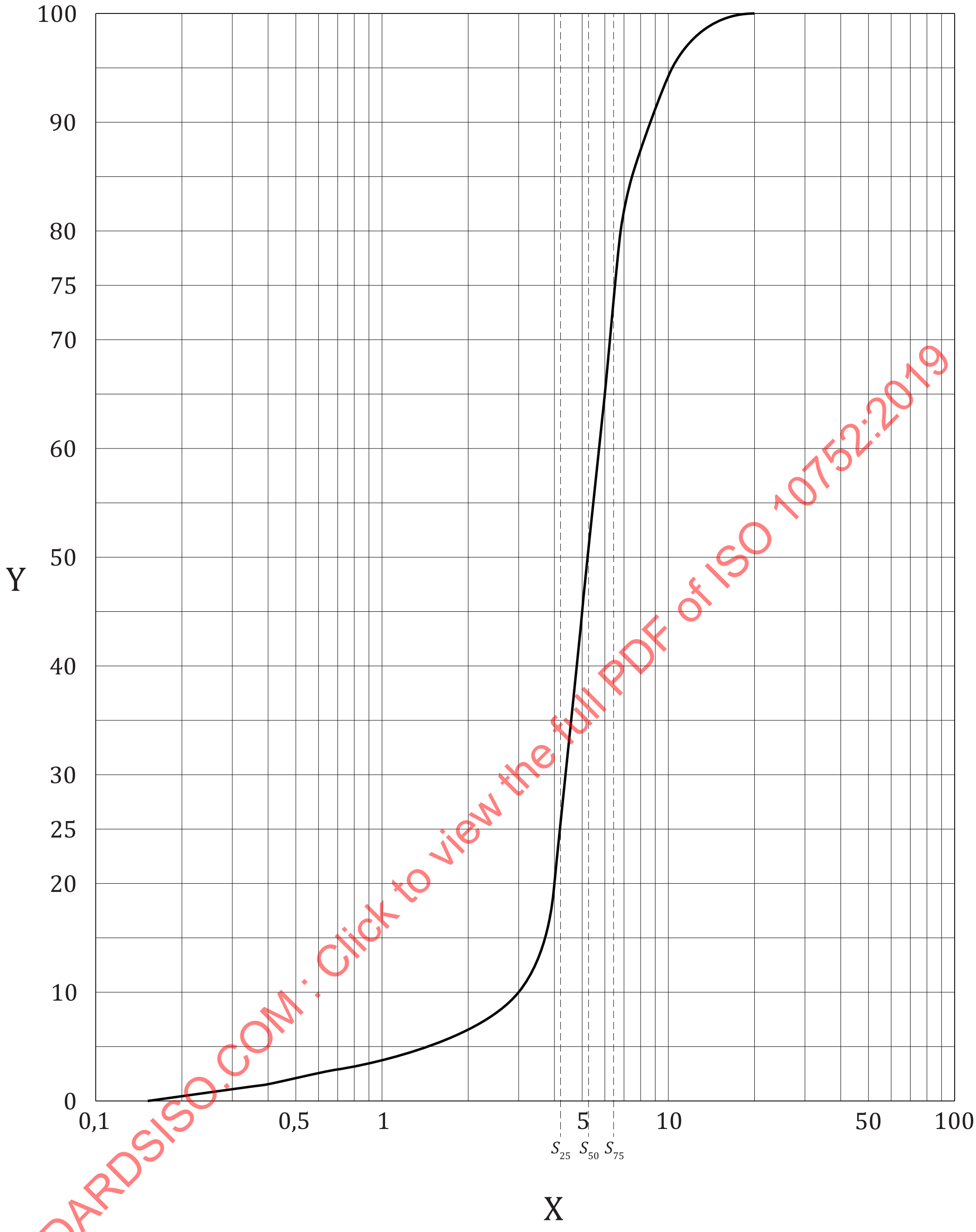
Table 2 — Partition coefficients and misplaced material data

13	14	1	15	16	17
Geometric mean size mm	**Partition coefficient** (to coarser product) %	**Size limit** mm	**Misplaced material** (as a percentage of the reconstituted feed)		
		Upper	**Coarser product** **Cumulative percent less than S_1**	**Finer product** **Cumulative percent greater than S_1**	**Total**
$\sqrt{S_1 \times S_2}$	$\frac{(9)}{(11)} \times 100$	S_1	Σ (9) ↑[a]	Σ (10) ↓[b]	(15) + (16)

NOTE A column number in parentheses denotes a respective value taken from a column in this table or Table 1.

[a] Summation to considered value of S_1 (in column 1 of Table 1) from S_1 equal to zero.

[b] Summation from considered value of S_1 (in column 2 of Table 1) to S_1 equal to zero.

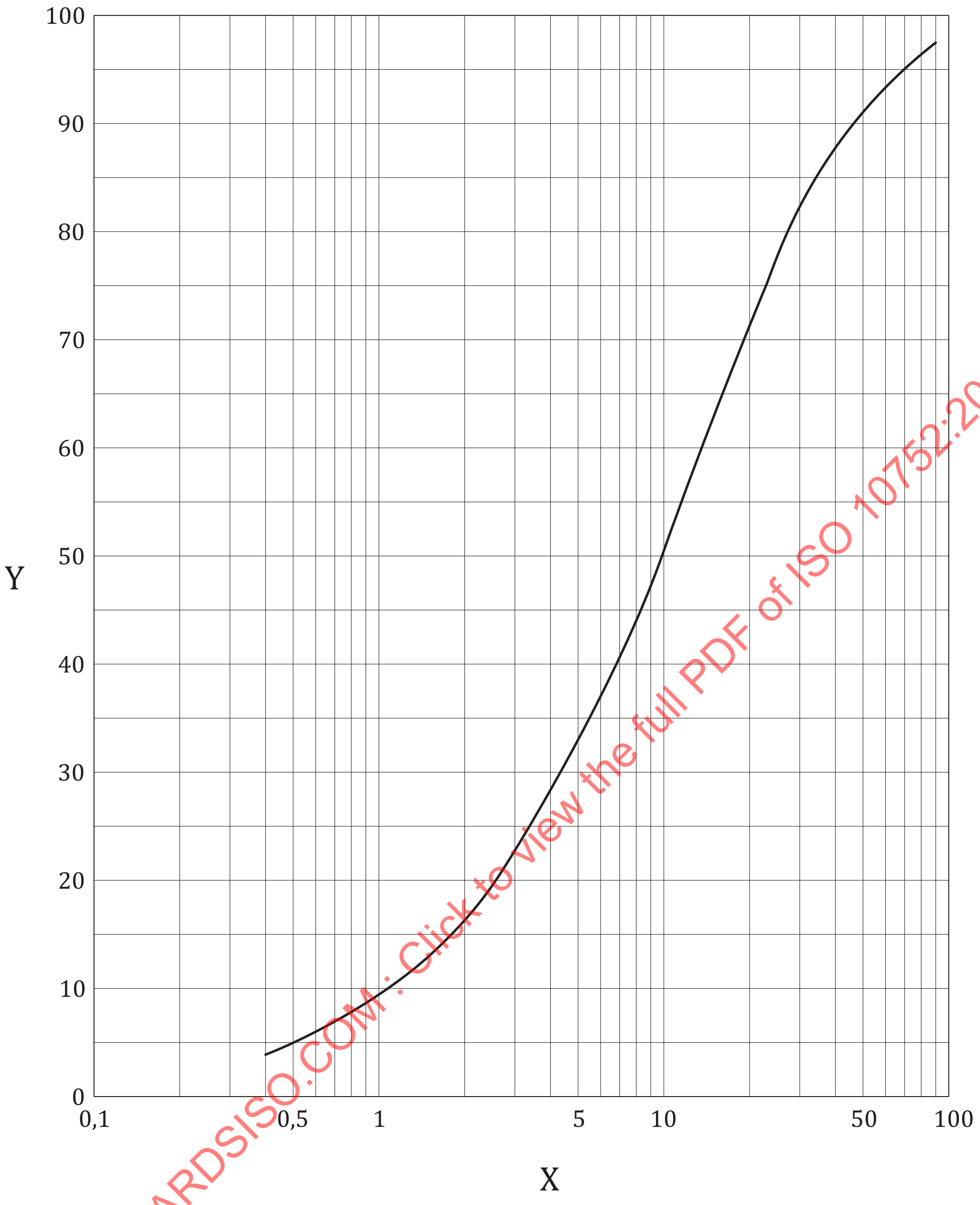


Key

X geometric mean size, mm (see Table 2, column 13)

Y partition coefficient, % (see Table 2, column 14)

Figure 1 — Partition curve

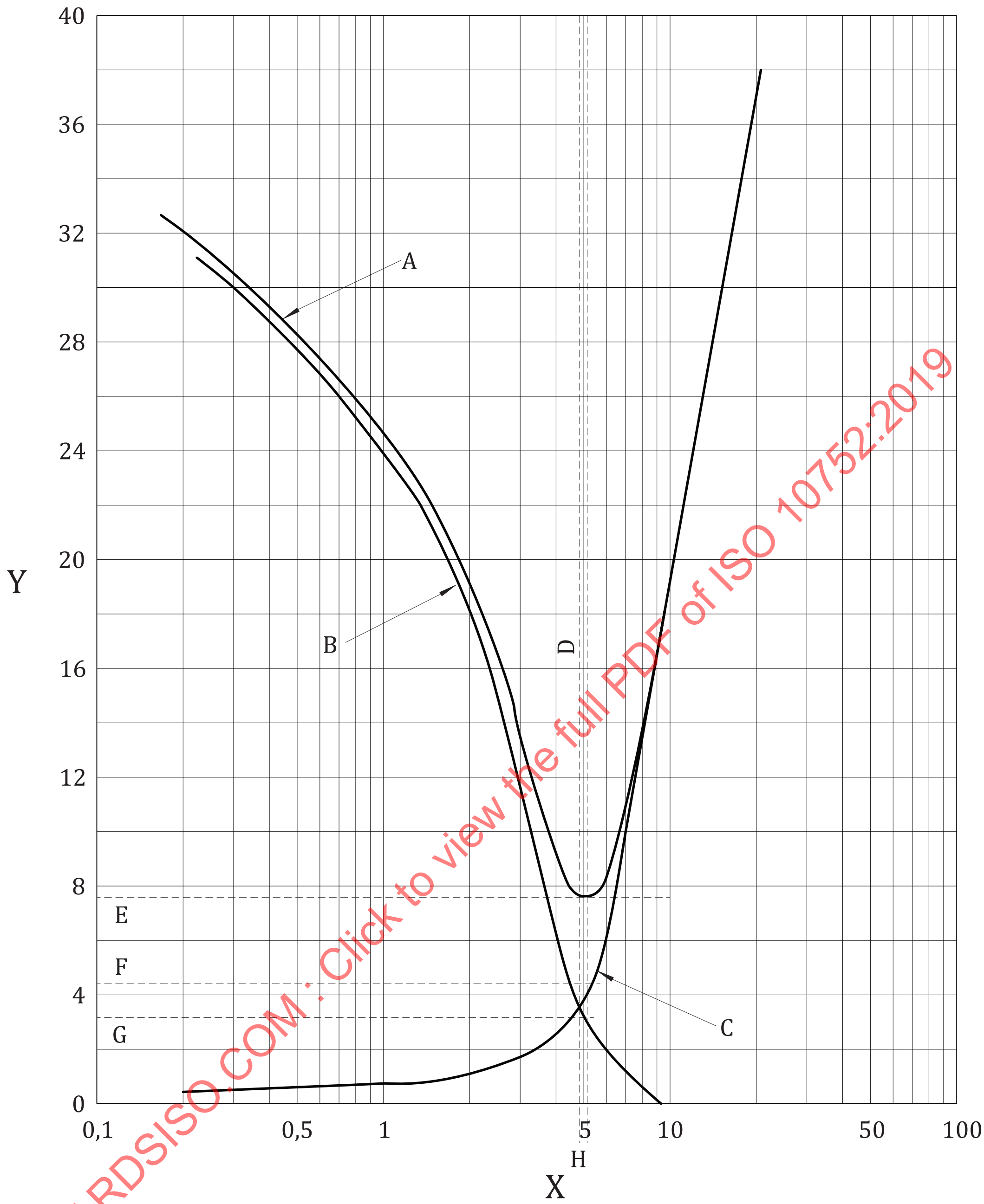


Key

X upper size limit, mm (see Table 1, column 1)

Y cumulative percent less than upper size limit (see Table 1, column 12)

Figure 2 — Size distribution curve for the reconstituted feed



Key

X upper size limit, mm (see Table 1, column 1)

Y misplaced material, % (see Table 2, columns 15, 16 and 17)

Figure 3 — Misplaced material curves

Table 3 — Statement of sizing equipment performance

Performance parameters		Determined values		
Partition curve				
Partition size:	S_{50}			
25 % Intercept:	S_{25}			
75 % Intercept:	S_{75}			
Mean probable error:	$\frac{S_{75} - S_{25}}{2}$			
Upper probable error:	$(S_{75} - S_{50})$			
Lower probable error:	$(S_{50} - S_{25})$			
Misplaced material curves				
Equal errors size:	S_e			
		Percentage of feed (reconstituted)	**Percentage of product**	
Misplaced material in coarser product (M_c)				
at S_{50}				
at designated size (S_d)				
Misplaced material in finer product (M_f)				
at S_{50}				
at designated size (S_d)				
Total misplaced material				
at S_{50}				
at designated size (S_d)				
at S_e				
Product yield and material placement efficiencies			Method of determination	
Actual yield of coarser product:	Y_c			
Actual yield of finer product:	Y_f			
		at S_d	at S_{50}	at S_e
Theoretical yield of coarser product:	$Y_{c,t}$			
Theoretical yield of finer product:	$Y_{f,t}$			
Coarser material placement efficiency:	E_c			
Finer material placement efficiency:	E_f			
Overall separation index:	I_s			
Degree of difficulty involved				
Near-size material				

Annex A
(informative)

Calculation of the yield of each product of a size separation from size analyses of feed and product materials

A.1 Introduction

Clause 6 lists the methods recommended, in order of reliability, for the determination of the yields of the coarser product, Y_c, and the finer product, Y_f, of a size separation.

Clause 6 also describes the circumstances under which these yield values may be calculated from the size analyses of the actual feed and the product materials. The two methods recommended are each based on the principle of least-squares and are outlined in A.2.

It is recognized that several methods exist for the calculation of the yield values, and each can be used with careful interpretation. The recommendations are, however, based on test work carried out under carefully controlled conditions where comparison was made between yield values calculated by several of the available methods, using directly determined values as the standard for comparison.

More sophisticated methods, involving the use of computer programs, are being developed, some of which are already available. Use of these methods can sometimes be justified by the nature of the work involved. Such methods are under review for possible future inclusion in this document.

A.2 Recommended methods for the calculation of yield values from the size analysis

A.2.1 Symbols

The following symbols have been used in the calculations for both recommended methods.

Y_f is the fractional yield of finer product;

Y_c is the fractional yield of coarser product (= 1 − Y_f);

i_F is the percentage of the i_{th} fraction in the actual feed;

$i_{F(rec)}$ is the percentage of the i_{th} fraction in the reconstituted feed;

i_f is the percentage of the i_{th} fraction in the finer product;

i_c is the percentage of the i_{th} fraction in the coarser product.

A.2.2 Calculation of yield values from cumulative size analyses

This method is based on a least-squares principle, the yield values being calculated so that the sum of the squared deviations between the reconstituted feed and the actual feed size fractions, taken in terms of the actual feed size fraction, is at a minimum.

Thus:

$$\Sigma\frac{\left[i_{\mathrm{F}}-i_{\mathrm{F(rec)}}\right]^{2}}{i_{\mathrm{F}}}=\text{a minimum value} \tag{A.1}$$

Since

$$i_{\mathrm{F(rec)}}=Y_{\mathrm{f}}i_{\mathrm{f}}+i_{\mathrm{c}}\left(1-Y_{\mathrm{f}}\right) \tag{A.2}$$

then, by substitution of (A.2) in (A.1)

$$\Sigma\frac{\left(i_{\mathrm{F}}-Y_{\mathrm{f}}i_{\mathrm{f}}-i_{\mathrm{c}}+Y_{\mathrm{f}}i_{\mathrm{c}}\right)^{2}}{i_{\mathrm{F}}^{2}}=\text{a minimum value}$$

Therefore

$$2\Sigma\frac{\left[i_{\mathrm{F}}-i_{\mathrm{c}}-Y_{\mathrm{f}}\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)\right]\times\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)}{i_{\mathrm{F}}^{2}}=0$$

Therefore

$$\Sigma\frac{\left(i_{\mathrm{F}}-i_{\mathrm{c}}\right)\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)}{i_{\mathrm{F}}^{2}}=Y_{\mathrm{f}}\times\Sigma\frac{\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)2}{i_{\mathrm{F}}^{2}}$$

$$Y_{\mathrm{f}}=\frac{\Sigma\dfrac{\left(i_{\mathrm{F}}-i_{\mathrm{c}}\right)-\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)}{i_{\mathrm{F}}^{2}}}{\Sigma\left[\dfrac{i_{\mathrm{f}}-i_{\mathrm{c}}}{i_{\mathrm{F}}}\right]^{2}} \tag{A.3}$$

Using the cumulative form of the size analyses of actual feed, finer and coarser products, Formula (A.3) can be rewritten as follows:

$$Y_{\mathrm{f}}=\frac{\Sigma\left[\dfrac{\left(\Sigma i_{\mathrm{F}}-\Sigma i_{\mathrm{c}}\right)\left(\Sigma i_{\mathrm{f}}-\Sigma i_{\mathrm{c}}\right)}{\Sigma i_{\mathrm{F}}^{2}}\right]}{\Sigma\left[\dfrac{\Sigma i_{\mathrm{f}}-\Sigma i_{\mathrm{c}}}{\Sigma i_{\mathrm{F}}}\right]^{2}} \tag{A.4}$$

Thus, Formula (A.4) will allow calculation of the yield of the finer product from the cumulative size analyses of the actual feed and the finer and coarser products of the size separation.

A.2.3 Calculation of yield values from elementary size analyses

This method is based on a statistical "goodness of fit" test and is also a least-squares method.

The condition applied is as follows:

$$\Sigma\left[\frac{i_{\mathrm{F}}-i_{\mathrm{F(rec)}}}{i_{\mathrm{F}}}\right]^2 = \text{a minimum value} \tag{A.5}$$

The following equation can be derived from Formula (A.5) by a method similar to that used in A.2.2.

$$Y_{\mathrm{f}}=\frac{\Sigma\left[\frac{\left(i_{\mathrm{F}}-i_{\mathrm{c}}\right)\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)}{i_{\mathrm{F}}}\right]}{\Sigma\left[\frac{\left(i_{\mathrm{f}}-i_{\mathrm{c}}\right)^2}{i_{\mathrm{F}}}\right]} \tag{A.6}$$

Formula (A.6) will allow calculation of the yield of the finer product from the elementary size analyses of the actual feed and the finer and coarser products of the size separation.

Annex B
(informative)

Worked example — Vibrating screen

Data sheet 1 — Test equipment data (vibrating screen)

Reference	Date of test	Name of plant
WE/S/1	17/9/83	Standard coal preparation plant

Equipment details and duty	
Type of sizing unit	Double-deck vibrating screen
Nominal size of unit	2,44 m × 6,1 m
Inclination	20°
Type of motion	Circular
Direction of motion	Contra-flow
Stroke	9 mm
Frequency	16 Hz
Number of decks	2
and configuration	Superimposed
Deck 1	Relieving
Nominal area	14,9 m^2
Effective area	13,4 m^2
Type of deck	Woven wire
Aperture	38,1 mm × 38,1 mm
Open area	77 %
Deck 2	Sizing
Nominal area	14,9 m^2
Effective area	13,4 m^2
Type of deck	Woven wire
Aperture	6,35 mm × 6,35 mm
Open area	57 %
Designated size	5,0 mm
Rated capacity	150 t/h Two-product size separation at designated size
Feed characteristics	
Nature of feed	Raw coal
Size limits	<100 mm
Bulk density	1,4 t/m^3
Total moisture	7,1 %
Surface (free) moisture	5,5 %
Ash (dry basis)	25,0 %

Test conditions			
Test masses			
	Method of determination	**Mass** tonnes	**Content** % (*mm*)
Feed	Calculated	945	100,0
Coarser product	Belt-weigher	640	67,6
Finer product	Direct weighing in wagons	305	32,4
Duration of test		7 h 36 min	
Average feed rate		124,5 t/h	
Test samples			
	Method of sampling	**Number of increments**	**Mass of increments** kg
Feed	Manual	40	400
Coarser product	Manual	40	400
Finer product	Mechanical	40	100
Method of size analysis		Dry sieving	
Apparatus		Test sieves	

Table B.1 — Size distribution of feed and products (vibrating screen)

1	2	3	4	5	6	7	8	9	10	11	12
Method of analysis: Test sieves with square mesh		**Analyses of feed and products**						**Percentage of reconstituted feed**		**Reconstituted feed**	
		Actual feed		**Coarser product**		**Finer product**		**Coarser product**	**Finer product**		
Size limits, mm		**Size fraction**	**Cumulative percent less than S_1**	**Size fraction**	**Cumulative percent less than S_1**	**Size fraction**	**Cumulative percent less than S_1**	**Actual yield** $Y_c = 67,6$ %	**Actual yield** $Y_f = 32,4$ %	**Size fraction**	**Cumulative percent less than S_1**
Upper	**Lower**	%		%		%		**Size fraction %**	**Size fraction %**	%	
S_1	S_2		Σ (3) ↑		Σ (5) ↑		Σ (7) ↑	$(5)\times\frac{Y_c}{100}$	$(7)\times\frac{Y_f}{100}$	(9) + (10)	Σ (11) ↑
125,0	63,0	6,0	100,0	7,1	100,0	0	100,0	4,8	0	4,8	100,0
63,0	31,5	13,3	94,0	17,9	92,9	0	100,0	12,1	0	12,1	95,2
31,5	16,0	20,5	80,7	30,4	75,0	0	100,0	20,6	0	20,6	83,1
16,0	8,0	17,9	60,2	26,2	44,6	1,9	100,0	17,7	0,6	18,3	62,5
8,0	5,6	8,3	42,3	10,5	18,4	6,5	98,1	7,1	2,1	9,2	44,2
5,6	4,0	7,6	34,0	4,3	7,9	13,3	91,6	2,9	4,3	7,2	35,0
4,0	2,8	5,9	26,4	1,4	3,6	19,1	78,3	1,0	6,2	7,2	27,8
2,8	2,0	4,3	20,5	0,5	2,2	12,3	59,2	0,3	4,0	4,3	20,6
2,0	1,0	6,7	16,2	0,5	1,7	20,4	46,9	0,3	6,6	6,9	16,3
1,0	0,5	3,8	9,5	0,5	1,2	12,6	26,5	0,3	4,1	4,4	9,4
0,5	0	5,7	5,7	0,7	0,7	13,9	13,9	0,5	4,5	5,0	5,0
Totals		100,0	—	100,0	—	100,0	—	67,6	32,4	100,0	—

NOTE — A column number in parentheses denotes a respective value taken from that column.

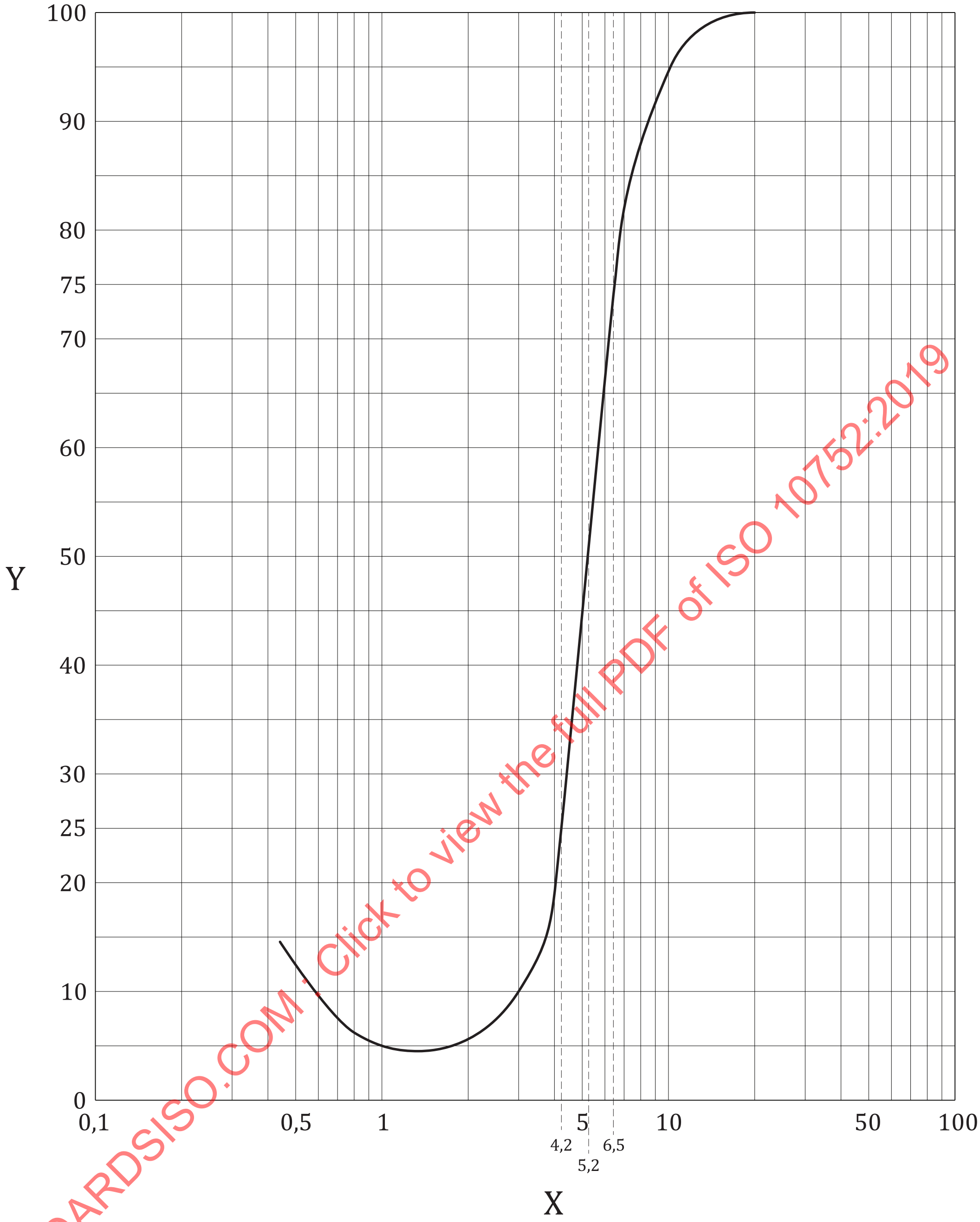
Table B.2 — Partition coefficients and misplaced material data (vibrating screen)

13	14	1	15	16	17
Geometric mean size mm	**Partition coefficient** (to coarser product) %	**Size limit** mm	**Misplaced material** (as a percentage of the reconstituted feed)		
		Upper	**Coarser product** **Cumulative percent less than S_1**	**Finer product** **Cumulative percent greater than S_1**	**Total**
$\sqrt{S_1 \times S_2}$	$\frac{(9)}{(11)} \times 100$	S_1	Σ (9) ↑[a]	Σ (10) ↓[b]	(15) + (16)
88,7	100	125,0	67,6	0	67,6
44,5	100	63,0	62,8	0	62,8
22,4	100	31,5	50,7	0	50,7
11,3	96,7	16,0	30,1	0	30,1
6,69	77,2	8,0	12,4	0,6	13,0
4,73	40,3	5,6	5,3	2,7	8,0
3,35	13,9	4,0	2,4	7,0	9,4
2,37	7,0	2,8	1,4	13,2	14,6
1,41	4,3	2,0	1,1	17,2	18,3
0,71	6,8	1,0	0,8	23,8	24,6
—	10,0	0,5	0,5	27,9	28,4
—	—	0	0	32,4	32,4
—	—	—	—	—	—

NOTE A column number in parentheses denotes a respective value taken from a column in this table or Table B.1.

[a] Summation to considered value of S_1 (in column 1 of Table B.1) from S_1 equal to zero.

[b] Summation from considered value of S_1 (in column 2 of Table B.1) to S_1 equal to zero.

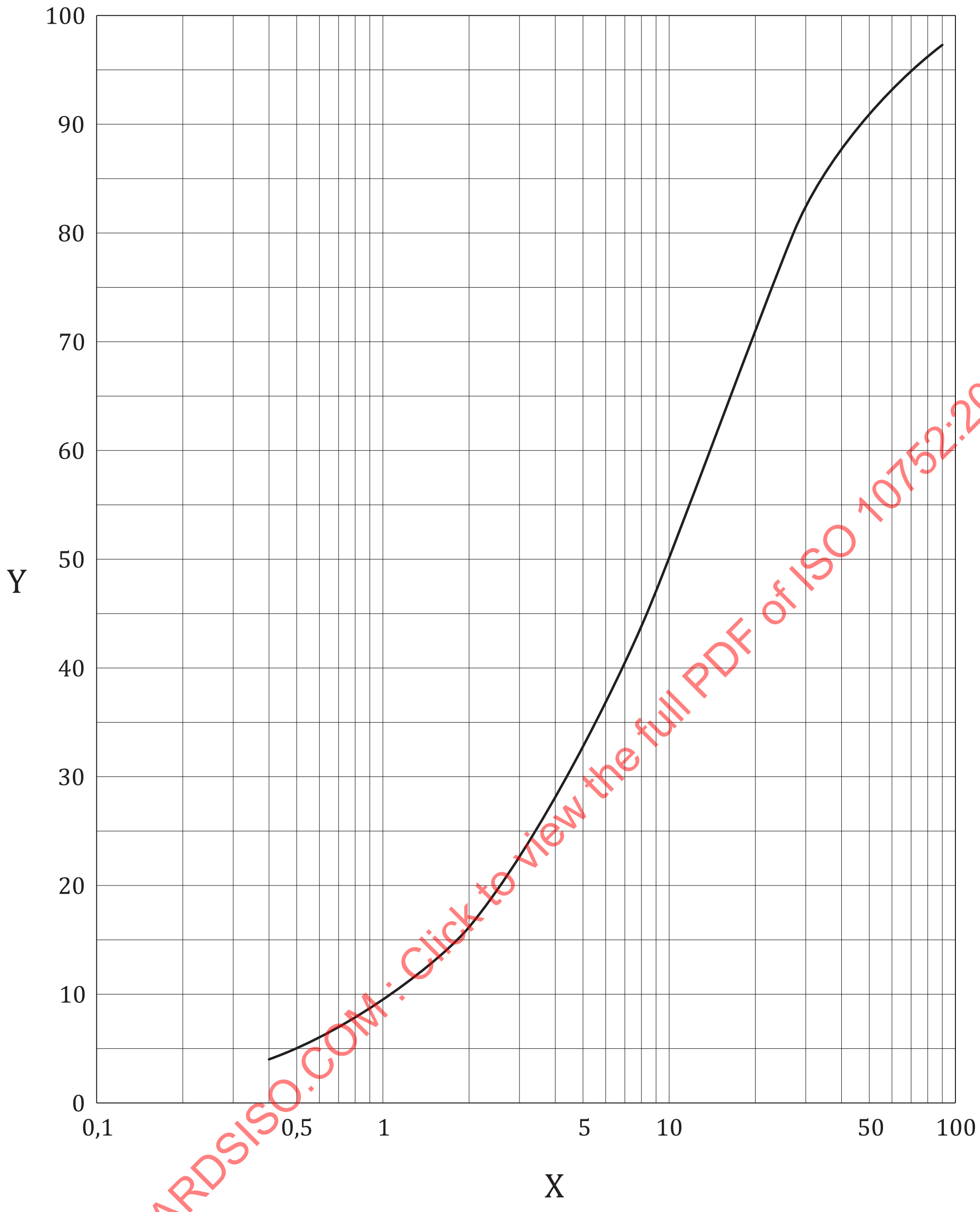


Key

X geometric mean size, mm

Y partition coefficient

Figure B.1 — Partition curve (vibrating screen)

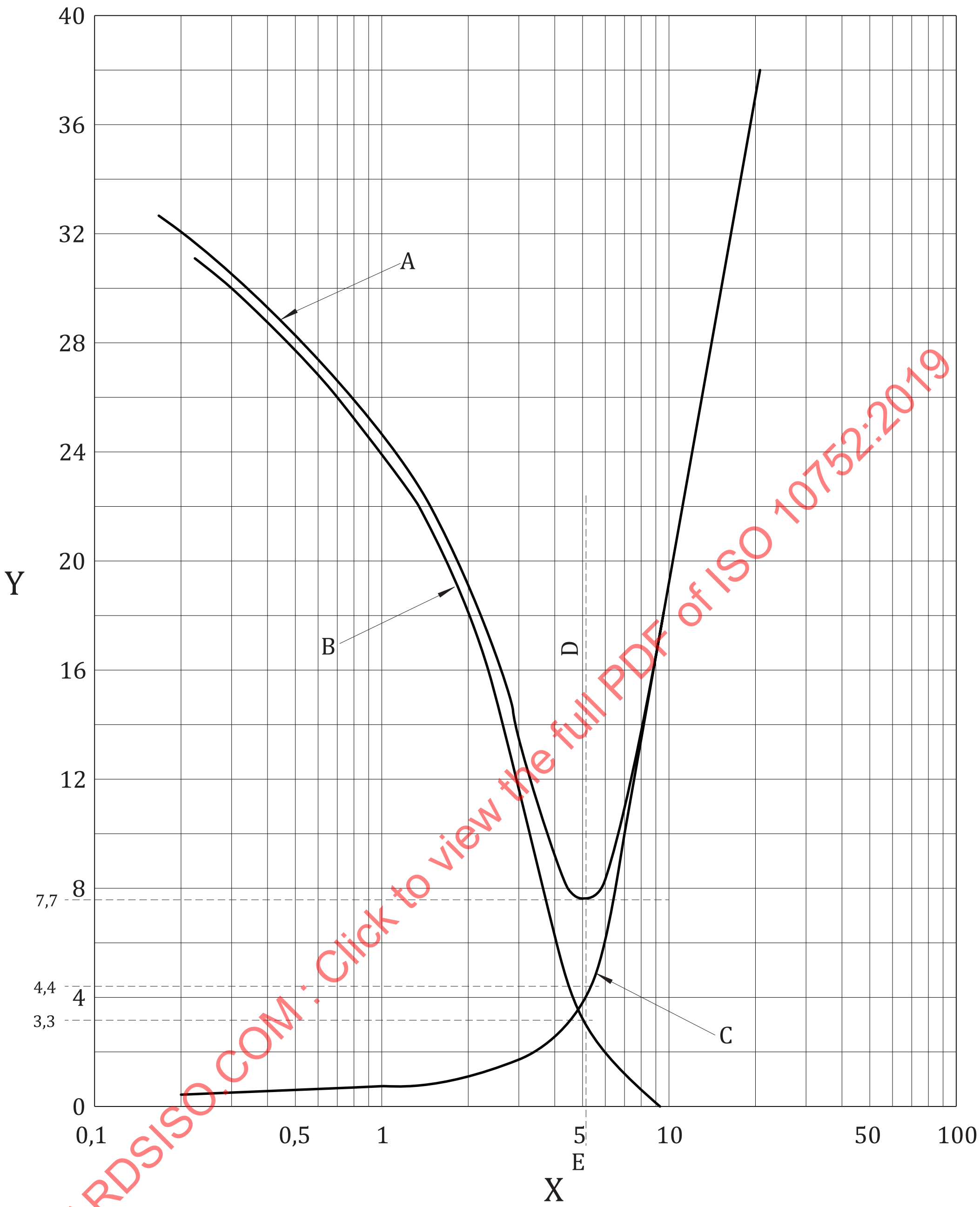


Key

X upper size limit, mm

Y cumulative percent less than upper size limit

Figure B.2 — Size distribution curve for the reconstituted feed (vibrating screen)



Key

X equal errors size: 4,8. Upper size limit, mm

Y misplaced material, %

Figure B.3 — Misplaced material curves (vibrating screen)

Table B.3 — Statement of sizing equipment performance (vibrating screen)

Performance parameters		Determined values mm		
Partition curve				
Partition size:	S_{50}	5,2		
25 % Intercept:	S_{25}	4,2		
75 % Intercept:	S_{75}	6,5		
Mean probable error:	$\frac{S_{75}-S_{25}}{2}$	1,15		
Upper probable error:	$(S_{75} - S_{50})$	1,3		
Lower probable error:	$(S_{50} - S_{25})$	1,0		
Misplaced material curves				
Equal errors size:	S_e	4,8		
		Percentage of feed (reconstituted)	**Percentage of product**	
Misplaced material in coarser product (M_c)				
at S_{50}		4,4	6,5	
at designated size (S_d)	5,0 mm	4,0	5,9	
Misplaced material in finer product (M_f)				
at S_{50}		3,3	10,2	
at designated size (S_d)	5,0 mm	3,7	11,4	
Total misplaced material				
at S_{50}		7,7		
at designated size (S_d)	5,0 mm	7,7		
at S_e		7,8		
Product yield and material placement efficiencies				
Actual yield of coarser product:	Y_c	67,6 %		
Actual yield of finer product:	Y_f	32,4 %		
		at S_d	at S_{50}	at S_e
Theoretical yield of coarser product:	$Y_{c,t}$	68,0 %	66,5 %	68,5 %
Theoretical yield of finer product:	$Y_{f,t}$	32,0 %	33,5 %	31,5 %
Coarser material placement efficiency:	E_c	93,5 %	95,0 %	93,3 %
Finer material placement efficiency:	E_f	89,7 %	86,9 %	90,5 %
Overall separation index:	I_s	83,2 %	81,9 %	83,5 %
Degree of difficulty involved				
Near-size material		11,5 %	11,6 %	11,4 %

Annex C
(informative)

Worked example — Cyclone

Data sheet 2 — Test and equipment data (cyclone)

Reference	Date of test	Name of plant
WE/C/1	2/1/84	Coal preparation plant

Equipment details and duty	
Type of sizing unit	Hydrocyclone
Nominal diameter	75 mm
Inlet type	Volute
Inlet size	20 mm × 15 mm
Cylindrical section:	
— length	75mm
Vortex finder:	
— diameter	25 mm
— length	50 mm
Conical section:	
— length	200 mm
— total angle	15°
Nozzle:	
— diameter	25 mm
Designated size	10 µm
Rated capacity	10 m^3/h at 2 bar
Feed characteristics	
Nature of feed	Sand
Source of feed	Chance cone effluent
Size limits	−63 µm
R. D.	2,6
Test conditions	
Duration of test	2 h

Test samples			Total sample	
	Method of sampling	**Number of increments**	**Volume** litres	**Mass of solids** kg
Feed	Manual	24	66	0,607
Coarser product	Manual	24	40	0,968
Finer product	Manual	24	53	0,275

Sample analysis			
	Concentration of solids g/l	**Relative density of solids**	**Method of size analysis**
Feed	9,3	2,6	Coulter counter
Coarser product	24,2	2,6	
Finer product	5,2	2,6	

Flow rates of liquids and solids				
	Method of determination	**Flow rate of liquids** m^3/h	**Flow rate of solids** t/h	**Content of solids** % (m/m)
Feed	Calculated	9,57	0,089	100,0
Coarser product	At regular timed increments	2,07	0,050	56,0
Finer product		7,50	0,039	44,0

Table C.1 — Size distribution of feed and products (cyclone)

1	2	3	4	5	6	7	8	9	10	11	12
Method of analysis: Coulter counter		**Analyses of feed and products**						**Percentage of reconstituted feed**		**Reconstituted feed**	
		Actual feed		**Coarser product**		**Finer product**		**Coarser product**	**Finer product**		
Size limits, mm		**Size fraction**	**Cumulative percent less than S_1**	**Size fraction**	**Cumulative percent less than S_1**	**Size fraction**	**Cumulative percent less than S_1**	**Actual yield** $Y_c = 56$ %	**Actual yield** $Y_f = 44$ %	**Size fraction**	**Cumulative percent less than S_1**
Upper	**Lower**	%		%		%		**Size fraction %**	**Size fraction %**	%	
S_1	S_2		Σ (3) ↑		Σ (5) ↑		Σ (7) ↑	$(5)\times\frac{Y_c}{100}$	$(7)\times\frac{Y_f}{100}$	(9) + (10)	Σ (11) ↑
63,00	52,00	2,30	100,00	3,10	100,00	1,20	100,00	1,74	0,53	2,27	100,00
52,00	41,00	3,95	97,10	5,30	96,90	2,25	98,80	2,97	0,99	3,96	97,73
41,00	33,00	7,75	93,75	9,80	91,60	5,15	96,55	5,49	2,27	7,76	93,77
33,00	26,00	11,40	86,00	14,60	81,80	7,25	91,40	8,18	3,19	11,37	86,01
26,00	20,00	12,65	74,60	16,80	67,20	7,35	84,15	9,41	3,23	12,64	74,64
20,00	16,00	12,55	61,95	14,90	50,40	9,55	76,80	8,34	4,20	12,54	62,00
16,00	13,00	10,95	49,40	10,70	35,50	11,35	67,25	5,99	4,99	10,98	49,46
13,00	10,00	9,10	38,45	7,40	24,80	11,25	55,90	4,14	4,95	9,09	38,48
10,00	8,00	7,60	29,35	5,40	17,40	10,35	44,65	3,02	4,56	7,58	29,39
8,00	6,20	6,55	21,75	4,10	12,00	9,65	34,30	2,30	4,25	6,55	21,81
6,20	5,00	5,25	15,20	3,10	7,90	7,95	24,65	1,74	3,50	5,24	15,26
5,00	4,00	3,75	9,95	2,00	4,80	6,05	16,70	1,12	2,66	3,78	10,02
4,00	3,10	2,70	6,20	1,30	2,80	4,55	10,65	0,72	2,00	2,72	6,24
3,10	2,50	2,30	3,50	1,00	1,50	4,00	6,10	0,56	1,76	2,32	3,52
2,50	2,00	1,20	1,20	0,50	0,50	2,10	2,10	0,28	0,92	1,20	1,20
2,00	0	0	0	0	0	0	0	0	0	—	—
Totals		100,00	—	100,00	—	100,00	—	56,00	44,00	100,00	—

NOTE A column number in parentheses denotes a respective value taken from that column.

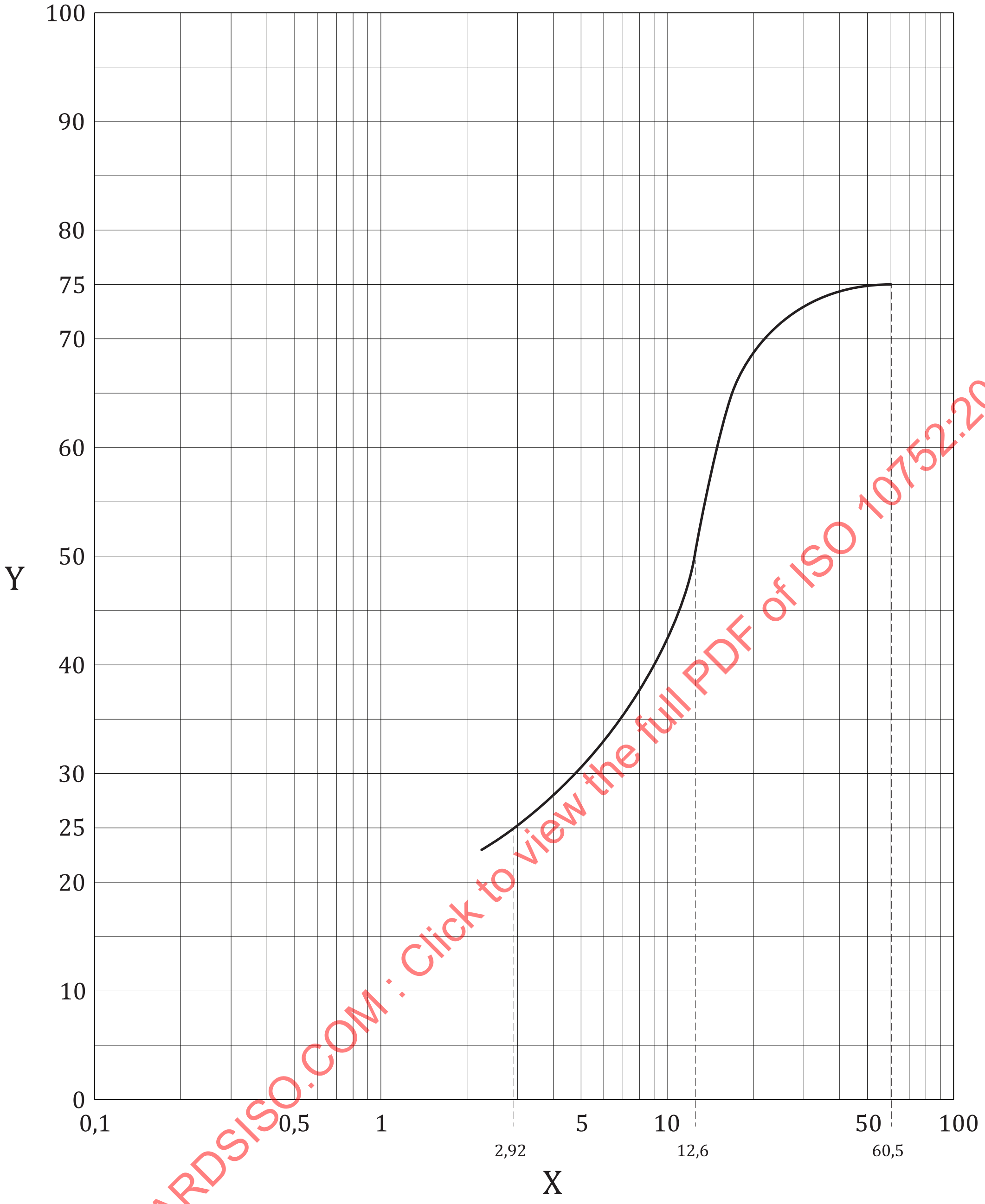
Table C.2 — Partition coefficients and misplaced material data (cyclone)

13	14	1	15	16	17
Geometric mean size mm	**Partition coefficient** (to coarser product) %	**Size limit** µm	**Misplaced material** (as a percentage of the reconstituted feed)		
			Coarser product	**Finer product**	
		Upper	**Cumulative percent less than S_1**	**Cumulative percent greater than S_1**	**Total**
$\sqrt{S_1 \times S_2}$	$\frac{(9)}{(11)} \times 100$	S_1	Σ (9) ↑[a]	Σ (10) ↓[b]	(15) + (16)
57,24	76,75	63,00	56,00	0	56,00
46,17	75,00	52,00	54,26	0,53	54,79
36,78	70,74	41,00	51,29	1,52	52,81
29,29	71,94	33,00	45,80	3,79	49,59
22,80	74,45	26,00	37,62	6,98	44,60
17,89	66,51	20,00	28,21	10,21	38,42
14,42	54,55	16,00	19,87	14,41	34,28
11,40	45,54	13,00	13,88	19,40	33,28
8,94	39,84	10,00	9,74	24,35	34,09
7,04	35,11	8,00	6,72	28,91	35,63
5,57	32,21	6,20	4,42	33,16	37,58
4,47	29,63	5,00	2,68	36,66	39,34
3,52	26,47	4,00	1,56	39,32	40,88
2,78	24,14	3,10	0,84	41,32	42,16
2,37	23,33	2,50	0,28	43,08	43,36
—	—	2,00	0	44,00	44,00

NOTE A column number in parentheses denotes a respective value taken from a column in this table or Table C.1.

[a] Summation to considered value of S_1 (in column 1 of Table C.1) from S_1 equal to zero.

[b] Summation from considered value of S_1 (in column 2 of Table C.1) to S_1 equal to zero.

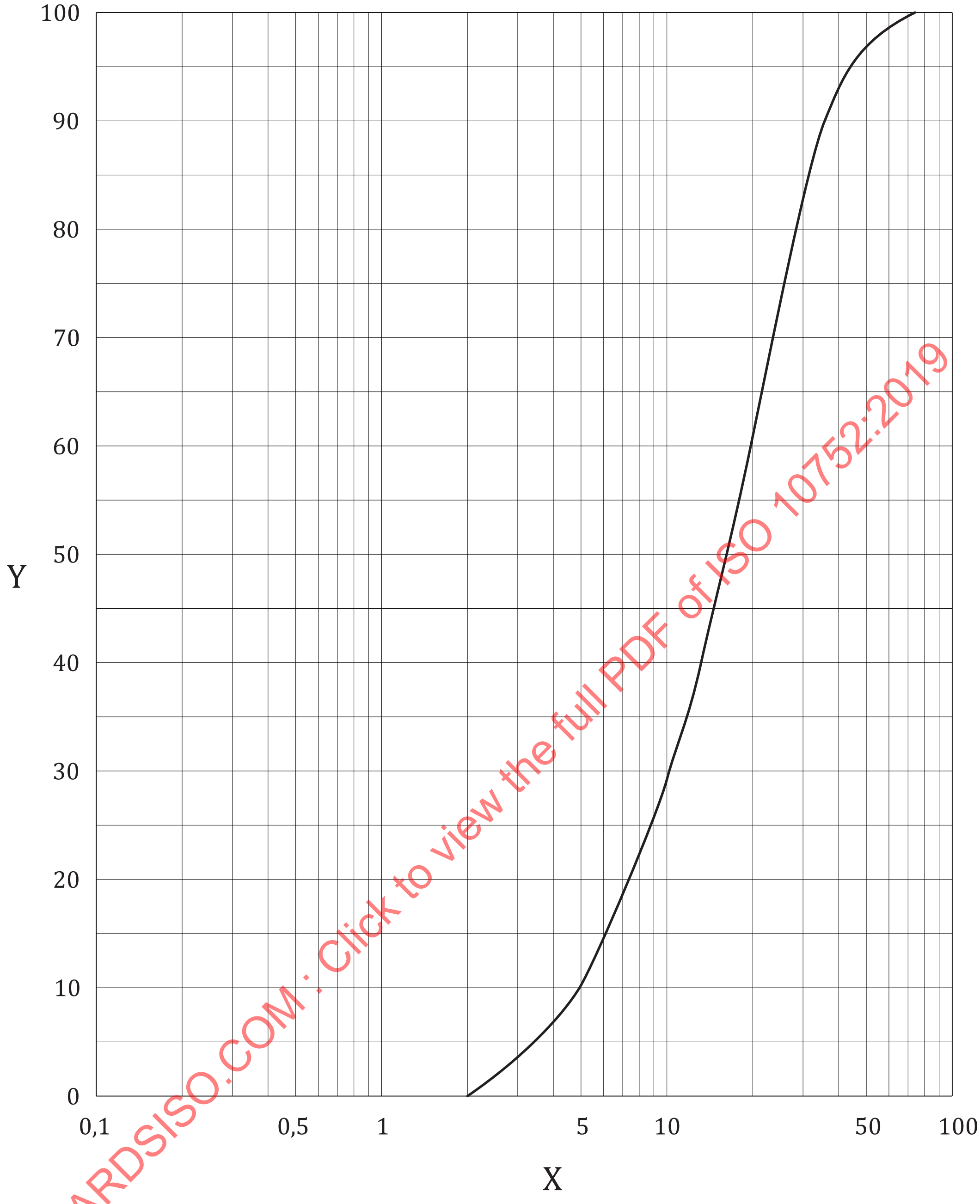


Key

X geometric mean size, µm

Y partition coefficient, %

Figure C.1 — Partition curve (cyclone)

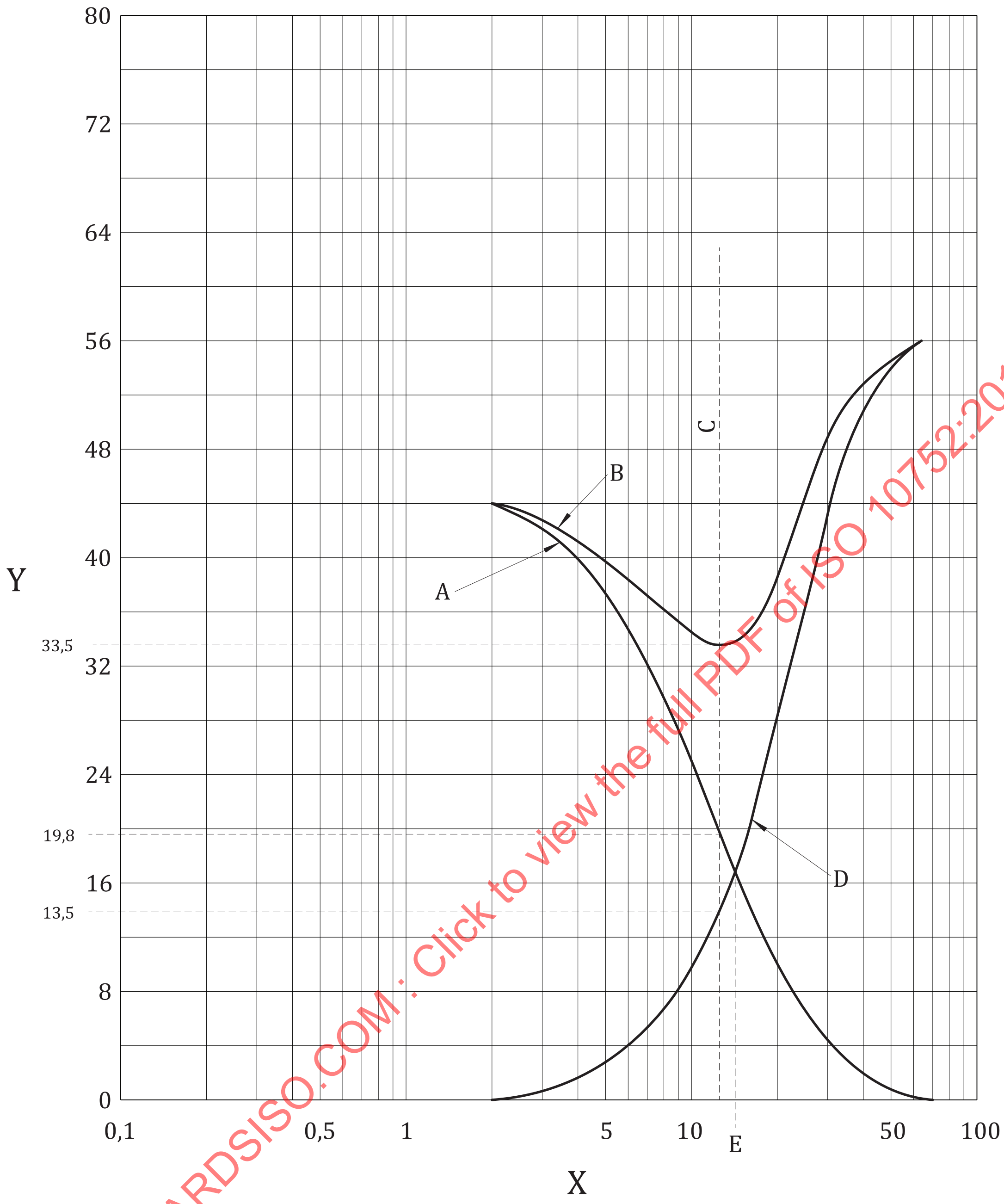


Key

X upper size limit, µm

Y cumulative percent less than upper size limit

Figure C.2 — Size distribution curve for the reconstituted feed (cyclone)



Key

X upper size limit, µm

Y misplaced material, %

Figure C.3 — Misplaced material curves (cyclone)