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Coal sizing equipment — Performance evaluation

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

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10752 was prepared by Technical Committee ISO/TC 27, *Solid mineral fuels*, Subcommittee SC 1, *Coal preparation. Terminology and performance*.

Annex A forms an integral part of this International Standard. Annexes B, C and D are for information only.

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 International Standard 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 International Standard applies to all types of sizing equipment, categorized as follows:

a) screens;

b) classifiers;

c) others.

The procedure described in this International Standard 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 standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1170:1977, *Coal and coke — Calculation of analyses to different bases.*

ISO 1213-1:1993, *Solid mineral fuels - Vocabulary — Part 1: Terms relating to coal preparation.*

ISO 1953:1972, *Hard coals — Size analysis.*

ISO 1988:1975, *Hard coal — Sampling.*

3 Definitions

For the purposes of this International Standard, the definitions given in 1213-1 and the following definitions apply.

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): That product of size separation that contains a greater proportion of coarser material than does the feed.

3.1.6 finer product (f): That product of size separation that contains a greater proportion of finer material than does the feed.

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

3.2 Performance parameters

3.2.1 theoretical yield (sizing): The 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)**:** The percentage of coarser material in the reconstituted feed that reports to the coarser product.

3.2.3 finer material placement efficiency (E_f)**:** The percentage of finer material in the reconstituted feed that reports to the finer product.

3.2.4 overall separation index: The 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.

NOTES

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

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

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

4 Conditions should be kept uniform during a test.

5 Performance parameters

For the standard expression of performance of a separation, the criteria 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 5 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 International Standards if available; for solids under other conditions, ISO 1988 applies.

NOTE 6 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:

a. 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;

b. taking regular timed increments over the duration of the test;

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

NOTES

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

8 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.

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

10 Where the solids are conveyed by a fluid, it may be more convenient to make volumetric measurements.

11 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.

NOTE 12 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.

NOTES

13 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.

14 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.

NOTES

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

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

17 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 18 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

NOTES

19 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.

20 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 21 The partition size can be determined from the misplaced material curves (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 (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:

$$E_{pm} = \frac{S_{75} - S_{25}}{2} \qquad \ldots (1)$$

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 S_1 (column 1 of table 1. The recommended scales are

size: $\log_{10}$ 1 cycle = 50 mm

misplaced material: 1 % = 5 mm

NOTE 22 If it is necessary to use an alternative scale, this should be a simple multiple of the recommended scale; for an example see annex C, figure C.3.

8.8 Misplaced material

The misplaced material is read from each respective curve at the reference size, or sizes (see note 23), and the values are entered 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 24), and the converted values are entered into the statement in table 3.

NOTES

23 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.

24 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).

25 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 entered 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

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

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 entered into the statement of sizing equipment performance in table 3.

NOTES

26 Misplaced material values are in terms of percentages of reconstituted feed.

27 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 entered into the statement of sizing equipment performance in table 3. The calculations are as follows.

a) Coarser material placement efficiency (E_c)

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

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

b) Finer material placement efficiency (E_f)

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

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 as defined in 8.10.

c) Overall separation index (S_i)

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

NOTES

28 Misplaced material values are in terms of percentage of reconstituted feed.

29 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 entered 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 entered 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 entered 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	**Partition coefficient** (to coarser product)	**Size limit** mm	**Misplaced material** (as a percentage of the reconstituted feed)		
		Upper	**Coarser product**	**Finer product**	**Total**
			Cumulative percent less than S_1	**Cumulative percent greater than S_1**	
mm	%				
$\sqrt{S_1 \times S_2}$	$\frac{(9)}{(11)} \times 100$	S_1	Σ (9) ↑ 1)	Σ (10) ↓ 2)	(15) + (16)

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

1) Summation to considered value of S_1 (in column 1 of table 1) from S_1 equal to zero.

2) Summation from considered value of S_1 (in column 2 of table 1) to S_1 equal to zero.

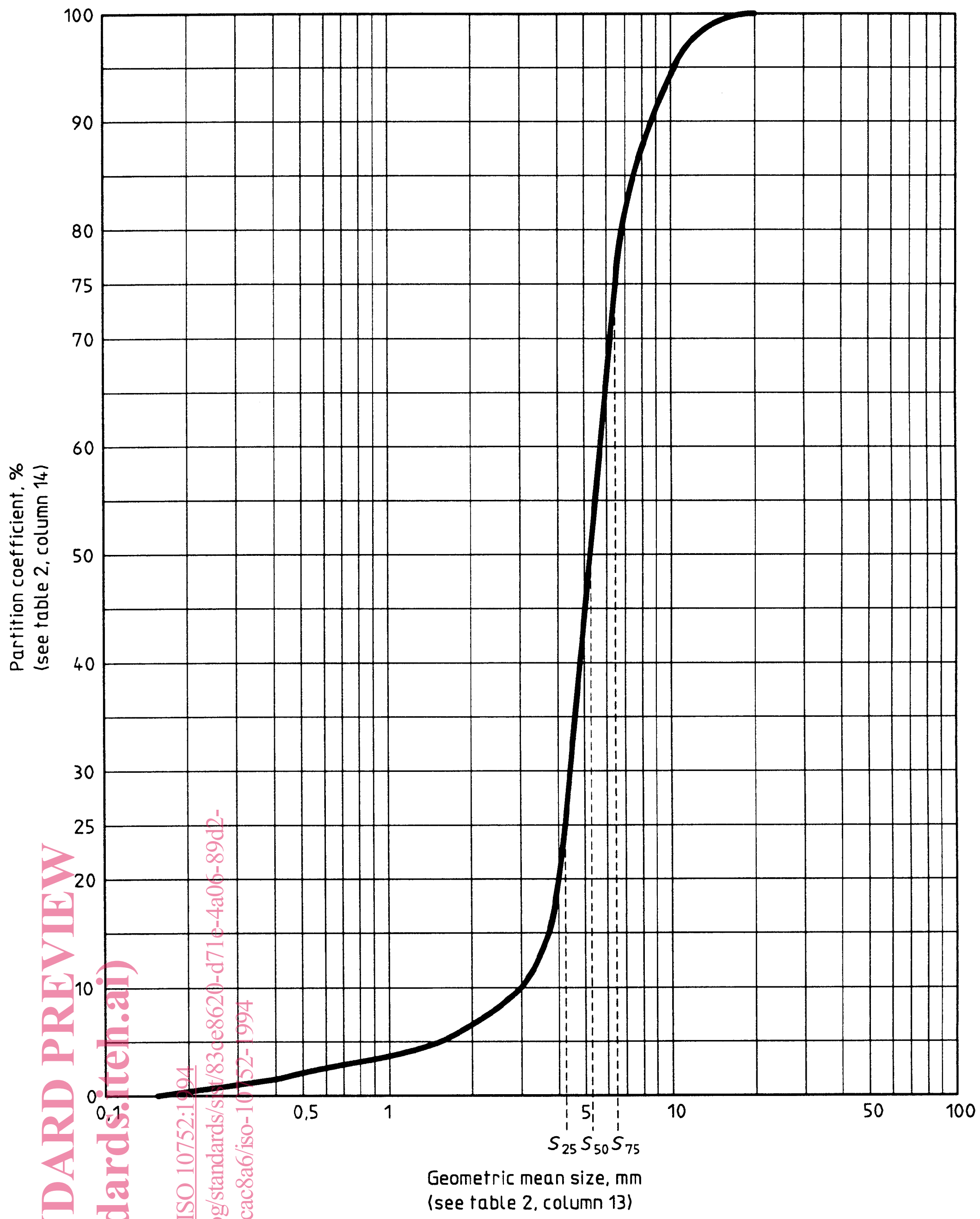

Figure 1 — Partition curve