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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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

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

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:

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

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

b) Finer material placement efficiency, E_f:

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