INTERNATIONAL STANDARD

ISO 923

Third edition
2022-11

Coal — Density separation equipment for coal — Performance evaluation

Charbon — Equipement de séparation par masse volumique pour le charbon — Evaluation des performances

Reference number
ISO 923:2022(E)

Contents

Page

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.

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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, *Coal and Coke*, Subcommittee SC 1, *Coal preparation: Terminology and performance.*

This third edition cancels and replaces the second edition (ISO 923:2000), which has been technically revised.

The main changes are as follows:

— example calculations have been updated to reflect a dense medium separation, which is most commonly employed in industry;

— performance measures have been updated to include the bypass fractions;

— new versions of the tables for two and three product separations included to align with currently common applications.

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.

Coal — Density separation equipment for coal — Performance evaluation

1 Scope

This document describes the principles and methods for evaluating the performance of density separation equipment used for coal cleaning operations. Testing and sampling procedures are specified, and methods of presenting test results are detailed. Performance parameters are recommended and defined, and their determination is formulated, thereby permitting their use in evaluating, comparing and predicting performance levels of coal cleaning operations.

This document is applicable to the following types of coal cleaning equipment using relative density (RD) as the main characteristic for separation:

a) dense-medium separators;

b) jigs;

c) other density-based separators, including spiral separator, hindered settling cleaners, shaking table, water-only cyclone, etc.

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 1170, *Coal and coke — Calculation of analyses to different bases*

ISO 1213-1, *Coal and coke — Vocabulary — Part 1: Terms relating to coal preparation*

ISO 1953, *Hard coal — Size analysis by sieving*

ISO 5048, *Continuous mechanical handling equipment — Belt conveyors with carrying idlers — Calculation of operating power and tensile forces*

ISO 7936, *Coal — Determination and presentation of float and sink characteristics — General directions for apparatus and procedures*

3 Terms and definitions

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

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

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

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

4 Performance measures

The following criteria are used:

a) the feed rate, expressed as mass per unit time and/or volume per unit time basis;

b) reference density of separation;

c) sharpness of separation;

d) correctly placed and misplaced material;

e) ash error and yield error;

f) the degree of difficulty of separation;

g) the bypass fractions;

h) material characteristics.

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

Conditions, including feed rate, should be kept uniform, monitored and maintained within prescribed tolerance limits during a test.

Where performance test results are used for prediction, the impacts of different process conditions to those tested should be taken into account.

5 Performance criteria

For the standard expression of performance of a cleaning operation, the following criteria apply:

a) the feed rate, expressed as mass per unit time and/or volume per unit time basis;

— It is essential to maintain the feed rate as uniform as possible throughout the performance test and determine it over the duration of the test by the most accurate method available.

— Where the feed to the equipment is by belt conveyor, the feed rate shall be determined in accordance with ISO 5048.

b) the reference density of separation, preferably expressed as both partition density and equal-errors cut-point (density);

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

d) the distribution of correctly placed and incorrectly placed material in each product, presented graphically with respect to relative density (RD), and the particular value of misplaced material in each product, determined at the reference density of separation;

e) the ash error expressed as the difference between the actual ash in the cleaned coal and the theoretical ash at the actual yield value;

f) the yield error expressed as the difference between the actual yield and the theoretical yield at the actual clean-coal ash value;

g) the degree of difficulty of separation expressed in terms of near-density material (and by other relevant characteristics);

h) the bypass of low-density material to reject at an RD of 1,20 (the ‘low-density tail’);

i) the bypass of high-density material to clean coal at an RD of 2,70 (the ‘high-density tail’).

6 Performance determination parameters

The equipment to be tested, the feed composition and the means of handling the feed and products, vary widely. A single international standard to cover all cases is not applicable. The following general procedures shall be followed.

a) Samples shall be taken from the feed and from each of the products. The sampling techniques, number of increments and increment mass shall ensure that all samples taken are representative and shall conform to existing international standards where available. Sampling of coal is covered by ISO 18283 and size analysis of coal is covered by ISO 1953.

   To enable checking of results and assessment of the effects of degradation, representative samples shall be taken from all relevant streams to and from the equipment to be tested.

b) It is essential to determine the feed rate and the percentage yield to each of the products on an air-dry or dry basis in accordance with ISO 1170. This shall be achieved in accordance with one of the procedures given below.

Determine the mass of each product by one or more of the following methods, which are listed in order of reliability.

a) By 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) By taking regular timed increments over the duration of the test.

c) By determining the mass of each product collected simultaneously over a selected period of the test.

d) By calculation of mass balance using all available analytical parameters, which typically include ash, size distribution and density distribution.

NOTE 1 If it is feasible to measure both the mass of the feed (e.g. by belt weigher, weigh hopper, flowmeter) and the mass of the products, this provides a check.

NOTE 2 If the mass of one of the products cannot be obtained, it can be derived from a mass balance between the feed and other product(s).

NOTE 3 Where the solids are conveyed by a fluid, it can be more convenient to make volumetric measurements.

Representative samples should be taken from streams to determine free moisture or total moisture mass fraction or mass fraction of solids as appropriate, so that results can be reported on a dry or air-dry basis.

7 Analytical procedures

The methods and procedures of size analysis and float-sink analysis shall be in accordance with ISO 1953 and ISO 7936, respectively.

The feed sample and each of the product samples should be separated into various particle size fractions depending on the degree of detail required. Because the performance of coal cleaning equipment is usually different for different size particles, the size ranges should be as specified in ISO 7936.

ISO 4077[1)] should also be considered as it discusses options to reduce sample mass by limiting analysis top-size if the float-and-sink analysis standard (see ISO 7936) cannot otherwise be conformed to.

The relative density of the lowest density floats fraction and highest density sinks fraction each need to be determined.

1) Under preparation. Stage at the time of publication: ISO/DIS 4077:2022.

8 Expression of performance

Methods for the expression of the results of coal cleaning tests and the performance of the separation processes are given in Annex A.

For the purpose of meeting the requirements stated in the Scope, no single method suffices by itself.

Annex B describes recommended methods for the calculation and tabulation of test results, and Annex C gives graphical presentations.

Annex A
(informative)

Methods of expressing performance

	Formula	Derived from	Remarks
A.1	Separation density a) Partition density b) Equal-errors cut-point (density)	Partition curves M-curves Washability curves	Describes one characteristic of the separation but does not indicate its accuracy.
A.2	Misplaced material	M-curves Washability curves	Measure of quantity of misplaced material (without reference to its quality) at the separation density.
A.3	Total of correctly placed material	M-curves Washability curves	Measure of quantity of correctly placed material at the separation density (without reference to its quality).
A.4	Ash error	M-curves Washability curves	Reflects both the quantity and quality of misplaced material in terms of the specific property of coal (percentage of ash) that the separation is designed to control; i.e. measures qualitative efficiency.
A.5	Yield error	M-curves Washability curves	Reflects both the quantity and quality of misplaced material and measures quantitative efficiency.
A.6	Organic efficiency	M-curves Washability curves	Related to yield error but expressed as a percentage.
A.7	Error area	Partition curves	Measure of quantity of misplaced material in terms of density.

NOTE 1 Meyer (M)-curves and washability curves describe graphically the character of the raw coal and of the products, in terms of mass and ash. Partition curves describe only the products in terms of mass and density; they can be constructed without the necessity to determine ash.

NOTE 2 M-curves have wider direct applications than washability curves, especially, for example, in three-product separations. The construction of such curves is described in ISO 7936.

NOTE 3 Partition density *(dp*, d_{50}); known as the *Tromp cut-point*, the density corresponding to 50 % recovery as read from a *partition curve* and *écart probable (moyen)*; *epm* (means probable error) which is one half of the difference between the densities corresponding to the 75 % and 25 % ordinates as shown in the partition curve.

NOTE 4 The *écart probable (moyen)* and imperfection reflect the influence of changes in the separation process rather than in the raw coal, in contrast to the formulae derived from M-curves or washability curves, which reflect changes in the raw coal as well as in the separation process.

NOTE 5 The separation density, although not a measure of efficiency, is an important characteristic of the separation and is essential to any comprehensive statement of the results of a given test.

NOTE 6 The misplaced material and the total of correctly placed material at the separation density, the ash error, the yield error, the organic efficiency and the error area can all be used for performance guarantee tests and occasional control tests to give an indication of the accuracy of a given separation on a given coal, and hence of economic efficiency; but they are of little value in the prediction of probable results of cleaning a range of coals by one specific process.

NOTE 7 Partition coefficients, *écart probable (moyen)* and imperfection are valuable for the purpose of prediction but do not give an adequate indication of the accuracy of a given separating operation on a particular coal.

	Formula	Derived from	Remarks
A.8	Partition coefficients	Partition curves	Special applications only.
A.9	*Écart probable (moyen)*	Partition curves	Gives an indication of the quantitative errors inherent in the separating process at a given separation density.
A.10	Imperfection	Partition curves	Modification of *écart probable (moyen)* to include the effect of varying separation density.
A.11	Yield loss	Product samples	States results without reference to accuracy of separation.
A.12	Bypass – low-density tail	Partition curve	Sample degradation following sampling can give a false result for bypass.
A.13	Bypass – high-density tail	Partition Curve	Sample degradation following sampling can give a false result for bypass.

NOTE 1 Meyer (M)-curves and washability curves describe graphically the character of the raw coal and of the products, in terms of mass and ash. Partition curves describe only the products in terms of mass and density; they can be constructed without the necessity to determine ash.

NOTE 2 M-curves have wider direct applications than washability curves, especially, for example, in three-product separations. The construction of such curves is described in ISO 7936.

NOTE 3 Partition density *(dp, d_{50})*; known as the *Tromp cut-point*, the density corresponding to 50 % recovery as read from a *partition curve* and *écart probable (moyen)*; *epm* (means probable error) which is one half of the difference between the densities corresponding to the 75 % and 25 % ordinates as shown in the partition curve.

NOTE 4 The *écart probable (moyen)* and imperfection reflect the influence of changes in the separation process rather than in the raw coal, in contrast to the formulae derived from M-curves or washability curves, which reflect changes in the raw coal as well as in the separation process.

NOTE 5 The separation density, although not a measure of efficiency, is an important characteristic of the separation and is essential to any comprehensive statement of the results of a given test.

NOTE 6 The misplaced material and the total of correctly placed material at the separation density, the ash error, the yield error, the organic efficiency and the error area can all be used for performance guarantee tests and occasional control tests to give an indication of the accuracy of a given separation on a given coal, and hence of economic efficiency; but they are of little value in the prediction of probable results of cleaning a range of coals by one specific process.

NOTE 7 Partition coefficients, *écart probable (moyen)* and imperfection are valuable for the purpose of prediction but do not give an adequate indication of the accuracy of a given separating operation on a particular coal.

Annex B
(informative)

Recommendations for standard methods of presenting coal cleaning test data

B.1 Description of the tables

Two sets of tables are required (see Clauses B.4 to B.6):

a) for two-product separation (cleaned coal and reject);

b) for three-product separation (cleaned coal, middlings and reject).

For convenience, an identical layout has been adopted for both sets of tables but, in those intended for use with two-product separations, the columns that relate only to three-product separation have been left blank to avoid confusion.

Each set of tables is presented in two ways.

a) Blank tables, to show the method of printing (see Form 1 and Form 3 in Clauses B.4 and B.6, respectively).

b) Tables completed by filling in the figures relating to test results. For example, Form 2 and Form 4 shown in Clauses B.5 and B.6 give the results of a test using a Baum jig washer.

NOTE The example described in this annex was carried out prior to the publication of ISO 7936. The particle sizes used therefore are not in accordance with those specified in this document.

For the test described in this example, the dense medium cyclone was supplied with coal sized at -50 mm and +2,0 mm. The tables and figures used refer to the fraction sized between 31,5 mm and 4 mm. The fine material below 4 mm was removed from the samples before carrying out float-and-sink analysis.

For a full analysis of the test, tables similar to those given for the 31,5 mm to 4,0 mm size would be required for the other sizes of the raw coal, in this instance 50 mm to 31,5 mm, and 4 mm to 2 mm. Such tables would enable the performance on the different sizes to be compared. By adding together the results on the four individual sizes, a further set of tables can be constructed giving cumulative data for the whole of the 50 mm to 2 mm coal fed to the process unit.

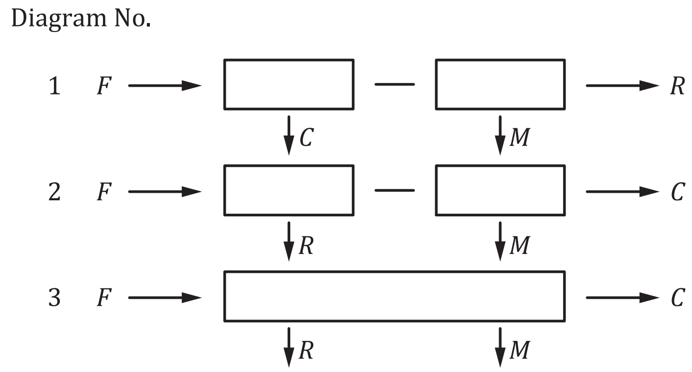
In this test, two products were made: cleaned coal and reject. The reject is the material discharged at the cyclone underflow (spigot) and the cleaned coal is discharged at the cyclone overflow. The tables headed "two- product separation" are built up from float-and-sink analysis at various relative densities from 1,30 to 2,20 on samples of each of the feed and products. The density intervals used are strongly dependent on the type of separator and the expected density of separation. For dense medium cyclones, 0,025 density intervals are recommended within ±0,1 of the expected reference density of separation, d_{50}. For other separators, intervals of 0,05 within ±0,2 of the expected d_{50}.

The figures in the tables headed "three-product separation" have been calculated from these same figures for a spiral separator example.

B.2 Expression of efficiency in the three-product separation

Three-product separation can be regarded as a combination of two distinct two-product separations (i.e. a low-density cut and a high-density cut), whether these two stages are in fact carried out in different separating vessels or in different parts of the same vessel.

The diagrams in Figure B.1 illustrate different combinations of the two stages.



Key

F feed (reconstituted raw coal), mass units

C cleaned coal, mass units

R reject, mass units

M intermediate product (middlings), mass units

Figure B.1 — Different combinations of the two stages

Diagrams 1 and 2 represent typical arrangements for a two-stage separation, the only difference being that the low-density cut comes first in diagram 1 and second in diagram 2, whereas diagram 3 represents a normal three-product separation as achieved in a jig. The middlings, *M*, may be collected as a separate product, or recirculated, or otherwise dealt with, but provided that any recirculated middlings are included in the reconstituted feed *F*, the argument is unaffected.

The efficiency of a three-product separation may be calculated in two different ways:

a) Method A, by regarding it as two distinct and individual separations, each with its own feed.

b) Method B, by regarding it as a single comprehensive separation, the feed for which is the reconstituted raw coal.

To calculate the partition coefficients expressed as a percentage, the appropriate formulae for these two methods, for the combinations of plant illustrated in the diagrams, are as follows:

For diagram 1

a) Method A: low-density cut $$\frac{100C(M+R)}{(C+M+R)}$$

high-density cut $$\frac{100M}{(M+R)}$$

b) Method B: low-density cut $$\frac{100C}{(C+M+R)}$$

high-density cut $$\frac{100M}{(C+M+R)}$$

The numerical factor 100 is used to convert the dimensionless partition coefficient to a percentage, %.

