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EXPRESSION AND PRESENTATION OF RESULTS OF COAL CLEANING TESTS

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BRIEF HISTORY

The ISO Recommendation R 923, *Expression and presentation of results of coal cleaning tests*, was drawn up by Technical Committee ISO/TC 27, *Solid mineral fuels*, the Secretariat of which is held by the British Standards Institution (BSI).

Work on this question led to the adoption of a Draft ISO Recommendation.

In February 1967, this Draft ISO Recommendation (No. 1058) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Australia	India	Switzerland
Austria	Iran	Thailand
Belgium	Japan	Turkey
Bulgaria	Korea, Rep. of	U.A.R.
Canada	Netherlands	United Kingdom
Czechoslovakia	New Zealand	U.S.A.
Denmark	Poland	U.S.S.R.
France	Romania	Yugoslavia
Germany	South Africa, Rep. of	
Greece	Spain	

No Member Body opposed the approval of the Draft.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in January 1969, to accept it as an ISO RECOMMENDATION.

ISO Recommendation | R 923 | January 1969

EXPRESSION AND PRESENTATION OF RESULTS OF COAL CLEANING TESTS

INTRODUCTION

A number of formulae are in use in different countries for expressing the results of coal cleaning tests and for determining the efficiency of the separation processes (see Annex A). Bearing in mind the different purposes for which such tests are carried out, it is considered that no one of these formulae, taken by itself, is adequate. It is, therefore, recommended that four formulae should be used in conjunction for expressing the basic data (see clause 4.2). In addition, recommendations are made for standard methods of presenting these data in tabular and graphical form (see Annex B and Appendix).

The general adoption of these formulae, tables and graphs should simplify the exchange of information relating to the efficiency and performance of coal preparation plant, and the accumulation of data resulting from their use on a variety of coals treated in different types of machine in different parts of the world should enable them to be simplified at a later date.

1. SCOPE

This ISO Recommendation outlines the principles on which the expression of the efficiency of operation of coal cleaning plant should be based, recommends the criteria, coefficients and formulae to be used and also gives methods for tabulation and graphical presentation of the test data.

2. FIELD OF APPLICATION

Expressions of the efficiency of coal cleaning processes are required for

(*a*) the indication of the accuracy (or inaccuracy) of a given separating operation on a particular coal,

(*b*) the prediction of the probable results of treating different coals by a given separating operation, and

(*c*) the comparison of different separating processes.

3. DEFINITIONS

The terms used in this ISO Recommendation are defined in ISO Recommendation R ...,* *Vocabulary of terms relating to solid mineral fuels – Part I : Terms relating to coal preparation.*

* At present Draft ISO Recommendation No. 1057.

4. STANDARD EXPRESSION OF EFFICIENCY

4.1 Many different formulae have been proposed to express the results of coal cleaning tests and the efficiency of the separation processes. Those commonly used are listed in Annex A. For the purpose of meeting the requirements stated in section 2, no one of these formulae, by itself, suffices.

4.2 For a standard expression of efficiency, the following formulae should be used in conjunction :

4.2.1 *Separation density* expressed as

(*a*) partition density, and/or

(*b*) equal errors cut-point (density).

4.2.2 *Total of correctly placed material* at the separation density, expressed as a percentage of the reconstituted feed, and, where required, the *misplaced material* in each product at the separation density, expressed as a percentage of the product.

4.2.3 *Ecart probable (moyen)* and *Imperfection.*

4.2.4 *Ash error* or *organic efficiency*

5. TABULATION AND GRAPHICAL PRESENTATION OF TEST RESULTS

The formulae for the expression of efficiency are derived by standard methods of calculation from the basic test data; for convenience, the tables and graphs in which these data are presented should also follow a standard pattern.

Annex B and the Appendix describe and exemplify recommended methods for the tabulation and graphical presentation of test results.

6. SIZE OF COAL

In expressing efficiency, it is essential to state the nominal size limits of the coal to which the calculations refer.

7. MULTIPLE-PRODUCT SEPARATION

In multiple-product separation, the criteria should be expressed at each separation density (see also Annex B, section B.2).

ANNEX A

METHODS OF EXPRESSING EFFICIENCY

	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 misplaced (without reference to its quality) at the separation density.
A.3	**Total of correctly placed material**	M-curves Washability curves	Measure of quantity correctly placed (without reference to its quality) at the separation density.
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) which the separation is designed to control; 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.
A.8	**Partition coefficients**	Partition curves	Special applications only.
A.9	**Ecart 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 *Ecart probable (moyen)* to include effect of varying separation density.
A.11	**Yield loss**	Product samples	States results without reference to accuracy of separation.

NOTES

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

2. *M-curves* have wider direct applications than *washability curves*, especially, for example, in three-product separations.

3. 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.

4. 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.

5. 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 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.

6. *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

RECOMMENDATIONS FOR STANDARD METHODS OF PRESENTING COAL CLEANING TEST DATA

B.1 DESCRIPTION OF THE TABLES

B.1.1 Two sets of tables are required (see section B.4) :

(*a*) for three-product separation (cleaned coal, middlings and reject);

(*b*) for two-product separation (cleaned coal 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 which relate only to three-product separation have been struck through so as to avoid confusion.

B.1.2 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 section B.4);

(*b*) completed tables by way of example, by filling in the figures relating to the results of a test on a Baum jig washer (see Form 2 and Form 4 in section B.4).

B.1.3 For the test described in this example, the washer was supplied with coal sized from 152 mm to 0 (6 in to 0). The figures used refer to the fraction sized between 12.7 mm ($\frac{1}{2}$ in) and 0.5 mm. The fine material below 0.5 mm was removed from the samples before carrying out float and sink tests, because this fine material presents difficulties in testing. Moreover, the jig is not expected to clean material smaller than 0.5 mm.

B.1.4 For a full analysis of the test, tables similar to those given for the 12.7 mm ($\frac{1}{2}$ in) – 0.5 mm size would be required for the other sizes of the raw coal, in this instance, 152 – 51 mm (6 – 2 in), 51 – 25.4 mm (2 – 1 in), and 25.4 – 12.7 mm (1 – $\frac{1}{2}$ in). 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 could be constructed representing the whole of the 152 mm (6 in) – 0.5 mm coal.

B.1.5 In this test, three products were made : cleaned coal, middlings and reject. The reject is the material removed by the primary reject elevator and the middlings is the reject from the secondary reject elevator. The tables headed *Three-product separation* are built up from float and sink tests at various relative densities from 1.30 to 2.00 on samples of each of these three products. Although intervals of 0.1 relative density have been used for the example, different ranges and intervals may be required in other cases.

B.1.6 The figures in the tables headed *Two-product separation* have been calculated from these same figures on the assumption that the products from both elevators (i.e. the middlings and the reject) were combined so that there were two products only, cleaned coal and a single reject.

B.2 EXPRESSION OF EFFICIENCY IN THE THREE-PRODUCT SEPARATION

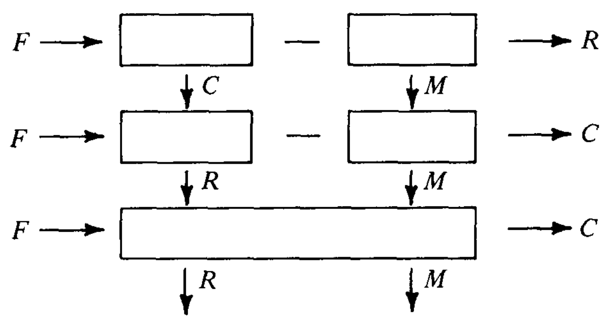
B.2.1 Three-product separation may be regarded as a combination of two distinct two-product separations (i.e. a low-density cut and a high-density cut), whether these two stages are in fact carried out in different separating vessels or in different parts of the same vessel.

The following diagrams illustrate different combinations of the two stages :

Diagram 1.

Diagram 2.

Diagram 3.



where

F is the feed (reconstituted raw coal),
C is the cleaned coal,
R is the reject,
M is the intermediate product (middlings).

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

B.2.2 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.

B.2.2.1 In order to calculate the partition coefficients, the appropriate formulae for these two methods, for the combinations of plant illustrated in the diagrams, are as follows :

B.2.2.1.1 FOR DIAGRAM 1

(*a*) *Method A*

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

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

(*b*) *Method B*

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

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

B.2.2.1.2 FOR DIAGRAM 2

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

low-density cut $\frac{100M}{C+M}$

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

low-density cut $\frac{100M}{C+M+R}$

B.2.2.1.3 FOR DIAGRAM 3

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

low-density cut $\frac{100M}{C+M}$

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

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

B.2.2.2 While for *Method A* the formulae are identical for Diagrams 2 and 3, in the latter case there is no sharp dividing line between the first and second cuts. The first (high-density) cut separates the reject R from the combination of the cleaned coal C and middlings M, and it is this combination which becomes the feed to the second stage of the separation.

B.2.2.3 *Method A* enables the efficiency of each of the two separations to be studied individually, for only the material actually admitted to the separation is included in the calculation. This is of advantage when considering the performance of each machine or stage in the separation process.

B.2.2.4 *Method B* does not show up so emphatically the actual performance of the second machine or stage, but by referring each separation back to the reconstituted raw feed it facilitates comparisons of the efficiency of the whole separation process in terms of the results on the original raw coal. (The sequence of operations included in this complete process may include steps not shown in Diagrams 1 to 3, e.g. crushing of the middlings and its recirculation to the feed, which is common in jig washing and may also occur in dense medium separation).

B.2.3 It is essential, whenever the efficiency of a three-product separation is expressed (e.g. in descriptions of plant and efficiency statements and guarantees), that it should be clearly stated which of these two bases has been used for the calculation. To facilitate this, it is proposed that *Method A* should be described as the *Equipment performance basis,* and *Method B* as the *Coal performance basis.*

B.2.4 The attached tables for the three-product separations are drawn up on the *Coal performance basis.* When calculations are made on the *Equipment performance basis* it is recommended that two-product tables should be used (one for each stage). It is possible, however, to deduce the results from the three-product table; thus, partition coefficients for the second cut would be calculated on the *Equipment performance basis* as follows :

– For diagram 1 (see clause B.2.1), column (12) would be calculated from (7)/(9) instead of (7)/(10).

– For diagram 2 and 3 (see clause B.2.1), column (13) would be calculated from (6)/(8) instead of (9)/(10).

B.3 DESCRIPTION OF THE GRAPHS (see Appendix)

B.3.1 In order to calculate the efficiency by the four formulae proposed (see clause 4.2), the data in these tables must be represented in graphs. Graphs relating to the test results are shown in Figures 1 to 4. The graphs have been prepared from the data for three-product separation; but the curves for the low-density cut apply to the two-product example.

B.3.2 Figure 1 has been drawn to a scale such that 0.2 unit on the relative density axis equals 10 % on the partition coefficient axis. It is proposed to standardize this relation for drawing partition curves, when using (as in Figure 1) linear co-ordinates, but similar standard scales for the other curves are not at present considered to be practicable. The curves can also be drawn using other than linear co-ordinates.

B.3.3 The following clauses explain the construction and use of the graphs in Figures 1 to 4 (see Appendix) :

B.3.3.1 *Partition curves (three-product)* (see Fig. 1).

B.3.3.1.1 The partition coefficients in columns (12) and (13) are plotted against the mean of the relative densities shown in the table for each fraction.

B.3.3.1.2 The curve on the right represents the high-density cut because it refers to the removal of the final reject.

B.3.3.1.3 The table columns from which the coefficients are extracted are shown on each curve.

B.3.3.1.4 The relative density at which the curves cross 50 % is by definition the *partition density.* Similarly *écart probable (moyen) (Epm)* is defined in terms of the relative densities d_{25} and d_{75} at which the curves cross 25 % and 75 % respectively. The imperfection (I) is derived from these as shown.

B.3.3.2 *Ash error and organic efficiency* (see Fig. 2).

B.3.3.2.1 The curve shows the cumulative weight on the reconstituted feed plotted against the cumulative ash per cent, the figures being from columns (43) and (45).

B.3.3.2.2 The point X represents the actual yield and ash for the high-density cut (total cleaned coal and middlings), and the point Y represents those for the low-density cut (total cleaned coal).

B.3.3.2.3 Regarding X

- the actual ash is 5.61 % and the theoretical float and sink ash for the actual yield of 93.4 % as given by the curve is 5.05 %. The ash error is the difference between these two ash percentages.

- the actual yield is 93.40 % at 5.61 % ash. The theoretical float and sink yield for 5.61 % ash is given by the curve as 94.60 %. The organic efficiency is derived from the ratio of these two yields.

B.3.3.2.4 Similar considerations apply to point Y.

B.3.3.3 *Correctly placed (and misplaced) material – high-density cut* (see Fig. 3)

B.3.3.3.1 The two lower curves show the amounts of misplaced material in the reject (column 18) and the cleaned coal plus middlings product (column 17) – the fraction which in this example goes forward for further treatment. The upper curve shows the sum or total of the misplaced material in these two products combined (column 19). The total amount (percentage) of correctly placed material (100 minus misplaced material) is read from the scale on the right-hand side of the graph.

B.3.3.3.2 The equal errors cut-point (density) is the relative density at which the two lower curves intersect; in this example this density is 1.770. The partition density is 1.835.

B.3.3.3.3 The relative densities of 1.770 and 1.835 correspond respectively to 96.6 and 96.7 % for the amounts of correctly placed material.

B.3.3.4 *Correctly placed (and misplaced) material – low-density cut* (see Fig. 4)

The same considerations apply as for the high-density cut, the amounts of misplaced materials in each product being plotted from columns (23) and (24) and the total from column (25). The equal errors cut-point and the partition densities are 1.400 and 1.505 and the amounts of correctly placed material 89.9 and 91.0 % respectively.

B.3.4 The curves in Figures 1 to 4 (see Appendix) have been drawn on the coal performance basis, all yields being expressed as a percentage of the reconstituted raw coal. On the equipment performance basis, the washing operation being regarded as two distinct two-product separations, the construction of the curves follows exactly the same method as for any two-product separation and presents no difficulties. The curves which apply to the high-density cut (Fig. 1 : lower curve; Fig. 2 : point X; Fig. 3 : upper curve) are identical for both bases.