

Australian Standard™

Coal preparation

Part 7: Coal size classifying equipment— Performance evaluation

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Australian Coal Association
Australian Coal Preparation Society
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RECONFIRMATION

OF

AS 4156.7—1999

Coal preparation

Part 7: Coal size classifying equipment—Performance evaluation

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NOTES

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Part 7: Coal size classifying equipment— Performance evaluation

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PREFACE

This Standard was prepared by the Standards Australia Committee MN/1, Coal and Coke to supersede of AS 1634—1974, *Recommended procedures for expression and presentation of results of tests of coal size classifying equipment*.

This Standard is based on, but not equivalent to, ISO 10752:1994, *Coal sizing equipment—Performance evaluation*. It includes an additional Australian Appendix which provides a worked example for sieve bend.

The objective of this Standard is to provide users of coal sizing equipment with a standard expression of performance which is required to define the accuracy of separation of a particular item and to assist in the comparison of the performance of different items of coal sizing equipment and in the prediction of separation results.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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STANDARDS AUSTRALIA

Australian Standard

Coal preparation

Part 7: Coal size classifying equipment—Performance evaluation

1 SCOPE This Standard sets out 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 Standard applies to all types of sizing equipment, categorized as follows:

- (a) Screens.
- (b) Classifiers.
- (c) Others.

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

2 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

- 1038 Coal and coke—Analysis and testing
- 1038.16 Part 16: Acceptance and reporting of results
- 2418 Coal and coke—Glossary of terms
- 3881 Higher rank coal—Size analysis
- 4264 Coal and coke—Sampling (series)

3 DEFINITIONS For the purpose of this Standard, the definitions given in AS 2418 and those below 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 Reference size—the separation size, designated particle size or control size used to define size analysis of the products of a sizing operation.

3.1.2.1 Coarser material—material that is coarser than the reference size.

3.1.2.2 Finer material—material that is finer than the reference size.

3.1.2.3 Designated size—the particle size at which a feed is to be separated by a sizing operation.

3.1.2.4 Equal errors size—the separation size at which equal portions of the feed material are wrongly placed in each of two products of a size separation.

3.1.3 Product—material discharged from the sizing equipment prior to any further treatment or recirculation.

3.1.3.1 Product coarser (c)—that product of size separation that contains a greater proportion of coarser material than does the feed.

3.1.3.2 Product finer (f)—that product of size separation that contains a greater proportion of finer material than does the feed.

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 Material placement efficiency, coarser (E_c)—the percentage of coarser material in the reconstituted feed that reports to the coarser product.

3.2.3 Material placement efficiency, finer (E_f)—the percentage of finer material in the reconstituted feed that reports to the finer product.

3.2.4 Overall separation index (I_s)—the sum of the coarser material placement efficiency and the finer material placement efficiency minus 100.

3.2.5 Sharpness of separation—an assessment of the deviation from a perfect separation, usually expressed in terms of mean probable error (E_{pm}).

4 PERFORMANCE CRITERIA The following criteria should be determined where applicable:

- (a) Feed rate.
- (b) 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 or volume bases.
- (b) The reference size, preferably expressed as designated size (S_d), partition size (S_{50}) and equal errors size (S_e).

NOTE: It is recognized that partition size is not always obtainable from the results of a size separation and that an alternative reference size has therefore 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—
 - (i) coarser material placement efficiency (E_c);
 - (ii) finer material placement efficiency (E_f); and
 - (iii) overall separation index derived from Items (i) and (ii).
- (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 and any deviations from the procedures should be reported. The following general recommendations are made:

- (a) The average feed rate and product flow rates should be determined by the most accurate method possible in the particular circumstances. Typical procedures that may be used are—
 - (i) direct assessment of the mass or volume of the whole of the feed and products during the test;
 - (ii) continuous assessment by means of a calibrated belt weigher or flowmeter and integration during the test; or
 - (iii) 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 Standards if available; for solids under other conditions, AS 4264.1 applies.

NOTE: Tentative 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 actual yield of each product on a dry basis in accordance with AS 1038.16.

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

- (i) Direct weighing of the whole of the feed and 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. 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 Appendix A.

NOTES:

- 1 The methods given in Items (c) (i), (ii) and (iii) are listed in order of reliability.
- 2 It is preferable to measure the mass of the feed (by belt weigher, weigh hopper, flowmeter, or similar) and the mass of the products.
- 3 If the mass of one of the products cannot be measured, it can be estimated from a mass balance between the feed and the other products, but it may be seriously erroneous.

- 4 If the mass of none of the products can be measured, it may be estimated by undertaking representative sampling procedures and subsequent statistical analysis of a number of coal properties.
- 5 Where the solids are conveyed by a fluid, it may be more convenient to make volumetric measurements. This method should not be used in isolation and should be supported by the statistical analyses mentioned in Note 4.
- 6 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.
- 7 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 Size analysis by sieving should be in accordance with AS 3881 or, depending on particle size, by a series of small cyclones. 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:

- 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.
- 2 Size distribution curves for the products can be used for—
 - (a) providing data for additional partition coefficients; and
 - (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 prescribed tabular and graphical format is given in Clause 9.

NOTES:

- 1 Specific worked examples are included in Appendices B, C, D and E.
- 2 Primary calculation procedures are shown in Tables 1 and 2.
- 3 The origins of plotted values are shown in Figures 1 and 2 by reference to Table and Column numbers.
- 4 Reference to definitions of performance parameters in Clause 3 supports the brief explanation of their derivation given in relevant Clauses 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 plus 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—

- (a) size: $\log_{10} 1 \text{ cycle} = 50 \text{ mm}$; and
- (b) partition coefficient: $1\% = 2 \text{ mm}$.

NOTES:

- 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.
- 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 (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:

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

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:

$$\text{Upper probable error} = S_{75} - S_{50}$$

$$\text{Lower probable error} = S_{50} - S_{25}$$

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—

- (a) size: $\log_{10} 1 \text{ cycle} = 50 \text{ mm}$; and
- (b) misplaced material: $1\% = 5 \text{ mm}$.

NOTE: If it is necessary to use an alternative scale, this should be a simple multiple of the recommended scale; for an example see Appendix C, Figure C3.

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 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 2), and the converted values are entered into the statement.

NOTES:

- 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_c), to assist in reading the three intercepting misplaced values.
- 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).
- 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 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:

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

where

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

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

NOTES:

- 1 Misplaced material values are in terms of percentages of reconstituted feed.
- 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 entered into the statement of sizing equipment performance in Table 3. The calculations are as follows:

- (a) Coarser material placement efficiency (
- E_c
-)

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

where

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

- (b) Finer material placement efficiency (
- E_f
-)

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

where

Y_f = the yield value of the finer product

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

M_f = as defined in Clause 8.10

- (c) Overall separation index (
- I_s
-)

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

NOTES:

- 1 Misplaced material values are in terms of percentage of reconstituted feed.
- 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 $\pm 25\%$ 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.

NOTE: Examples are given in Appendices B, C, D and E.

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.

NOTE: 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 Appendices B, C, D and E.

9 TABULAR AND GRAPHIC PRESENTATION Examples of blank Tables and specimen Figures are given. The order of presentation shall be as follows:

- (a) Data sheet — Test and equipment data (see Clause 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

NOTE: The use of these is illustrated in Appendices B, C, D and E.

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		$\Sigma (3)\uparrow$		$\Sigma (5)\uparrow$		$\Sigma (7)\uparrow$	$(5) \times \frac{Y_c}{100}$	$(7) \times \frac{Y_f}{100}$	$(9) + (10)$	$\Sigma (11)\uparrow$
Totals											

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

