Standard Practice for Mechanical Collection and Within-System Preparation of a Gross Sample of Coal from Moving Streams[1]

This standard is issued under the fixed designation D 7256 / D 7256M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Analysis data obtained from coal samples are used in establishing price, controlling mine and cleaning plant operations, allocating production costs, and determining plant or component efficiency. The task of obtaining a sample of reasonable weight to represent an entire lot presents a number of problems and emphasizes the necessity for using standard sampling procedures.

Coal is one of the most difficult of materials to sample, varying in composition from noncombustible particles to those which can be burned completely, with all gradations in between. The task is further complicated by the use of the analytical results, the sampling equipment available, the quantity to be represented by the sample, and the degree of precision required.

This practice gives the overall requirements for the collection and within-system preparation of coal samples through the use of mechanical sampling systems. The wide varieties of coal-handling facilities preclude the publication of detailed procedures for every sampling situation. The proper collection of the sample involves an understanding and consideration of the physical character of the coal, the number and weight of increments, and the overall precision required.

1. Scope

1.1 This practice covers procedures for the mechanical collection of a sample under Classification I-B-1 and I-B-2 (Practice D 2234) and the within-system preparation (reduction and division) of gross samples utilizing various components of the mechanical sampling system.

1.2 This practice describes mechanical sampling procedures for coals *(1)* by size and condition of preparation (for example, mechanically cleaned coal or raw coal) and *(2)* by sampling characteristics.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, use each system independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 121 Terminology of Coal and Coke

D 2013 Practice for Preparing Coal Samples for Analysis

D 2234/D 2234M Practice for Collection of a Gross Sample of Coal

D 4702 Practice for Quality Management of Mechanical Coal Sampling Systems

D 6518 Practice for Bias Testing a Mechanical Coal Sampling System

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions of Terms Specific to This Standard*—Many terms used in this practice may be found in Terminologies D 121 and E 456 and in Practice E 177.

[1] This practice is under the jurisdiction of ASTM Committee D05 on Coal and Coke and is the direct responsibility of Subcommittee D05.23 on Sampling.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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3.1.1 *activation interval*—for a falling-stream or cross-belt cutter, the time from the beginning of movement for taking an increment, to the beginning of movement for taking of the next increment.

3.1.2 *cross-belt sampler*—a single sampling machine or component of a mechanical sampling system designed to extract an increment directly from a conveyor belt surface by sweeping a sampling device (cutter) through the material on the conveyor.

3.1.3 *falling-stream sampler*—a single sampling machine or component of a mechanical sampling system designed to extract an increment from a falling stream of coal at the discharge end of a conveyor or chute by moving a sampling device (cutter) through the falling stream of material.

3.1.4 *mechanical sampling system*—a single machine or series of interconnected machines whose purpose is to extract mechanically, or process (divide and reduce), or a combination thereof, a sample of coal.

3.1.5 *within-system preparation*—the process of gross sample preparation carried out mechanically by sequential crushing (reduction) equipment and/or division equipment. It may be carried out by processing increments individually or by batching increments together and processing them together as a group. In any case, within-system preparation is conducted in a manner to minimize moisture changes and without removing the gross sample or its increments from the sampling system.

4. Summary of Practice

4.1 The general-purpose sampling procedures are intended to provide, in 19 of 20 cases, dry ash results that are within an interval of ±1⁄10 of the average dry ash results that would be obtained in hypothetical repeated sampling.

4.2 Special-purpose sampling procedures apply to the sampling of coal when other precision limits are required, or when other constituents are used to specify precision, or for performance tests.

4.3 For coals of known size and condition of preparation, a table (Table 1) is given for the determination of the number and weight of increments required for a gross sample for both general- and special-purpose sampling.

4.4 The only processes of sample division and reduction covered in this document are the use of mechanical sample dividers for the division of the sample, and mechanical crushing equipment for the reduction of the sample, both of which are within-system components of the mechanical sampling system.

4.5 The procedures appear in the following order:

Test Method	Section
Sampling of Coals Based on Size and Condition of Preparation	8.1
General-Purpose Sampling Procedure	8.1.1
Number and Weight of Increments	8.1.1.2
Number of Gross Samples	8.1.1.4
Special-Purpose Sampling	8.1.2
Number and Weight of Increments	8.1.2.2
Number of Gross Samples	8.1.2.3
Division of the Gross Samples Before Crushing	8.2
Reduction and Division	8.3

5. Significance and Use

5.1 It is intended that this practice be used to provide a sample representative of the coal from which it is collected. Because of the variability of coal and the wide variety of mechanical sampling equipment available, caution should be used in all stages of the sample collection process, the design of sampling system specifications, the equipment procurement and the acceptance testing of installed equipment.

5.2 After removal from the sampling system and further preparation (Practice D 2013), the sample may be analyzed for a number of different parameters. These parameters may define the lot's value, its ability to meet specifications, its environmental impact, as well as other properties.

6. Increment Collection Classification

6.1 The type of selection, the conditions under which individual increments are collected, and the method of spacing of increments from the coal consignment or lot are classified according to the following descriptions and Table 1 in Practice D 2234.

6.2 *Types of Increments*—the only type of selection of increments covered by this document are Type I where there is no human discretion in the selection of the pieces of coal or portions of the coal stream. Type I selection increments generally yield more accurate results than Type II where human discretion is exercised in the selection of specific pieces of coal or of specific portions of the stream, pile, or shipment.

6.3 *Conditions of Increment Collection*—The conditions under which individual increments are collected are the conditions of the main body of coal relative to the portion withdrawn. Only Condition B (Full-Stream Cut), in which a full cross-section cut is removed from a moving stream of coal is covered by this document.

6.4 *Spacing of Increments*—The spacing of increments pertains to the kind of intervals between increments. Two

TABLE 1 Number and Weight of Increments for General-Purpose Sampling Procedure[A]

Top Size	16 mm [5⁄8 in.]	50 mm [2 in.]	150 mm [6 in.][B]
Mechanically Cleaned Coal[C]			
Minimum number of increments	15	15	15
Minimum weight of increments, kg [lb]	1 [2]	3 [6]	7 [15]
Raw (Uncleaned Coal)[C]			
Minimum number of increments	35	35	35
Minimum weight of increments, kg [lb]	1 [2]	3 [6]	7 [15]

[A] Conditions C and D are not addressed in this standard.

[B] For coals above 150-mm [6-in.] top size, the sampling procedure should be mutually agreed upon in advance by all parties concerned.

[C] If there is any doubt as to the condition of preparation of the coal (for example, mechanically cleaned coal or raw coal), the number of increments for raw coal shall apply. Similarly, although a coal has been mechanically cleaned, it may still show great variation because of being a blend of two different portions of one seam or a blend of two different seams. In such cases, the number of increments should be as specified for raw (uncleaned) coal.

spacing methods are recognized: systematic and random. Systematic spacing is usually preferable.

6.4.1 *Systematic Spacing 1*, in which the movements of individual increment collection are spaced evenly in time or in position over the lot. This standard allows both time-based and mass-based distribution of increments.

6.4.2 *Random Spacing 2*, in which the increments are spaced at random in time or in position over the lot.

7. Organization and Planning of Sampling Operations

7.1 This practice provides definitive procedures for the collection of a gross sample. Parties claiming to use this practice must adhere to the procedures as set out in this standard. If the sampling is not done in accordance with the procedures set out in this practice then that sample may not be suitable for comparison with a sample collected by the procedures described in this practice. Since it may be impracticable or impossible to take another sample of a given lot of coal it is essential that parties agree on sampling procedures prior to undertaking sampling.

7.2 *Selection of Appropriate Sampling Procedure*—Variations in coal-handling facilities make it impossible to publish rigid rules covering every sampling situation in complete and exact detail. Proper sampling involves an understanding and proper consideration of the minimum number and weight of increments, the size consist of the coal, the condition of preparation of the coal, the variability of the constituent sought, and the degree of precision required.

7.2.1 *Number and Weight of Increments*—The number and weight of increments required for a given degree of precision depends upon the variability of the coal. This variability increases with an increase in free impurity. A coal high in inherent impurity and with comparatively little free impurity may exhibit much less variability than a coal with a low inherent impurity and a relatively high proportion of free impurity. For most practical purposes, an increase in the ash content of a given coal usually indicates an increase in variability. It is imperative that not less than the minimum specified number of increments of not less than the minimum specified weight be collected from the lot.

7.3 *Distribution of Increments*—It is essential that the increments be distributed throughout the lot to be sampled. This distribution is related to the entire volume of the lot, not merely its surface or any linear direction through it or over it. If circumstances prevent the sampler from applying this principle, the lot is sampled only in part, and the gross sample is representative only of this part. The spacing of the increments shall be varied if the possibility exists that increment collection may get "in phase" with the sequence of coal variability. Example: routine sampling of commercial coal from a continuous stream (conveyor belt) in which increment collection is automatic and its sequence coincides with the "highs" or "lows" in the content of fines.

7.4 *Dimensions of Sampling Device*—The opening of the sampling device shall be no less than 2.5 times the nominal top size of the coal and no less than 30 mm [1.25 in.]. The sampling device shall be of sufficient capacity to completely retain or entirely pass the increment without spillage at the maximum rate of coal flow.

7.5 *Characteristics and Movement of Sampling Device*—In sampling from moving streams of coal, the sampling device shall be designed to collect each increment with no selective rejection of material by size and with no contamination by nonsample material.

7.5.1 *Falling-Stream Sampler*—In collecting an increment, the falling-stream cutter should move at a constant velocity through the entire cross section of the stream of coal. The mass m, in kg [lb] of material collected in one pass through the stream by a falling-stream cutter, with cutting edges and cutter velocity perpendicular to the stream flow, is calculated from the following equation:

$$m = \frac{Cw}{3.6v_c}\left[m = \frac{C_w}{1.8v_c}\right] \tag{1}$$

where:

C = the stream flow rate in Mg/h [ton/h],
w = the tip-to-tip cutter aperture width in mm [in.], and
v_c = the average cutter speed in mm/s [in./s].

NOTE 1—Falling stream cutter speeds of 460 mm/s [18 in./s] or less have been found to produce acceptable results.

NOTE 2—The constant value 3.6 [1.8] in the denominator of Eq 1 converts Mg/h to kg/s [ton/h to lb/s].

NOTE 3—If the falling-stream cutter velocity is not constant as it traverses the material stream, the mass of collected material may not agree with that calculated using Eq 1.

7.5.2 *Cross-Belt Sampler*—The cross-belt cutter should be designed and operated at a velocity across the conveyor surface that is high enough to prevent selective rejection of material by size, prevent contamination of the sample with material not collected within the cutter, and avoid mechanical problems due to damming of conveyed material against the outside of the cutter body as the cutter travels though the stream. Furthermore, the design should assure a complete increment extraction, and the arc of travel of the sweep-arm cutter should closely fit the configuration of the conveyor belt. The mass m, in kg [lb], of material collected in one pass through the moving stream by a cutter with cutting edges and cutter velocity perpendicular to the stream flow is calculated from the following equation:

$$m = \frac{Cw}{3.6v_b}\left[m = \frac{Cw}{1.8v_b}\right] \tag{2}$$

where:

C = the stream flow rate in Mg/h [tons/h],
w = the tip-to-tip cutter aperture width in mm [in.], and
v_b = the conveyor belt speed in mm/s [in./s].

NOTE 4—The constant value 3.6 [1.8] in the denominator of Eq 2 converts Mg/h to kg/s [ton/h to lb/s].

NOTE 5—To avoid mechanical problems and spillage and to assure correct sample delimitation the higher ratio of cutter speed to belt speed the better. Ratios of cutter speed to belt speed of 1.5 or greater have been found to produce acceptable results.

7.6 There shall be no structural member or other impediment with a cutter body that impedes either sample collection or sample discharge.

7.7 *Preservation of Moisture*—The increments obtained during the sampling period shall be protected from changes in composition as a result of exposure to rain, snow, wind, sun, contact with absorbent materials, and extremes of temperature. The circulation of air through equipment must be reduced to a minimum to prevent both loss of fines and moisture. Samples in which moisture content is important shall be protected from excessive air flow and then shall be stored in moisture-tight containers. Metal cans with airtight lids, or heavy vapor-impervious bags, properly sealed, are satisfactory for this purpose.

7.8 *Contamination*—The sampling arrangement shall be planned so that contamination of the increments with foreign material or unrelated coal does not create bias of practical consequence.

7.9 *Mechanical System Features*—It is essential that mechanized systems as a whole, including sampling machines, chutes, feed conveyors, crushers and other devices, be self-cleaning and non-clogging and be designed and operated in a manner that will facilitate routine inspection and maintenance.

7.10 *Personnel*—Because of the many variations in the conditions under which coal must be sampled, and in the nature of the material being sampled, it is essential that the samples be collected under the direct supervision of a person qualified by training and experience for this responsibility.

7.11 *Criteria of Satisfactory Performance*—A satisfactory sampling arrangement is one that takes an unbiased sample at the desired degree of precision of the constituent for which the sample is to be analyzed. One fundamental characteristic of such an arrangement is that the size consist of the sample will adequately represent the true size consist of the coal. Sampling systems shall be tested initially and at regular intervals to determine whether the sample adequately represents the coal. In addition, sampling systems should be given a rough performance check as a matter of routine. This is done by comparing the weight or volume of collected sample with that of the total flow of coal to ensure a constant sampling ratio. Information on the quality assurance of mechanical sampling systems can be found in Practice D 4702.

7.12 *Relative Location of Sampling and Weighing*—It is preferable that coal be weighed and sampled at the same time. If there is a lapse in time between these two events, consideration should be given by both the purchaser and the seller to changes in moisture during this interval and the consequent shift in relationship of moisture to the true quality of the coal at the instant when ownership of the coal transfers from one to the other.

8. Procedures

8.1 *Sampling of Coals Based on Size and Condition of Preparation*:

8.1.1 *General-Purpose Sampling*:

8.1.1.1 Where probability sampling is employed, the general-purpose sampling procedures are intended to provide, in 19 of 20 cases, dry ash results that are within the interval of ±1⁄10 of the average dry ash results that would be obtained in hypothetical repeated sampling.

8.1.1.2 *Number and Weight of Increments*—Obtain the number and weight of increments as specified in Table 1 except as provided in 8.1.1.5*(2)*. Determine the minimum number of increments from the condition of preparation, and determine the minimum weight of each increment from the top size of the coal. Classify the coals to be sampled according to the general purpose procedure into three groups by top size. Further classify each of these groups into two subgroups in accordance with the condition of preparation. These classifications are shown in Table 1.

8.1.1.3 Variations in construction of the sampling device and flow, structure, or size consist of the coal may make it impracticable to collect increments as small as the minimum weight specified in Table 1. In such cases, collect an increment of greater weight. However, do not reduce the minimum number of increments, regardless of large excesses of individual increment weights. Table 1 lists the absolute minimum number of increments for general-purpose sampling which may not be reduced except as specified in 8.1.1.5*(2)*. Other considerations may make it advisable or necessary to increase this number of increments.

8.1.1.4 *Number of Gross Samples*—Under the general-purpose sampling procedure, for quantities up to approximately 1000 Mg [1000 tons] it is recommended that one gross sample represent the lot. Take this gross sample in accordance with the requirements prescribed in Table 1.

8.1.1.5 For quantities over 1000 Mg [1000 tons], use any of the following alternatives:

(1) Take one gross sample for the lot and analyze it to represent the quality of the lot. Collect the number of increments N calculated from Eq 3:

$$N = K \sqrt{\frac{L}{1000}} \tag{3}$$

where:

L = the number of Mg [tons], and
K = 15 for mechanically cleaned coal or 35 for raw coal (see Table 1).

(2) Divide the lot into sub-lots and take a separate gross sample from each sub-lot. Use Eq 3 to determine the minimum number of increments for each sub-lot, with L being the sub-lot quantity. Weight-average the analyses of the sub-lot samples to represent the quality of the original lot.

8.1.1.6 The maximum lot size shall be chosen by mutual agreement between the seller and the buyer of the coal, with each party taking into account the risks associated with the choice. Potential consequences include:

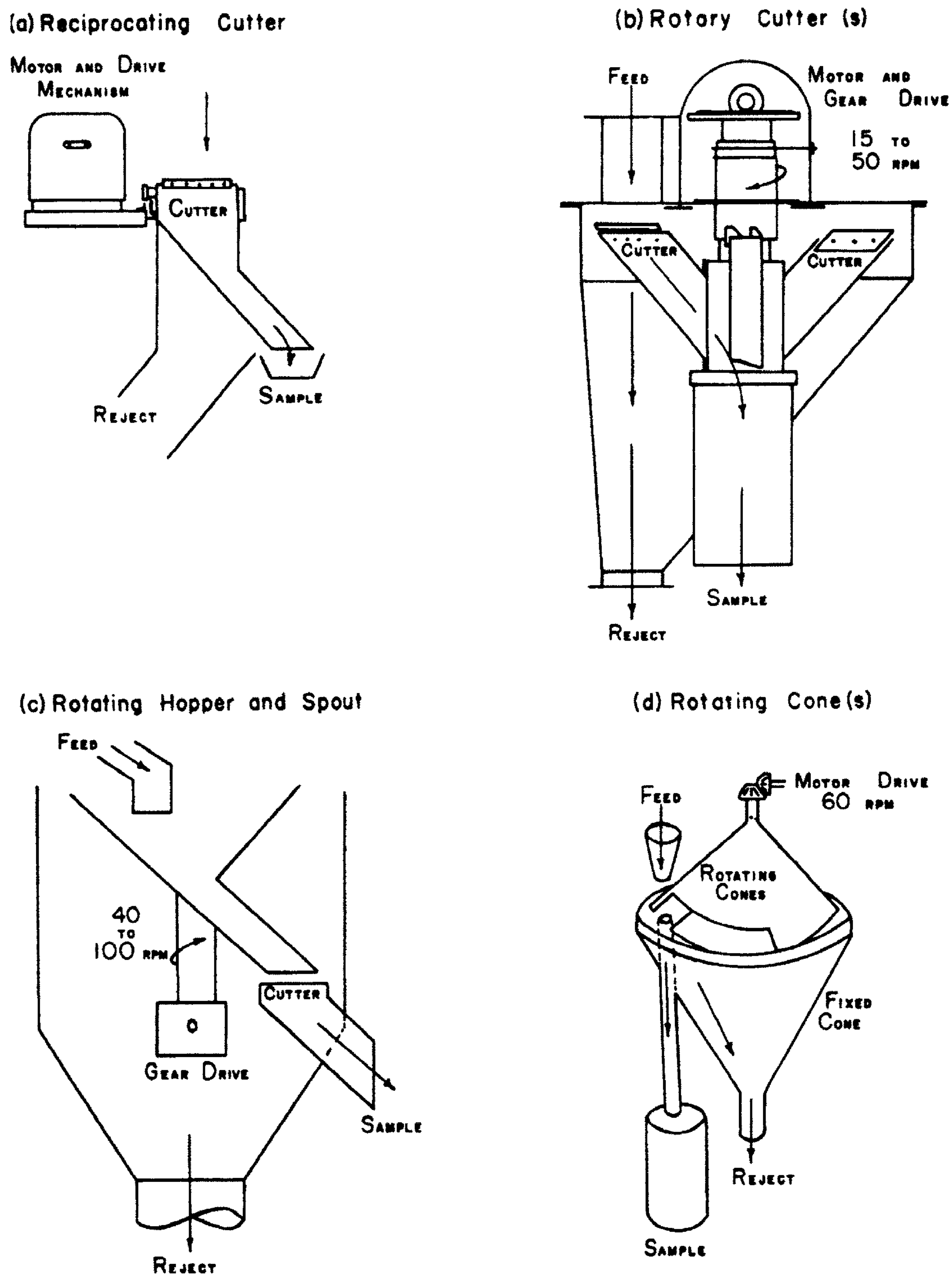
(1) Large samples requiring excessive off-line preparation steps can result in sampling moisture losses.

(2) No quality information is obtained on within-lot variability. Lot sizes generally should not exceed quantities for which critical quality levels apply in use of the coal.

(3) When a given quantity of coal that might be represented by a single lot is divided into multiple sub-lots, the imprecision of the reported quality for that given quantity is reduced. For a given quantity, the component of imprecision due to sample preparation and analysis is reduced by $1/\sqrt{m}$ where m is the number of sub-lots.

8.1.2 *Special-Purpose Sampling*:

8.1.2.1 This special-purpose sampling procedure shall apply to the sampling of coal when increased precision is required, and the only knowledge of the coal is its top size and conditions of preparation.



(a) Reciprocating Cutter—Fig. 1*(a)* shows a section of a cutter which is moved across a stream of coal. At regular intervals, the cutter movement is reversed and a sample increment is collected on each trip through the coal stream.

(b) Rotating Cutter—Fig. 1*(b)* shows two cutters attached to a hollow, rotating shaft. Each cutter is designed to extract increments from the feed and to discharge these into the hollow shaft. One or more cutters may be used.

(c) Rotating Hopper and Spout—Fig. 1*(c)* shows the totaling hopper that receives the crushed sample and discharges it through a spout over one or more stationary cutters.

(d) Rotating Cone—A sampler developed by the British National Coal Board. Two slotted cones are locked together and rotated on a vertical shaft so that on each revolution the common slot operating intercepts the falling stream of coal and collects an increment.

FIG. 1 Mechanical Sample Dividers

8.1.2.2 *Number and Weight of Increments*—Take the same number and weight of increments per gross sample as specified in Table 1, or as specified in 8.1.1.5*(2)*.

8.1.2.3 *Number of Gross Samples*—To obtain increased precision for the final result for a given consignment, increase the number of gross samples collected from that consignment and analyze each gross sample separately, reporting the average of results. To reduce errors to one half, that is, to "double" the precision, take four times as many gross samples. Similarly, to reduce errors to one third, to "triple" the precision, take nine times as many gross samples.

8.2 *Division of the Gross Sample Before Crushing*:

8.2.1 Large primary increments may be divided in quantity before crushing by secondary sampling. In the case of dividing a primary increment before crushing, the minimum increment weight must meet the weight specified in Table 1 for the top size listed.

8.2.1.1 If each primary increment is reduced in quantity by secondary sampling, take at least six secondary increments from each uncrushed primary increment. The method of collection of secondary increments must be proved to be free from bias. In no case shall the weight of a secondary increment be less than shown in the schedule of Table 1.

8.3 *Reduction and Division*:

8.3.1 Reduce the gross or divided sample in stages and divide by suitable mechanical sample dividers (see 8.4.2) to quantities not less than those shown in Table 1 of Practice D 2013.

8.3.2 Mechanical division of the sample consists of automatically collecting a large number of increments of the properly reduced sample. Distribute this large number of increments equally throughout the entire discharge from the sample crusher because crushers can introduce appreciable segregation. At each stage of division, take at least 60 increments.

NOTE 6—Reduction and division of the mechanical samples that do not involve within-system components of the mechanical sampling system are not covered by this document but governed by Practice D 2013.

NOTE 7—It is recommended that, in the case of mechanical division in which an increment is not thoroughly mixed with other increments before division, a portion of each increment be collected by the subsequent stage increment collection process.

8.4 *Reduction and Division Apparatus*:

8.4.1 *Crushers or Grinders*—Jaw, cone, or rotary crusher; hammer mill; roll; or other suitable crusher to reduce the sample. Crushers should be designed and operated in a manner to minimize the effect of induced air circulation and thus the potential for drying the coal.

8.4.1.1 *Hammer Mill*—Completely enclosed to avoid loss of dust or moisture.

8.4.2 *Sample Dividers: Mechanical*—A mechanical sample divider using a reciprocating or rotating cutter, a rotating hopper and spout, a rotating slotted cone, a reciprocating hopper and fixed cutter, bucket cutter with either bottom dump or inverting discharge, slotted belt, rotary disk divider, mechanical stopped or moving belt sweeper, or other acceptable devices for dividing the sample. Typical mechanical sample dividers are shown in Fig. 1. These illustrate various designs, but other acceptable designs are available.

9. Maintenance of Mechanical Sampling Equipment

9.1 Assure that mechanical sampling equipment is easily and safely accessible throughout to facilitate inspection, cleaning, or repairs.

9.2 Wear of mechanical components may eventually cause a system, which had originally been checked satisfactorily for bias, to produce biased samples. Inspect mechanical systems frequently and in accordance with a planned maintenance scheme in order to ensure continuous reliable operation by detecting and repairing system components that have undergone wear beyond a critical level or are broken.

10. Precision and Bias

10.1 The precision of the general-purpose sampling procedure, based on size and condition of preparation, is stated in 8.1.1.1. If a different precision is required, see 8.1.2.

10.2 Mechanical sampling systems are tested for bias using the procedures of Practice D 6518.

11. Keywords

11.1 coal; coal sampling; mechanical sampling; sample division; sample reduction

ANNEX

(Mandatory Information)

A1. TEST METHOD FOR ESTIMATING THE OVERALL VARIANCE FOR INCREMENTS

A1.1 Scope

A1.1.1 This test method describes the procedure for estimating the overall variance for increments of one fixed weight of a given coal. It is applicable to mechanical sampling when there is no need to explore system and random variance components, but there is a need for obtaining the overall variance for increments (the size of increments is dictated by the sampling equipment).

TABLE A1.1 Variance Ratio Limit Values

Increment per Set	Variance Ratio Limit	"C" Factor
10	3.18	1.92
20	2.17	1.53
30	1.86	1.40
40	1.70	1.33
50	1.61	1.29

TABLE A1.2 Determination of the Overall Variance for Increments[A]

Series 1			Series 2		
Increment Number, *n*	Dry Ash[B] (*x*)	(Dry Ash)[2B] $(x)^2$	Increment Number, *n*	Dry Ash[B] (*x*)	(Dry Ash)[2B] $(x)^2$
1	4.17	17.3889	11	3.07	9.4249
2	3.62	13.1044	12	4.88	23.8144
3	1.79	3.2041	13	5.14	26.4196
4	4.37	19.0969	14	3.63	13.1769
5	4.64	21.5296	15	3.17	10.0489
6	7.03	49.4209	16	7.20	51.8400
7	6.27	39.3129	17	3.52	12.3904
8	3.91	15.2881	18	0.87	0.7569
9	6.04	36.4816	19	0.72	0.5184
10	4.18	17.4724	20	4.78	22.8484
Sum	46.02	232.2998	Sum	36.98	171.2388

[A] This example involves increment weights in the approximate range from 45 to 90 kg (100 to 200 lb).

[B] 10 % ash was subtracted from each of the ash results to simplify the calculations.

Series 1:

$s_1^2 = (232.2998 - (46.02)^2/10)/9 = 2.2795$

Series 2:

$s_2^2 = (171.2388 - (36.98)^2/10)/9 = 3.8319$

Variance ratio limit from Table A1.1 = 3.18.

Variance ratio for two test series:

$s_2^2/s_1^2 = 3.8319/2.2795 = 1.68 < 3.18$

Since the computed value for the ratio is less than 3.18, variances are combined to give an estimate of the overall variance for increments, s_o^2:

$s_o^2 = [1.92(2.2795 + 3.8319)]/2 = 5.867$

A1.2 Procedure

A1.2.1 The following procedure should be used to determine the overall variance of increments:

A1.2.2 Collect two series of individual increments at widely spaced intervals, for example, a series of ten increments, two each day for five days, followed by a second series of ten collected in similar fashion. Both series must be from the same coal.

A1.2.3 Collect each increment by using as much of the equipment and procedure used in routine sampling operations as possible. Remove the individual increment from the sampling system without mixing with or contaminating by any other increment. Where possible, allow it to pass through any mechanical crusher or subsampler, or both, which is located in the system before the point of blending with other increments.

A1.2.4 Then weigh the individual increment (if desired for record purposes) and reduce to a laboratory sample by procedures identical as possible to those used in the routine preparation and reduction of gross samples.

A1.2.5 Analyze the sample for the constituents for which the variance calculations are to be made. Usually sampling specifications are based on dry ash, but where total moisture or as-received Btu is of particular concern, the analyses should be made for these.

A1.3 Calculation

A1.3.1 For each series, compute a variance value from the analyses of the ten increments as follows:

$$s^2 = (\Sigma x^2 - (\Sigma x)^2/n) / (n - 1) \quad \text{(A1.1)}$$

where:

s^2 = variance value for series,
Σx^2 = sum of squares of ash results,
$(\Sigma x)^2$ = square of the sum of ash results, and
n = number of individual ash results in the series.

A1.3.2 For the two series, the ratio of the larger variance to the smaller should not exceed the value given in Table A1.1, Column 2. If they differ by less than this amount, the variances are combined to give the estimated overall increment variance for the coal as follows:

$$s_o^2 = C\,[(s_1^2 + s_2^2) / 2] \quad \text{(A1.2)}$$

where:

s_o^2 = probable maximum value of the overall variance for increments,
C = factor from Table A1.1, Column 3, corresponding to the number of increments per set,
s_1^2 = s^2 from first series, and
s_2^2 = s^2 from second series.

A1.3.3 If the ratio of the larger variance to the smaller does give a greater value than the Table A1.1, Column 2 value, the two series are to be considered in a single set of increments, and another set equal to this enlarged set is to be taken. For example, if originally 2 sets of 10 increments were taken, these would be combined to give a set of 20. Then an additional set of 20 increments would be collected, giving 2 sets of 20 increments each. Variance values are computed for the two new series and the test is repeated using the appropriate factors given in Table A1.2. If these results have a ratio which is less than the appropriate value in Column 2 of Table A1.2, they are combined by using Eq A1.2 and used as the new variance for increments.

A1.3.4 *Example*—The example given in Table A1.2 illustrates the computation of the overall variance for increments, s_o^2. Two series of ten increments each are used.

APPENDIX

(Nonmandatory Information)

X1. MONITORING COAL SAMPLING RATIOS USING CONTROL CHARTS

X1.1 Scope

X1.1.1 This procedure may be used to monitor the consistency of coal sampling ratios obtained with common mechanical sampling system control settings of cutter operating intervals, cutter openings, cutter speeds (for falling-stream samplers), and belt speeds (for cross-belt samplers). Out-of-control conditions (see Section X1.4) or excessive variation (see Section X1.5) will serve to alert the operator to potential problems that need to be investigated.

X1.2 Rationale (Commentary)

X1.2.1 The standard suggests that sampling systems should be given a rough performance check as a matter of routine by comparing the weight or volume of the collected sample with that of the total flow of coal to ensure a constant sampling ratio (see 7.11). The procedure offered in this Appendix is one means of continual monitoring of the consistency of the sampling ratio using methodology following the general principles of the *ASTM Manual on Presentation of Data and Control Chart Analysis*. An explanation of the value and use of control charts is given in *Out of the Crisis*.[3]

X1.3 Data Collection and Charting Procedure

X1.3.1 For each lot sampled using a common sampling scheme, obtain and record the net weight of the sample collected at the final stage of mechanical sampling before any off-line sample preparation. Weights should be accurate to within 0.5 % of the weight recorded.

X1.3.2 Obtain and record the lot size (in Mg or tons) using belt scales or other similarly accurate device normally used for determining the lot size.

X1.3.3 Divide the sample weight by the lot size and express the result in pounds per 1000 kilograms or tons per 1000 metric tons.

X1.3.4 Calculate the average sampling ratio $\bar{r}$ using Eq X1.1, where n is the number of sampling ratios in the chart and r_j is the ith sampling ratio in the series of ratios numbered 1 to n. The central line on the chart (CL) is equal to the average, $\bar{r}$.

$$\bar{r} = \frac{1}{n}\sum_{i=1}^{n} r_i \qquad (X1.1)$$

X1.3.5 Calculate the average moving range $\bar{R}$ using Eq X1.2, where Abs denotes the absolute value.

$$\bar{R} = \frac{1}{n-1}\sum_{i=2}^{n} \text{Abs}(r_i - r_{i-1}) \qquad (X1.2)$$

X1.3.6 Calculate the lower control limit line (LCL) and upper control limit line (UCL) as:

$$LCL = \bar{r} - 2.66\bar{R} \qquad (X1.3)$$

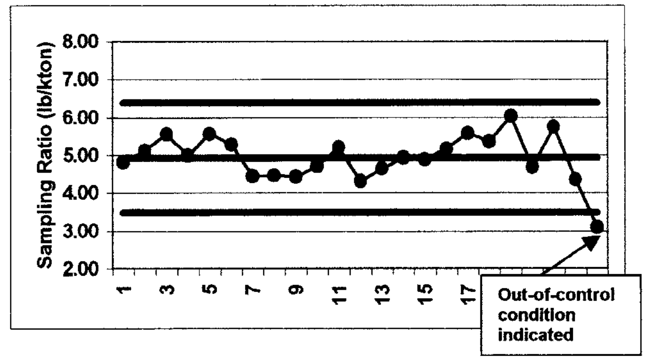


FIG. X1.1 Sampling Ratio Values

$$UCL = \bar{r} + 2.66\bar{R}$$

NOTE X1.1—The values of these limits are such that if there is a common system of chance causes of variation (no special cause is present) there is only about 1 chance in 100 that a sampling ratio value will be either below the value LCL or above the value UCL.

NOTE X1.2—The constant 2.66 is not a function of the number of n of sampling ratios being charted.

X1.3.7 Plot the sampling ratios on a line chart, with the vertical axis denoting sampling ratio values the horizontal axis denoting dates (and times, if appropriate). Sampling ratios values should always be plotted in chronological order. Add the central line (CL), the lower control limit line (LCL), and the upper control limit line (UCL) to the chart. See Fig. X1.1.

X1.4 Detection of Special Causes (Out-of-Control Conditions)

X1.4.1 A special cause of variation is indicated if one or more values are either above the upper control line or below the lower control line.

X1.4.2 A special cause of variation is indicated when there is a run defined by one of the following:

X1.4.2.1 At least seven consecutive values are on one side of the central line.

X1.4.2.2 At least ten out of eleven consecutive values are on one side of the central line.

X1.4.2.3 At least twelve out of fourteen consecutive points on one side of the central line.

X1.4.3 A special cause of variation is indicated if there is a trend indicated by at least seven consecutive points increasing continually or at least seven consecutive points decreasing continually.

X1.4.4 If no out-of-control conditions are indicated, the sampling system is considered to be stable and in-control.

X1.5 Monitoring the Coefficient of Variation

X1.5.1 When there are 20 or more sampling ratios charted ($n \geq 20$) and the system is stable, calculate the percent coefficient of variation ($\%cv$) using:

[3] Deming, W. E., *Out of the Crisis*, MIT Center for Advanced Engineering Studies, 1986, pp. 309–370.

TABLE X1.1 Calculations of Systems Design Sampling Ratio

	w	t	v	d	r_D
Primary stage	6 in.	190 s	100 in./s	0.0003158	
Secondary stage	2 in.	21 s	14 in./s	0.0068027	
System				2.148E-06	4.30 lb/ktons

$$\%cv = \frac{s_r(100)}{\bar{r}} \quad \text{(X1.4)}$$

where s_r is the sample standard deviation of the sampling ratios obtained from:

$$s_r = \left[\frac{1}{n-1}\sum_{i=1}^{n}(r_i - \bar{r})^2\right]^{1/2} \quad \text{(X1.5)}$$

X1.5.2 A value for the *%cv* greater than 15 may indicate a need for system improvement. Among the items to be checked include the consistency of velocity of sampling system cutters; the cleanliness of oil and filters; hydraulic oil temperature variations; proper operation of all valves, cylinders, and pumps; the consistency of operation of timers; and the accuracy of the sample weights and lot sizes used in the calculations.

X1.6 Monitoring the Average Observed Sampling Ratio

X1.6.1 The division ratio d of either a falling stream or a cross-belt sampler is calculated from the following equation:

$$d = \frac{w}{tv} \quad \text{(X1.6)}$$

where:
w = the tip-to-tip cutter aperture width, in mm [in.],
t = the activation interval, in seconds, and
v = the velocity of the cutter (for falling stream samplers) or velocity of the conveyor belt (for cross-belt samplers) in mm/s [in./s].

X1.6.2 The division ratio d_{sys} for a sampling system consisting of N sampling stages is calculated from the following equation:

$$d_{sys} = d_1 d_2 ... d_N \quad \text{(X1.7)}$$

where:
d_1 = the division ratio for the primary stage
d_2 = the division ratio for the secondary stage, and
d_N = the division ratio for the Nth stage.

X1.6.3 The expected value of the observed sampling ratio is the design sampling ratio (alternatively known as the theoretical sampling ratio). The value r_D, in kg per thousand Mg [pounds per thousand tons] is calculated from the following equation:

$$r_D = d_{sys}K \quad \text{(X1.8)}$$

where:
K = 1 000 000 [2 000 000].

NOTE X1.3—The term design sampling ratio means the sampling ratio expected (by design), given the specific set of operating parameters (w, t, v) for each sampling stage. If one or more of these operating parameters is changed at any stage of sampling, the design sampling ratio changes.

NOTE X1.4—The constant value K in Eq X1.8 converts the division ratio from a fraction to units of kg/1000 Mg [lb/1000 ton]. Table X1.1 illustrates an example of such calculations.

X1.6.4 When there are twenty or more observed sampling ratios charted with no out-of-control condition indicated and the *%cv* calculated using Eq X1.4 is less than fifteen percent, compare the average observed ratio to the calculated design ratio. If the difference between the design ratio and the average observed ratio is greater than ten percent of the design ratio, an investigation of the cause is needed. One of the following may have occurred: *(1)* There is a significant error in one of the measured parameters w, t, or v for one or more stages of sampling. *(2)* There is a mechanical problem with the sampling system.

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