



Designation: D 409 – 97<sup>ε02</sup>

## Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method<sup>1</sup>

This standard is issued under the fixed designation D 409; 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.

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<sup>1</sup> ~~NOTE Footnote 6 has been updated editorially in August 2000.~~

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<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-5 D05 on Coal and Coke and is the direct responsibility of D05.07 on Physical Characteristics of Coal. Current edition approved Nov. April 10, 1997, 2002. Published May 1998, July 2002. Originally published as D 409 – 51. Last previous edition D 409 – 93a7<sup>ε2</sup>.

## 1. Scope

1.1 This test method<sup>2</sup> covers the determination of the relative grindability or ease of pulverization of coals in comparison with coals chosen as standards. A prepared and sized sample receives a definite amount of grinding energy in a miniature pulverizer, and the size consist of the pulverized product is determined by sieving. The resultant size consist is used to produce an index relative to the ease of grinding (Hardgrove Grindability Index (HGI)).

1.1.1 Some coals, such as some high-volatile bituminous, subbituminous, and lignite coals, can undergo physical change as the natural or seam moisture is released during handling and preparation. This change is often sufficient to alter the grindability characteristics that will be reported when tested in the laboratory and could produce different indices dependent on the conditions of drying and the moisture level of the 1.18-mm by 600- $\mu$ m (No. 16  $\times$  No. 30) (see Test Method D 4749) materials used for the test. Therefore, the repeatability and reproducibility cited in this test method may not apply for these high-volatile bituminous, subbituminous, and lignite coals.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses may be approximate.

1.3 It is recognized that the term *weight* is considered equivalent to *mass* as used in this test method.

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:*

D 2013 Method of Preparing Coal Samples for Analysis<sup>3</sup>

D 2234 Practice for Collection of a Gross Sample of Coal<sup>3</sup>

D 4749 Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size<sup>3</sup>

E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>4</sup>

## 3. Significance and Use

3.1 This test method develops a measurement of grinding or pulverizing characteristics that can be used to evaluate the yield, or energy input, or both, required in a grinding or pulverizing process.

## 4. Apparatus

4.1 *Air-Drying Oven*—A device for passing slightly heated air over the sample. The oven shall be capable of maintaining a temperature of 10 to 15°C (18 to 27°F) above room temperature with a maximum oven temperature of 40°C (104°F) unless ambient temperature is above 40°C, in which case ambient temperature shall be used. In the case of easily oxidized coals, the temperature shall not be over 10°C (18°F) above room temperature unless ambient temperature is above 37°C (100°F) in which case ambient temperature shall be used. Air changes shall be at the rate of 1 to 4 air volumes of oven capacity per minute.

4.2 *Drying Pans*—Drying pans of sufficient size so that the sample may be spread to a depth of not more than 25 mm (1.0 in.) with sides not more than 38 mm (1.5 in.) high. The pans shall be nonreactive with coal and unaffected by the method of air drying selected.

4.3 *Balances*—Two balances may be required: one with a sensitivity of 10 mg and a minimum capacity of 800 g and one with a sensitivity of 0.5 g in 1000 g and sufficient capacity to weigh a  $\geq$ 1000-g sample along with the drying pan. A single balance meeting these specifications is permitted.

4.3.1 *Calibration Weights*—These calibration weights shall be used to monitor the response of each balance over the range of normal use each time HGIs are determined.

4.4 *Sample Divider*—An enclosed riffle divider as described in Method D 2013 is required and shall be used.

4.5 *Standard Sieves*—A working set of circular, standard testing sieves which are 203 mm (8 in.) in diameter and conform to Specification E 11, are required in the following sizes, together with cover and catch pan (receiver):

Standard (ISO Designation)	Sieve Designation	Alternate (U.S.A. Designation)
16.0 mm		5/8 in.
4.75 mm		No. 4
2.36 mm		No. 8
1.18 mm		No. 16

<sup>2</sup> For information concerning the experimental work on which this test method is based, see paper by Hardgrove, R. M., "Grindability of Coal," *Transactions, American Society of Mechanical Engineers*, Vol 54, F.S.P., p. 37, 1932.

D05.07.02 on Grindability is conducting ongoing investigations in regard to quality control during preparation, distribution, and use of standard reference materials and during preparation and testing of actual samples.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 05.06.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 14.02.

600  $\mu\text{m}$   
75  $\mu\text{m}$

No. 30  
No. 200

4.5.1 These working sieves must be periodically inspected for wear or damage. Any excessively worn or damaged sieves (sieves with holes, tears cracks, and so forth, see Note 1). must be replaced immediately, and the HGI calibration procedure must be repeated after the damaged sieves are replaced (see Section 8). Since the HGI depends upon the sieve analysis and since the 75- $\mu\text{m}$  (No. 200) sieve is fragile, it is recommended that at least one set of working sieves be obtained, identified, and used exclusively for HGI determinations and that only this exclusive set of sieves be used.

NOTE 1—Excessive wear may be indicated by poor repeatability or by failure of quality control checks (8.1.1) to agree reasonably with the initial calibration data.

4.5.2 Normal wear on sieves is compensated by the use of proper standard reference samples (SRSs) and proper calibration of equipment; excessive wear such as holes or tears in the sieve cloth, and so forth is not compensated by SRSs. Because excessive wear is unacceptable, inspect sieves carefully before each test to ensure the absence of excessive wear. For the 75- and 600- $\mu\text{m}$  (No. 200 and 30) sieves, use only a soft-bristled brush (such as short-bristled camel hair) for brushing and cleaning.

NOTE 2—It is good practice to keep a separate primary 75- $\mu\text{m}$  (No. 200) check sieve to be used only to check the 75- $\mu\text{m}$  working sieve described in 4.5.1 when the working sieve becomes suspect. This check is done by running a comparative HGI test between the two 75- $\mu\text{m}$  sieves. Use of the working sieve for HGIs should be discontinued if HGI difference between the sieves is greater than 1 HGI unit.

4.6 *Crusher*—A laboratory plate mill capable of reducing 4.75-mm (No. 4) sieve size coal particles with the production of a minimum of minus 600- $\mu\text{m}$  (minus No. 30) sieve size material (Note 3). The crusher plates shall be serrated and about 100 mm (4 in.) in diameter (Note 4). The distance between the plates shall be adjustable, and the relative speed of rotation of the plates shall not exceed 200 r/min.

NOTE 3—Evidence from HGI standard reference sample user-response forms (8.4) indicates that the median value of percent recovery of the 4.75-mm (No. 4) material as 1.18-mm by 600- $\mu\text{m}$  (Nos. 16 by 30) material, regardless of the HGI level, is about 55 %.

NOTE 4—The most frequently used plate mill can be equipped with “fine” or “coarse” plates. One independent study<sup>5</sup> has found evidence of differences in percent recovery resulting from use of different types of plate. Only the coarse plate should be used in preparation of both HGI calibration standards and unknown samples.

4.7 *Mechanical Sieving Machine*—The mechanical sieving machine shall accept an assembly of vertically nested circular sieves of 203 mm (8 in.) in diameter, together with cover and receiver. The machine shall simulate the motions given testing sieves during hand sieving by imparting a horizontal oscillatory motion of approximately 28-mm (1.1-in.) amplitude at a rate of approximately 300 oscillations or cycles per minute (cpm). Simultaneously, the top of the oscillating assembly is struck at a rate of approximately 150 blows per minute by a weight of 1.9 kg (4.2 lb) moving through a vertical distance of approximately 28 mm (1.1 in.) under the influence of gravity.

4.8 *Grindability Machine*—The Hardgrove Grindability Machine such as is shown in Fig. 1 is required for this test. Essential tolerances and specifications are shown in Fig. 2. The grindability machine includes a stationary grinding bowl of polished cast iron, with a circular horizontal track that holds eight polished steel balls, each  $25.40 \pm 0.13$  mm ( $1.000 \pm 0.005$  in.) in diameter. The balls are driven by an upper grinding ring which is rotated at  $20 \pm 1$  r/min by means of the upper spindle and which, in turn, is driven by an electric motor through reduction gears and, in newer models, belts. Weights are added to the driving spindle so that the total vertical force on the balls as a result of the weights, shaft, top grinding ring, and gear is equal to  $29.0 \pm 0.2$  kg ( $64 \pm 0.5$  lb). The machine is equipped with a counter and automatic device which can be properly adjusted for stopping the machine after  $60 \pm 0.25$  revolutions.

4.8.1 The position of the counter trip mechanism before and after the test must be used to determine the number of revolutions completed. Sometimes, it may be necessary to position strategically the counter trip mechanism at the beginning of the test to accomplish the desired number of revolutions (that is, watch where the trip mechanism is initially, count the number of revolutions from the point of origin, determine where the trip mechanism is at the end of the test, and determine if the specified  $60 \pm 0.25$  revolutions are obtained. If not, adjust the position of the trip mechanism at the beginning of the test until the specified number of revolutions are obtained).

## 5. Standard Reference Samples (SRSs) for Calibration<sup>6</sup>

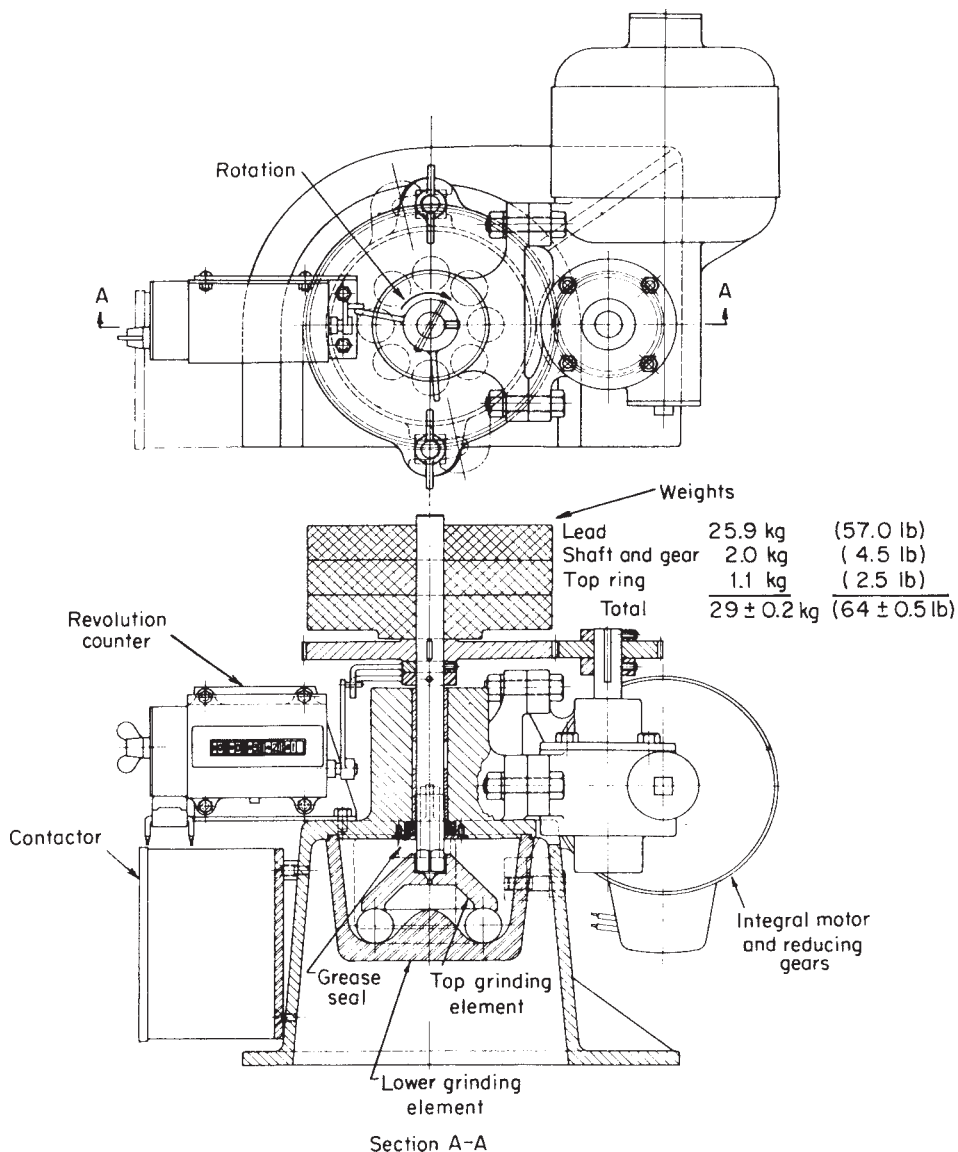
5.1 Four SRSs prepared especially for this purpose (in accordance with Annex A1) and representing grindability indices of approximately 40, 60, 80, and 100 shall be used for calibration. (See Section 8.)

5.1.1 Upon receipt, each of the SRSs should be examined for the following:

5.1.1.1 Preparation date (no more than six months old).

<sup>5</sup> D05.07 Minutes, J. Gardner, Georgia Power and G. Linton, October 1990.

<sup>6</sup> Primary standard reference samples are available from the U.S. Department of Energy, Colleen Butcher, National The Pennsylvania State University, Ronald S. Wasco The Energy Technology Laboratory, PO Box 10940, Pittsburgh, Institute, C-211 CUL, University Park, PA 15236, 16802, Telephone: 412-386-5805; 814-863-5384, Fax: 412-386-4806; 814-863-7432, email: rxw19@psu.edu, www.energy.psu.edu/HGI. ASTM Subcommittee D05.07 and the ASTM/DOE Liaison Task Group maintain oversight for production of only the primary standard reference samples. Secondary standard reference samples are available from other sources.



Section A-A  
**FIG. 1 Hardgrove Grindability Machine**

5.1.1.2 Oversize (material retained on a 4.75-mm (No. 4) sieve). [Less than 5 % + 4.75 mm and no particle on a 6.30-mm (1/4-in. square-holed sieve).] (See 7.3.)

5.1.1.3 Foreign, noncoal material (no wood, rock, slate, and so forth).

5.1.1.4 Excessive fines (-600-µm (-No. 30) material) (less than 30 %). (See 7.3.)

5.1.2 When any of these parameters are unacceptable, contact the agency responsible for production of the SRSs and report the data on the response form accompanying the SRSs (see 8.4).

**6. Gross Samples**

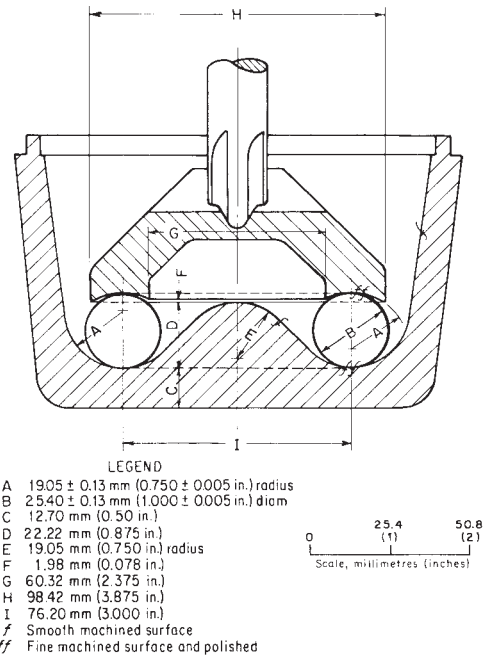
6.1 Collect a gross sample of coal, representative of the material from which it is taken, in accordance with Practice D 2234, and prepare the sample in accordance with Method D 2013 except that the sample topsize shall not be reduced beyond the 4.75-mm (No. 4) sieve, and the sample shall weigh at least 1000 g.

**7. Preparation of Test Samples**

7.1 Prepare a 1.18-mm × 600-µm (No. 16 × No. 30) test sample for establishing the HGI of SRSs, for calibration, or for routine determination of HGI.

7.2 When necessary, divide the quantity of 4.75-mm (No. 4) sieve size coal to not less than 1000-g lots using an enclosed riffle, and air dry each sample in conformance with Method D 2013.

7.3 Sieve the entire amount (1000 g) of air-dried 4.75-mm (No. 4) sieve size sample in lots of no greater than 250 g, for 2 min ± 10 s in the mechanical sieving machine. Use a set of nested sieves consisting of a 1.18-mm (No. 16) sieve on top of a 600-µm



SECTIONAL VIEW  
**FIG. 2 Grinding Elements of Hardgrove Machine**

(No. 30) sieve. [It may be appropriate to include a 4.75-mm (No. 4) and a 2.36-mm (No. 8) sieve in this nest of sieves to record the particle size distribution and the topsize of the sample.] Weigh and record the mass of each sieve size.

7.4 Stage crush the material retained on the 1.18-mm (No. 16) sieve with the crusher adjusted so that only the largest particles are crushed. Take the crushed material in lots no greater than 250 g and sieve for 2 min ± 10 s in the mechanical sieving machine. Return the oversize to the crusher, after setting the crusher so that only the largest particles are crushed. Continue the stage crushing and sieving procedure until all the material passes the 1.18-mm sieve. Retain the 1.18-mm × 600-µm (No. 16 × No. 30) material.

7.5 Mix well all the 1.18-mm × 600-µm (No. 16 × No. 30) material accumulated from the stage crushing and sieving and divide the quantity using an enclosed riffle to obtain approximately 120 ± 10 g.

7.6 As the final step in preparation of the test sample, dedust the 120- ± 10-g sample from 7.5 by sieving on a 600-µm (No. 30) sieve for 5 min ± 10 s using the mechanical sieving machine.

## 8. Calibration

8.1 Calibrate each grindability machine, together with all ancillary equipment including sieves and plate mill, that will be used for this test when new, modified, repaired, suspected of being defective, or when operated by new personnel.

8.1.1 SRSs shall not be used for calibration beyond 18 months from their preparation date. It is good practice to check the calibration of the HGI apparatus periodically with at least one of the SRSs (quality control check sample) even if none of the conditions in 8.1 apply. This will ensure that the system is still in control and it will allow for detection of problems previously unnoticed or not then occurring, and it will allow for use of the SRSs before their expiration date.

8.2 For each calibration, process four standard reference samples with indices of approximately 40, 60, 80, and 100 separately as described above. Process the samples as outlined below (Section 9), and use the results to determine the equation of the line by use of the sum of least squares method (8.3) and, if desired, to prepare a calibration chart (8.3.1).

8.3 By the method of the sum of least squares, determine the equation of the line that best fits the analytical results obtained from the four HGI SRSs. An example HGI calculation from SRS data, shown in Table 1, illustrates this method.

8.3.1 *Example—Sum of Least Squares Fit*—The equation of the line for the sum of least squares takes the form of:

**TABLE 1 Example HGI Data Calculation—Actual Weight of Materials, g**

HGI <sup>A</sup>	Weight, i <sup>B</sup>	+ 200	-200	Recovered	Lost	Calculated, - 200
40	50.00	45.65	4.27	49.92	0.08	4.35
58	50.00	42.86	7.11	49.97	0.03	7.14
83	50.00	39.56	10.23	49.79	0.21	10.44
100	49.99	36.61	13.25	49.86	0.13	13.38

<sup>A</sup>Value issued with the SRSs.

<sup>B</sup>Initial weight.

$$Y = a + bX \quad (1)$$

where:

$Y$  = HGI,

$a$  =  $y$  axis intercept,

$b$  = slope of the regression line, and

$X$  = calculated  $-75\text{-}\mu\text{m}$  (–No. 200) material.

$a$  and  $b$  can be determined by use of the following table and equations:

$Y$	$X$	$X^2$	$XY$
40	4.35	18.92	174.00
58	7.14	50.98	414.12
83	10.44	108.99	866.52
100	13.38	179.02	1338.00
$\Sigma Y = 281$	$\Sigma X = 35.31$	$\Sigma(X^2) = 357.91$	$\Sigma(XY) = 2792.64$

$$a = \frac{\Sigma Y \Sigma X^2 - \Sigma X \Sigma XY}{n \Sigma X^2 - (\Sigma X)^2} \quad (2)$$

$$b = \frac{n \Sigma XY - \Sigma X \Sigma Y}{n \Sigma X^2 - (\Sigma X)^2} \quad (3)$$

where:

$\Sigma Y$  = 281,

$\Sigma X$  = 35.31,

$\Sigma(X^2)$  = 357.91,

$\Sigma(XY)$  = 2792.64,

$(\Sigma X)^2$  = 1246.80, and

$n$  = 4.

By doing these calculations,  $a = 10.63$  and  $b = 6.75$ . Therefore, the equation of the line for this database is  $\text{HGI} = 10.63 + 6.75$  (calculated  $-75\text{-}\mu\text{m}$  (–No. 200) material).

8.3.2 Use results from standard reference samples processed in accordance with Sections 7 and 9 in determining the equation of the line by the sum of least squares method and (optionally) in preparing the calibration chart (see Fig. 3).

8.4 A standard form for reporting data obtained during calibration is received with each set of HGI SRSs received from the producer of the primary standard. This form shall be completed and returned to the producer of the primary standard as noted on the form. A copy of this form is sent by the producer of the primary standard to the ASTM D-5 Producer Liaison Task Group for use in monitoring the primary HGI SRSs.

## 9. Procedure

9.1 Clean the grindability machine thoroughly, place the machine on a level surface, and space the balls as evenly as possible around the grinding bowl. Set the automatic stopping device so that the motion of the grindability machine will stop after  $60 \pm 0.25$  revolutions of the upper grinding ring.

9.1.1 If the grindability machine makes a different number of revolutions other than the specified  $60 \pm 0.25$  revolutions, the machine must be adjusted to within the tolerance specified. (This is normally done by strategically placing the counter tripper arm at the start of the test.)

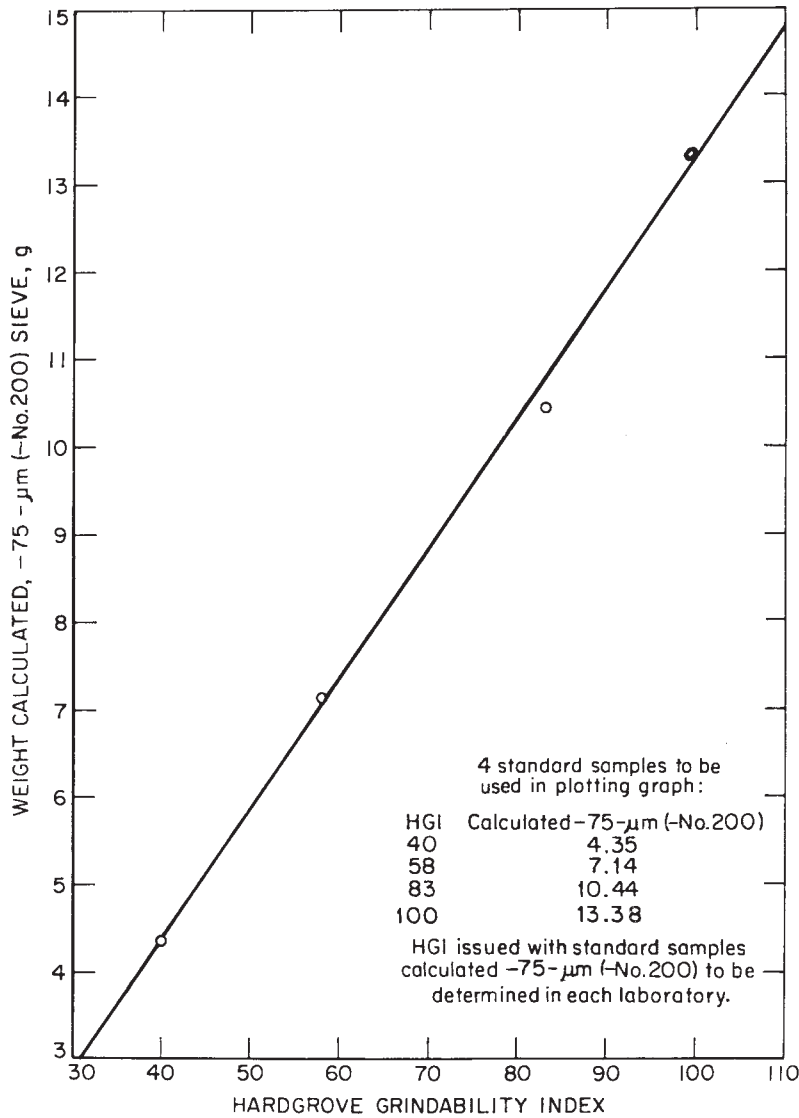
9.2 Weigh  $50 \pm 0.01$  g of the  $1.18\text{-mm} \times 600\text{-}\mu\text{m}$  (No. 16  $\times$  No. 30) sieve size dedusted material from 7.6 and distribute it evenly in the grinding bowl, brushing any material that falls on the elevated section of the lower grinding element into the lower grinding element which contains the balls. Fasten the bowl in position and make sure the load is fully applied to the driving spindle.

9.3 Operate the machine for the specified  $60.00 \pm 0.25$  revolutions.

9.4 Remove the bowl from the machine, lift out the upper grinding ring, and carefully brush adhering coal dust from the bowl and grinding ring onto a 16-mm ( $5/8$ -in.) sieve nested on a  $75\text{-}\mu\text{m}$  (No. 200) sieve and a closely fitting receiving pan. Carefully empty the contents of the bowl onto the 16-mm ( $5/8$ -in.) sieve. Brush off material adhering to the balls and remove them from the 16-mm ( $5/8$ -in.) sieve. Brush material adhering to the 16-mm ( $5/8$ -in.) sieve, including the underside of the sieve, onto the  $75\text{-}\mu\text{m}$  sieve. Replace the 16-mm ( $5/8$ -in.) sieve with a close-fitting cover and shake the nested  $75\text{-}\mu\text{m}$  sieve; cover and pan for  $10 \text{ min} \pm 10 \text{ s}$  in a mechanical sieving machine. After the  $10\text{-min} \pm 10\text{-s}$  period, carefully brush coal dust from the underside of the  $75\text{-}\mu\text{m}$  sieve into the receiving pan using a soft-bristled brush to avoid damaging the sieve. Repeat the shaking of the ball-milled material and the cleaning of the underside of the  $75\text{-}\mu\text{m}$  sieve for two more periods each of  $5\text{-min} \pm 10\text{-s}$  duration.

9.5 Weigh separately to the nearest 0.01 g the coal retained on the  $75\text{-}\mu\text{m}$  (No. 200) sieve and the coal passing the  $75\text{-}\mu\text{m}$  sieve.

9.6 Alternatively, weigh the  $75\text{-}\mu\text{m}$  (No. 200) sieve and its contents. Subtract the tare mass to obtain the mass of the  $+75\text{-}\mu\text{m}$  ( $+ \text{No. 200}$ ) material. Weigh the catch pan and its contents. Subtract the tare mass to obtain the mass of the  $-75\text{-}\mu\text{m}$  (–No. 200) material. If the sum of these weights differs by more than 0.50 g from the initial weight of  $50 \pm 0.01$  g, reject the test and repeat.



Note—Example: Use certified SRSs and develop similar calibration chart(s) for each HGI apparatus, or sieve sets, or both.

FIG. 3 Example Calibration Chart

Use the calculated weight of the coal passing the 75-µm sieve, determined by subtracting the weight retained on the 75-µm sieve from the test specimen weight, in determining the sum-of-least-squares fit (8.3.1), in preparation of the calibration chart (8.3.2) or in calculation of the grindability index of the sample (10.1).

**10. Calculation and Report**

10.1 Calculate the grindability index corresponding to the calculated weight of test specimen passing the 75-µm (No. 200) sieve (9.5) directly from the equation of the line prepared in 8.3 and report to the nearest whole number.

10.2 For ease of comparison between or among laboratories, report the percent residual moisture in a portion of the unused 1.18-mm by 600-µm (No. 16 by No. 30) sample. [Use Procedure C, D 3302, except maintain the sample at 1.18-mm (No. 16) top-size and use approximately 10 g.] Additionally, report the yield percent of 1.18-mm by 600-µm (No. 16 by No. 30) material generated from the initial 1000 g of 4.75-mm (No. 4) top-size sample.

10.3 If other than primary HGI SRSs are used for calibration of the test apparatus and method, report the source of the calibration standards used.

TABLE 2 Repeatability and Reproducibility for HGI of Coal

Repeatability Limit	Reproducibility Limit
$\frac{r}{2}$	$\frac{R}{3}$

10.4 An example of a typical HGI preparation log sheet that has found application for record keeping during preparation of samples to be used for HGI determination is shown in Fig. 4.

## 11. Precision and Bias

11.1 *Precision*: NOTE 5—The interlaboratory study to develop the

~~11.1.1 The precision statement for of this standard did not identify test method for the coal seams tested. D05.07.02 on determination of Hardgrove Grindability Index of Coal is shown in Table 2.~~

~~11.1.2 For the HGI method, the Repeatability Limit (r) in Table 2 is the value which the absolute difference between two test results of designing an interlaboratory study to define precision statements for different ranks of coal.~~

~~11.1.1 Repeatability—Results of separate and consecutive test determinations pe, carformed out on the same sample samples in the same laboratory by the same operator using the same apparatus shall not differ by more than two index points.~~

~~11.1.2 Reproducibility—The means on samples taken at random from a single quantity of results homogeneous 4 mesh material, may be expected to occur with a probability of determinations performed by approximately 95%.~~

~~11.1.3 For the HGI method, the Reproducibility Limit (R) in Table 2 is the value which the absolute difference between two test results, carried out in different laboratories on riffled splits of the 4.75-mm (No. 4) 4.75 mm (4 mesh) analysis sample shall not differ by more than three index points. sample, may be expected to occur with a probability of approximately 95%.~~

11.2 *Bias*—Since this test method (using a calibration procedure) is an empirical standard, the degree of absolute bias cannot be determined.

## 12. Keywords

12.1 grindability; Hardgrove-Grindability Index (HGI); pulverization

Sample I.D.: \_\_\_\_\_ Date: \_\_\_\_\_ Analyst: \_\_\_\_\_  
 Sample Description: \_\_\_\_\_

**[AIR-DRYING]**

Air-dry pan wt, (a).....	_____ g	Ambient Temp.....	_____ °F
Initial sample and air-dry pan wt, (b).....	_____ g	Time into oven....	_____
Final sample and air-dry pan wt, (c).....	_____ g	Time out of oven.	_____
Air-dried sample wt, c - a, (d).....	_____ g	Temperature.....	_____ °F
Wt loss on drying, b - c, (e).....	_____ g	Heat on at.....	_____
Initial sample wt, b - a, (f).....	_____ g	Heat off at.....	_____
% Wt loss on drying, e/f x 100%, (g)	_____ %	Fan on at.....	_____
		Fan off at.....	_____

**[INITIAL SIEVED WEIGHTS]**

+No. 4, (h).....	_____ g	No. 16 X No. 30, (k)	_____ g
No. 4 x No. 8, (i).....	_____ g	-No. 30, (l).....	_____ g
No. 8 x No. 16, (j).....	_____ g	Topsize.....	_____
Total recovered wt after sieving, (h + i + j + k + l), (m).....	_____ g		
Wt loss on sieving, d-m, (n).....	_____ g		
% Wt loss on sieving, (n/d) X 100%, (o).....	_____ %		

**[REDUCTION OF +NO. 16]**

	<u>Weight of +No. 16</u>		<u>Weight of +No. 16</u>
Initially, h + i + j, (p).....	_____ g	> 6th crushing of oversize, (v).....	_____ g
> 1st crushing of oversize, (q).....	_____ g	> 7th crushing of oversize, (w).....	_____ g
> 2nd crushing of oversize, (r).....	_____ g	> 8th crushing of oversize, (x).....	_____ g
> 3rd crushing of oversize, (s).....	_____ g	> 9th crushing of oversize, (y).....	_____ g
> 4th crushing of oversize, (t).....	_____ g	> 10th crushing of oversize, (z).....	_____ g
> 5th crushing of oversize, (u).....	_____ g		

Final total wt of No. 16 x No. 30, (A).....	_____ g
Final total wt of -No. 30, (B).....	_____ g
Final total recovered wt, (A + B), (C).....	_____ g
Loss on crushing, (m-C), (D).....	_____ g
% loss on crushing, (D/d) x 100%, (E).....	_____ %
% Yield of No. 16 x No. 30, A/d x 100%, (F)	_____ % *

**[DEDUSTING 120G OF NO. 16 x NO. 30 AND MILLING]**

Wt of No. 16 x No. 30 dedusted sample placed into HGI bowl, (G)	_____ g
No. of increments collected, (H).....	_____
Start position.....	_____
Stop position.....	_____
Start time.....	_____
Stop time.....	_____
	Number of revolutions, (I)..... _____
	Seconds to mill, (J)..... _____ sec
	RPM, [(I/(J/60))], (K)..... _____ RPM

**[SIEVING OF MILLED PRODUCT]**

Tare wt of catch pan, (L).....	_____ g	Wt of -No. 200, (N-L), (P).....	_____ g
Tare wt of No. 200 sieve, (M).....	_____ g	Wt of +No. 200, (O-M), (Q).....	_____ g
Wt of catch pan and -No. 200, (N).....	_____ g	Total recovery, (P + Q), (R).....	_____ g
Wt of No. 200 sieve and +No. 200, (O).....	_____ g	Loss (≤0.50 g), (G-R), (S).....	_____ g
Calculated wt of -No. 200, (G-Q), (T).....	_____ g		

**[ANALYTICAL RESULTS]**

HGI Formula (from Least Squares Regression) \_\_\_\_\_  
 HGI (U) \_\_\_\_\_

Determine the percent total moisture (@ 107°C for 90 min) on 10g of No. 16 x No. 30 dedusted material not used, (V) \_\_\_\_\_ % (Reference ASTM D-3302, Procedure C)

Determine the percent ash on a 1.00-gram sample of the recombined (and remixed) ± No. 200 milled product, (W) \_\_\_\_\_ %

\*% Yield depends upon the topline of the original sample, whether the sample has been "dedusted" prior to preparation, etc.

**FIG. 4 HGI Log Sheet Is for Example Only and Is Nonmandatory**

## ANNEX

### (Mandatory Information)

#### A1. METHOD FOR PREPARING AND DETERMINING GRINDABILITY INDEXES OF PRIMARY HGI STANDARD REFERENCE SAMPLES

##### A1.1 Scope

A1.1.1 This method prescribes the procedure for preparing standard reference samples by the authority preparing reference samples for use in determining the Hardgrove Grindability Index.

A1.1.2 This method also prescribes the procedure to be used in determining the Hardgrove Grindability Index of standard reference samples.

##### A1.2 Apparatus

A1.2.1 All apparatus and equipment is essentially as prescribed in Section 4 but with the following special precautions being taken:

A1.2.2 A mechanical sieving machine (4.7) and a grindability machine (4.8) are both to be reserved for use only for determining Hardgrove Grindability Index of standard reference samples.

A1.2.3 At least four specially calibrated, stainless steel 75- $\mu\text{m}$  (No. 200) sieves shall be set aside for use only in determining the HGI of the SRSs [in determining the amount of material passing the 75- $\mu\text{m}$  (No. 200) sieve in 9.5]]. One of the sieves (the primary “master” sieve) is to be used to check the secondary sieve(s) as needed. The secondary sieve is used to check the working sieves annually. The working sieves are to be used on standard reference samples only.

##### A1.3 Standard Coals

A1.3.1 Coals having Hardgrove Grindability Indexes of approximately 40, 60, 80, and 100 shall be collected as HGI SRS feedstock.

A1.3.2 The feedstock coals shall consist of not less than 80 kg (175 lb).

A1.3.3 The feedstock coals shall be from a single seam, containing no blended materials.

A1.3.4 The feedstock coals shall be double-sieved to pass a 63-mm (2.5-in.) square-hole sieve while being retained on a 3.35-mm ( $\frac{1}{8}$ -in.) square-holed sieve.

A1.3.5 The coal shall be mechanically cleaned, having been through a preparation or wash plant to remove noncoal material.

A1.3.6 The coal shall be visually inspected upon its receipt by the primary standard producer to assure the absence of foreign material or undersized ( $-3.35\text{-mm}$ ) or oversized ( $+63\text{-mm}$ ) particles. If any foreign material (wood, rock, slate, steel, and so forth) is present or if undersized or oversized material constitutes greater than 5 % of the lot, the entire shipment shall be rejected.

A1.3.7 The feedstock coal supplier shall obtain a separate sample of the feedstock and perform an analysis of each lot for dry ash content. The supplier shall provide a certificate of analysis with each lot, showing that the feedstock has a dry ash content of less than 12 %.

A1.3.7.1 The primary standard producer may elect to resample the lot upon its arrival. If analysis of a sample of this material used to prepare HGI SRMs shows that, after air drying, the residual moisture is greater than 2 % or if the dry ash content is greater than 12 %, the entire shipment shall be rejected.

##### A1.4 Preparation of Standard Reference Samples

A1.4.1 Air dry the standard coal sample and reduce to 4.75-mm (No. 4) top size. Perform the air drying at room temperature for a minimum 12 h until fine particles do not adhere to the larger ones.

A1.4.2 Conduct the size reduction such that not more than 5 % of the sample is retained on a 4.75-mm (No. 4) sieve or such that not less than 5 % of the sample is retained on a 2.36-mm (No. 8) sieve. The object of this operation is to maximize the amount of the material occurring in the 1.18-mm by 600- $\mu\text{m}$  (No. 16 by No. 30) size fraction while maintaining a 4.75-mm (No. 4) topsize.

A1.4.2.1 Dedust the material on a continuous sieving device, removing the  $-0.30\text{-mm}$  ( $-\text{No. } 50$ ) material.

A1.4.3 Process the entire sample of 80 kg (175 lb) and retain for further use.

A1.4.4 Blend and subdivide the standard coals, after air drying and size reduction, into 24 subsamples which become Standard Reference Samples.

A1.4.5 Before subdivision, thoroughly mix all of each standard coal for 15 min in a tumbler similar in design to a concrete mixer.

A1.4.6 Subdivide the coal by feeding the coal at a uniform rate through a stationary funnel into 24 4-L (1-gal) containers located on the perimeter of a wheel rotating steady at 6 r/min. Adjust the feed rate such that each container receives approximately 34 increments. Seal the containers and label according to lot and container.

### A1.5 Determination of Grindability Index of Each Lot of Standard Reference Samples

A1.5.1 Subdivide 2 of each given lot of 24 standard reference samples prepared in A1.4.6 with a riffle and test each of the 4 resultant subsamples for Hardgrove Grindability Index. (Two different technicians shall each test one portion obtained from each of the two selected samples.)

A1.5.2 Prepare a test sample from each of the four subsamples in accordance with Section 7.

A1.5.3 Process each of the four subsamples in the grindability machine in accordance with Section 9 and note the weight of the original sample (50 g) minus the weight of the material retained on the 75- $\mu\text{m}$  (No. 200) sieve.

A1.5.4 Determine the value of Hardgrove Grindability Index for each subsample from the standardization graph derived originally from the correlation of data between the standardization equipment reserved exclusively for HGI SRS standardization purposes and the original equipment previously used by the Babcock & Wilcox Co. (the “Hardgrove” sieve) for standard samples.

A1.5.5 Calculate the average and the standard deviation of the four values obtained in A1.5.4 to the nearest whole number and use the average (two different technicians shall each test one portion obtained from each of the two selected samples) as the Hardgrove Grindability Index of the remaining 22 standard reference samples in that lot.

A1.5.6 Report the average value and the standard deviation (as well as individual analyses, technician identity, can identity, sieve identity, and so forth) to the chairman of the ASTM/Producer Liaison Task Group.

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