



# Standard Test Method of Tumbler Test for Coal<sup>1</sup>

This standard is issued under the fixed designation D441; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the relative friability of a particular size of sized coal. It affords a means of measuring the liability of coal to break into smaller pieces when subjected to repeated handling at the mine or subsequently, by the distributor or by the consumer. This test method is serviceable for ascertaining the similarity of coals in respect to friability rather than for determining values within narrow limits to emphasize their dissimilarity. This test method also may serve to indicate the relative extent to which sized coals will suffer size degradation in certain mechanical feed devices. This test method may be used for differentiating between certain ranks and grades of coal, and therefore the test method is of service for coal classification purposes.

1.2 The values stated in inch-pound units shall be regarded as the standard. Mass may be expressed in metric values.

1.3 *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:*<sup>2</sup>

[D2234/D2234M Practice for Collection of a Gross Sample of Coal](#)

[D4749 Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size](#)

[E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves](#)

## 3. Significance and Use

3.1 This test method is a measure of the resistance of the coal to breakage upon impact and abrasion as the coal rubs together and against the walls of the transportation vehicle.

<sup>1</sup> This method is under the jurisdiction of ASTM Committee D05 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characteristics of Coal.

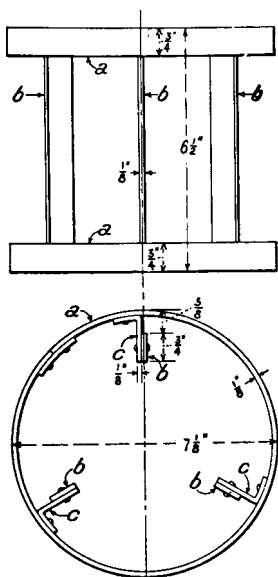
Current edition approved Oct. 1, 2007. Published October 2007. Originally approved in 1937. Last previous edition approved in 2002 as D441 – 86 (2002). DOI: 10.1520/D0441-07.

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

## 4. Apparatus

4.1 *Porcelain Jar Tumbler*, consisting of a cylindrical porcelain jar of uniform dimensions, 7¼ in. (184 mm) in diameter and 7¼ in. in depth, inside measurements, such as is used for pulverizing coal samples for analysis. The jar shall be fitted inside an iron frame with lifting shelves constructed as shown in Fig. 1. The two rings, *a*, shall be 7⅞ in. (181 mm) in outside diameter and shall be made of ¾- by ⅛-in. (19- by 3-mm) iron. The three ledges or shelves, *b*, 6½ by ¾ by ⅛ in. (165 by 19 by 3 mm), shall be attached radially to the rings by means of small brackets, *c*, the ends of the shelves being flush with the outer edges of the rings. The shelves shall be attached so that there will be ⅝-in. (15.9-mm) clearance between their outer edge and the outside of the ring. Rivets, not bolts, shall be used in constructing the frame. As the jars available commercially are not of absolutely uniform size, the measurements of the frame may be slightly varied to suit individual cases. The frame shall be fixed inside the jar by means of wedges between the rings and the inside wall of the jar so that its axis shall coincide as nearly as possible with the axis of the jar, and so that the frame will rotate with the jar. The jar shall be closed by a set-in porcelain lid resting upon a heavy rubber gasket and sealed tightly according to the customary procedure with such jars, that is, by means of a bolt working against the lid. The bolt shall be set in a crossbar, the ends of which shall be held by a metal strip which fits around the body of the jar. For tumbling, the jar shall be laid in a horizontal position in a suitable support or rack and rotated about its cylindrical axis at the rate of 40 rpm. The assembled apparatus is illustrated in Fig. 2.

4.2 *Optional Iron Jar Tumbler*—An iron jar may be substituted for the porcelain jar specified in 4.1, provided it has approximately the same internal dimensions, namely, 7¼ in. in diameter by 7¼ in. in depth. A jar constructed of cast iron is recommended, and the interior machined to the required internal dimensions. For making it sufficiently light for lifting, the jar may have a wall thickness of not less than ¼ in. (6.35 mm), except at each end. It is recommended that the lid, rubber gasket, and the metal strip that passes from the bottom up the outside of the jar to serve in holding in place the crossbar above the lid, be similar in design with those for the porcelain jar. The wall of the iron jar for a distance of approximately 1 in. (25.4 mm) from the top shall have a thickness of at least ½ in. (12.7 mm) to correspond with that of the porcelain jar; and in order



Metric Equivalents

in.	1/8	5/8	3/4	6 1/2	7 1/8
(mm)	(3.18)	(15.9)	(19.0)	(165)	(181)

FIG. 1 Steel Frame Used in Jar Mill

metal-framed sieves 8 in. (200 mm) in diameter are suitable. The sieves shall conform to Specification E11.

4.4 *Balance*—The balance used for weighing the sample shall be sensitive to 1 g.

## 5. Sampling

5.1 *Collection of Gross Sample*—Collect the gross sample of coal in accordance with Practice D2234/D2234M and Test Method D4749.

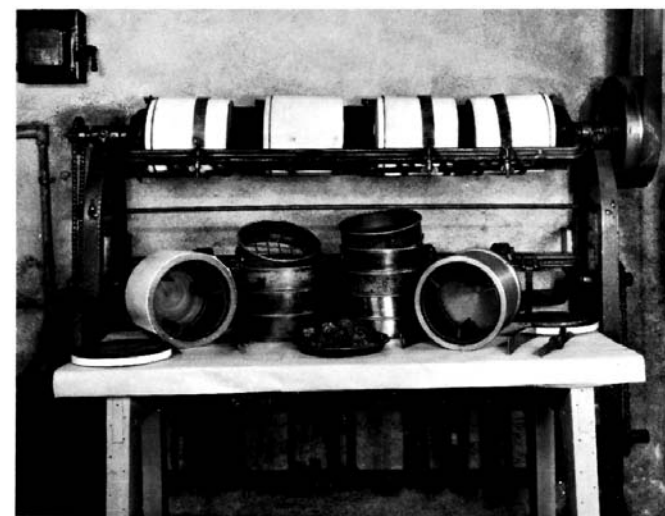
### 5.2 Preparation of Sample:

5.2.1 Make a preliminary sieving of a representative portion, approximately 100 lbs (45 kg), of the gross sample, using square-hole sieves with 1.06- and 1.50-in. (26.9- and 38.1-mm) openings. If this preliminary sieving indicates that the pieces of coal are mostly smaller than 1.50 in., sieve successive representative portions of the gross sample until at least 25 lbs (11 kg) of the 1.06- to 1.50-in. size are obtained. If most of the pieces obtained by the preliminary sieving are larger than 1.50 in., conduct sieving of representative portions of the gross sample until at least 50 lbs (23 kg) of the sieved material remaining on the 1.06-in. sieve are available. Then break the pieces so obtained that are larger than 1.50 in. with a hammer until they pass the 1.50-in. sieve, avoiding as much as possible the production of pieces smaller than 1.06 in. Should the combined weights of the 1.06- to 1.50-in. size, obtained by sieving before and after hammer breakage of the larger pieces, be less than the required 25 lbs, augment the amount by further sieving and breakage of additional representative portions, or the remainder of the gross sample, taking care to discard all pieces in which noticeable cracks have developed by hammer breakage. Take care also to provide pieces covering the whole range of the 1.06- to 1.50-in. size in both the 25-lbs composite sample, and in each 1000-g sample taken for test as in Section 5. This may be accomplished by the use of a 1.25-in. (31.5-mm) sieve to see that approximately half of the weight of the pieces comprising these samples will be between 1.06 and 1.25 in. and half between 1.25 and 1.50 in.

5.2.2 Mix thoroughly the total quantity of the 1.06- to 1.50-in. size and then resieve it to pass the 1.50-in. sieve and be retained on the 1.06-in. sieve. Place only a thin layer of coal on the sieve so as to allow the pieces to be in direct contact with the sieve openings. Upend by hand individual pieces of coal not passing readily through the sieve to determine whether in any position they pass the sieve.

## 6. Procedure

6.1 Weigh approximately 1000 g of the coal sample, prepared in accordance with 5.1, and place it in the jar. Rotate the jar for 1 h in the tumbler test machine at  $40 \pm 1$  rpm. To standardize the time of tumbling, use a revolution counter, either periodically or as permanent accessory equipment to the machine, to ensure that the total number of revolutions during a test is approximately 2400. After tumbling, thoroughly grade the coal as to size upon the sieves designated in 4.3. Carry out the sieving in such small increments as to permit satisfactory contact between the individual pieces of coal and the sieve. On the two larger sieves, 1.06- and 0.750-in. (26.9- and 19.0-mm)



NOTE 1—On the bench are shown typical jar mills in which the three-vane iron frames are fitted, together with a set of 8-in. (200 mm) diameter sieves and a 1000-g charge of 1.06- to 1.50-in. (26.5 to 38.1-mm) size coal. The jar to the left is one of the regular porcelain jars, and that to the right an optional iron jar.

FIG. 2 Tumbler Test Apparatus

that the metal strip may fit evenly, the lower inch of the wall should also have a thickness of not less than 1/2 in.

4.3 *Sieves*—For sizing the sample for test, square-hole sieves having 1.50- and 1.06-in. (38.1- and 26.9-mm) actual openings between the wires shall be used. These sieves may be fitted into frames, 12 by 30 in. (305 by 762 mm) or larger. For sieving the coal after tumbling, square-hole sieves having 1.06-, 0.750-, 0.530-, 0.375-, 0.0469-, and 0.0117-in. (26.9-, 19.0-, 13.5-, 9.51-, 1.19-, and 0.297-mm) actual openings between the wires shall be used. For this purpose, round,

upend by hand individual pieces of coal not readily passing through the sieves to determine whether in any position they pass the sieve.

6.2 Sieving may be carried out either by hand or mechanically, though the former method is preferable.

6.3 Make at least four single-jar tests, and, provided sufficient sample is available, it is recommended that two or more four-jar tests be made. When only four single-jar tests are made, sieve the contents of each jar separately in order to be sure that there is satisfactory agreement between the results obtained. When two or more four-jar tests are made, the contents of the four jars from each set may be mixed and sieved together. Make the weighings to the nearest 1 g.

## 7. Calculations

7.1 The product of the weight percent of the initial 1.06- by 1.50-in. sample and its average sieve opening in inches is normalized to equal 100 % (see Table 1). This is  $S$ .

7.2 After testing, the resultant weight percent distribution is determined. The products of the various normalized average size opening of the size fractions and the respective weight percent are determined. These products are summed. This sum is  $s$  (see Table 1).

7.3 Friability is calculated as  $100 \times (S - s)/S$  and is reported to the nearest 0.5 %.

7.4 Dust index is numerically equal to the percent of -No. 50 (USA Standard) material produced during the tumbler test and is reported as the nearest whole number index (see Table 1).

## 8. Report

8.1 Report friability in percent to the nearest 0.5 %. This is

the percentage reduction in average size of the coal during the tumbler test.

NOTE 1—A numerical example of the method of calculating friability is given in Table 1, where the average of the openings of the retaining and passing sieves is expressed in inches (millimetres) to the nearest 0.001 in. (0.025 mm). The data shown are for a typical coal of medium friability. It is from the average of the sieve openings that the approximate relative size factors, shown as column (3) are derived. In the column to the extreme right,  $S$  represents the average size of the coal pieces before tumbling, and  $s$  the average size of the tumbled coal, the value for  $S$  being arbitrarily chosen as 100 times its corresponding size factor.

## 9. Precision and Bias

9.1 Data for repeatability and reproducibility do not exist but are being determined.

9.2 This is an empirical test method and no statement of bias is possible.

## 10. Keywords

10.1 breakage; coal; coal handling; friability; size stability; tumbler

**TABLE 1 Sieve Analysis of Coal Using Square-Hole Sieves**

NOTE 1—Friability, % =  $100(S - s)/S = 100(100 - 68.56)/100 = 31.4$ . To be reported as: Friability, 31.5 %.

Retained On	Passing	Weight, % (1)	Average of Sieve Openings		Product of (1) × (2)
			Inches	Normalizing Factor (2)	
SAMPLE					
1.06 in. (26.5 mm)	1.50 in. (38.1 mm)	100.0	1.280	1	100.00 = $S$
TUMBLER COAL					
1.06 in. (26.5 mm)	1.50 in. (38.1 mm)	46.2	1.280	1	46.2
0.750 in. (19.0 mm)	1.06 in. (26.5 mm)	26.9	0.905	0.7	18.83
0.530 in. (13.2 mm)	0.750 in. (19.0 mm)	4.0	0.640	0.5	2.00
0.375 in. (9.5 mm)	0.530 in. (13.2 mm)	1.6	0.452	0.35	0.56
0.0469 in. (No. 16)	0.375 in. (9.5 mm)	5.5	0.211	0.16	0.880
0.0117 in. (No. 50)	0.0469 in. (No. 16)	0.5	0.029	0.023	0.012
	0.0117 in. (No. 50) <sup>A</sup>	15.3 <sup>B</sup>	0.006	0.005	0.077
Total (Sum of products (1) × (3) for tumbled coal)					68.56 = $s$

<sup>A</sup> Including loss, not to exceed 0.5 %.

<sup>B</sup> The percentage of "fines and dust" passing the 0.0117-in. (No. 50) sieve represents the proportion of the breakage due to attrition or abrasion rather than to shattering, and may be reported as "dust index" to the nearest whole percent to indicate the relative dust-producing properties of coals when subjected to severe handling. Hence both the friability in percent and the "dust index" may be reported as follows: Friability, % = 31.5; with dust index of 15.

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