Designation: D 6393 – 99

Standard Test Method for Bulk Solids Characterization by Carr Indices[1]

This standard is issued under the fixed designation D 6393; 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.

1. Scope

1.1 This test method covers the apparatus and procedures for measuring properties of bulk solids, henceforth referred to as Carr Indices.[2]

1.2 This test method is suitable for free flowing and moderately cohesive powders and granular materials up to 2.0 mm in size. Materials must be able to pour through a 7.0 ± 1.0-mm diameter funnel outlet when in an aerated state.

1.3 This method consists of eight measurements and two calculations to provide ten tests for Carr Indices. Each individual test or a combination of several tests can be used to characterize the properties of bulk solids. These ten tests are as follows:

1.3.1 *Test A*—Measurement of Carr Angle of Repose
1.3.2 *Test B*—Measurement of Carr Angle of Fall
1.3.3 *Test C*—Calculation of Carr Angle of Difference
1.3.4 *Test D*—Measurement of Carr Loose Bulk Density
1.3.5 *Test E*—Measurement of Carr Packed Bulk Density
1.3.6 *Test F*—Calculation of Carr Compressibility
1.3.7 *Test G*—Measurement of Carr Cohesion
1.3.8 *Test H*—Measurement of Carr Uniformity
1.3.9 *Test I*—Measurement of Carr Angle of Spatula
1.3.10 *Test J*—Measurement of Carr Dispersibility

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. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *Carr angle of difference*, *n*—the difference between the Carr angle of repose and Carr angle of fall.

2.1.2 *Carr angle of fall*, *n*—an angle of repose measured from a powder heap to which a defined vibration has been given.

2.1.3 *Carr angle of repose*, *n*—a measurement from the powder heap built up by dropping the material through a vibrating sieve and funnel above a horizontal plate.

2.1.4 *Carr angle of spatula*, *n*—a measurement by which a spatula is inserted into a powder heap parallel to the bottom and then lifting it up and out of the material.

2.1.5 *Carr cohesion*, *n*—a descriptive measure of interparticle forces based on the behavior of the material during sieving.

2.1.6 *Carr compressibility*, *n*—a calculation made by using Carr loose bulk density and Carr packed bulk density as determined in 5.8.

2.1.7 *Carr dispersibility*, *n*—a measurement by which a powder sample is dropped through a hollow cylinder above a watch glass and then the amount of powder collected by the watch glass is measured.

2.1.8 *Carr dynamic bulk density*, *n*—a calculated bulk density of a material. It is used to compute vibration time for the Carr cohesion measurement.

2.1.9 *Carr loose bulk density*, *n*—a measurement obtained by sieving the sample through a vibrating chute to fill a measuring cup.

2.1.10 *Carr packed bulk density*, *n*—a measurement obtained by dropping a measuring cup, which is filled with the sample, a specific number of times from the same height. Sometimes known as a *tapped density*.

2.1.11 *Carr uniformity*, *n*—a measurement calculated from the particle size distribution of the powder as measured by sieving.

3. Significance and Use

3.1 This test method provides measurements that can be used to describe the bulk properties of a powder or granular material.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.24 on Characterization and Handling of Powders and Bulk Solids.

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[2] Carr, R.L., "Evaluating Flow Properties of Solids," *Chemical Engineering*, January 18, 1965, pp. 163–168.

3.2 The measurements can be combined with practical experience to provide relative rankings of various forms of bulk handling behavior of powders and granular materials for a specific application.

4. Apparatus

4.1 The main instrument includes a *timer/counter* (A), a *vibrating mechanism* (B), an *amplitude gage* (C), a *rheostat* (D), and a *tapping device* (E) (see Fig. 1).[3]

4.1.1 *Timer/Counter*—The timer is used to control the duration of vibration and the number of taps. A minimum 180-s timer for 60 Hz power supply is required. Alternatively, a counter can be used to control the number of taps.

4.1.2 *Vibrating Mechanism*, to deliver vibration at 50 to 60 Hz to the vibration plate at an amplitude of 0.0 to 3.0 mm.

4.1.3 *Amplitude Gage*, mounted on the vibration plate to measure the amplitude of the vibration from 0.0 to 4.0 mm.

4.1.4 *Rheostat*—A dial used to adjust the vibration amplitude of vibration plate from 0.0 to 3.0 mm.

4.1.5 *Tapping Device*, consists of tap holder and tapping lift bar (tapping pin), which lifts and free-fall drops a measuring cup a stroke of 18.0 ± 0.1 mm and a rate of 1.0 ± 0.2 taps/s.

4.2 The spatula assembly consists of a *spatula blade* (A), a *pan base/elevator stand* (B), and a *shocker* (C) (see Fig. 2).

4.2.1 *Spatula Blade*—A chrome-plated brass plate mounted on the blade receiver to retain powder while elevator stand lowers the powder-filled pan. The dimensions of the spatula blade are 80 to 130 mm length, 22.0 ± 0.3-mm width and 3.0 ± 0.3-mm thick.

4.2.2 *Shocker*—A sliding bushing with a mass of 110.0 ± 1.0 g at a drop height of 150.0 ± 10.0 mm, measured from the lower edge of the bushing to the shocker base for the measurement of angle of spatula. The total mass of the shocker assembly including the sliding bushing, pole, spatula blade, and blade receiver is 0.65 ± 0.35 kg.

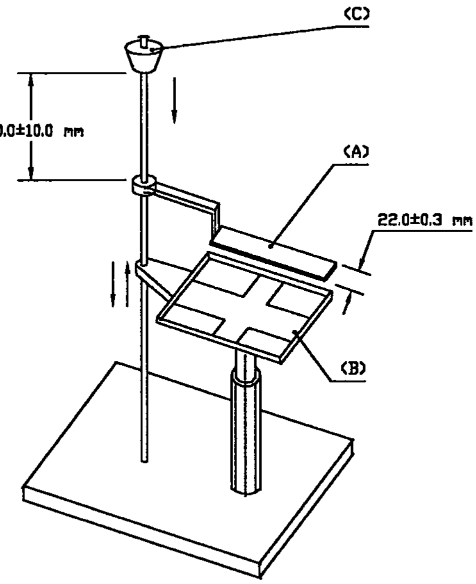

FIG. 2 Carr Spatula Assembly

4.3 A dispersibility measuring unit consists of a *container* (A) with *shutter cover* (B), a *cylindrical glass tube* (C), and a *watch glass* (D), (see Fig. 3).

4.3.1 *Container*—A hopper unit with a shutter cover at the bottom to support a powder sample. The shutter cover opens horizontally to release the powder sample which then falls through the glass tube onto the watch glass.

4.3.2 *Cylindrical Glass Tube*, located vertically 170.0 ± 10.0 mm under the shutter cover to confine the scattering/dispersed powder. The dimension of the tube is 100.0± 5.0-mm diameter and 330.0 ± 10.0-mm length.

4.3.3 *Watch Glass*, centered 101.0 ± 1.0 mm under the cylindrical glass tube to collect undispersed powder. The

[3] Available from Hosokawa Micron International Inc., New York, NY.

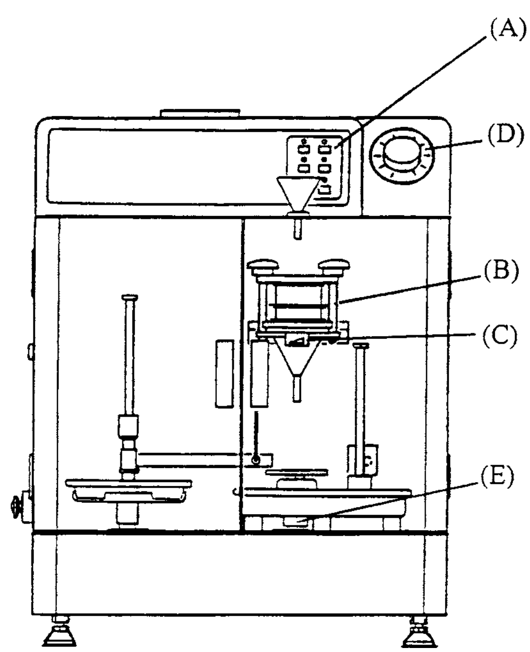

FIG. 1 Powder Characteristics Tester for Carr Indices

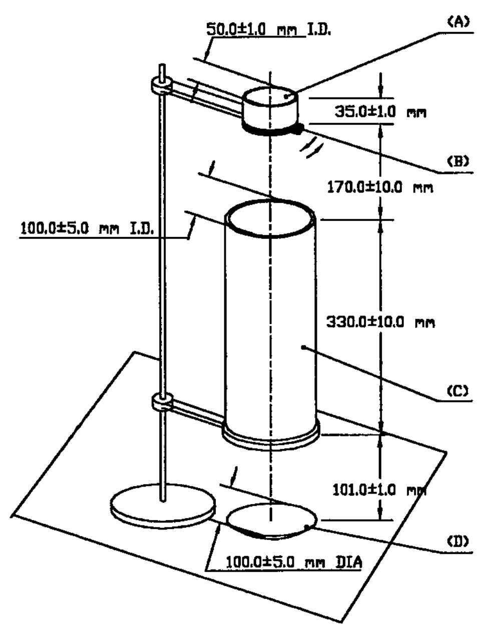

FIG. 3 Carr Dispersibility Measuring Unit

dimension of watch glass is 100.0 ± 5.0-mm diameter and 2.0 ± 0.1-mm thickness with the radius of curvature of 96.3 mm, concave upwards.

4.4 *Accessories*:

4.4.1 *Spatula Pan*—A stainless steel pan with at least a 100.0-mm width, a 125.0-mm length, a 25.0 mm height, and a 1.0-mm thickness, used to retain powder for the preparation of the measurement of Carr angle of spatula.

4.4.2 *Scoop*—A stainless steel container used to transport powder.

4.4.3 *Scraper*—A chrome plated brass or stainless steel plate used to scrape off excess powder in the cup.

4.4.4 *Cup*—A 100-cm^3 stainless steel cylindrical container with the inside dimensions of 50.5 ± 0.1-mm diameter and 49.9 ± 0.1-mm height used for Carr bulk density measurement. The wall thickness of the cup is 1.75 ± 0.25 mm. The interior walls of the cup are sufficiently smooth that machining marks are not evident.

4.4.5 *Cup Extension*—A white Delrin™[4] extension sleeve for the 100 cm^3 measuring cup, 55.0 ± 0.1 mm in diameter by 48.0 ± 1.0 mm in height.

4.4.6 *Funnel for Angle of Repose*—A glass funnel with 55° angle bowls as measured from the horizontal, 7.0 ± 1.0-mm bottom outlet diameter and outlet stem length 33.5 mm for the measurement of Carr angle of repose.

4.4.7 *Stationary Chute*—A stainless steel conical chute with the dimensions of 75.0-mm top diameter, 55.0-mm height, and 50.0-mm bottom diameter to guide the powder flow into the measuring cup (see 4.4.4).

4.4.8 *Vibration Chute*—A stainless steel conical chute with the dimensions of 75.0-mm top diameter, 55.0-mm height, and 50.0-mm bottom diameter installed on the vibration plate to guide the powder flow to the stationary chute or cup extension.

4.4.9 *Sieves*, certified 76.0-mm diameter stainless steel sieves with the opening of 710 µm, 355 µm, 250 µm, 150 µm, 75 µm, and 45 µm.

4.4.10 *Sieve Extension*—A stainless steel extension piece used as a spacer in the vibration unit when only one sieve is used.

4.4.11 *Spacer Ring*—A white Delrin™ spacer inserted between sieve and vibration chute or glass funnel to protect them from damage.

4.4.12 *Sieve Holding Bar*—A chrome-plated brass holding bar used to hold sieve assembly on the vibration plate.

4.4.13 *Pan*, with base for tapping device, measuring cup, and shocker. A stainless steel pan, at least 210.0-mm length, 150.0-mm width, 35.0-mm height, and 1.0-mm thickness, designed to accept tapping device, measuring cup and platform, as well as provide a stand base for shocker.

4.4.14 *Platform*—A chrome-plated brass circular platform with a diameter of 80.0 ± 0.3 mm and a height of 59.0 ± 2.0 mm to be used for the measurement of Carr angle of repose.

4.4.15 *Shocker*—A sliding bushing with a mass of 110.0 ± 1.0 g at a drop height of 150.0 ± 10.0 mm, measured from the lower edge of the bushing to the shocker base for the measurement of Carr angle of fall. The total mass of the shocker, platform, and pan for the measurement of angle of fall is 1.35 ± 0.25 kg.

NOTE 1—The pan has molded-in feet so it is slightly raised from the table top. This helps make vibration more consistent.

4.4.16 *Brush*, a laboratory brush for dust removal.

4.4.17 *Cover*, for measuring dispersibility. A removable enclosure to confine the dust of sample powder when it falls onto the watch glass for the measurement of Carr dispersibility.

4.5 *Balance*, capable of measuring sample mass to an accuracy of ± 0.01 g with a max of 2.0 kg.

4.6 *Data Acquisition Equipment*—A microprocessor or computer may be used to guide the measuring operation, collect data, calculate data, and print test results.

5. Procedure

5.1 A representative powder sample from process stream should be riffled carefully into portions for each individual measurement.

5.2 All the measurements should be performed on a strong, horizontally-leveled bench or work table. If possible, use a concrete or stone-topped table.

Test A—Measurement of Carr Angle of Repose

5.3 *Placement of Parts*:

5.3.1 Place the parts onto the vibration plate in the following order starting at the bottom:

5.3.1.1 Glass funnel;

5.3.1.2 Spacer ring;

5.3.1.3 Sieve with opening of 710 µm;

5.3.1.4 Sieve extension; and,

5.3.1.5 Sieve holding bar.

5.3.2 Fasten the vibration assembly with knob nuts located on both sides of sieve holding bar.

5.3.3 Center the platform under the glass funnel.

5.3.4 Position the stem end of the glass funnel 76.0± 1.0 mm above the platform.

5.3.5 Set desired vibration time on timer (usually 180 s on 60 Hz vibrating frequency is selected).

5.3.6 Pour 200 to 300 cm^3 of powder over the sieve using the scoop.

5.3.7 Set vibration adjustment dial (Rheostat) to 0.

5.3.8 Turn on the vibrating mechanism and timer.

5.3.9 Gradually increase the amplitude of the vibration, no more than 0.2 mm at a time, by incrementally turning the vibration adjustment dial until powder starts to flow out of the end of the glass funnel and builds up on the circular platform in a conical shape.

5.3.10 Turn off the vibration mechanism when the powder starts to fall from the edge of the platform and the powder pile is completely formed.

5.3.11 If a conical shape is not completely formed, remove the powder pile and repeat steps 5.3.6-5.3.10.

5.3.12 After the cone has been built up, calculate an average angle of the cone (from horizontal) in relation to the edge of the platform by the equation below. This average angle is called the Carr angle of repose.

$$\text{Carr Angle of Repose} = \tan^{-1} [H/R] \quad (1)$$

[4] Delrin™