~~Designation:D6393–99 (Reapproved 2006)~~ Designation: D 6393 – 08

# 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

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

1.1 This test method covers an 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~~6.0 to 8.0-mm diameter funnel outlet when in an aerated state.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 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~~1.4.1 *Test A*—Measurement of Carr Angle of Repose

~~1.3.2~~

1.4.2 *Test B*—Measurement of Carr Angle of Fall

~~1.3.3~~

1.4.3 *Test C*—Calculation of Carr Angle of Difference

~~1.3.4~~

1.4.4 *Test D*—Measurement of Carr Loose Bulk Density

~~1.3.5~~

1.4.5 *Test E*—Measurement of Carr Packed Bulk Density

~~1.3.6~~

1.4.6 *Test F*—Calculation of Carr Compressibility

~~1.3.7~~

1.4.7 *Test G*—Measurement of Carr Cohesion

~~1.3.8~~

1.4.8 *Test H*—Measurement of Carr Uniformity

~~1.3.9~~

1.4.9 *Test I*—Measurement of Carr Angle of Spatula

~~1.3.10~~

1.4.10 *Test J*—Measurement of Carr Dispersibility

~~1.4~~

1.5 *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~~ Referenced Documents

2.1 *ASTM Standards:* [3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids



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

~~Current edition approved Oct. 15, 2006. Published April 2007. Originally approved in 1999. Last previous edition approved in 1999 as D6393–99.~~

Current edition approved Oct. 1, 2008. Published October 2008. Originally approved in 1999. Last previous edition approved in 2006 as D 6393 – 99 (2006).

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

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

[3] 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.

***A Summary of Changes section appears at the end of this standard.**

D 3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D 6026 Practice for Using Significant Digits in Geotechnical Data

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*
2.1.1*Carr angle of difference*For common definitions of terms in this test method, refer to Terminology D 653.
3.1.1 *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*—the difference between the Carr Angle of Repose and Carr Angle of Fall.
3.1.2 *Carr Angle of Fall*, *n*—an angle of repose measured from a powder heap to which a defined vibration impulse shock has been given.
2.1.33.1.3 *Carr angleAngle of reposeRepose*, *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*
3.1.4 *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*—a measurement from the powder heap formed on a spatula that had been buried and then extracted from a bed of powder.
3.1.5 *Carr Cohesion*, *n*—a descriptive measure of interparticle forces based on the behavior of the material during sieving.
2.1.6*Carr compressibility*—a descriptive measure of interparticle forces based on the rate at which particles pass through sieves.
3.1.6 *Carr Compressibility*, *n*—a calculation made by using Carr loose bulk density and Carr packed bulk density as determined in 5.8—a calculation made by using Carr Loose Bulk Density and Carr Packed Bulk Density as determined in 6.8.
2.1.7*Carr dispersibility*
3.1.7 *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*
3.1.8 *Carr Dynamic Bulk Density*, *n*—a calculated bulk density of a material. It is used to compute vibration time for the Carr cohesionCohesion measurement.
2.1.93.1.9 *Carr loose bulk densityLoose 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*
3.1.10 *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*Tapped Bulk Density.
2.1.11*Carr uniformity*
3.1.11 *Carr Uniformity*, *n*—a measurement calculated from the particle size distribution of the powder as measured by sieving.



## 3.Significance and Use

3.1This test method provides measurements that can be used to describe the bulk properties of a powder or granular material.
3.2The 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.

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NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors. Practice D 3740 was developed for agencies engaged in the testing or inspection (or both) of soil and rock. As such it is not totally applicable to agencies performing this standard. However, users of this standard should recognize that the framework of Practice D 3740 is appropriate for evaluating the quality of an agency performing this standard. Currently there is no known qualifying national authority that inspects agencies that perform this standard.

## 5. Apparatus

4.1The5.1 The main instrument includes a *timer/counter* (A), a *vibrating mechanism* (B), an *amplitude gage* amplitude gauge (C), a *rheostat* (D), and a *tapping device* (E) (see Fig. 1).

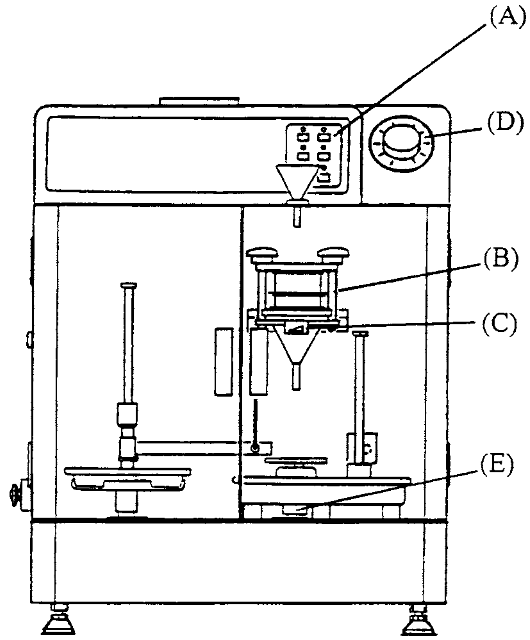


FIG. 1 Powder Characteristics Tester for Carr Indices

4.1.1[4]

5.1.1 *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

5.1.2 *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*

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

4.1.4

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

4.1.5

5.1.5 *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 andat a rate of 1.0 ± 0.2 taps/s.

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



[4] Delrin®

[4] The sole source of supply of the apparatus known to the committee at this time is Hosokawa Micron International Inc., 10 Chatham Road, Summit, NJ. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

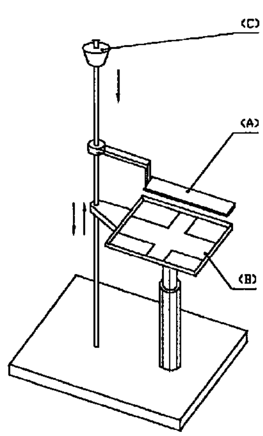


FIG. 2 Carr Spatula Assembly

~~4.2.1~~

5.2.1 *Spatula Blade*— A chrome-plated brass plate mounted on the blade receiver to retain powder while the elevator stand lowers the powder-filled pan. The dimensions of the spatula blade are 80 to 130 mm length, ~~22.0 ± 0.3-mm~~21.0 to 23.0-mm width and 3.0 ~~± 0.3-mm~~to 6.0-mm thick.

~~4.2.2~~5.2.2 *Spatula Shocker*— A sliding bushing with a mass of ~~110.0 ± 1.0~~109.0 to 111.0 g ~~at~~and a drop height of ~~150.0 ± 10.0~~140.0 to 160.0 mm, measured from the lower edge of the bushing to the shocker base for the measurement of Carr Angle of ~~spatula.~~Spatula. The total mass of the shocker assembly including the sliding bushing, pole, spatula blade, and blade receiver is ~~0.65 ± 0.35~~0.3 to 1.0 kg.

~~4.3~~5.3 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~~

5.3.1 *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~~

5.3.2 *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~~*, located vertically 160 to 180 mm under the shutter cover to confine the scattering/dispersed powder. The dimension of the tube is 90 to 110-mm diameter and 320 to 360-mm length.*

5.3.3 *Watch Glass*, centered ~~101.0 ± 1.0~~100 to 105 mm under the cylindrical glass tube to collect undispersed powder. The dimension of watch glass is ~~100.0 ± 5.0-mm~~90 to 110-mm diameter and ~~2.0 ± 0.1-mm~~ about 2.0-mm thickness with the radius of curvature of about 96.3 mm, concave upwards.

~~4.4~~5.4 *Accessories*:

~~4.4.1~~

5.4.1 *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~~Angle of ~~spatula.~~Spatula.

~~4.4.2~~5.4.2 *Scoop*—A stainless steel container used to transport powder.

~~4.4.3~~

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

~~4.4.4~~

5.4.4 *Cup*—A 100-cm $^3$ stainless steel cylindrical container with the inside dimensions of ~~50.5 ± 0.1-mm~~49.9 to 50.1-mm diameter and 49.9 ~~± 0.1-mm~~ to 50.1 mm height used for Carr ~~bulk density~~Bulk Density measurement. The wall thickness of the cup is ~~1.75 ± 0.25~~1.3 to 2.3 mm. The interior walls of the cup are sufficiently smooth that machining marks are not evident.

~~4.4.5~~5.4.5 *Cup Extension*— A white ~~Delrin™~~ Delrin (trademarked) 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~~*measuring cup, 53.0 to 55.0 mm in diameter by 47.0 to 49.0 mm in height.*

5.4.6 *Funnel for Carr Angle of Repose* —A glass funnel with about a 55° angle bowl as measured from the horizontal, 6.0 to 8.0 mm bottom outlet diameter and outlet stem length 32.0 to 36.0 mm for the measurement of Carr Angle of Repose.

5.4.7 *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~~— A stainless steel conical chute with the



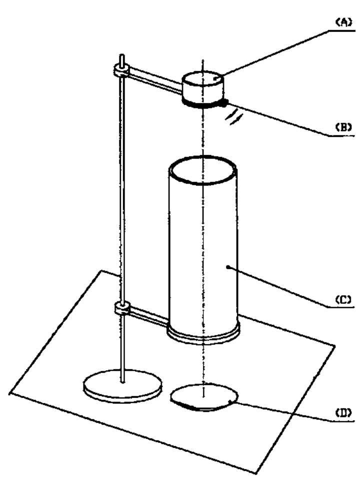


**FIG. 3 Carr Dispersibility Measuring Unit**

dimensions of 73.0 to 77.0 mm top diameter, 53.0 to 57.0 mm height, and 48.0 to 52.0 mm bottom diameter to guide the powder flow into the measuring cup (see 5.4.4).

~~4.4.8~~

5.4.8 *Vibration Chute*— A stainless steel conical chute with the dimensions of ~~75.0-mm~~ 73.0 to 77.0 mm top diameter, ~~55.0-mm~~ 53.0 to 57.0 mm height, and ~~50.0-mm~~ 48.0 to 52.0 mm bottom diameter installed on the vibration plate to guide the powder flow to the stationary chute or cup extension.

~~4.4.9~~5.4.9 *Sieves*, certified 76.0-mm diameter stainless steel sieves with ~~the opening~~ openings of 710 µm, 355 µm, 250 µm, 150 µm, 75 µm, and 45 µm.

~~4.4.10~~5.4.10 *Sieve Extension*— A stainless steel extension piece used as a spacer in the vibration unit when only one sieve is used.

~~4.4.11~~

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

~~4.4.12~~5.4.12 *Sieve Holding Bar*—A chrome-plated brass holding bar used to hold sieve assembly on the vibration plate.

~~4.4.13~~

5.4.13 *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.~~ , with base for tapping device, measuring cup, and shocker. A stainless steel pan, at least 200-mm length, 140-mm width, 30-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.

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~~ *2—The pan has molded-in feet so it is slightly raised from the table top. This helps make vibration more consistent.*

5.4.14 *Platform*—A chrome-plated brass circular platform with a diameter of 79.0 to 81.0 mm and a height of 58.0 to 62.0 mm to be used for the measurement of Carr Angle of Repose.

5.4.15 *Shocker*—A sliding bushing with a mass of 109.0 to 111.0 g at a drop height of 140.0 to 160.0 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 1.1 to 1.6 kg.

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

~~4.4.17~~

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

~~4.5~~5.5 *Balance*, capable of measuring sample mass to an accuracy of ± 0.01 g with a max of 2.0 kg.

~~4.6~~

5.6 *Scale (ruler)*, with mm increments, at least 150 mm long.

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

**~~5.~~—A microprocessor or computer may be used to guide the measuring operation, collect data, calculate data, and print test results. Also, a properly calibrated photo image of the powder cone can be used for relevant measurement.**

## 6. Procedure

~~5.1A~~6.1 A representative powder sample from process stream should be riffled carefully into portions for each individual measurement.

~~5.2All~~6.2 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~~

6.3 *Placement of Parts*:

~~5~~6.3.1 Place the parts onto the vibration plate in the following order starting at the bottom:

~~5~~6.3.1.1 Glass funnel;

~~5~~6.3.1.2 Spacer ring;

~~5~~6.3.1.3 Sieve with opening of 710 µm;

~~5~~6.3.1.4 Sieve extension; and,
~~5~~6.3.1.5 Sieve holding bar.
~~5~~6.3.2 Fasten the vibration assembly with knob nuts located on both sides of sieve holding bar.
~~5~~6.3.3 Center the platform under the glass funnel.
~~5~~6.3.4 Position the stem end of the glass funnel ~~76.0± 1.0~~ 75.0 to 77.0 mm above the platform.
~~5.3.5Set~~6.3.5 Set desired vibration time on timer (usually 180 s on 60 Hz vibrating frequency is selected).
~~5.3.6~~6.3.6 Pour 200 to 300 $cm^3$ of powder over the sieve using the scoop.
~~5.3.7Set~~6.3.7 Set vibration adjustment dial (Rheostat) to 0.
~~5~~6.3.8 Turn on the vibrating mechanism and timer.
~~5~~6.3.9 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~~6.3.10 Turn off the vibration mechanism when the powder starts to fall from the edge of the platform and the powder pile is completely formed.
~~5.3.11If~~6.3.11 If a conical shape is not completely formed, remove the powder pile and repeat steps ~~5.3.6-5.3.10~~6.3.6-6.3.10.
~~5.3.12~~6.3.12 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~~Angle of ~~repose.~~Repose.

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

where:
$H$ = Height of the powder pile, mm, and
$R$ = Radius of the circular platform, mm.

~~5.3.13~~
6.3.13 Indicate the shape of the cone either Concave Up (A), Concave Down (B), or Straight (C) (see Fig. 4) in the report.
~~5.3.14If~~6.3.14 If the cone is irregular in shape, repeat the test three times and obtain an average.
~~5.3.15If~~6.3.15 If the powder has free-flowing characteristics or has coarse particles larger than 710 µm, the vibration and 710 µm sieve are not necessary. In this case, use the scoop to slowly pour the powder through the funnel. Adjust the pouring rate so that it takes 15 to 30 s to form the conical pile.



**Test B—Measurement of Carr Angle of Fall**

~~5.4After~~6.4 After determining the Carr Angle of Repose as in ~~5.3~~6.3, place the shocker on the shocker base.
~~5.5Then~~6.4.1 Then raise the sliding bushing carefully (so that the cone will not be disturbed) to the upper end of the pole (at a drop height of ~~150.0 ± 10.0~~140.0 to 160.0 mm) and let it fall to give a shock to the pan. Repeat this three times. The powder layer will be collapsed and exhibit a smaller angle of repose.
~~5.6Wait~~6.4.2 Wait for 30 s after the final shock and then measure the angle as described in ~~5.3.12-5.3.14~~6.3.12-6.3.14. This new, lower angle is called Carr ~~angle~~Angle of ~~fall.~~ Fall.

**Test C—Calculation of Carr Angle of Difference**

~~5.7Subtract the Carr angle of fall from the Carr angle of repose to obtain the Carr angle of difference.~~
6.5 Subtract the Carr Angle of Fall from the Carr Angle of Repose to obtain the Carr Angle of Difference.

**Test D—Measurement of Carr Loose Bulk Density**

~~5.8~~
6.6 *Placement of Parts*:
~~5.8.1Place~~6.6.1 Place the parts onto the vibration plate in the following order starting at the bottom:
~~5.8.1.1Vibration~~6.6.1.1 Vibration chute;
~~5.8.1.2Spacer~~6.6.1.2 Spacer ring;
~~5.8.1.3Sieve~~6.6.1.3 Sieve with opening of 710 µm;
~~5.8.1.4Sieve~~6.6.1.4 Sieve extension; and,

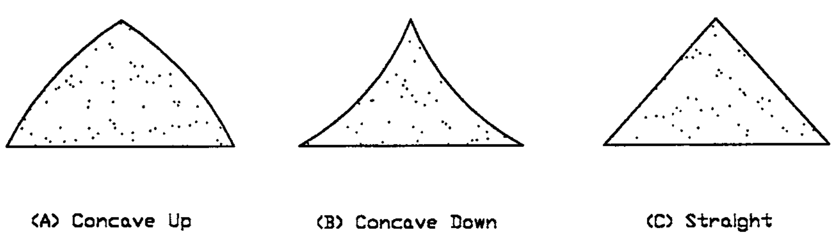


**FIG. 4 The Shape of the Powder Pile**