Change to read:

⟨616⟩ BULK DENSITY ▲▲ (USP 1-May-2024) OF POWDERS

Change to read:

▲▲ (USP 1-MAY-2024)

This general chapter has been harmonized with the corresponding texts of the *European Pharmacopoeia* and/or the *Japanese Pharmacopoeia*. Portions of this chapter that are national *USP* text, and are not part of the harmonized text, are marked with symbols (♦♦) to specify this fact.

The bulk density of a powder is the ratio of the mass of a ▲▲ (USP 1-May-2024) powder sample ▲to▲ (USP 1-May-2024) its volume, including the contribution of the interparticulate void volume. Hence, the bulk density depends on ▲the material density and the packing arrangement in the powder bed.▲ (USP 1-May-2024) Bulk density is ▲commonly▲ (USP 1-May-2024) expressed in grams per milliliter ▲▲ (USP 1-May-2024) (1 g/mL = ▲1 g/cm^3 =▲ (USP 1-May-2024) 1000 kg/m^3) ▲▲ (USP 1-May-2024)·

The bulk▲▲ (USP 1-May-2024) properties of a powder are dependent upon the preparation, treatment, and storage of the sample, i.e., how it ▲has been▲ (USP 1-May-2024) handled. The particles can be packed to have a range of bulk densities. ▲Therefore, it is necessary to differentiate the untapped bulk density and tapped bulk density.

The tapped and untapped bulk densities are used to evaluate powder flow. A comparison of the tapped bulk and untapped bulk densities can give an indirect measure of the relative importance of the interparticulate interactions influencing the bulk properties of a powder. For comparison specifics, please see section *Measures of Powder Compressibility*. For additional context, please see general chapter *Powder Flow ⟨1174⟩*.

Untapped Bulk Density▲ (USP 1-May-2024)

The ▲untapped▲ (USP 1-May-2024) bulk density of a powder is determined by measuring the volume of a known ▲mass▲ (USP 1-May-2024) of powder sample, ▲which▲ (USP 1-May-2024) may have been passed through a sieve, in ▲▲ (USP 1-May-2024) a graduated cylinder (*Method 1*), or by measuring the mass of a known volume of powder that has been passed through a volumeter into a cup (*Method 2*) or ▲has been introduced into▲ (USP 1-May-2024) a measuring vessel (*Method 3*).

▲The slightest disturbance of the powder bed may result in a changed untapped bulk density, especially for cohesive powders. In these cases, the untapped bulk density is often very difficult to measure with good reproducibility and, in reporting the results, it is essential to specify how the determination was made.▲ (USP 1-May-2024)

Method 1—Measurement in a Graduated Cylinder

PROCEDURE

Pass a quantity of ▲powder▲ (USP 1-May-2024) sufficient to complete the test through a sieve with apertures greater than or equal to 1.0 mm, if necessary, to break up agglomerates that may have formed during storage; this must be done gently to avoid changing the nature of the ▲powder. Gently pour approximately 100 g (m) of the test sample, weighed with 0.1% accuracy, into a dry graduated 250-mL cylinder (readable to 2 mL). Any significant compacting stress should be avoided, for example, by using a funnel or by tilting the graduated cylinder. If necessary,▲ (USP 1-May-2024) carefully level the powder without compacting, and read the ▲untapped bulk▲ (USP 1-May-2024) volume (V_0) to the nearest graduated unit. Calculate the ▲untapped▲ (USP 1-May-2024) bulk density in grams per milliliter ▲using▲ (USP 1-May-2024) the formula m/V_0. ▲▲ (USP 1-May-2024) Replicate determinations ▲performed on separate powder samples▲ (USP 1-May-2024) are desirable ▲▲ (USP 1-May-2024)·

If the powder density is too low or too high, such that the test sample has an untapped ▲bulk▲ (USP 1-May-2024) volume of ▲▲ (USP 1-May-2024) more than 250 mL or less than 150 mL, it is not possible to use 100 g of powder sample. ▲In this case,▲ (USP 1-May-2024) a different amount of powder ▲is▲ (USP 1-May-2024) selected as the test sample, such that its untapped ▲bulk▲ (USP 1-May-2024) volume is ▲between▲ (USP 1-May-2024) 150 mL and 250 mL (▲i.e. untapped bulk▲ (USP 1-May-2024) volume greater than or equal to 60% of the total volume of the ▲graduated▲ (USP 1-May-2024) cylinder); the ▲mass▲ (USP 1-May-2024) of the test sample is specified in the expression of results.

For test samples having an ▲untapped bulk▲ (USP 1-May-2024) volume between 50 mL and 100 mL, a 100-mL ▲graduated▲ (USP 1-May-2024) cylinder readable to 1 mL can be used; the volume of the ▲graduated▲ (USP 1-May-2024) cylinder is specified in the expression of results.

Method 2—Measurement in a Volumeter

APPARATUS

The apparatus[1] (*Figure 1*) consists of a top funnel fitted with a 1.0-mm sieve, ▲▲ (USP 1-May-2024) mounted over a baffle box containing 4 glass baffles ▲▲ (USP 1-May-2024) over which the powder slides and bounces as it passes. At the bottom of the baffle box is a funnel that collects the powder and allows it to pour into a cup ▲▲ (USP 1-May-2024) mounted directly below it. The cup may be cylindrical (25.00 ± 0.05 mL volume with an ▲internal▲ (USP 1-May-2024) diameter of ▲29.50 ± 2.50▲ (USP 1-May-2024) mm) or

cubical (16.39 ± ▲0.05▲ (USP 1-May-2024) mL volume ▲▲ (USP 1-May-2024)). ▲
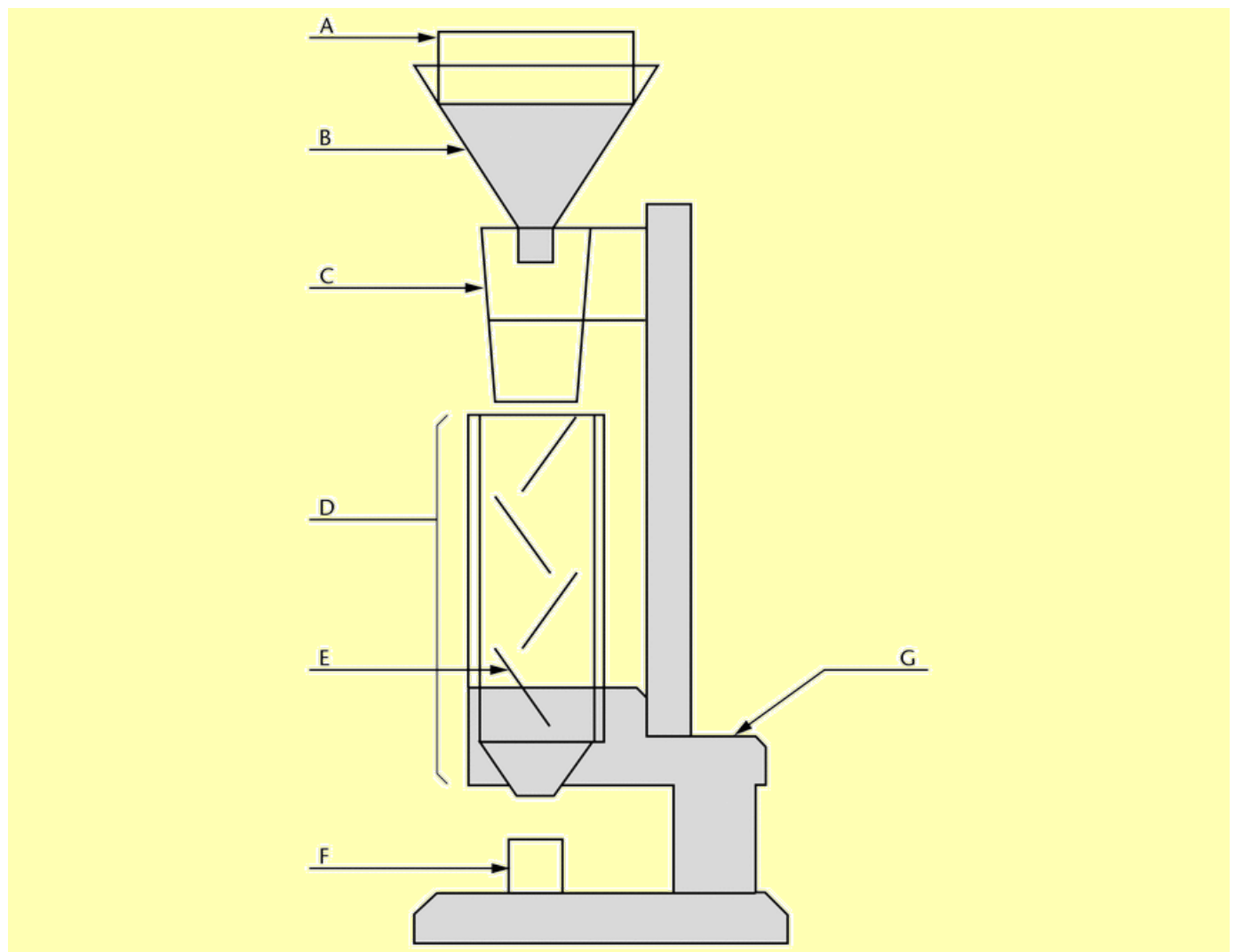
Click image to enlarge

Figure 1. Volumeter. (**A**) 1.0-mm sieve; (**B**) powder funnel; (**C**) loading funnel; (**D**) baffle box; (**E**) glass baffle; (**F**) cup; (**G**) stand.
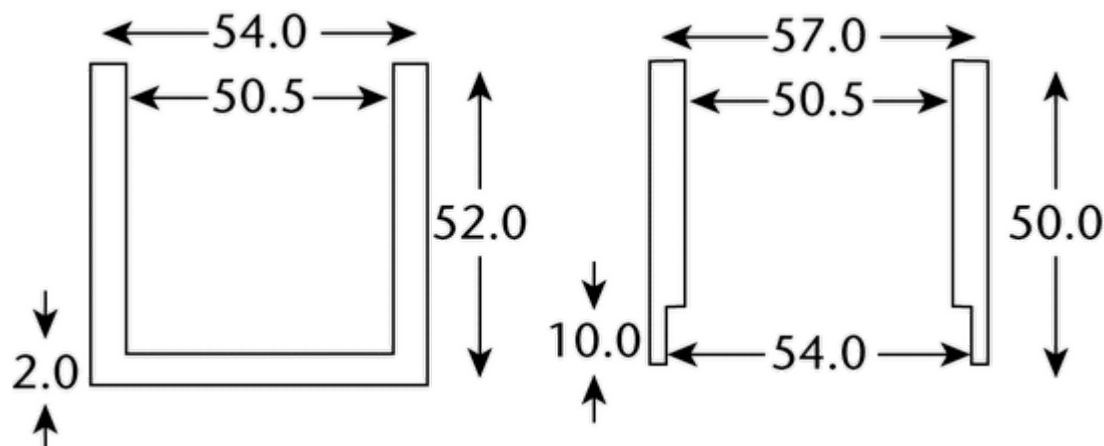
▲ (USP 1-May-2024)

PROCEDURE

Allow an excess of powder to flow through the apparatus into the sample receiving cup until it overflows, using a minimum of 25 cm^3 of powder with the ▲cubical▲ (USP 1-May-2024) cup and 35 cm^3 of powder with the cylindrical cup. Carefully, scrape excess powder from the top of the cup by smoothly moving the edge of a ▲reclined▲ (USP 1-May-2024) spatula ▲blade across▲ (USP 1-May-2024) the top surface of the cup, taking care to keep the spatula ▲tilted backwards▲ (USP 1-May-2024) to prevent packing or removal of powder from the cup. Remove any ▲powder▲ (USP 1-May-2024) from the side of the cup and determine the ▲mass▲ (USP 1-May-2024) (m) of the powder to the nearest 0.1%. Calculate the ▲untapped▲ (USP 1-May-2024) bulk density in grams per milliliter using the formula m/V_0 (where V_0 is the

volume ▲_{▲ (USP 1-May-2024)} of the cup). ▲Replicate determinations performed on separate powder samples are desirable.▲ (USP 1-May-2024)

Method 3—Measurement in a Vessel

APPARATUS

The apparatus consists of a 100-mL cylindrical ▲_{▲ (USP 1-May-2024)} stainless steel vessel with dimensions as specified in *Figure 2*.

Click image to enlarge

Figure 2. ▲Measuring vessel (left) and cap (right). Dimensions in millimeters.▲ (USP 1-May-2024)

PROCEDURE

Pass a quantity of powder sufficient to complete the test through a 1.0-mm sieve, if necessary, to break up agglomerates that may have formed during storage, and allow the obtained sample to flow freely into the measuring vessel until it overflows. Carefully scrape the excess powder from the top of the vessel as described under *Method 2*. Determine the ▲mass▲ (USP 1-May-2024) (m_0) of the powder to the nearest 0.1% by ▲subtracting▲ (USP 1-May-2024) the previously determined mass of the empty measuring vessel. Calculate the ▲untapped▲ (USP 1-May-2024) bulk density in grams per milliliter using the formula $m_0/100$. ▲Replicate determinations performed on separate powder samples are desirable.▲ (USP 1-May-2024)

Change to read:

TAPPED ▲BULK▲ (USP 1-MAY-2024) DENSITY

The tapped ▲bulk▲ (USP 1-May-2024) density is an increased bulk density attained after mechanically tapping a ▲receptacle▲ (USP 1-May-2024) containing the powder sample. The tapped ▲bulk▲ (USP 1-May-2024) density is obtained by mechanically tapping a graduated ▲_{▲ (USP 1-May-2024)} cylinder or vessel containing the powder sample. After ▲recording▲ (USP 1-May-2024) the initial ▲untapped bulk▲ (USP 1-May-2024) volume ▲(V_0) and mass (m_0) of the powder sample,▲ (USP 1-May-2024) the ▲graduated▲ (USP 1-May-2024) cylinder or

vessel is mechanically tapped, and volume or ▲mass▲ (USP 1-May-2024) readings are taken until little further volume or ▲mass▲ (USP 1-May-2024) change is observed ▲as described in the method.▲ (USP 1-May-2024) The mechanical tapping is achieved by raising the ▲graduated▲ (USP 1-May-2024) cylinder or vessel and allowing it to drop ▲▲ (USP 1-May-2024) a specified distance, under its own ▲mass,▲ (USP 1-May-2024) by ▲one▲ (USP 1-May-2024) of three methods as described below. Devices that rotate the ▲graduated▲ (USP 1-May-2024) cylinder or vessel during tapping may be preferred to ▲give a more leveled surface after tapping.▲ (USP 1-May-2024)

Method 1▲—Measurement in a Graduated Cylinder▲ (USP 1-May-2024)

APPARATUS

The apparatus (*Figure 3*) consists of the following:

- A 250-mL graduated cylinder (readable to 2 mL) with a mass of 220 ± 44 g.

- A ▲tapping▲ (USP 1-May-2024) apparatus capable of producing, per minute, ▲▲ (USP 1-May-2024) nominally 300 ± 15 taps from a height of 14 ± 2 mm. The support for the graduated cylinder, with its holder, has a mass of 450 ± 10 g.
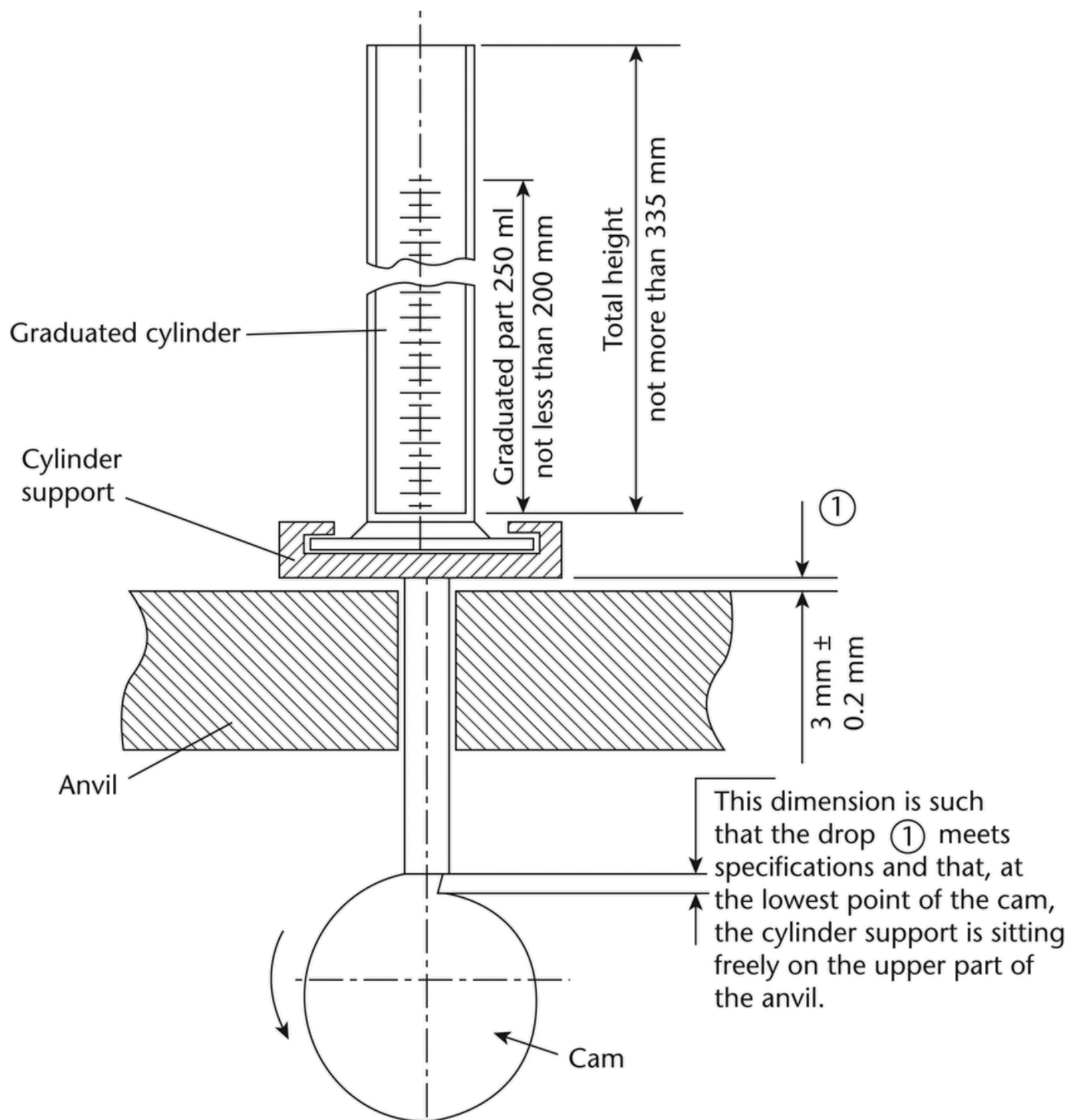
Figure 3. ▲Tapping device for powder samples. Dimensions in millimeters.▲ (USP 1-May-2024)

PROCEDURE

Proceed as described above for the determination of the ▲untapped▲ (USP 1-May-2024) bulk volume (V_0).

Secure the ▲graduated▲ (USP 1-May-2024) cylinder in the ▲support.▲ (USP 1-May-2024) Carry out 10, 500, and 1250 taps on the same powder sample and read the corresponding volumes V_{10}, V_{500}, and V_{1250} to the nearest graduated unit. If the difference between V_{500} and V_{1250} is less than or equal to 2 mL, V_{1250} is the tapped ▲bulk▲ (USP 1-May-2024) volume. If the difference between V_{500} and V_{1250} exceeds 2

mL, repeat in increments ▲of, for example,▲ (USP 1-May-2024) 1250 taps, until the difference between ▲successive▲ (USP 1-May-2024) measurements is less than or equal to 2 mL. Fewer taps may be appropriate for some powders, when validated. Calculate the tapped ▲bulk▲ (USP 1-May-2024) density in grams per milliliter using the formula m/V_f (where V_f is the final tapped ▲bulk▲ (USP 1-May-2024) volume). ▲▲ (USP 1-May-2024) Replicate determinations are desirable for the determination of this property. Specify the drop height with the results.

▲If the available sample amount is insufficient for an untapped volume of 150 mL,▲ (USP 1-May-2024) use a reduced amount and a suitable 100-mL graduated cylinder (readable to 1 mL) weighing 130 ± 16 g and mounted on a ▲support▲ (USP 1-May-2024) weighing 240 ± 12 g. ▲The untapped volume of the sample should be between 50 mL and 100 mL.▲ (USP 1-May-2024) If the difference between V_{500} and V_{1250} is less than or equal to 1 mL, V_{1250} is the tapped ▲bulk▲ (USP 1-May-2024) volume. If the difference between V_{500} and V_{1250} exceeds 1 mL, repeat in increments ▲of, for example,▲ (USP 1-May-2024) 1250 taps, until the difference between ▲successive▲ (USP 1-May-2024) measurements is less than or equal to 1 mL. The modified test conditions are specified in the expression of the results.

Method 2▲—Measurement in a Volumeter▲ (USP 1-May-2024)

▲▲ (USP 1-MAY-2024) PROCEDURE

Proceed as directed under *Method 1* except that the mechanical tester provides a fixed drop of 3 ± 0.2 mm at a nominal rate of 250 ▲± 15▲ (USP 1-May-2024) taps per minute.

Method 3▲—Measurement in a Vessel▲ (USP 1-May-2024)

▲▲ (USP 1-MAY-2024) PROCEDURE

Proceed as described in *Method 3* ▲▲ (USP 1-May-2024) for measuring the ▲untapped▲ (USP 1-May-2024) bulk density, using the measuring vessel equipped with the cap shown in *Figure 2*. The measuring vessel with the cap is lifted 50–60 times per minute by the use of a suitable tapped density tester. Carry out 200 taps, remove the cap, and carefully scrape excess powder from the top of the measuring vessel ▲by smoothly moving the edge of a reclined spatula blade across the top surface of the cup, taking care to keep the spatula tilted backward to prevent packing or removal of powder from the vessel. Determine the mass (m) of the powder to the nearest 0.1% by subtracting the previously determined mass of the empty measuring vessel.▲ (USP 1-May-2024) Repeat the procedure using 400 taps. If the difference between the 2 masses obtained after 200 and 400 taps exceeds 2%, ▲repeat the test▲ (USP 1-May-2024) using 200 additional taps until the difference between ▲successive▲ (USP 1-May-2024) measurements is less than 2%. Calculate the tapped ▲bulk▲ (USP 1-May-2024) density in grams per milliliter using the formula $m_f/100$ (where m_f is the ▲final tapped▲ (USP 1-May-2024) mass of powder in the measuring vessel). ▲Replicate determinations performed on separate powder samples are desirable.▲ (USP 1-May-2024) The test conditions, including tapping height, are specified in the expression of the results.

MEASURES OF POWDER COMPRESSIBILITY

Because the interparticulate interactions influencing the bulk ▲▲ (USP 1-May-2024) properties of a powder ▲▲ (USP 1-May-2024) also ▲▲ (USP 1-May-2024) interfere with powder flow, a comparison of the ▲untapped▲ (USP 1-May-2024) bulk and tapped ▲bulk▲ (USP 1-May-2024) densities can give an ▲indirect▲ (USP 1-May-2024) measure of the relative importance of these interactions in a given powder. Such a comparison is often used as an index of the ability of the powder to flow, for example the compressibility index ▲(Carr index)▲ (USP 1-May-2024) or the Hausner ratio ▲▲ (USP 1-May-2024).

The compressibility index and Hausner ratio are measures of the propensity of a powder to be compressed as described above. ▲▲ (USP 1-May-2024)

Compressibility Index

▲▲ (USP 1-May-2024)

$$100(V_0 - V_f)/V_0$$

V_0 = ▲untapped bulk▲ (USP 1-May-2024) volume

V_f = final tapped ▲bulk▲ (USP 1-May-2024) volume

Hausner Ratio

$$V_0/V_f$$

Depending on the ▲powder,▲ (USP 1-May-2024) the compressibility index can be determined using V_{10} instead of V_0. ▲If V_{10} is used, it is clearly stated with▲ (USP 1-May-2024) the results.

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[1] The apparatus (the Scott Volumeter) conforms to the dimensions in ▲ISO 3923-2:1981 or▲ (USP 1-May-2024) ASTM B329–▲14.▲ (USP 1-May-2024)

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