Designation: F2608 – 15$^{\varepsilon 1}$

An American National Standard

Standard Test Method for Determining the Change in Room Air Particulate Counts as a Result of the Vacuum Cleaning Process[1]

This standard is issued under the fixed designation F2608; 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.

ε[1] NOTE—Added research report footnote to Section 13 editorially in September 2016.

1. Scope

1.1 This test method provides a laboratory test for the measurement of particulate generated as a direct result of the vacuuming process.

1.2 This test method is applicable to all residential/ commercial uprights, canisters, stickvacs, central vacuum systems, and combination cleaners.

1.3 This test method applies to test dust removal from floor coverings not the removal of surface litter and debris.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.5 *This test method may involve hazardous materials, operations, and equipment. 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:*[2]

F555 Test Method for Motor Life Evaluation of an Upright Vacuum Cleaner

F608 Test Method for Evaluation of Carpet Embedded Dirt Removal Effectiveness of Household/Commercial Vacuum Cleaners

F655 Specification for Test Carpets and Pads for Vacuum Cleaner Testing

F884 Test Method for Motor Life Evaluation of a Built-In (Central Vacuum) Vacuum Cleaner

F922 Test Method for Motor Life Evaluation of an Electric Motorized Nozzle

F1038 Test Method for Motor Life Evaluation of a Canister, Hand-held, Stick, and Utility Type Vacuum Cleaner Without a Driven Agitator

F1334 Test Method for Determining A-Weighted Sound Power Level of Vacuum Cleaners

F1409 Test Method for Straight Line Movement of Vacuum Cleaners While Cleaning Carpets

2.2 *AHAM Standard:*

ANSI/AHAM AC-1-2006 Test Method for Performance of Portable Household Electric Room Air Cleaners[3]

2.3 *Other References:*

IEC 60312 Vacuum Cleaners for Household Use—Methods for Measuring the Performance

Standard Laboratory Practice for Quantifying Respirable Particulate Emissions Generated by Residential/ Commercial Vacuums and Central Vacuum Systems, Carpet and Rug Institute, 12/4/02

3. Terminology

3.1 *Definitions:*

3.1.1 *model, n*—designation of a group of vacuum cleaners having identical mechanical and electrical construction with only cosmetic or nonfunctional differences.

3.1.2 *population, n*—total of all units of a particular model vacuum cleaner being tested.

3.1.3 *repeatability limit, n*—value below which the absolute difference between two individual test results obtained under the repeatability condition may be expected to occur with a probability of approximately 0.95 (95 %).

3.1.4 *test run, n*—definitive procedure that produces a singular measured result.

3.1.5 *unit, n*—single vacuum cleaner of the model being tested.

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[1] This test method is under the jurisdiction of ASTM Committee F11 on Vacuum Cleaners and is the direct responsibility of Subcommittee F11.23 on Filtration.

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[2] 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.

[3] Available from the Association of Home Appliance Manufacturers, 19th St. NW, Suite 402, Washington, DC 20036.

4. Significance and Use

4.1 In this test method, the amount of particulate generated into the air by operating a vacuum cleaner over a specific floor covering that is contaminated with dust will be determined. Particles from the motor, floor covering, and the test dust will all be measured. The amount of dust generated in the laboratory practice will differ from that in residential/commercial installations because of variations in floor coverings, soil and other solid particulate compositions, the vacuuming process used by individual operators, the air exchange rate of heating, ventilation, and air conditioning (HVAC) systems, and other factors.

4.2 To provide a uniform basis for measuring the performance in 4.1, a standardized test chamber, equipment, floor covering material, and dust particulate are used in this test method.

4.3 Due to the large range of generated particle counts observed among products in the vacuum cleaner industry at the present time, the test results of the maximum particle counts generated under this test method are expressed in Log_{10} equivalents for evaluation and comparison of product performance.

5. Apparatus

5.1 An air-conditioned laboratory at 21 ± −1.5°C (70 ± 5°F) and 50 % relative humidity ±5 % is to be used for sample preparation.

5.2 *Environmentally Controlled Test Chamber (per ANSI/AHAM AC-1-2006):*

5.2.1 *Chamber Size*—Nominal dimensions of 3.2 by 3.7 by 2.4 m (10.5 by 12 by 8 ft) up to a 20 % difference in volume is permitted.

5.2.2 *Framework*—Standard 5.1 by 10.2 cm (2 by 4 in.) or equivalent construction sealed to the floor line with caulking compound.

5.2.3 *Walls*—Any hard, cleanable surface, such as wallboard (sealed with a washable latex semi-gloss paint) or stainless steel. Seal with caulking compound.

5.2.4 *Flooring*—Any hard, seamless cleanable surface such as seamless full-width vinyl, stainless steel, or sealed concrete.

5.2.5 *Filtration*—HEPA filtration (>99.97 % at 0.3 µm, 0.5 m^3/s (1000 ft^3/min) minimum).

5.2.6 *Motor and Blower for Conditioning Loop*—0.35-m^3/s (750-ft^3/min) fan.

5.2.7 *Relative Humidity*—50 ± 5 %.

5.2.8 *Temperature*—21 ± 1.5°C (70 ± 5°F).

5.2.9 *Chamber Sealing*—Chamber sealing shall be verified as follows: Particulate level in the sealed room shall not rise above 1000 particles/ft^3 at ≥0.3 µm after 20 min of HEPA off, with the room static.

5.3 Real-time aerosol particle counter in the range of 0.3 to 5 µm. A laser photometer may be used, in addition to the particle counter, with a range of 0.1 to 1000 µg/m^3.

5.4 Particulate sampling pickoff probe shall be 152.4 ± 12.7 cm (60 ± 5 in.) above the test carpet, facing up, on centerline of carpet.

5.5 *Weighing Scale (for Weighing Test Dirt),* accurate to 0.01 g (0.000353 oz) and having a weighing capacity of at least 100 g (3.53 oz) for weighing the dust for embedding.

5.6 *Dirt Embedment Tool*—Roller may be locked or unlocked (see Fig. 1).

5.7 *Dirt Dispenser*—Dispensing system that provides the operator with a method to distribute the test dirt uniformly on the carpet test area.

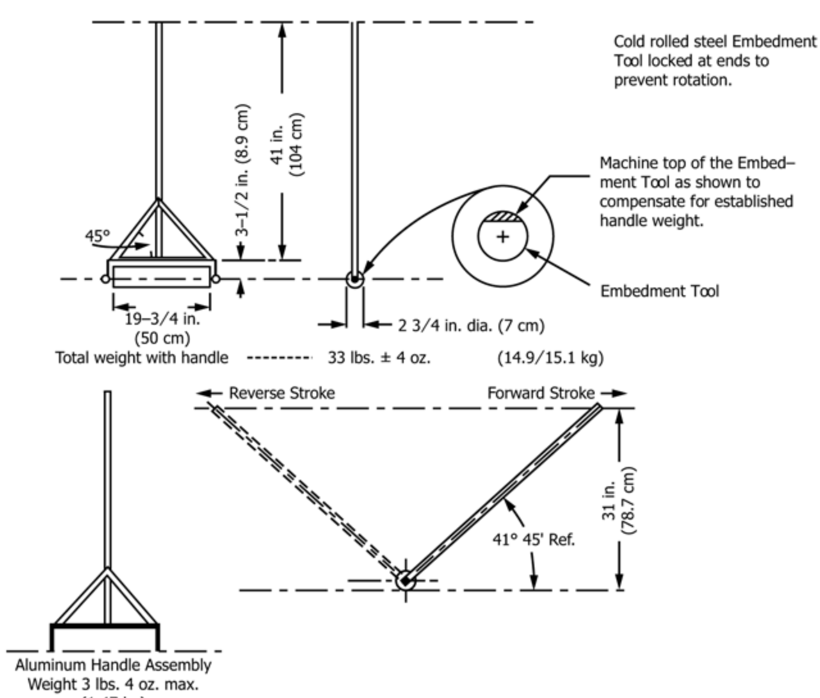

FIG. 1 Dirt Embedment Tool

5.8 *Voltmeter,* to measure input volts to the vacuum cleaner, to provide measurements accurate within ±1 %.

5.9 *Voltage-Regulator System,* to control the input voltage to the vacuum cleaner. The regulator shall be capable of maintaining the vacuum cleaner's rated voltage ±1 % and rated frequency having a wave form that is essentially sinusoidal with 3 % maximum harmonic distortion for the duration of the test.

5.10 Carpet bed length of 182.9 cm (72 in.) and minimum width of 68.6 cm (27 in.). See an example of a suitable cleaning bed apparatus in Fig. 2.

5.11 Drive for carpet or vacuum cleaner capable of maintaining specified test speed of 55 cm/s (1.8 ft/s) both forward and reverse in a straight pattern. Bed must be equipped with brackets to hold the test vacuum handle at 80 cm (31.5 in.) above the test material.

5.12 If moving the vacuum cleaner, a suitable system is described in Test Method F608. Travel length and width are as specified in the procedure.

5.13 Tachometer or equivalent device for calibrating conveyor or vacuum drive speed.

5.14 *Rotating Agitator Conditioning Vacuum Cleaner/Equipment or a Central Vacuum Cleaning System equipped with a powered, rotating agitator-equipped nozzle,* for conditioning new test carpets and removing residual dirt from the test carpet before each test run. This cannot be the unit tested.

6. Materials

6.1 *Level Loop Carpet and Padding,* as described in Specification F655.

6.2 *ISO 12103-A2 Arizona Test Dust (IEC 60312)*—Weigh and record 10 g of test dust in a room meeting the requirements of 5.1. See Table 1 for a description of the dust.

NOTE 1—Relative humidity can have a significant effect upon the weight and amount of test dust.

TABLE 1 ISO 12103-1, A2 Fine Test Dust Particle Distribution

Cumulative Volume Numeric Data	
Size, µm	Less Than, %
1	2.6
2	11.3
3	20.4
4	28.9
5	35.8
7	44.6
10	52.9
20	70.7
40	88.2
80	99.8

7. Sampling

7.1 A minimum of three units of the same model vacuum cleaner selected at random, in accordance with good statistical practice, shall constitute the population sample.

7.2 To determine the best estimate of the total particulate counts during the activity of cleaning for the population of the vacuum cleaner model being tested, the arithmetic mean of the particulate level in the air rating of the samples from the population shall be established by testing to a 90 % confidence level within ±5 % of the mean value.

7.3 Annex A1 provides a procedural example for determining the 90 % confidence level and when the sample size shall be increased.

8. Standard Test Carpet Preparation

8.1 Cut panels as needed of the test carpet, specified in 6.1, to a size of 68.6 cm (27 in.) warp by 182.9 cm (72 in.) fill.

8.2 Mark the carpet panel(s) with test identification numbers for later reference.

8.3 *Preconditioning New Test Carpet Panels:*

8.3.1 Vacuum new test carpet panels using a rotating agitator-equipped vacuum cleaner to remove any loose materials before soiling and testing.

FIG. 2 Cleaning Bed Apparatus

8.3.2 Vacuum the carpet with the first stroke in the direction of the pile lay and continue vacuuming the entire area of the carpet until less than 2 g of carpet fiber or soil is picked up after 5 min of cleaning.

8.4 *Reconditioning Used Carpet Panels:*

8.4.1 Using the vacuum cleaner or a central vacuum cleaning system listed in 5.14, clean then entire carpet area for 5 min using a stroke rate of 0.55 m/s (1.8 ft/s) in the direction of the pile lay to ensure removal of all residual dust embedded in the carpet. Clean the test chamber in accordance with 9.2.

8.5 *Clean Carpet Particle Background Counts*—Perform the following test to establish a baseline for clean carpet particle counts for use in referencing and calibration checks. This test is to be performed when carpet is new and after every 20 test runs.

8.5.1 Position the test carpet on the supporting surface.

8.5.2 Mark a baseline test area 40 by 102 cm (16 by 40 in.). This area is based upon a standard nozzle width of 25 cm (10 in.), plus an additional 7.6 cm (3 in.) per side. Nozzle width is measured at the extreme outside dimension of the nozzle. For nozzle widths exceeding 25 cm (10 in.), the test area width shall be increased accordingly.

8.5.3 Place the control vacuum cleaner with new bag and filters on the test carpet 10 to 15 cm (4 to 6 in.) in front of the test area. Set the drive run to include carpet an additional 10 to 15 cm (4 to 6 in.) after the test area as well.

8.5.4 Exit the test chamber and initiate the particulate counter or photometer or both. Set the instrument(s) to take continuous readings throughout the duration of the test. The particle counter range sizes are 0.3, 0.5, and 1.0 µm (other particle size ranges are optional).

8.5.5 Energize the chamber purge/room air purifier until the baseline particulate level is under 1000 particles/ft^3 at 0.3 µm and count variation is under 10 % for 5 min at the 0.3-µm range. For the photometer, the µg/m^3 baseline should be less than 1 µg/m^3, with a variation of less than 10 % from the mean.

8.5.6 De-energize both the chamber purge/room air purifier and room-conditioning equipment.

NOTE 2—Testing is to be conducted in a static environment.

8.5.7 Immediately energize vacuum and monitor particle counts (and concentration if using photometer) for 10 min. A hard surface or a method for raising the agitator off of the carpet should be employed to protect the carpet during this portion of the test. If a hard surface is employed it shall not be included in the test strokes.

8.5.8 Set conveyor or vacuum stroke counter at the proper number of strokes to accomplish 10 min ± 5 s of back and forth vacuuming at 55 cm/s (1.8 ft/s), then energize conveyor and continue to monitor particle counts (and concentration if using photometer).

8.5.9 At the conclusion of 10 min of vacuuming, de-energize the conveyor with the vacuum in its original position, then de-energize the vacuum.

NOTE 3—For products employing a soft dust bag, emissions generated due to bag collapse ("blow-back") when powering down will be monitored and captured during the settling period of this test.

8.5.10 Record the photometer readings (if used) and particle counts from step 8.5.7 for the 0.3, 0.5, and 1.0 µm particle size ranges. This information will act as a baseline for reference and calibration checks after every 20 test runs performed on the test carpet. Replace carpeting or evaluate potential problems with test system whenever the particle counts from reference and calibration checks of test carpet vary from the baseline level by ±20 %.

9. Test Chamber Setup and Conditioning

9.1 All components involved in the test shall remain and be exposed in the controlled environment for at least 16 h before the start of the test.

9.2 *Test Chamber Cleaning Procedure*—To be performed as needed:

9.2.1 Using the vacuum cleaner or a central vacuum cleaning system listed in 5.14, clean all surfaces of the test chamber and equipment to remove all residual dust.

9.2.2 Wipe down all surfaces of the test equipment with a tack cloth or damp rag to remove any dust not removed by the vacuum cleaner.

10. Vacuum Cleaners

10.1 *New Test Vacuum Cleaners:*

10.1.1 *Preconditioning a New Test Vacuum Cleaner*—Run the vacuum cleaner in at rated voltage (±1 %) and frequency (±1 Hz) with filters in place for 1 h.

10.1.1.1 *Preconditioning Rotating Agitator-Type Vacuum Cleaner*—In a stationary position, operate the vacuum cleaner for 1 h with the agitator bristles not engaged on any surface.

10.1.1.2 *Preconditioning a Straight Air Canister Vacuum Cleaner*—Operate the vacuum cleaner for 1 h with a wide-open inlet (without hose).

10.2 *Used Test Vacuum Cleaners:*

10.2.1 *Recondition a Used Vacuum Cleaner*—Before each test run:

10.2.1.1 Thoroughly remove excess dirt from the vacuum cleaner. Without using tools for disassembly, clean the entire outer surface, brushes, nozzle chamber, ductwork, inside of the chamber surrounding the primary filter, and inside hose and wands.

10.2.1.2 For vacuum cleaners using disposable filters as the primary filters, use a new disposable primary filter from the manufacturer for each test.

10.2.1.3 For vacuum cleaners using non-disposable dirt receptacles, empty in accordance with the manufacturer's instructions after each test run, clean the receptacle, and then install it as recommended by the vacuum cleaner manufacturer.

NOTE 4—Effectiveness of this cleaning can be seen in the uniformity of the successive runs.

10.3 *Test Vacuum Cleaner Settings*—If various settings are provided, set the motor speed setting, suction regulator, nozzle height, or combination thereof using the manufacturer's specifications as provided in the instruction manual for this type of carpet. Contact the manufacturer if no instructions are given or if the instructions are unclear or inadequate.

10.4 The settings to be used for this test method (nozzle, motor speed, suction regulator, and so forth) shall be the same settings that are used in conducting straight line movement (Test Method F1409), sound power (Test Method F1334), embedded dirt cleaning effectiveness (Test Method F608), and motor life evaluation (Test Methods F555, F884, F922, and F1038) for the specified carpet employed in this standard (level loop per Specification F655).

11. Procedure

11.1 Position the test carpet and padding on the supporting surface. Place the particle sampling system 152.4 cm (60 in.) above the carpet, at the carpet centerline, facing up.

11.2 Mark a baseline test area of 40.6 by 101.6 cm (16 by 40 in.). This area is based upon a standard nozzle width of 25.4 cm (10 in.), plus an additional 7.6 cm (3 in.) per side. For nozzle widths exceeding 25.4 cm (10 in.), the test area width shall be increased accordingly. Nozzle width is measured at the extreme outside dimension of the nozzle.

11.3 Calculate the amount of test dust required for the overall test area based upon a density of 0.003875 g/cm^2 (0.0008825 oz/in.^{2}); for example, for a nozzle width of 30.48 cm (12 in.), the amount of dirt required will be:

(12 in. {nozzle width} + 6 in. {3 in. each side of nozzle})
× 40 in. {cleaning path length} × 0.0008835 oz/in.^{2}
= 0.6354 oz. (18 g) of test dust

[(30.48 cm + 15.24 cm) × 101.6 cm × 0.003875 g/cm^2
= 18 g of test dust)]

11.4 Measure and distribute the test dirt uniformly on the test area using any convenient spreading method.

11.5 Embed the test dirt into the carpet using the dirt embedment tool. Perform the embedding process by using a dragging motion in both directions with the handle held at the angle shown. Drag the dirt embedment tool over the test area exactly 30 strokes, alternating directions forward and back. (A movement in one direction is one "stroke.") Use a uniform movement to provide a stroke rate of 55 cm/s (1.8 ft/s). The first forward stroke shall be in the direction of the carpet lay.

NOTE 5—An acceptable laboratory practice shall be used to ensure that the embedment tool shall not fall short of reaching the end boundaries of the test area, and the tool shall cover both side boundaries of the test area at all times.

11.6 Clean the embedding tool as needed.

11.7 *Positioning the Test Vacuum Cleaner:*

11.7.1 *Upright Vacuum Cleaners*—Install vacuum cleaner (with new bag, drive belt if equipped, and filters) on the test carpet 10.2 to 15.2 cm (4 to 6 in.) in front of the test area. Set the conveyor run to include 10.2 to 15.2 cm (4 to 6 in.) after the test material, as well. Set the handle height to 80 cm (31.5 in.) above the carpet.

11.7.2 *Canister Vacuum Cleaners*—Place canister at same height as the test carpet to either side at the approximate midpoint of the bed. Orient the canister perpendicular to the test bed ensuring that the exhaust air does not blow across the dust embedded carpet. Install the nozzle on the test carpet 10.2 to 15.2 cm (4 to 6 in.) in front of the test area. Set the conveyor run to include 10.2 to 15.2 cm (4 to 6 in.) after the test material, as well. Set the handle height to 80 cm (31.5 in.) above the carpet. Non-pivoting heads should be left at the manufacturer's set position.

NOTE 6—The actual position of the canister may be dependent upon the length of the hose.

11.7.3 *Central Vacuum Cleaners*—Place motor and receiver outside the test room. Install the nozzle on the test carpet 10.2 to 15.2 cm (4 to 6 in.) in front of the test area. Set the conveyor run to include 10.2 to 15.2 cm (4 to 6 in.) after the test material as well. Set the handle height to 80 cm (31.5 in.) above the carpet. Non-pivoting heads should be left at the manufacturer's set position.

11.8 Exit the test chamber and initiate the particle counter or photometer or both. Set the instrument(s) to take continuous readings of particle counts throughout the duration of the test.

11.9 Energize the chamber purge/room air purifier until the baseline particulate level is under 1000 particles/ft^3 at 0.3 µm and count variation is under 10 % for 5 min at the 0.3-µm range. For the photometer, the µg/m^3 baseline shall be less than 1 µg/m^3 with a variation of less than 10 % from the mean.

11.10 De-energize both the chamber purge/room air purifier and room-conditioning equipment.

NOTE 7—Testing is to be conducted in a static environment.

11.11 Immediately energize vacuum and monitor particle counts (and concentration if using photometer) for 10 min.

11.12 Set conveyor or vacuum stroke counter at the proper number of strokes to accomplish 10 min ± 5 s of back-and-forth vacuuming at 55 cm/s (1.8 ft/s), then energize conveyor and continue to monitor particle counts for an additional 10 min ± 5 s.

11.13 At the conclusion of 10 min of vacuuming, de-energize the drive with the vacuum in its original position, then de-energize the vacuum.

NOTE 8—For products employing a soft dust bag, emissions generated due to bag collapse ("blow-back") when powering down will be monitored and captured during the settling period of this test.

11.14 Continue to monitor particulate counts after de-energizing the vacuum for 5 min.

11.15 Before entering the test chamber, energize the chamber purge/room air purifier to purge contaminant from the room.

11.16 Enter the test chamber and remove the test specimen.

11.17 Recondition the test vacuum according to 10.2 and the test carpet panel per 8.4.

11.18 Install a new vacuum bag, drive belt (if equipped), and filters if so equipped and reinstall vacuum cleaner to test apparatus. Repeat steps 11.1 through 11.18 two more times on the sample unit. If the results from the three test runs of this sample unit comply with the repeatability limits, proceed to 11.19.

11.19 Repeat steps 11.1 through 11.18, using other test units from the population sample, until a 90 % confidence level within ±5 % of the mean result has been achieved.

12. Report

12.1 Report vacuum cleaner manufacturer, model, filter and bag types, and other descriptive information.

12.2 Report vacuum cleaner settings per 10.3.

12.3 Report test dust lot number and recorded dust amount used for each test.

12.4 Report full description of particle measurement instrumentation (model number, serial number, calibration date, and sample flow rate).

12.5 Report all particle count and particle concentration data (count at each size or $\mu g/m^3$).

12.6 Report maximum particle count at 0.3 µm and greater and, if taken, maximum particle concentration in $\mu g/m^3$. Maximum particle count data are converted to Log_{10} data for evaluating results against the repeatability and reproducibility limits in the Precision and Bias section, or for comparison of emissions performance between two or more products.

13. Precision and Bias[4]

13.1 The repeatability standard deviation (*r*) of the Log_{10} peak particle count equal to or larger than 0.3 µm has been determined to be 0.161. The 95 % repeatability limit within a single laboratory has therefore been determined to be the respective value of 0.45 (2.8 × *r*). With 95 % confidence it can be stated that within a single laboratory, a set of measured results derived from testing a unit should be considered suspect if the difference between any of the three values is greater than the repeatability limit of 0.45.

13.2 The expected standard deviation of reproducibility of the average of a set of measured results between multiple laboratories, *sR*, has been found to be 0.240. The 95 % reproducibility limit within a laboratory, *R*, has been found to be 0.67, where *R* = 2.8 (*sR*). With 95 % confidence, it can be stated that the average of the measured results from a set of three test runs performed in one laboratory, as compared to a second laboratory, should be considered suspect if the difference between those two values is greater than the respective values of the reproducibility limit of 0.67. If the absolute value of the difference between the average of the measured results from the two laboratories is not equal to or less than 0.67, the set of results from both laboratories shall be considered suspect.

13.3 No justifiable statement on the bias of this test method to determine the change in room air particulate counts as the result of the activity of vacuum cleaning can be made. Currently, the true value of the property cannot be established by an acceptable referee method.

14. Keywords

14.1 emissions; particle counts; vacuum cleaner

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F11-1022. Contact ASTM Customer Service at service@astm.org.

ANNEX

(Mandatory Information)

A1. MATHEMATICAL METHOD FOR DETERMINING WITH 90 % CONFIDENCE THE ROOM AIR PARTICULATE COUNTS OF A POPULATION OF VACUUM CLEANERS

A1.1 *Theory*:

A1.1.1 The most common and ordinarily the best estimate of the population mean, µ, is simply the arithmetic mean, $\bar{X}$, of the individual scores (measurements) of the units comprising a sample taken from the population. The average score of these units will seldom be exactly the same as the population mean; however, it is expected to be fairly close so that in using the following procedure it can be stated with 90 % confidence that the true mean of the population, µ, lies within a determined interval of the calculated mean, $\bar{X}$, of the sample taken from the population as stated in Section 7.

A1.1.2 The following procedure provides a confidence interval about the sample mean which is expected to bracket µ, the true population mean, 100(1 – α) % of the time where α is the chance of being wrong. Therefore, 1 – α is the probability or level of confidence of being correct.

A1.1.3 The desired level of confidence is 1 – α = 0.90 or 90 % as stated in Section 7. Therefore, α = 0.10 or 10 %.

A1.1.4 Compute the mean, $\bar{X}$, and the standard deviation, *s*, of the individual scores of the sample taken from the population:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \quad \text{(A1.1)}$$

$$s = \sqrt{\frac{n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2}{n\,(n-1)}} \quad \text{(A1.2)}$$

where:

n = number of units tested, and

X_i = value of the individual test unit score of the ith test unit. As will be seen in the procedural example to follow, this is the average value of the results from three test runs performed on an individual test unit with the resulting set of data meeting the repeatability requirements of Section 13.

A1.1.5 Determine the value of the t statistic for $n - 1$ df, from Table A1.1 at a 95 % confidence level.

NOTE A1.1—The value of t is defined as t and is read as "t at 95 % confidence."

$$t \text{ statistic} = t_{1-\alpha/2} = t_{0.95} \quad (A1.3)$$

where:

$1 - \alpha/2$ = 1 – 0.10/2 = 1 – 0.05 = 0.95 or 95 %.

A1.1.6 The following equations establish the upper and lower limits of an interval centered about $\bar{X}$ that will provide the level of confidence required to assert that the true population mean lies within this interval.

$$CI_U = \bar{X} + ts/\sqrt{n} \quad (A1.4)$$

$$CI_L = \bar{X} - ts/\sqrt{n} \quad (A1.5)$$

where:

CI = confidence interval (U–upper limit; L–lower limit),

$\bar{X}$ = mean score of the sample taken from population,

t = t statistic from Table A1.1 at 95 % confidence level,

s = standard deviation of the sample taken from the population, and

n = number of units tested.

A1.1.7 It is desired to assert with 90 % confidence that the true population mean, μ, lies within the interval, CI_u to CI_L centered about the sample mean, $\bar{X}$. Therefore, the quantity $ts/\sqrt{n}$ shall be less than some value, A.

NOTE A1.2—Generally, the value of A is stated as a percentage of the estimated population mean.

A1.1.8 As $n \rightarrow \infty, ts/\sqrt{n} \rightarrow 0$. As this relationship indicates, a numerically smaller confidence interval may be obtained by using a larger number of test units, n, for the sample. Therefore, when the standard deviation, s, of the sample is large and the level of confidence is not reached after testing three units, a larger sample size, n, shall be used.

TABLE A1.1 Percentiles of the *t* Distribution[A]

df	$t_{0.95}$	$t_{0.975}$
1.000	6.314	12.706
2.000	2.920	4.303
3.000	2.353	3.182
4.000	2.132	2.776
5.000	2.015	2.571
6.000	1.943	2.447
7.000	1.895	2.365
8.000	1.860	2.306
9.000	1.833	2.262
10.000	1.812	2.228
11.000	1.796	2.201
12.000	1.782	2.179
13.000	1.771	2.160
14.000	1.761	2.145
15.000	1.753	2.131

[A] Adapted by permission from *Introduction to Statistical Analysis*, 2nd ed, W.J. Dixon and F.J. Massey, Jr., eds., Copyright, 1957. McGraw-Hill Book Co., Inc. Entries originally from Table III of *Statistical Tables* by R.A. Fisher and F. Yates, 1938, Oliver and Boyd, Ltd., London.

A1.2 *Procedure*—Graphical flowchart for the procedure shown in Fig. A1.1.

A1.2.1 Select three units from the population for testing as the minimum sample size.

A1.2.2 Obtain individual test unit scores by averaging the results of three test runs performed on each of the three individual test units. The data set resulting from the three test runs performed on each individual test unit shall meet the respective repeatability requirement found in Section 13.

A1.2.3 Compute $\bar{X}$ and s of the sample.

A1.2.4 Determine the statistic t for $n - 1$ df from Table A1.1, where n = number of test units.

A1.2.5 Compute $ts/\sqrt{n}$ for the sample and compare it to the value of A.

A1.2.6 If the value of $ts/\sqrt{n} > A$, an additional unit from the population shall be selected and tested, and the computations of A1.2.2 – A1.2.6 are repeated.

A1.2.7 If the value of $ts/\sqrt{n} < A$, the desired 90 % confidence level has been obtained. The value of the final $\bar{X}$ may be used as the best estimate of the particulate level for a specific particle size for the population.

A1.3 *Example*—The following data is chosen to illustrate how the mean value of particulate level at a given particle size, $\bar{X}$, for the population of a vacuum cleaner model is derived.

A1.3.1 Select three test units from the vacuum cleaner model population. A minimum of three test runs shall be performed using each test unit.

A1.3.2 Test run scores for Test Unit No. 1 maximum particle sizes ≥0.3 µm:

Test Run No. 1 = 167 500 max particle counts = 5.224 (Log)
Test Run No. 2 = 350 000 max particle counts = 5.544 (Log)
Test Run No. 3 = 480 000 max particle counts = 5.681 (Log)

A1.3.3 Maximum spread = 5.681 – 5.224 = 0.457. The repeatability value listed in Section 13 has been exceeded by the data spread so the results are to be discarded and three additional test runs performed.

A1.3.4 Test run scores for Test Unit No. 1:

Test Run No. 4 = 250 500 max particle counts = 5.399 (Log)
Test Run No. 5 = 550 000 max particle counts = 5.740 (Log)
Test Run No. 6 = 425 000 max particle counts = 5.628 (Log)

A1.3.5 Maximum spread = 5.740 – 5.399 = 0.341. This value of the spread is less than the value of the repeatability value of Section 13.

A1.3.6 Unit No. 1 score = (5.399 + 5.740 + 5.628) / 3 = 5.589.

NOTE A1.3—If it is necessary to continue repeated test run sets (7,8,9–10,11,12, and so forth) because the spread of data within a data set is not less than the repeatability limit requirement stated in Section 13, there may be a problem with the test equipment, the execution of the test procedure, or any of the other factors involved in the test procedure.

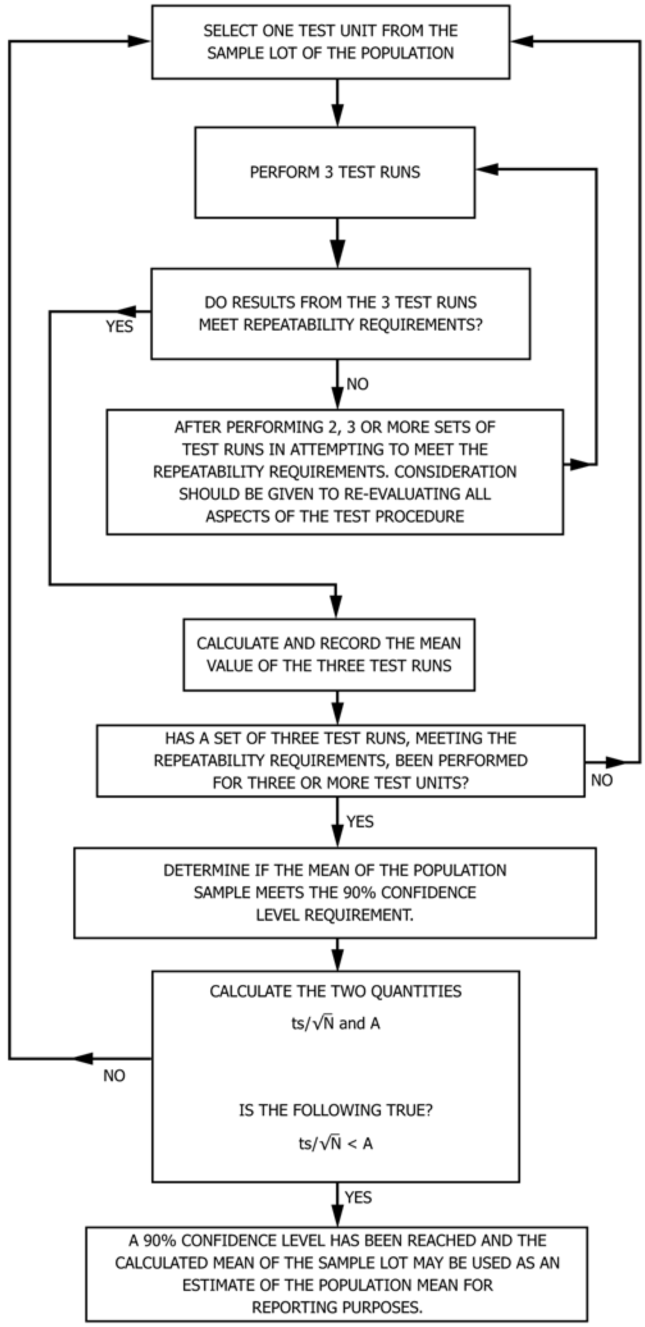

FIG. A1.1 Flow Chart for Procedure in A1.2

Consideration should be given to reevaluating all aspects of the test procedure for the cause(s).

A1.3.7 A minimum of two additional test units must be tested, each meeting the repeatability limit requirement. For this procedural example, assume those units met the repeatability requirements and the individual unit scores are:

Score of Test Unit No. 1 = 5.589
Score of Test Unit No. 2 = 5.751
Score of Test Unit No. 3 = 5.672
$X_{bar} = (5.589 + 5.751 + 5.672)/3 = 5.671$
s (std dev) = 0.081
Student $t_{@90\%} = 2.92$
$90\%\ C.I. = (t \times s \div \sqrt{n}) = (2.92 \times 0.081 / \sqrt{3}) = 0.1366$
$A = X_{bar} \times 0.05 = 0.2835$
$0.1366 < 0.2835$

A1.3.8 The requirement that the 90 % confidence interval be smaller than the *A* value has been met.

A1.3.9 Thus, the value of $\bar{X}$, 5.671 represents the max particulate counts score for the vacuum cleaner model tested and may be used as the best estimate of the for the population mean. In the same manner, the particulate counts for other particle sizes may be evaluated.