Designation: F2826 – 14

An American National Standard

Standard Test Method for Evaluating the Sustained Air Performance and Exhaust Emission Efficiencies of Central Vacuum Cleaning Units[1]

This standard is issued under the fixed designation F2826; 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 is a laboratory test for determining the sustained air performance and Exhaust Emissions of a central vacuum cleaner when tested under laboratory conditions.

1.2 This test method is applicable to all central vacuum cleaners with or without any type of internal filter. This test method is intended to help indicate how performance may be affected after multiple times of vacuuming over an extended period of time.

1.3 The inch-pound system of units is used in this standard except for weight measurements, which are measured in grams. The values stated in parentheses are given for information only.

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. Referenced Documents

2.1 *ASTM Standards:*[2]

E1 Specification for ASTM Liquid-in-Glass Thermometers

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F820 Test Method for Measuring Air Performance Characteristics of Central Vacuum Cleaning Systems

2.2 *ISO Standard:*[3]

ISO 5011 Inlet Air Cleaning Equipment for Internal Combustion Engines and Compressors—Performance Testing

3. Terminology

3.1 *Definitions:*

3.1.1 *exhaust emissions*—measure of the efficiency of a unit to capture the loading media. Exhaust Emissions is (1 – (the weight of the media exhausted into the exhaust emissions bag, divided by the weight of the media introduced) × 100).

3.1.2 *input power, W, n*—the rate at which electrical energy is absorbed by a vacuum cleaner motor/fan system.

3.1.3 *model, n*—the designation of a group of vacuum cleaner systems having the same mechanical and electrical construction.

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

3.1.5 *sample, n*—a group of vacuum cleaner systems taken from a large collection of vacuum cleaner systems of one particular model, which serves to provide information that may be used as a basis for making a decision concerning the larger collection.

3.1.6 *seal vacuum*—a water lift reading for a power unit when the inlet is entirely closed or sealed.

3.1.7 *standard air density, ρ_{std}, lb/ft^3, n*—atmospheric air density of 0.075 lb/ft^3 (1.2014 Kg/m^3).

3.1.7.1 *Discussion*—This value of air density corresponds to atmospheric air at a temperature of 68°F (20°C), 14.696 psi (101.325 kPa), and approximately 30 % relative humidity.

3.1.8 *suction, inches of water, n*—in a vacuum cleaner system, the absolute difference between ambient and sub-atmospheric pressure.

3.1.9 *sustained air performance, n*—the ability of a vacuum cleaner to maintain air performance with a known quantity of media aspirated into unit throughout a number of feeding cycles.

3.1.10 *test run, n*—the definitive procedure that produces the singular result.

3.1.11 *test station pressure, B_p, inches of mercury, n*—for a vacuum cleaner system, the absolute barometric pressure at the test location (elevation), and test time.

3.1.11.1 *Discussion*—It is not the equivalent mean sea level value of barometric pressure typically reported by the airport and weather bureaus. It is sometimes referred to as the

[1] This test method is under the jurisdiction of ASTM Committee F11 on Vacuum Cleaners and is the direct responsibility of Subcommittee F11.22 on Air Performance.

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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 International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

uncorrected barometric pressure (that is, not corrected to the mean sea level equivalent value).

3.1.12 *unit, n*—a single vacuum cleaner system of the model being tested.

3.1.13 *working vacuum*—a water lift reading value at an orifice causing a vacuum equivalent to a standard cleaning tool applied to the floor or rug.

4. Significance and Use

4.1 The test results allow comparison of sustained air performance of central vacuum cleaners that employ various methods of separating the dirt from the air used to convey the dirt to the central power unit. The results will be expressed as a percentage of the original vacuum performance after loading a prescribed weight of media.

4.2 The test results will allow a comparison of emissions by measuring the media emitted during the test and expressing this as an Exhaust Emissions.

5. Apparatus

5.1 *Water Manometer, or equivalent instruments,* to provide measurements from 0 to 150 in. (3810 mm) of water in increments of 0.1 in. (2.5 mm).

5.2 *Wattmeter,* to provide measurements accurate to within ±1 %.

5.3 *Voltmeter,* to provide measurements accurate to within ±1 %.

5.4 *Barometer,* with an accuracy of ±0.05 in. (1.27 mm) Hg, with scale divisions 0.02 in. (0.51 mm) or finer.

5.5 *Thermometer,* solid stem thermometer having a range from 18 to 89°F (8 to 32°C) with gradation of 0.2°F (0.1°C) increments and conforming to the requirements for thermometer 63°F or 63°C as prescribed in Specification E1.

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

5.7 *Weighing Scale (for weighing media),* accurate to 0.0035 oz. (0.1 g) and having a weighing capacity of at least 1000 g.

NOTE 1—All available scales may not be suitable for this test method. Any scale considered for use in this test method shall be checked for suitability in accordance with the requirements listed above.

5.8 *Stop Watch/Clock,* with a second hand or other type of equipment capable of establishing the specified rate of movement and total cycle time.

5.9 *Suction Fixture,* used to feed test media and make vacuum readings. The suction fixture will be used for feeding the media and measuring the vacuum by interchanging the feed tube and manometer tube. (See Fig. 1.)

5.10 *Emissions Collection Bag,* minimum 6 gal capacity, 15.2 mill disposable filter bag with a minimum quality of the following features: 98.4 % dust retention of particle sizes down to and including 0.3 microns (as tested per ISO 5011), an air permeability rating of 239 L/m^2·s, an initial pressure loss of 480 Pa, and a 277 kPa burst strength. (For units without an

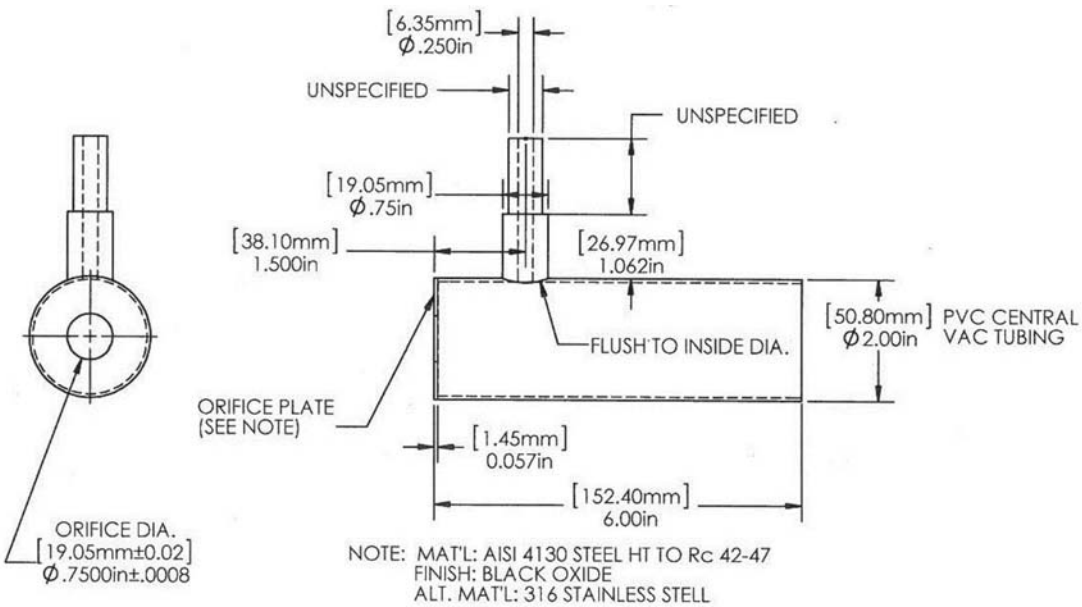

FIG. 1 Suction Fixture

integral discharge tube, a non-permeable shroud shall be fitted over the discharge area such that all emissions are routed into the emissions bag.)

6. Sampling

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

6.1.1 To determine the best estimate of the sustained air performance and Exhaust Emissions for the population of the central vacuum cleaner system model being tested, the arithmetic mean of the Sustained Air Performance and Exhaust Emissions of the sample from the population shall be established by testing it to a 90 % confidence level within ±5 % of the calculated mean.[4]

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

7. Materials

7.1 *Medial*—Commercial grade talcum.

8. Conditioning

8.1 *Test Room*—The test room shall be maintained at 70 ± 5°F (21 ± 3°C) and 45 to 55 % relative humidity.

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

9. Preparation for Test

9.1 *New Test Central Vacuum Systems:*

9.1.1 *Preconditioning a New Central Vacuum System*—Run the system in a rated voltage ±1 % and rated frequency ±1 Hz with filters in place for 1 h. Unit is to run in at full open orifice during preconditioning period.

9.1.2 For systems with non-disposable filters, weigh and record the filter's original weight to the nearest 0.0035 oz (0.1 g). This may not be possible with some systems in which the non-disposable filter cannot be removed.

9.2 *Used Test Central Vacuum Systems:*

9.2.1 Recondition a used test central vacuum system prior to each test run as follows:

9.2.1.1 Thoroughly remove excess dirt from the test central vacuum system. Without using tools for disassembly, clean the entire outer surface, ductwork, and inside of the chamber surrounding any and all filters (disposable or not).

9.2.1.2 For systems using disposable filters, use new disposable filter(s) for each test. Thoroughly clean the inside of the chamber surrounding the primary filter each time the filter is replaced.

9.2.1.3 For systems using cloth filter bags or other types of non-disposable dirt receptacles, empty according to manufacturer's instructions after each test run, and clean the cloth filter bag or non-disposable dirt receptacle until its weight is within 0.07 oz (2 g) of its original weight (see 9.1.2).

9.3 *Set-Up for Sustained Air Performance and Exhaust Emissions Test:*

9.3.1 Set up the test equipment and test unit as shown in Fig. 2. Connect the suction fixture to the inlet side of the test unit and the emissions collection bag to the discharge side of the test unit. Ensure connections are secure and sealed. Do not attach a muffler to the exhaust line during this test.

[4] Two sources of the talcum (USP Grade Supreme Talc) known to the committee at this time are Fischer Scientific Co., 1600 West Glen Avenue, Box 171, Itasca, IL 60143 and Luzenac America (Rio Tinto Minerals), 8051 E. Maplewood Ave., Building 4, Greenwood Village, CO 80111.

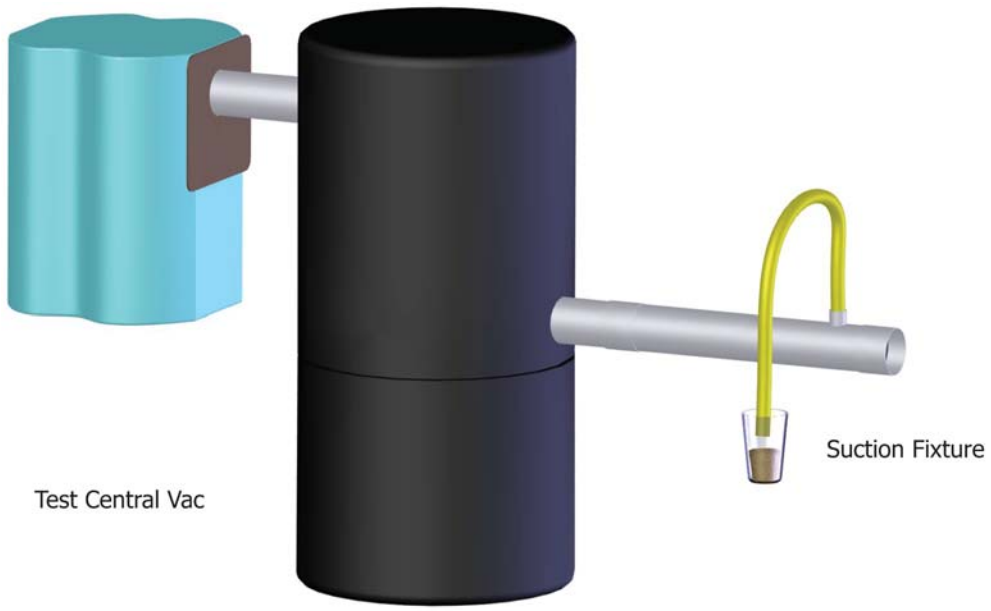

FIG. 2 Sustained Air Performance and Exhaust Emissions Setup

9.3.1.1 Energize the test unit for 60 min with the inlet reduced to a ½ in. orifice, at rated voltage ±1 % and rated frequency ±1 Hz to eliminate any moisture in the emissions collection bag. For vacuum cleaners with dual nameplate voltage ratings, conduct the test at the highest voltage.

9.3.1.2 Ensure that there is no leakage between the discharge side of the test unit and emissions collection bag. Ensure that there is no leakage of the emissions collection bag.

9.3.1.3 De-energize the vacuum cleaning system and immediately weigh the emissions collection bag. Record its weight to the nearest 0.0035 oz (0.1 g).

9.3.2 Connect manometer or equivalent instrument to the tap on the suction fixture. With the central vacuum de-energized, set manometer to zero and check all instruments for proper operation.

NOTE 2—The suction fixture and manometer will be alternately connected to the suction fixture to feed media and record vacuum respectively during the test cycle.

9.3.3 Record absolute barometric pressure (not corrected for altitude) and dry- and wet-bulb temperature readings of the test area. Read barometric pressure to the nearest 0.02 in. of mercury (0.51 mm Hg), and the dry- and wet-bulb temperatures to the nearest 0.2°F (0.1°C).

9.3.4 Connect a wattmeter and voltmeter in accordance with Fig. 3.

9.3.4.1 *Wattmeter Correction*—If needed, the indication may be corrected for voltmeter and wattmeter potential coil loss by opening the load circuit on the load side of the wattmeter with the line voltage at the operation value. The wattmeter current connection may be at its most sensitive position. Subtract this loss value from the total load indication to obtain the true load. As an alternate method, use the following equation:

$$W_C = W_I - V^2/R_T \quad (1)$$

Where:

W_C = corrected wattage,
W_I = indicated wattage,
V = voltmeter reading, and
R_T = $R_p - X\ R_v / (R_p + R_V$.

Where:

R_T = total resistance,
R_p = wattmeter potential coil resistance, and
R_v = voltmeter coil resistance.

10. Test Procedures

10.1 *Sustained Air Performance and Exhaust Emissions:*

10.1.1 Condition or restore test units in accordance with 9.1 through 9.2.1.3.

10.1.2 Maintain power unit and dirt canister in their normal operation orientation with the setup described in 9.3.1 through 9.3.4.1 for sustained air performance and exhaust emissions measurement.

10.1.3 After the five minute run-in and with the vacuum cleaning system operating at a constant rated voltage ±1 % and rated frequency ±1 Hz. Record the initial suction and input power in that order. Read the suction to the nearest gradation of the appropriate instrument.

10.1.3.1 Take the suction readings (working vacuum at 0.75 in. (19.00 mm) orifice – referred to as "suction" from here forward) as soon as the manometer reaches a true peak. (When using a fluid type manometer, the liquid level may peak, drop, and peak again. The second peak is the true peak reading. A person conducting the test for the first time shall observe at least one run before recording data. (See Test Method F820 for instructions on how to minimize the overshoot (first peak) of the liquid level.)

10.1.4 With the power unit still energized, disconnect the manometer and connect the suction fixture to the tap on the apparatus as shown in Fig. 1.

10.1.5 Feed the test media at the rate of 1.76 ± 0.07 oz/min (50.0 ± 2.0 g/min) into the suction fixture. Allow the power unit to pick-up all 50.0 g of the test media.

10.1.6 De-energize the power unit until the motor stops rotating; reconnect suction fixture to manometer.

10.1.7 Re-energize the power unit and let it run for 10 s at a constant rated voltage ±1 % and rated frequency ±1 Hz. Record the suction and input power in that order. Read the suction to 0.1 in. of water lift.

10.1.8 Take the suction reading as soon as the manometer reaches a true peak. (When using a fluid type manometer, the liquid level may peak, drop, and peak again. The second peak is the true peak reading. A person conducting the test for the first time shall observe at least one run before recording data. See Test Method F820 for instructions on how to minimize the overshoot (first peak) of the liquid level.)

10.1.9 Repeat 10.1.5 through 10.1.8 eight times until a total of 400 g of test media are ingested. Record the suction and

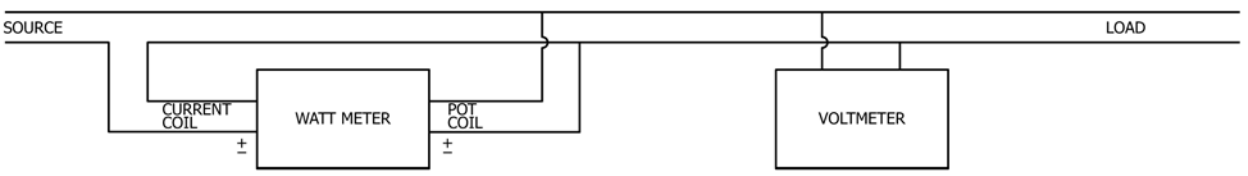

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FIG. 3 Schematic Diagram of Meter Connections

input power versus the cumulative amount of test media ingested. See Table 1.

10.1.10 De-energize the unit after ingesting 400 g of test media and immediately record the weight of the emissions collection bag, then subtract the clean bag weight that was recorded in 9.3.1.3 to determine the media weight that was exhausted into the emissions collection bag.

10.1.11 The new emissions collection bag must be conditioned per 9.3.1.1 through 9.3.1.3 before moving to step 10.1.12.

10.1.12 Repeat sections 10.1.9 through 10.1.11 a total of three times. Record weights to the nearest 0.1 g.

10.1.13 Once all 1200 g of test media have been ingested, add the total weight of the exhaust emissions collected in the three emission collection bags.

11. Calculations

11.1 *Correction of Data to Standard Conditions:*

11.1.1 *Air Density Ratio*—The density ratio, D_r, is the ratio of the air density at the time of test, ρ_{test}, to the standard air density, ρ_{std} = 0.075 lb/ft^3 (1.2014 kg/m^3). It is used to correct the vacuum and wattage readings to standard conditions. Find ρ_{test} (lb/ft^3 or kg/m^3) from standard psychrometric charts or ASHRAE tables and calculate D_r as follows:

$$D_r = \frac{\rho_{test}}{\rho_{std}} \quad (2)$$

Where:

ρ_{test} = the air density at the time of test, lb/ft^3, and
ρ_{std} = the standard air density, 0.075 lb/ft^3.

As an alternative, the following equation is intended to be used for correcting ambient conditions where the barometric pressure exceeds 27 in. of mercury and the dry-bulb and wet-bulb temperatures are less than 100°F (37.8°C) and may be used as an alternate method of calculating D_r (See Appendix X1 of Test Method F820 for derivation and accuracy analysis).

$$D_r = \frac{[17.68\ B_t - 0.001978\ T_w^2 + 0.1064\ T_w + 0.0024575\ B_t\ (T_d - T_w) - 2.741]}{(T_d + 459.7)}$$

Where:

B_t = test station pressure at time of test, in. of mercury,
T_d = dry-bulb temperature at time of test, °F, and
T_w = wet-bulb temperature at time of test, °F.

11.1.2 *Corrected Suction*—Corrected suction, h_s, is the manometer reading, h, times the correction factor, C_s, as follows:

$$h_s = C_s h \quad (3)$$

11.1.2.1 For series universal motor/fan systems, the correction factor, C_s, is calculated as follows:

$$C_s = 1 + 0.667(1 - D_r) \quad (4)$$

11.1.2.2 This test method does not have any formulas available for correcting suction for any other type of motor (permanent magnet, induction, etc.).

11.1.3 *Corrected Input Power*—Corrected input power, P_s, expressed in watts, is the wattmeter reading, P, times the correction factor, C_p, as follows:

$$P_s = C_p P \quad (5)$$

11.1.3.1 For series universal motor/fan systems, the correction factor, C_p, is calculated as follows:

$$C_p = 1 + 0.5(1 - D_r) \quad (6)$$

11.1.3.2 This standard does not have any formulas available for correcting input power for any other types of motor (permanent magnet, induction, etc.).

11.2 *Calculations for the Sustained Air Performance Test:*

11.2.1 For the sustained performance test, calculate the corrected suction and corrected input power for each increment of aspirated test media including the initial measurements. Fill in Table 1 with the corrected data.

11.2.2 Sustained air performance efficiency is the ratio of the vacuum of the system after loading to the unloaded system suction as shown in the following equation:

$$Sustained\ Air\ Performance\ Efficiency = \frac{Corrected\ \ Suction\ System\ Loaded}{Corrected\ Suction\ System\ Unloaded} \times 100 \quad (7)$$

11.3 *Calculation of the Exhaust Emissions Efficiency:*

NOTE 3—If the Exhaust Emissions efficiency is greater than 100 %, then the recorded result will be 100 %.

11.3.1 Exhaust Emissions Efficiency is (1 – (the weight of the media exhausted into the exhaust emissions collection bag, divided by the weight of the media introduced) × 100):

$$Exhaust\ Emissions\ Efficiency = 1 - \frac{Media\ Weight\ in\ Emissions\ Collection\ Bag}{Total\ Media\ Weight\ Ingested} \times 100$$

TABLE 1 Sustained Air Performance Test Results

Amount of Ingested Test Media (grams)	Corrected Vacuum (mm H_2O)	Corrected Input Power (watts)	Sustained Air Performance	Exhaust Emissions
0				N/A
50				N/A
100				N/A
150				N/A
200				N/A
250				N/A
300				N/A
350				N/A
400				N/A
450				N/A
500				N/A
550				N/A
600				N/A
650				N/A
700				N/A
750				N/A
800				N/A
850				N/A
900				N/A
950				N/A
1000				N/A
1050				N/A
1100				N/A
1150				N/A
1200				N/A

12. Report

12.1 The recorded data covering the performance of a given residential central vacuum cleaning system should include the following information:

12.1.1 Manufacturer's name, model number, and trade name.

12.1.2 Type of filtration; that is, paper bag, cloth bag, foam filter, centrifugal, etc.

12.1.3 The amount of ingested test media, corrected suction, and corrected input power.

12.1.4 Report the sustained air performance value and the test data summarized in Table 1.

12.1.5 Report the Exhaust Emissions (the total media collected in the emissions collection bag relative to the total media ingested in grams (to the nearest 0.1 g)).

13. Precision and Bias

13.1 The precision of this test method is based on an interlaboratory study of ASTM WK14392, New Standard Test Method for Sustained Air Performance and Exhaust Emissions, conducted in 2012. Three laboratories participated in this study, testing a single type of vacuum cleaner by two different analytical methods. Every "test result" represents an individual determination. The laboratories were asked to report three test results for each analysis. Except for the limited number of laboratories participating, Practice E691 was followed for the basic design and analysis of the data; the details are given in ASTM Research Report No. F11–1021.[5]

13.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

13.1.1.1 Repeatability limits are listed in Table 2 and Table 3 below.

13.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

13.1.2.1 Reproducibility limits are listed in Table 2 and Table 3 below.

13.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

13.1.4 Any judgment in accordance with 13.1.1 would normally have an approximate 95 % probability of being correct; however, the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of laboratories reporting results indicates that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than 95 % probability limit would imply. Consider the precision limits for Method A as a general guide and the associated probability of 95 % as only an indicator of what can be expected.

13.2 *Bias*—At the time of the study, no certified reference material suitable for determining the bias for this test method was available; therefore, no statement on bias is being made.

13.3 The precision statement was determined through statistical examination of all but one reported result, from three laboratories, on a single vacuum, for two methods.

14. Keywords

14.1 air performance; central vacuum; Exhaust Emissions; sustained air performance

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F11-1021. Contact ASTM Customer Service at service@astm.org.

TABLE 2 Sustained Air Performance Efficiency (%)

Material	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
Vacuum cleaner	47.044	1.409	2.587	3.944	7.243

[A] The average of the laboratories' calculated averages.

TABLE 3 Exhaust Emissions Efficiency (%)

Material	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
Vacuum cleaner	-0.3532	0.3721	0.5364	1.0419	1.5019

[A]The average of the laboratories' calculated averages.