Designation: F 1334 – 02

Standard Test Method for Determining A-Weighted Sound Power Level of Vacuum Cleaners[1]

This standard is issued under the fixed designation F 1334; 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 calculates the overall A-weighted sound power level emitted by small portable upright, canister, combination vacuum cleaners, and central vacuum cleaner motorized nozzles intended for operation in domestic and commercial applications.

1.2 A-weighted sound pressure measurements are performed on a stationary vacuum cleaner in a semi-reverberant room. This test method determines sound power by a comparison method for small noise sources, that is, comparison to a broadband reference sound source.

1.3 This test method describes a procedure for determining the approximate A-weighted sound power level of small noise sources. This test method uses a non-special semi-reverberant room.

1.4 Results are expressed as A-weighted sound power level in decibels.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are for information only.

1.6 *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:*

C 634 Terminology Relating to Environmental Acoustics[2]

E 177 Practice for Use of the Terms of Precision and Bias in ASTM Test Methods[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

F 608 Method for Evaluation of Carpet-Embedded Dirt Removal Effectiveness of Household Vacuum Cleaners (Laboratory Method)[4]

F 655 Specifications for Test Carpets and Pads for Vacuum Cleaner Testing[4]

2.2 *ANSI Standards:*

S1.4 Specifications for Sound Level Meters[5]

S1.26 Method for the Calibration of the Absorption of Sound by the Atmosphere[5]

S12.31 Precision Methods for the Determination of Sound Power Levels of Broad Band Noise Sources in Reverberant Rooms[5]

S12.32 Precision Methods for Determination of Sound Power Levels for Discrete Frequency and Narrow Band Noise Sources in Reverberant Rooms[5]

S12.33 Engineering Methods for Determination of Sound Power Levels of Noise Sources in a Special Reverberant Test Room[5]

2.3 *ISO Standards[5]:*

These standards are similar to and may be used in place of ANSI S12.31, S12.32, and S12.33, respectively:

3741 Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Precision Methods for Reverberation Rooms

3742 Acoustics—Determination of Sound Power Levels of Noise Sources—Precision Method for Discrete-Frequency and Narrow-Band Sources in Reverberation Rooms

3743 Acoustics—Determination of Sound Power Levels of Noise Sources—Engineering Methods for Small, Movable Sources in Reverberant Fields

2.4 *IEC Standard:*

60704.1 Test Code for the Determination of Airborne Acoustical Noise Emitted by Household and Similar Electrical Appliances[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *population, n*—the total of all of the units of the particular model and/or type of vacuum cleaner being tested.

3.1.2 *population sample or sample, n*—three or more test units, randomly taken from the population.

[1] This test method is under the jurisdiction of ASTM Committee F11 on Vacuum Cleaners and is the direct responsibility of Subcommittee F11.25 on Sound Measurement.

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[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 15.08.

[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

3.1.3 *reference sound source*, *n*—a standard source of broadband sound with a certified set of sound power emissions.

3.1.4 *source*, *n*—a device that emits sound. This may be the vacuum cleaner or a motorized nozzle.

3.1.5 *test unit or unit*, *n*—a single vacuum cleaner or nozzle of the model and/or type being tested.

3.1.6 Unless otherwise indicated, definitions are in accordance with Terminology C 634.

4. Significance and Use

4.1 The test results enable the comparison of A-weighted sound emission from vacuum cleaners when tested under the condition of this test method.

5. Test Room Requirements

5.1 The test room shall be semi-reverberant. It shall contain sufficiently little sound absorption material so the requirements of 5.2 can be met. It should be large enough to meet the dimension requirements of 5.2.

5.1.1 When a central vacuum cleaner motorized nozzle is to be tested, the test room should be plumbed for a central vacuum system according to the manufacturer's instructions using standard 2.00 inch diameter thin-wall PVC tubing. A single wall inlet shall be located in the test room.

5.2 Identify a location on the test room floor which can accommodate six equally spaced microphone positions 60° apart located at a height of 60 in. (1.5 m) above the floor on a 12 ft (3.6 m) diameter circle the center of which is the center of the sound source. These positions shall result in a standard deviation of the six sound pressure measurements of not more than 2.3 dB when measuring the reference sound source. This location is suitable for the vacuum cleaner and reference sound source for this test method. Refer to Figs. 1-4 for typical layouts.

5.3 *Environmental*—Ambient test conditions within the test room shall be controlled to within 20 ± 4°C and 30 to 70 % relative humidity.

5.4 Also, any room which has qualified in accordance with ANSI S1.26, S12.31, S12.32, S12.33, ISO 3741, 3742 and 3743 may be used to measure the sound power levels of vacuum cleaners.[6]

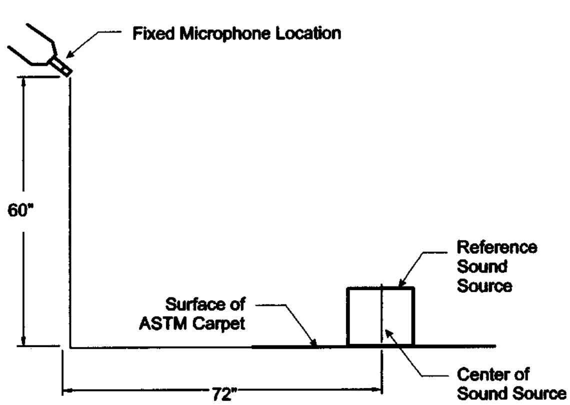

FIG. 1 Sound Set Up

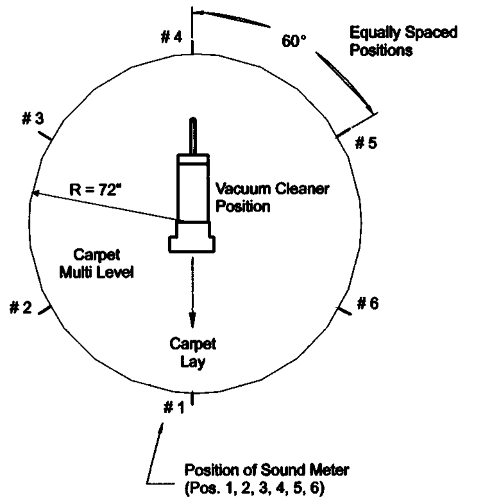

FIG. 2 Sound Test Pattern for Uprights

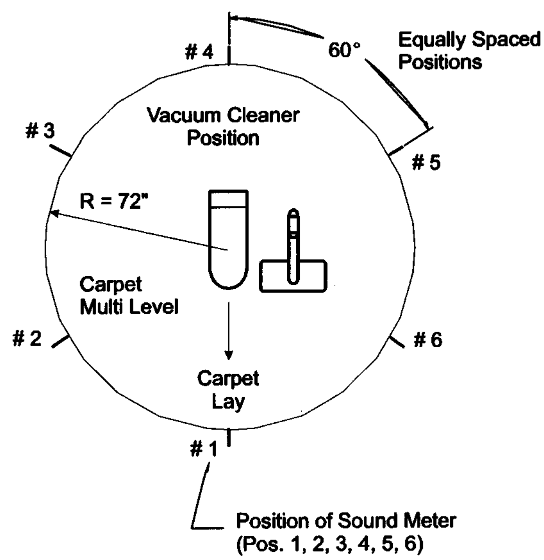

FIG. 3 Sound Test Pattern for Canisters

5.5 The measured A-weighted sound pressure levels shall be corrected for the influence of background noise according to Table 1. When the steady background-noise sound pressure level is more than 6 dB below the sound pressure level at each measurement point, the measured A-weighted sound pressure levels shall be corrected for the influence of background noise according to Table 1. If this difference is less than 6 dB no correction is allowed and any reported data must include a note indicating that the background noise requirements of this standard were not satisfied.

6. Instrumentation and Equipment

6.1 *Acoustical Instrumentation*—The sound measurement system shall be as specified in ANSI S1.4.

[6] Further information provided in ANSI S1.26 Method for the Calibration of the Absorption of Sound by the Atmosphere, available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

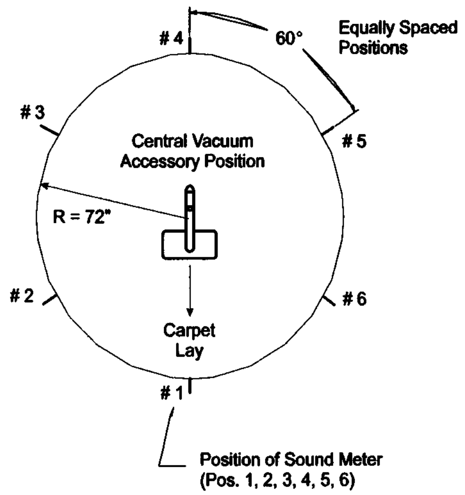

FIG. 4 Sound Test Pattern for CV Accessories

TABLE 1 Corrections for Background Noise Levels

Difference Between Sound Pressure Level Measured with Sound Source Operating and Background Noise Level Alone, dB		Correction to be Subtracted from Sound Pressure Level Measured with Sound Source Operating to Obtain Sound Pressure Level Due to Sound Source Alone, dB
Less than	6	No correction allowed
	6	1
	7	1
	8	1
	9	0.5
	10	0.5
Greater than	10	0

6.2 *Voltage Regulator System*—The regulator shall be capable of maintaining the vacuum cleaner's rated voltage (±1 %) and frequency (±1 Hz) having a waveform that is essentially sinusoidal with 3% maximum harmonic distortion for the duration of the test.

6.3 *Test Carpet and Pad*—The test carpet and pad shall be 54 in. wide (137 cm) and 72 in. (183 cm) long. The carpet shall be multilevel. Carpet and pad shall be as specified in Specification F 655.

NOTE 1—For this test method two standard size 27 by 72-in. (69 by 183-cm) long test carpets could be placed side by side to make it 54 by 72-in. (138 by 183-cm) long. It is recommended that the two pieces of test carpet be taped to the floor, side by side with the pile running in the same direction.

6.4 *Reference Sound Source*—The reference sound source shall meet the requirements of Section 9 of ANSI S12.31.

6.5 *Instrumentation*:

6.5.1 *Thermometer*, accurate to within ±2°C.

6.5.2 A means of measuring relative humidity, accurate to within ±2 % over the range used.

6.5.3 *Barometer*, accurate to within ±2 %.

7. Operation of Vacuum Cleaner

7.1 *Run-In*—Operate new test cleaners continuously for at least 1 h prior to testing. Canister cleaners shall be run open with no hose attached. Upright and power nozzles shall be run so that the rotating brush does not engage the carpet or the floor.

7.2 *Warm-Up*—Operate the cleaners for 10 min just prior to making sound pressure level measurements in the same configuration as described in 7.1.

7.3 *Test Configuration*:

7.3.1 The vacuum cleaner shall be configured for the carpet cleaning mode.

7.3.2 The dust bag or primary filter shall be new.

7.3.3 All belts shall be new at the start of the run-in.

7.3.4 Rotating agitator type cleaner including power nozzle shall use the same setting as specified in Method F 608 for cleaning multilevel carpet which is as follows:

7.3.4.1 If various settings are provided, set the motor speed setting, suction regulator, or nozzle height, or combination thereof, using the manufacturer's specified setting for cleaning multilevel carpet. Momentary or instantaneous speeds are not to be used.

7.3.5 For straight air canister cleaners use the same setting specified in Method F 608 for cleaning multilevel carpet, which is as follows:

7.3.5.1 If various settings are provided, set the motor setting, suction regulator, or nozzle height, or combination thereof, using the manufacturer's specific setting for cleaning multilevel carpet. If no specific instructions are given, or if judged to be inadequate or unclear, position the nozzle on the carpet so the maximum suction is provided, taking care to maintain the tilt angle throughout the test. Momentary or instantaneous speeds are not to be used.

7.3.6 *Voltage*—Tests are to be conducted at the nameplate voltage (±1 %) and frequency (±1 Hz) throughout the test. For cleaners with dual nameplate voltage ratings, conduct sound tests at the highest voltage.

7.3.7 *Central Vacuum Power Unit*—The central vacuum power unit shall be remotely located (outside the semi-reverberate room) so that the noise levels generated by the power unit do not affect the test results of the central vacuum (motorized or straight air) nozzle being tested.

8. Location of Sound Sources and Equipment

8.1 *Carpet and Pad*—Lay the carpet and pad on the floor with the geometric center of the carpet directly over the center of the circle defined in 5.2.

8.2 Locate the vacuum cleaner or the reference sound source at the position determined in 5.2. All modules (generally the motor/blower and its housing in the base of an upright unit, or in the canister of a canister unit) shall be adequately secured in a manner which will not affect the sound pressure readings.

8.2.1 *Reference Sound Source Location*—Position the center of the radiating portion (fan blades, for an aerodynamic source) over the location defined above. The reference sound source is placed directly on the carpet.

8.2.2 *Vacuum Cleaner Location*:

8.2.2.1 Center the principal module over the source location as determined in 5.2.

8.2.2.2 Take care to ensure the rotating brush model does not damage the carpet seam (that is, center upright on carpet on center of carpet with the rotating brush perpendicular to seam).

8.2.2.3 *Second Module*—If there is a second module not integral with the basic unit (for example, the power nozzle), it shall be positioned on the side of the principle module away from the center of the room. Position the second module in such a way that, to the maximum extent possible, its sound emissions are not shielded by the principal module, and vice versa. For example, a position shall be such that air exhaust noise will radiate into the room in a direction other than toward the second module.

8.2.3 *Handle*—Any operating handle shall be separately supported in a position such that the handle grip is 31½ in. (80 cm) above the carpet surface. Take care that the support structure does not introduce additional rattles, etc. There shall be a resilient clamping of the handle to the support structure.

8.2.4 *Central Vacuum Cleaner Power (or Straight Air) Nozzles*—For central vacuum power (or straight air) nozzles, the hose is connected to the wall inlet valve. The hose assembly with power (or straight air) nozzle is then positioned in the same manner as the hose assembly and power head for a canister vacuum cleaner. See 8.2.2-8.2.3.

9. Sampling

9.1 Test a sufficient number of samples of each vacuum cleaner model until a 90 % confidence level is established within ±2.0 dBA of the mean value. Test a minimum of three samples.

10. Measurement Procedure

10.1 Check the calibration of each microphone according to the instrument manufacturer's directions.[7]

10.2 At each of the six microphone positions determined in 5.2, measure the background A-weighted sound pressure level. Step 10.2 can be ignored if it is known that the background sound pressure levels are more than 10 dB below the sound pressure levels of all sources being considered at all microphone locations.

10.3 With the reference sound source in the location defined in Section 8 and running in accordance to the manufacturer's recommendations, measure the A-weighted sound pressure level at the six microphone positions. After making the necessary corrections for the influence of the background noise at each microphone location and ensuring that the standard deviation requirement of 5.2 is met, calculate the space-averaged A-weighted sound pressure level of the reference sound source, L_{pr}, using the equation:

$$L_p \text{ or } L_{pr} = 10 \log \left\{ \frac{1}{N_m} \sum_{i=1}^{N_m} 10^{L_i/10} \right\} \quad (1)$$

where:

L_p *or* L_{pr} = A-weighted sound pressure level averaged over all microphone positions, for a single source location, dB,

L_i = A-weighted sound pressure level for the *i* th microphone position, dB, and

N_m = number of microphone positions.

10.4 Replace the reference sound source with the test unit. With the test unit operating in accordance to Section 7, measure the A-weighted sound pressure level at the six microphone locations. After making the necessary corrections for the influence of the background noise at each microphone location, calculate the space-averaged A-weighted sound pressure level, L_p, of the test unit using the equation of 10.3.

10.5 Using the space-averaged A-weighted sound pressure levels, L_{pr} and L_p, and the known A-weighted sound power level of the reference sound source, calculate the A-weighted sound power level of the test unit using the procedure of 11.1.

10.6 Using the same test unit repeat steps 10.2-10.5 two (2) additional times for a total of three (3) test runs.

10.7 The sound power level (score) for each individual test unit is the arithmetic average of the A-weighted sound power levels of three test runs which meet the repeatability requirements of Section 14. See Annex A1 for a procedural example and to determine if additional test runs need to be conducted.

10.8 A minimum of two additional test units of the same model must be selected in accordance with the sampling statement of Section 9. Repeat 10.2-10.7 for each additional test unit. See Annex A1 for a procedural example and whether additional test units need to be tested.

10.8.1 When testing central vacuum cleaner accessories, a minimum of two (2) additional accessories of the same model must be selected in accordance with the sampling statement in Section 9.

10.9 The best estimate of A-weighted sound power level for the population of the vacuum cleaner model being tested is the arithmetic mean of sound power level of the sample population meeting the requirements of the sampling statement in Section 9.

10.9.1 The best estimate of A-weighted sound power level for the population of the central vacuum cleaner accessory model being tested is the arithmetic mean of A-weighted sound power level of the sample population meeting the requirements of the sampling statement in Section 9.

11. Calculation of A-Weighted Sound Power Levels for the Comparison Method

11.1 The A-weighted sound power level produced by the test unit shall be calculated as follows. Subtract the A-weighted sound pressure level produced by the reference sound source (corrected for background noise according to 5.5) from the A-weighted sound pressure level of the test unit under test (corrected for the background noise according to 5.5). Add the difference to the known A-weighted sound power level produced by the reference sound source:

$$L_W = L_{wr} + L_p - L_{pr} \quad (2)$$

where:

L_W = the A-weighted sound power level, in decibels, produced by the test unit under test.

L_p = the average A-weighted sound pressure level, in decibels, produced by the test unit under test, as determined in accordance with 10.3,

L_{wr} = the known A-weighted sound power levels, in decibels, produced by the reference sound source, and

[7] Further information provided in ANSI S1.10 Method for the Calibration of Microphones, available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

L_{pr} = the average A-weighted sound pressure level, in decibels, produced by the reference sound source, as determined in accordance with 10.2.

12. Information

12.1 *General*—Record the name and location of the test laboratory, including the date and time of the measurements.

12.2 *Test Room*—Record the description of the room construction, dimensions, configurations, and deployment of absorptive materials, etc.

12.3 *Equipment*—Maintain recorded diagram of the acoustical data acquisition system. This shall include the model number and serial number of all microphones, preamplifiers, filters, meters, etc. Describe microphone cables specifically. Record the calibrator model number and serial number, output frequency and calibrated level. Record any other pertinent equipment information.

12.4 *Geometry*—Record the source location point and the microphone positions.

12.5 *Vacuum Cleaner*—Record the manufacturer, model name and number, and unit serial number.

12.6 *Environment*—Record the temperature, relative humidity, and barometric pressure.

12.7 *Calibration Check*—Record the actual readout level with the calibrator on the microphone, both at the beginning and end of the measurement period, to the nearest 0.1 dB, or as closely as the instrumentation permits.

12.8 *Ambient Sound Pressure Level*—Record the ambient overall (A-weighted) sound pressure levels at each of the microphone locations to the nearest 0.1 dB.

12.9 *Reference Sound Source*—Record the overall A-weighted sound pressure levels at each of the microphone positions to the nearest 0.1 dB. Include a copy of the sound power data calibration sheet as supplied from the source manufacturer.

12.10 *Vacuum Cleaner*—Record the overall A-weighted sound pressure levels at each of the microphone locations to the nearest 0.1 dB.

12.11 Record any other pertinent data or comments.

13. Test Report

13.1 Report the following information:

13.1.1 A description of the test samples used and the means used to distinguish them from other similar specimens (make, model, serial number, manufacturing date),

13.1.2 Approximate size and weight of the models tested and whether an operator was present during the sound level measurements, and

13.1.3 Average A-weighted sound power level (calculated) shall be reported to the nearest decibel.

14. Precision and Bias [8]

14.1 *Precision*—The following precision statements are based on interlaboratory tests involving ten laboratories and three test units:

14.1.1 The statistics have been calculated as recommended in Practice E 691.

14.1.2 The following statements regarding repeatability limit and reproducibility limit are used as directed in Practice E 177.

14.1.3 The standard deviations of repeatability and reproducibility of the calculated A-weighted sound power level results have been derived from ten sets of data, where each set of three test runs has been performed by a single analyst within each of the ten laboratories on multidays using the test unit which produced the largest value of average A-weighted sound power level of 89.4 dBA.

14.1.4 *Repeatability (Single Operator and Laboratory; Multiday Testing)*—The ability of a single analyst to repeat the test within a single laboratory.

14.1.4.1 The expected standard deviation of repeatability of the calculated A-weighted sound power level results within a laboratory, S_r, has been found to be 0.7 dBA.

14.1.4.2 The 95 % repeatability limit within a laboratory, r, has been found to be 1.94 dBA, where $r = 1.96 \sqrt{2} (S_r)$.

14.1.4.3 With 95 % confidence, it can be stated that within a laboratory a set of calculated A-weighted sound power level results derived from testing a test unit should be considered suspect if the difference between any two of the three values is greater than the respective value of the repeatability limit, r.

14.1.4.4 If the absolute value of the difference of any pair of calculated A-weighted sound power level results from three test runs performed within a single laboratory is not equal to or less than the respective repeatability limit, r, that set of test results shall be discarded.

14.1.5 *Reproducibility (Multiday Testing and Single Operator within Multilaboratories)*—The ability to repeat the test within multiple laboratories.

14.1.5.1 The expected standard deviation of reproducibility of the average of a set of calculated A-weighted sound power level results between multiple laboratories, S_R, has been found to be 1.2 dBA.

14.1.5.2 The 95 % reproducibility limit within a laboratory, R, has been found to be 3.4 dBA, where $R = 1.96 \sqrt{2} (S_R)$.

14.1.5.3 With 95 % confidence, it can be stated that the average of the calculated A-weighted sound power level 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 value of the reproducibility limit, R.

14.1.5.4 If the absolute value of the difference between the average of the calculated A-weighted sound power level results from the two laboratories is not equal to or less than the respective reproducibility limit, R, the set of results from both laboratories shall be discarded.

14.2 *Bias*—No justifiable statement can be made on the bias of the method to measure and calculate the A-weighted sound power of household vacuum cleaners since the true value of the characteristics cannot be established by an acceptable refereed method.

[8] Supporting data are available from ASTM Headquarters, Request RR: F11-1011.

15. Keywords

15.1 A-weighted; central vacuum cleaner; motorized nozzle; reference sound source (RSS); sound power level; vacuum cleaners

ANNEX

(Mandatory Information)

A1. DETERMINATION OF THE POPULATION MEAN HAVING A 90 % CONFIDENCE INTERVAL[9]

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 test 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 ±2 dBA of the calculated mean, $\bar{X}$, of the sample taken from the population as stated in Section 9.

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 9. 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:

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

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

where:

n = number of units tested, and
X_i = the value of the individual test unit score of the *i* th 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 14.

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

NOTE A1.1—The value of *t* is defined as $t_{1-\alpha/2}$ and is read as "*t* at 95 % confidence".

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

df	*t*
1	6.314
2	2.92
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.86
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761
15	1.753

[A] Adapted by permission from Introduction to Statistical Analysis (2d ed.) by W. J. Dixon and F. J. Massey, Jr., 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.

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

where:

$$1 - \alpha/2 = 1 - 0.10/2 = 1 - 0.05 = 0.95, \text{ or } 95\ \% \quad (A1.4)$$

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:

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

$$CI_L = \bar{X} - ts/\sqrt{n}$$

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, as stated in 9.1, as established as 2 dBA for all cases.

NOTE A1.2—Generally, the value of A is stated as a percentage of the estimated population mean. As agreed to by ASTM Committee F11 on

[9] Natrella, Mary Gibbons, Experimental Statistics, National Bureau of Standards Handbook 91, U.S. Government Printing Office, Washington DC, 1963, pp. 2-1 to 2-3.

Vacuum Cleaners, in cooperation with Committee E33 on Environmental Acoustics, the value of 2 dBA has been established.

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 test units, a larger sample size, *n*, shall be used.

A1.2 *Procedure*—A graphical flow chart for the following procedure is shown in Fig. A1.1.

A1.2.1 Select three test 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 14.

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

A1.2.4 $A = 2.0$ dBA (for all cases).

A1.2.5 Determine the statistic *t* for $n - 1$ degrees of freedom from Table A1.1, where n = the number of test units.

A1.2.6 Compute $ts/\sqrt{n}$ for the sample and compare it to the value of A.

A1.2.7 If the value of $ts/\sqrt{n} > A$, an additional test unit from the population shall be selected and tested, and the computations of A1.2.2-A1.2.6 repeated.

A1.2.8 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 A-weighted sound power rating for the population.

A1.3 *Example*—The following data is chosen to illustrate how the mean value of A-weighted sound power, $\bar{X}$, for the population of a vacuum cleaner model is derived. The calculated A-weighted sound power level test results from three test

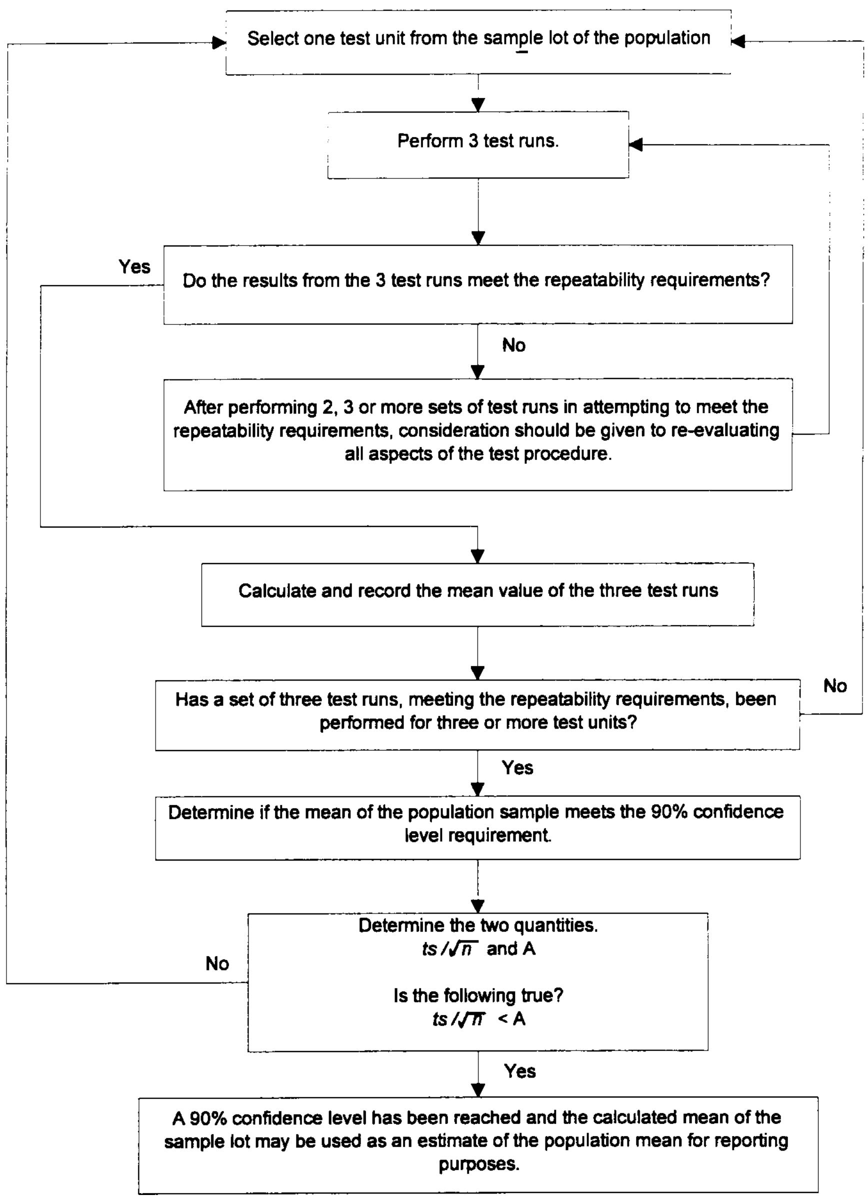

FIG. A1.1 Testing Procedure Flowchart

runs on each unit are required to have a repeatability limit not exceeding 1.94 dBA as indicated in Section 14.

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:

Test Run No. 1 = 85.5 dBA
Test Run No. 2 = 83.4 dBA
Test Run No. 3 = 85.1 dBA

A1.3.3 Maximum spread = 85.5 − 83.4 = 2.1 dBA.

A1.3.3.1 This value is greater than the repeatability limit required in Section 14. The results shall be discarded and three additional test runs performed.

A1.3.4 Test run scores for test unit No. 1:

Test Run No. 4 = 84.9 dBA
Test Run No. 5 = 85.1 dBA
Test Run No. 6 = 85.8 dBA

A1.3.5 Maximum spread = 85.8 − 84.9 = 0.9 dBA.

A1.3.5.1 This value is less than the repeatability limit requirement of Section 14.

A1.3.6 Unit No. 1 score = (84.9 + 85.1 + 85.8)/3 = 85.3 dBA.

NOTE A1.3—If it is necessary to continue repeated test run sets (7,8,9 − 10,11,12—etc.) because the spread of data within a data set is not less than the repeatability limit requirement stated in Section 14, 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. Consideration should be given to re-evaluating 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 test units met the repeatability requirements and the individual test unit scores are:

Score of Test Unit No. 1 = 85.27 dBA
Score of Test Unit No. 2 = 88.53 dBA
Score of Test Unit No. 3 = 87.41 dBA

A1.3.8 $\bar{X} = \frac{85.27 + 88.53 + 87.41}{3} = 87.1 \text{ dBA}$

A1.3.9

$$s = \sqrt{\frac{3[(85.27)^2 + (88.53)^2 + (87.41)^2 - [85.27 + 88.53 + 87.41]^2}{3(3-1)}} \quad \text{(A1.6)}$$

$$s = 1.656 \text{ dBA} \quad \text{(A1.7)}$$

A1.3.10 A = 2.0 dBA

A1.3.11 Degrees of freedom, $n - 1 = 3 - 1 = 2$

$$t_{0.95} \text{ statistic} = 2.920 \quad \text{(A1.8)}$$

A1.3.12 $tsl\sqrt{n} = 2.920\ (1.656)/\sqrt{3} = 2.792$ dBA

A1.3.13 2.792 > 2.0

A1.3.13.1 The requirement that $ts/\sqrt{n} < A$ has not been met because *s* is large. Therefore, an additional test unit from the population shall be tested.

A1.3.14 Score of test unit No. 4 = 86.3

A1.3.15 $\bar{X} = 85.27 + 88.53 + 87.41 + 86.34/4 = 86.9$ dBA

A1.3.16

$$s = \sqrt{\frac{4[(85.27)^2 + (88.53)^2 + (87.41)^2 + (86.34^2] - [85.27 + 88.53 + 87.41 + 86.34]^2}{4(4-1)}} \quad \text{(A1.9)}$$

$$s = 1.401 \text{ d}BA \quad \text{(A1.10)}$$

A1.3.17 A = 2.0 dBA

A1.3.18 Degrees of freedom, $n - 1 = 4 - 1 = 3$

$$t_{0.95} \text{ statistic} = 2.353 \quad \text{(A1.11)}$$

A1.3.19 $tsl\sqrt{n} = 2.353\ (1.401)/\sqrt{4} = 1.772$ dBA

A1.3.20 1.772 < 2.0 (meets requirements)

A1.3.21 Thus, the value of $\bar{X}$, 86.9 dBA, represents the A-weighted sound power level score for the vacuum cleaner model tested and may be used as the best estimate of the A-weighted sound power level rating for the population mean.