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

This standard is issued under the fixed designation F2544; 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 central vacuum power units, intended for operation in domestic applications. This standard applies to the power unit only at the power unit location. To test the sound power level of a central vacuum at the user's location, refer to Test Method F1334.

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

1.3 This test method describes a procedure for determining the 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 (referenced to 1 pW).

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:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

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

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

2.2 *ANSI Standards:*[3]

S1.10 Method for the Calibration of Microphones

S1.26 Method for the Calculation of the Absorption of Sound by the Atmosphere

S1.43 Specifications for Sound Level Meters, IEC 804 and IEC 61672

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

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

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

2.3 *ISO Standards:*[3]

ISO 3741, 3742, and 3743 are similar to and may be used in place of ANSI S12.31, S12.32, and S12.33 respectively

2.4 *IEC Standard:*[3]

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

3. Terminology

3.1 Unless otherwise indicated, definitions are in accordance with Terminology C634.

3.2 *Definitions:*

3.2.1 *population, n*—total of all of the units of the particular model or type, or both, of central vacuum power units being tested.

3.2.2 *population sample or sample, n*—three or more 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.

Current edition approved Nov. 1, 2011. Published December 2011. Originally approved in 2006. Last previous edition approved in 2006 as F2544 – 06$^{\varepsilon1}$. DOI: 10.1520/F2544-11.

[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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

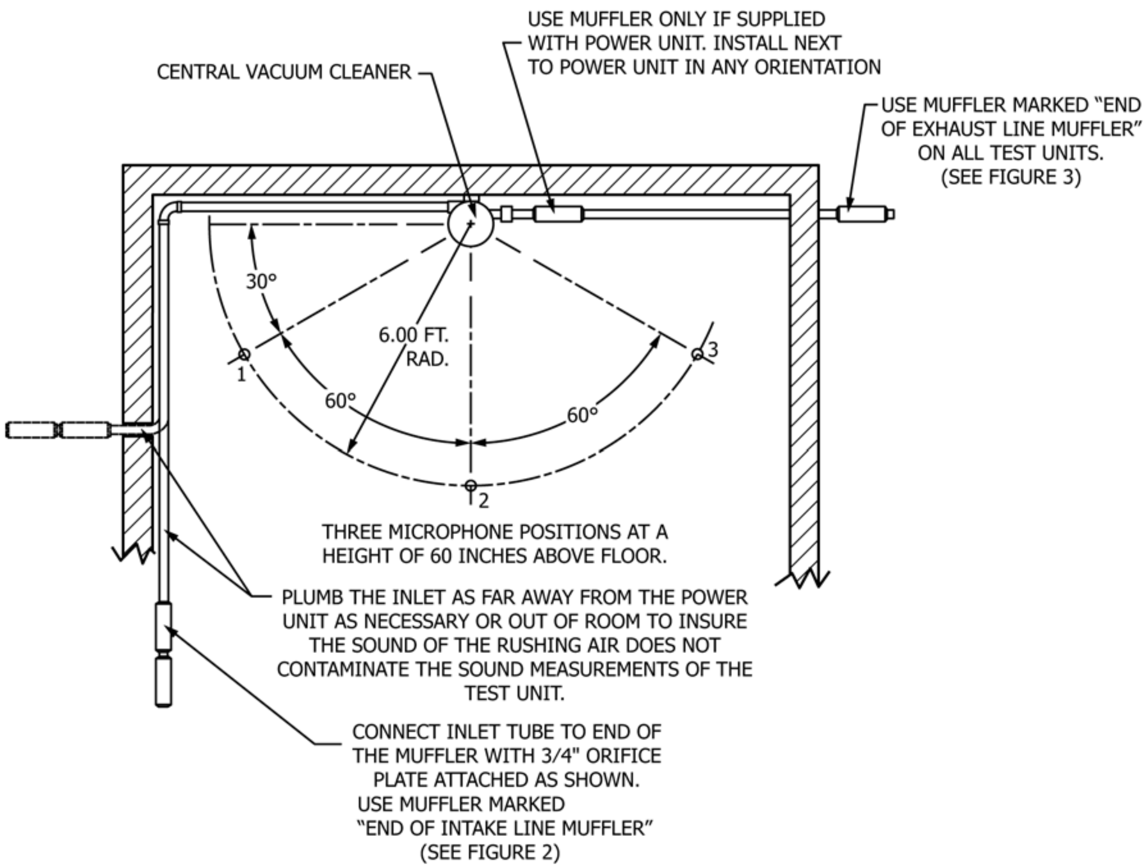

FIG. 1 Sound Test Layout

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

3.2.4 *source, n*—device that emits sound.

3.2.5 *test unit or units, n*—single central vacuum power unit of the model or type, or both, being tested.

4. Significance and Use

4.1 The test results enable the comparison of A-weighted sound emission from central vacuum power units 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 shall be large enough to allow a semi-circle with a 6-ft radius centered at the sound source (the central vacuum power unit) that shall be clear of all obstruction, including the operator, during the measurements.

5.1.1 The test room should be plumbed for the central vacuum according to the manufacturer's instructions using standard 2-in. outside diameter thin-wall PVC tubing. Units with multiple exhaust ports shall be plumbed with multiple exhaust lines per manufacturer's instructions. Units without exhaust ports shall not have an exhaust line plumbed outside the test room. The power unit is to be mounted on the wall per the manufacturer's recommendations.

5.2 Three microphone positions are to be used. The microphone positions are to be on a semi-circle with a 6-ft radius centered at the sound source (the central vacuum power unit). The microphone positions will be spaced 30° from the wall and 60° apart from each other on the semi-circle at a height of 60 in. (1.5 m). The microphone should be oriented per the microphone manufacturer's instructions. Refer to Fig. 1 for layout. These positions shall result in a standard deviation of the three sound pressure measurements of not more than 2.3 dB when measuring the reference sound source.

5.3 *Environmental*—Ambient test conditions within the test room shall be controlled to 70 ± 5°F (21 ± 3°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.

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

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

measurement point, the measured A-weighted sound pressure levels shall be corrected for the influence of background noise. 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 test method were not satisfied.

6. Instrumentation and Equipment

6.1 *Acoustical Instrumentation*—The sound measurement system shall be as specified in ANSI S1.43.

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

6.4 *Instrumentation:*

6.4.1 *Thermometer,* accurate to ±3°F (±2°C).

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

7. Operation of Central Vacuum Cleaner

7.1 *Run in*—Operate new test cleaners continuously for at least 10 min prior to testing. The central vacuum power unit should be run with the orifice adapter tube (as specified in Test Method F820) connected to the power unit inlet (for run-in only).

7.2 *Warm up*—Operate the cleaners for 10 min just prior to making sound pressure level measurements in the same configuration as shown in Fig. 1.

7.3 *Test Configuration:*

7.3.1 The inlet tube and exhaust line should be plumbed with PVC tubing as far away from the test unit as necessary or out of the test room to prevent from contaminating the sound test. Refer to Fig. 1 for proper test set up of test unit, intake tube, and exhaust line.

7.3.2 A muffler should only be attached to the exhaust line beside the test unit if it is supplied with the test unit. (See Fig. 2.)

7.3.3 The "end of intake line muffler" is part of the standard test set-up and should be used on all test units. Its intent is to dampen any noise created by the air rushing into the inlet tube to prevent contamination of the sound measurements of the test unit. This muffler is equipped with a ¾-in. sharp edge orifice plate (taking the place of the hose and floor tool). (See Fig. 2.)

7.3.4 The "end of exhaust line muffler" is part of the standard test set-up and should be used on all test units. Its intent is to dampen any noise created by the air rushing out of the exhaust tube to prevent contamination of the sound measurements of the test unit. This muffler does not include an orifice plate. (See Fig. 3.)

7.3.5 The dust bag or primary filter shall be new (if applicable).

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

8. Location of Sound Sources and Equipment

8.1 Locate the central vacuum power unit at the position determined in 5.1.1.

8.2 Locate the reference sound source on the floor (near but not touching) the wall, below the intended location of the vacuum power unit. The microphones should be placed on a 6-ft radius from the center of the vacuum power unit's intended location while testing the reference sound source.

9. Measurement Procedure

9.1 Check the calibration of each microphone according to the instrument manufacturer's directions.[4]

9.2 At each of the three microphone positions determined in 5.2, measure the background A-weighted sound pressure level. Step 9.2 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.

9.3 With the reference sound source in the location defined in Section 8 and running in accordance with the manufacturer's recommendations, measure the A-weighted sound pressure level at the microphone positions (as described in 5.2). 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.

9.4 Remove the reference sound source and mount the test unit per the manufacturer's recommendations. The microphones should be positioned as shown in Fig. 1. With the unit

[4] Further information is provided in ANSI S1.10.

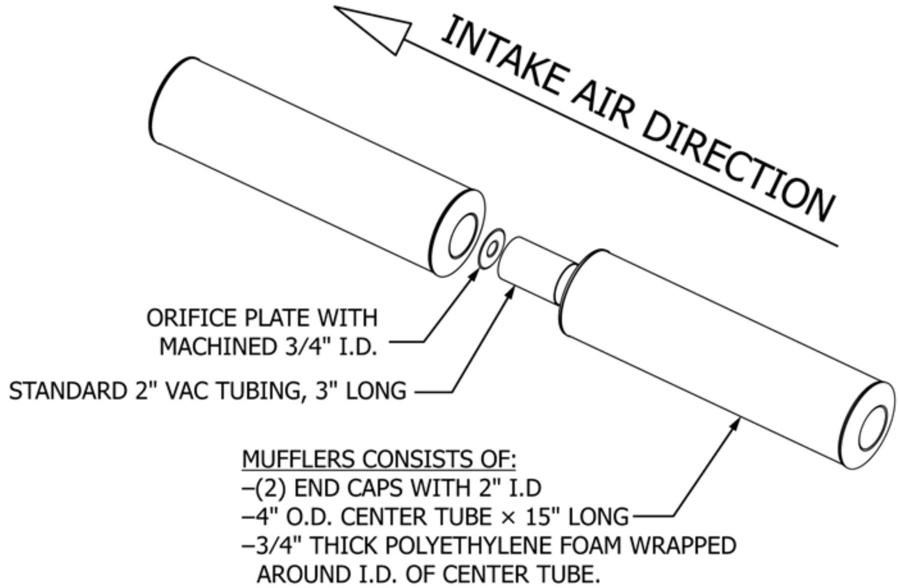

FIG. 2 End of Intake Line Muffler

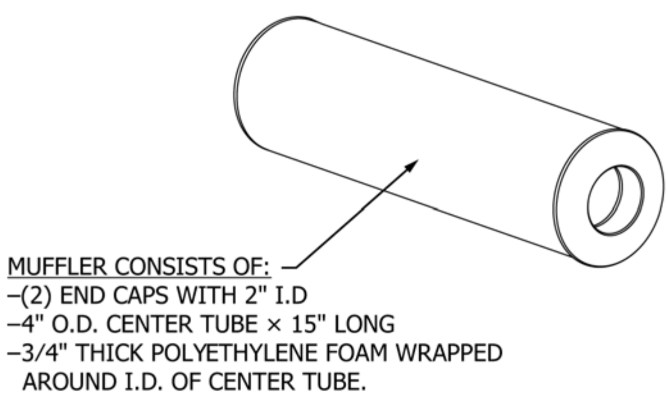

FIG. 3 Exhaust Line Muffler

operating in accordance with Section 7, measure the A-weighted sound pressure level at the same 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 in 9.3.

9.5 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 in 10.1.

9.6 Using the same test unit, repeat 9.2 – 9.5 two additional times for a total of three test runs.

9.7 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 that 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.

9.8 A minimum of two additional test units of the same model must be selected in accordance with the sampling statement in Section 11. Repeat 9.2 – 9.7 for each additional test unit. See Annex A1 for a procedural example and to determine if additional units need to be tested.

9.9 The best estimate of A-weighted sound power level for the population of the central vacuum power unit 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 11.

10. Calculation of A-weighted Sound Power Level for the Comparison Method

10.1 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 9.4,
L_{wr} = the known A-weighted sound power level, in decibels, produced by the reference sound source, and
L_{pr} = the average A-weighted sound pressure level, in decibels, produced by the reference sound source, as determined in accordance with 9.3.

11. Sampling

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

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 *Central 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 *Central Vacuum Power Unit*—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.

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

14. Precision and Bias[5]

14.1 *Precision*—The following precision statements are based on interlaboratory tests involving five laboratories and four central vacuum cleaning units.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F11-1017.

TABLE 2 Repeatability and Reproducibility

Type Cleaner	Standard Deviation of Repeatability, S_r	Repeatability Limit, r	Standard Deviation of Reproducibility S_R	Reproducibility Limit, R
CVS Unit	0.3	1.0	1.0	2.7

14.1.1 The statistics have been calculated as recommended in Practice E691 using five laboratories multi-day testing as ten laboratories single day testing.

14.1.2 The following statements regarding repeatability limit and reproducibility limit are used as directed in Practice E177.

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

14.1.3.1 The expected standard deviation of repeatability of the measured results within a laboratory, S_r, has been found to be the respective values listed in Table 2.

14.1.3.2 The 95 % repeatability limit within a laboratory, r, has been found to be the respective values listed in Table 2, where $r = 2.8\ (S_r)$.

14.1.3.3 With 95 % confidence, it can be stated that, within a laboratory, a set of measured results derived from testing a 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, listed in Table 2.

14.1.3.4 If the absolute value of the difference of any pair of measured results from three test runs performed within a single laboratory is not equal to or less than the respective repeatability limit listed in Table 2, that set of test results shall be considered suspect.

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

14.1.4.1 The expected standard deviation of reproducibility of the average of a set of measured results between multiple laboratories, S_R, has been found to be the respective values listed in Table 2.

14.1.4.2 The 95 % repeatability limit within a laboratory, R, has been found to be the respective values listed in Table 2, where $R = 2.8\ (S_R)$.

14.1.4.3 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, R, listed in Table 2.

14.1.4.4 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 the respective reproducibility limit listed in Table 2, the set of results from both laboratories shall be considered suspect.

14.2 *Bias*—No justifiable statement can be made on the bias of the method to evaluate the A-weighted sound power level of central vacuum power units. Since the true value of the property cannot be established by an acceptable referee method.

15. Keywords

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

ANNEX

(Mandatory Information)

A1. DETERMINATION OF THE POPULATION MEAN HAVING A90 % CONFIDENCE INTERVAL[6]

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 11.

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 a 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 11. 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:

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

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

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.

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* (2nd 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.

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

$$t \text{ statistic} = t_{1-\alpha/2} = t_{0.95} \tag{A1.2}$$

where:

1–α/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:

$$CI_U = \bar{X} + ts/\sqrt{n} \tag{A1.3}$$

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

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 11.1, as established as 2 dBA for all cases.

[6] 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.

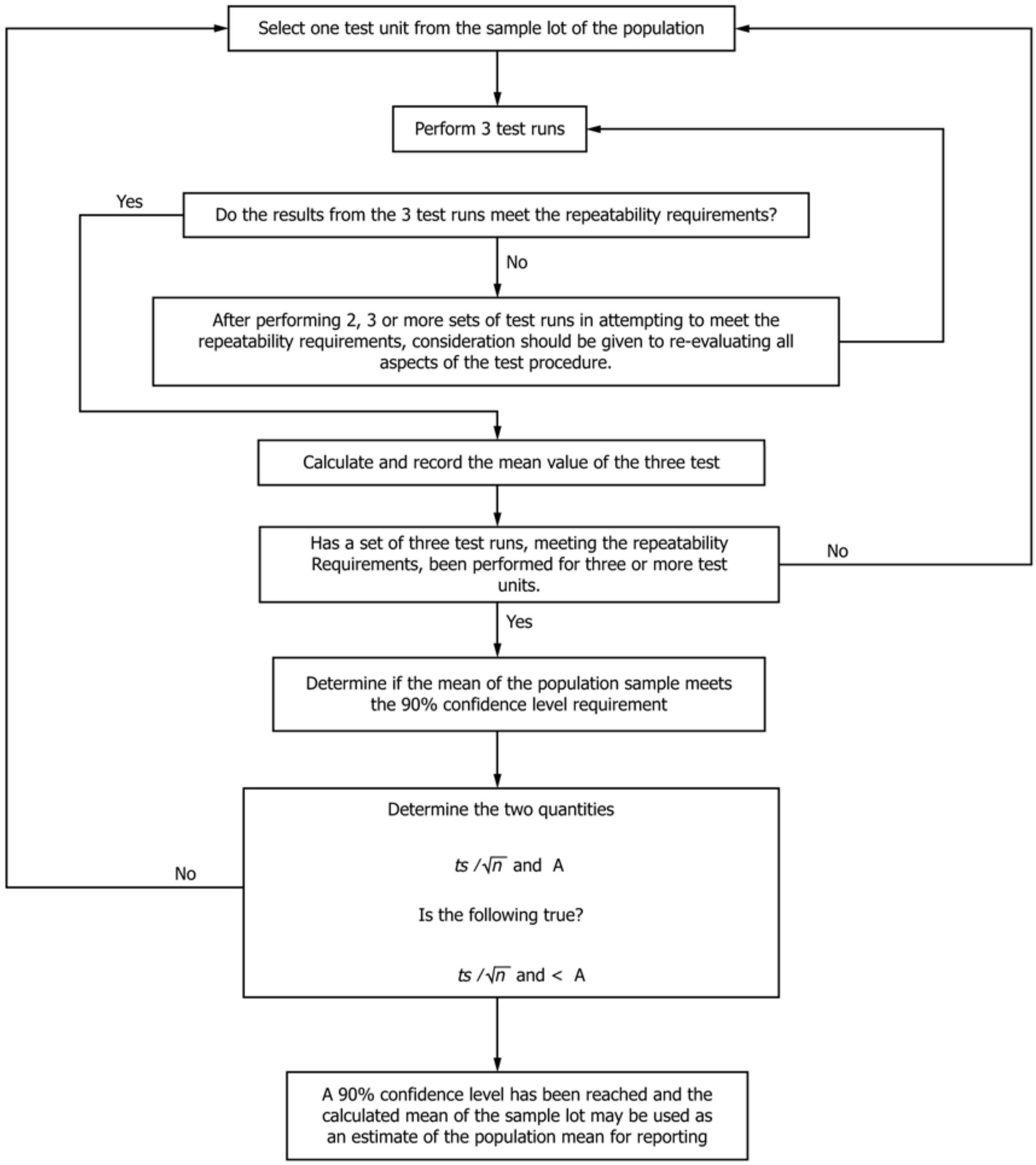

FIG. A1.1 Testing Procedure Flowchart

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 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 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 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 through 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 central vacuum power unit model is derived. The calculated A-weighted sound power level test results from three test runs on each unit are required to have a repeatability limit not exceeding 1.0 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.

$$\begin{gathered}\text{Test run scores for test unit No. 1:}\\ \text{test run No. 1} = 85.5\text{ dBA}\\ \text{test run No. 2} = 83.4\text{ dBA}\\ \text{test run No. 3} = 85.1\text{ dBA}\\ \text{Maximum spread} = 85.5 - 83.4 = 2.1\text{ dBA}\end{gathered}$$

A1.3.2 This value is greater than the repeatability limit required in Section 14. The results shall be discarded and three additional test runs performed.

$$\begin{gathered}\text{Test run scores for test unit No. 1:}\\ \text{test run No. 4} = 84.9\text{ dBA}\\ \text{test run No. 5} = 85.1\text{ dBA}\\ \text{test run No. 6} = 85.8\text{ dBA}\\ \text{Maximum spread} = 85.8 - 84.9 = 0.9\text{ dBA}\end{gathered}$$

A1.3.3 This value is less than the repeatability limit requirement of Section 14.

$$\text{Unit No. 1 score} = (84.9+85.1+85.8)/3 = 85.3\text{ dBA}$$

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).

A1.3.4 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:

$$\begin{gathered}\text{Score of test unit No. 1} = 85.27\text{ dBA}\\ \text{Score of test unit No. 2} = 88.53\text{ dBA}\\ \text{Score of test unit No. 3} = 87.41\text{ dBA}\\ \bar{X} = \frac{85.27+88.53+87.41}{3} = 87.1\text{ dBA}\end{gathered}$$

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

$$\begin{gathered}s = 1.656\text{ dBA}\\ \text{A} = 2.0\text{ dBA}\\ \text{Degrees of freedom, } n-1 = 3-1 = 2\\ t_{0.95}\text{ statistic} = 2.920\\ ts/\sqrt{n} = 2.920(1.656)/\sqrt{3} = 2.792\text{ dBA}\\ 2.792>2.0\end{gathered}$$

A1.3.5 The requirement that $ts/\sqrt{n}<A$ has not been met because s is larger. Therefore, an additional test unit from the population shall be tested.

$$\begin{gathered}\text{Score of test unit No. 4} = 86.3\\ \bar{X} = \frac{85.27+88.53+87.41+86.34}{4} = 86.9\text{ dBA}\\ \textit{Perform 3 test runs.}\\ s = 1.401\text{ dBA}\\ \text{A} = 2.0\text{ dBA}\\ \text{Degrees of freedom, } n-1 = 4-1 = 3\\ t_{0.95}\text{ statistic} = 2.353\\ ts/\sqrt{n} = 2.353(1.401)/\sqrt{4} = 1.648\text{ dBA}\\ 1.648<2.0\text{ (meets requirements)}\end{gathered}$$

A1.3.6 Thus, the value of $\bar{X}$, 86.9 dBA, represents the A-weighted sound power level score for the central vacuum power unit model tested and may be used as the best estimate of the A-weighted sound power level rating for the population mean.