



Designation: C384 – 04 (Reapproved 2022)

Standard Test Method for Impedance and Absorption of Acoustical Materials by Impedance Tube Method¹

This standard is issued under the fixed designation C384; 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 covers the use of an impedance tube, alternatively called a standing wave apparatus, for the measurement of impedance ratios and the normal incidence sound absorption coefficients of acoustical materials.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

C423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

C634 Terminology Relating to Building and Environmental Acoustics

E548 Guide for General Criteria Used for Evaluating Laboratory Competence (Withdrawn 2002)³

¹ This test method is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.01 on Sound Absorption.

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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 The last approved version of this historical standard is referenced on www.astm.org.

2.2 *ANSI Standards:*

S1.6 Preferred Frequencies and Band Numbers for Acoustical Measurements⁴

3. Terminology

3.1 The acoustical terminology used in this test method is intended to be consistent with the definitions in Terminology **C634**. In particular, the terms “impedance ratio,” “normal incidence sound absorption coefficient,” and “specific normal acoustic impedance,” appearing in the title and elsewhere in this test method refer to the following, respectively:

3.2 *Definitions:*

3.2.1 *impedance ratio, $z/\rho c \equiv r/\rho c + jx/\rho c$; [dimensionless]*—the ratio of the specific normal acoustic impedance at a surface to the characteristic impedance of the medium. The real and imaginary components are called, respectively, *resistance ratio* and *reactance ratio*. **C634**

3.2.2 *normal incidence sound absorption coefficient, α_n ; [dimensionless]*—of a surface, at a specified frequency, the fraction of the perpendicularly incident sound power absorbed or otherwise not reflected. **C634**

3.2.3 *specific normal acoustic impedance, $z \equiv r + jx$; [$\text{ML}^{-2}\text{T}^{-1}$]; mks rayl (Pa s/m)*—at a surface, the complex quotient obtained when the sound pressure averaged over the surface is divided by the component of the particle velocity normal to the surface. The real and imaginary components of the specific normal acoustic impedance are called, respectively, *specific normal acoustic resistance* and *specific normal acoustic reactance*. **C634**

4. Summary of Test Method

4.1 A plane wave traveling in one direction down a tube is reflected back by the test specimen to produce a standing wave that can be explored with a microphone. The normal incidence sound absorption coefficient, α_n , is determined from the standing wave ratio at the face of the test specimen. To determine the impedance ratio, $z/\rho c$, a measurement of the position of the standing wave with reference to the face of the specimen is needed.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.



4.2 The normal incidence absorption coefficient and impedance ratio are functions of frequency. Measurements are made with pure tones at a number of frequencies chosen, unless there are compelling reasons to do otherwise, from those specified in ANSI S1.6.

5. Significance and Use

5.1 The acoustical impedance properties of a sound absorptive material are related to its physical properties, such as airflow resistance, porosity, elasticity, and density. As such, the measurements described in this test method are useful in basic research and product development of sound absorptive materials.

5.2 Normal incidence sound absorption coefficients are more useful than random incidence coefficients in certain situations. They are used, for example, to predict the effect of placing material in a small enclosed space, such as inside a machine.

5.3 Estimates of the random incidence or statistical absorption coefficients for materials can be obtained from normal incidence impedance data. For materials that are locally reacting, that is, without sound propagation inside the material parallel to its surface, statistical absorption coefficients can be estimated from specific normal acoustic impedance values using an expression derived by London (1).⁵ Locally reacting materials include those with high internal losses parallel with the surface such as porous or fibrous materials of high density or materials that are backed by partitioned cavities such as a honeycomb core. Formulas for estimating random incidence sound absorption properties for both locally and bulk-reacting materials, as well as for multilayer systems with and without air spaces have also been developed (2).

6. Apparatus

6.1 The apparatus is essentially a tube with a test specimen at one end and a loudspeaker at the other. A probe microphone that can be moved along the length of the tube is used to explore the standing wave in the tube. The signal from the microphone is filtered, amplified, and recorded.

6.1.1 Tube:

6.1.1.1 *Construction*—The tube may be made of metal, plastic, portland cement, or other suitable material that has inherently low sound absorption properties. Its interior cross section may be circular or rectangular but must be uniform from end to end. The tube must be straight and its inside surface must be smooth, nonporous and free of dust to keep the sound attenuation with distance low. The interior of the tube may be sealed with paint, epoxy, or other coating material to ensure low sound absorption of the interior surface. The tube walls must be massive and rigid enough so that the propagation of sound energy through them by vibration is negligible.

6.1.1.2 *Diameter*—For circular tubes, the upper limit (3) of frequency is:

$$f < 0.586 c/d \quad (1)$$

where:

f = frequency, Hz,
 c = speed of sound in the tube, m/s, and
 d = diameter of tube, m.

For rectangular tubes, with d used as a symbol for the larger cross section dimension, the upper limit is:

$$f < 0.500 c/d \quad (2)$$

It is best to work well below these limits whether the tube is circular or rectangular. At frequencies above these limits, cross modes may develop and the incident and reflected waves in the tube are not likely to be plane waves. If sound with a frequency below the limiting value enters the tube as a non-plane wave, it will become a plane wave after traveling a short distance. For this reason, no measurement should be made closer than one tube diameter to the source end of the tube.

6.1.1.3 *Length*—The length of the tube is also related to the frequencies at which measurements are made. The tube must be long enough to contain that part of the standing wave pattern needed for measurement. That is, it must be long enough to contain at least one and preferably two sound pressure minima. To ensure that at least two minima can be observed in the tube, its length should be such that:

$$f > 0.75 c/(l - d) \quad (3)$$

where:

l = length of tube, m.

If, for example, the tube is 1 m in length and 0.1 m in diameter and the speed of sound is 343 m/s, the frequency should exceed 286 Hz if two sound pressure minima are to be observed.

6.1.2 *Test Specimen Holder*—The specimen holder, a detachable extension of the tube, must make an airtight fit with the end of the tube opposite the sound source. Provision must be made for containing the specimen with its face in a known position. The interior cross-sectional shape of the specimen holder must be the same as the tube itself. Provision must be made for backing the specimen with a metal backing plate that forms a seal with the interior of the specimen holder. A recommended backing is a solid steel plate with a thickness of not less than 2 cm. The sample holder may be constructed in such a way that a variable depth air space can be provided between the back of the test specimen and the surface of the metal backing plate. Provision must be made for substituting the metal backing plate for the specimen for calibration purposes.

6.1.3 Sound Source:

6.1.3.1 *Kind and Placement*—The sound source may be a loudspeaker or a horn-driver coupled to a short exponential horn. The source may face directly into the tube or, to avoid interference with the probe microphone, it may be placed to one side. Since the source diameter may be larger than the tube diameter, it is best to mount the source in an enclosure to which the tube is connected.

6.1.3.2 *Precautions*—Precautions should be taken to avoid direct transmission of vibration from the sound source to the probe microphone where it enters the tube or to the tube itself. Such vibrational transmission will be evidenced by a smaller

⁵ The boldface numbers in parentheses refer to the list of references at the end of this standard.