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Standard Guide for Measurement of In-Duct Sound Pressure Levels from Large Industrial Gas Turbines and Fans[1]

This standard is issued under the fixed designation E2459; 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 guide is intended to provide a simple and consistent procedure for the *in-situ* field measurement of in-duct sound pressure levels in large low pressure industrial air ducts, such as for gas turbines or fans, where considerations such as flow velocity, turbulence or temperature prevent the insertion of sound pressure sensors directly into the flow. This standard guide is intended for both ambient temperature intake air and hot exhaust gas flow in ducts having cross sections of four (4) square meters, or more.

1.2 The described procedure is intended to provide a repeatable and reproducible measure of the in-duct dynamic pressure level at the inlet or exhaust of the gas turbine, or fan. The guide is not intended to quantify the "true" sound pressure level or sound power level. Silencers, as well as Waste Heat Boilers, must be designed using the in-duct sound power level as the basis. Developing the true sound power level based on in-duct measurements of true sound pressure within a complete operating system is complex and procedures are developmental and often proprietary.

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 and health practices and determine the applicability of regulatory limitations prior to use. Extreme caution is mandatory when working near hot exhaust gas systems and appropriate safety precautions such as the installation of quick acting isolation valves are recommended.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

2.2 *ANSI Standards:*

S1.4 Specification for Sound Level Meters[3]

S1.43 Specification for Integrating Averaging Sound Level Meters[3]

3. Terminology

3.1 Definitions of the acoustical terms used in this guide are given in Terminology C634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *anechoic tube*—a constant diameter tube of sufficient length that a sound wave reflected from the far end of the tube termination arrives at the microphone position sufficiently attenuated that it will not appreciably affect the microphone reading.

3.2.2 *dynamic pressure*—the total instantaneous pressure incident upon the opening of the test port, including the influence of convective turbulence, local tangential modes, localized boundary layer effects at the test port and the indeterminate effects of all duct acoustical modes.

3.2.3 *fixture*—the apparatus containing the microphone fitting which locates the microphone flush with the inside diameter of the anechoic tube, the necessary fittings permitting airtight connection of the fixture and anechoic tube to the test port, and the anechoic tube.

3.2.4 *probe microphone*—a commercially available micro-diameter microphone probe that is inserted into the anechoic termination near the test port connection. Some probes require a pressure compensation connection. Use and installation shall follow manufacturer's procedures/instructions.

3.2.5 *test port*—the hole in the duct wall to which the anechoic tube is connected and whose diameter is equal to the inside diameter of the anechoic tube. In general the term test port, as used herein, will usually include any semi-permanently installed hardware in the wall of the duct permitting closure of the test port when not in use (ball valve and threaded pipe cap, or both) as well as the pipe elements permitting attachment of the fixture and the anechoic tube.

[1] This guide is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.08 on Mechanical and Electrical System Noise.

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

4. Summary of Guide

4.1 Key features of this guide:

4.1.1 A through-wall test port opening, 25.4 mm (nominally, 1 in.) or less, to which is connected the fixture, having a constant inside diameter tube, to which the anechoic tube is connected. The test port opening is flush with the inside surface of the duct wall. No apparatus are inserted into the flow path.

4.1.2 The microphone sensor is mounted in the fixture (3.2.3) outboard of the duct wall, with the microphone axis oriented normal to the centerline of the anechoic tube.

4.1.3 The tip of the microphone, usually with a protective grid, is positioned flush with, or more accurately tangential to, the inner wall of the fixture and as close to the duct wall as temperature or access limitations permit.

4.1.4 The diameter of the microphone shall always be less than or equal to the inside diameter of the anechoic tube.

4.1.5 The position of the microphone is critical for high temperature ducts, so as to limit the maximum temperature on the microphone during testing.

4.1.6 The anechoic tube shall have no inner wall discontinuities or changes in diameter that might create reflections or standing waves within the tube. It is important to avoid any protrusion of the apparatus into the gas flow path.

4.1.7 The anechoic termination may be achieved by loosely packing the "cold" end of the tube with mineral wool or steel wool. The tube end should be sealed airtight unless forced air is to be used to ensure adequate cooling of the anechoic tube.

4.1.8 The inner duct wall opening shall be as smooth as practicable, with a minimum of turbulence producing discontinuities at the duct wall inner surface. If the user chooses to mount a protective screen covering the inside duct wall opening, such screen shall not materially influence the sound pressure measurements, or a means of quantifying and accounting for such influence shall be included in the test protocol. (Be aware that such screens can become fouled with particles.)

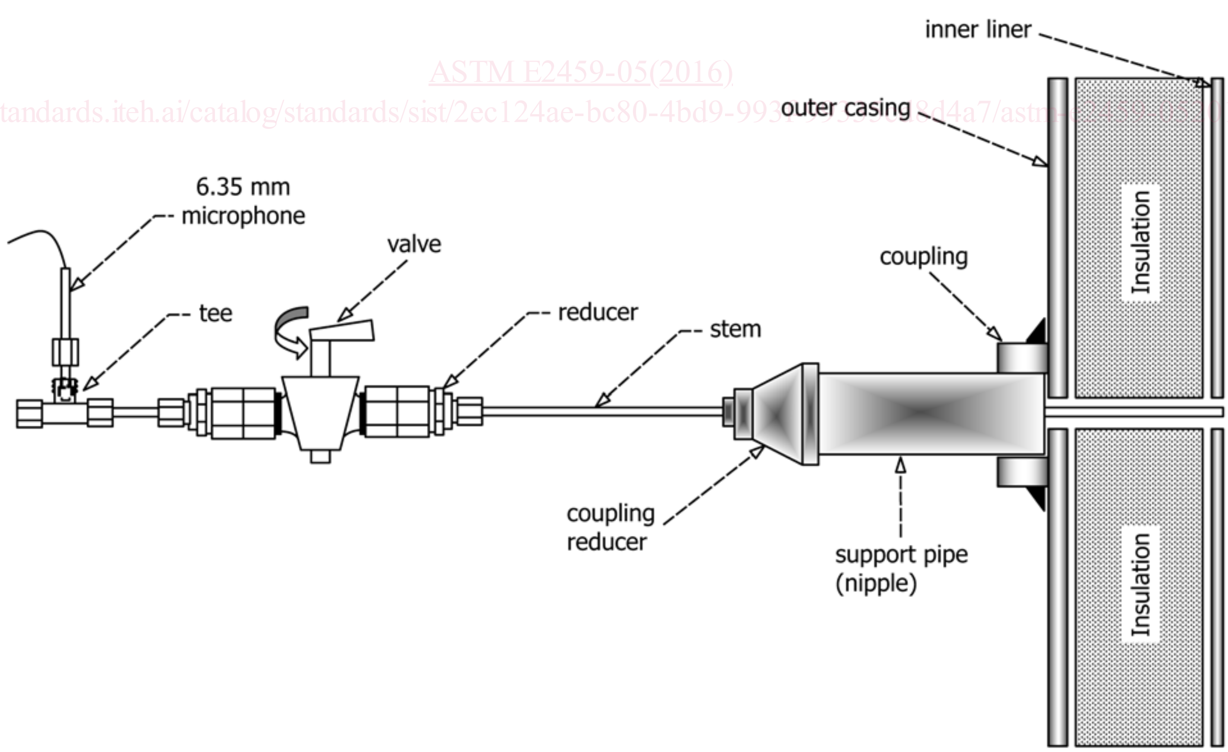
4.1.9 The inner duct wall opening shall be the same inside diameter as the inside diameter of the anechoic tube. That is, this guide does not permit the anechoic tube to be inserted into, or positioned within a duct wall port of larger size, unless means are provided to ensure that the inner wall surface at the test port is restored to a reasonable semblance of a smooth continuous wall surface.

4.2 A sketch of a typical Test Port is shown in Fig. 1. A sketch of a typical Fixture is shown in Fig. 2. Only the initial portion of the otherwise very long Anechoic Tube is depicted in each figure.

5. Significance and Use

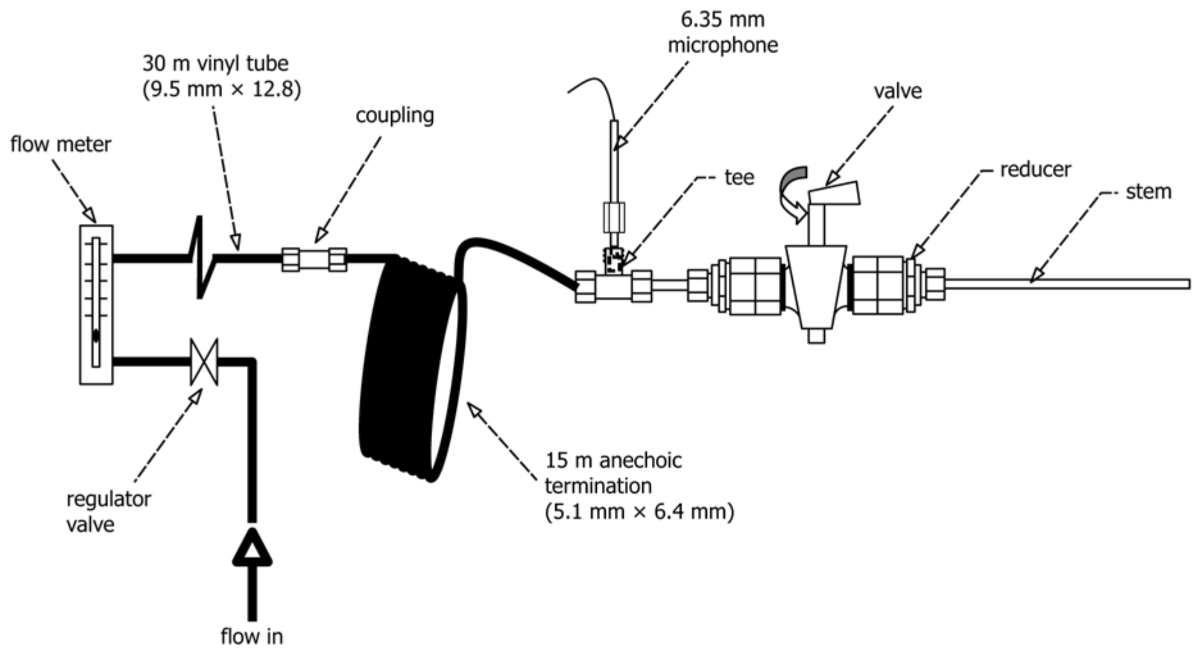
5.1 All noise control features associated with the inlet or exhaust of large industrial fans and gas turbines are, or should be, based upon inlet or exhaust sound power levels in octave bands of frequency. Sound power levels are not directly measurable, however, so they must be calculated indirectly, using estimated or measured duct interior sound pressure levels.

5.2 Estimated in-duct sound pressure level may be obtained by measuring exterior airborne sound pressure levels and applying a transfer function representing the transmission loss



NOTE 1—Showing a typical Fixture (see Fig. 2) installed in an insulated duct wall. Note the stem of the Fixture extends all the way to the inner duct wall surface, occupying a hole in the duct wall only slightly larger than the tube stem O.D.

FIG. 1 Typical Fixture



NOTE 1—Showing a shutoff (ball) valve, a tee connection in which to mount the microphone and various fittings which will maintain a constant inside diameter through the tee connection to the anechoic tube. The example shown uses a ¼ in. microphone attached to a ¼ in. ID anechoic tube. Note that if the orientation of the microphone is vertical, as shown, there is less likelihood of accumulating condensation on the microphone from hot exhaust gases.

FIG. 2 Typical Fixture

of the duct wall. Significant uncertainties are associated with such a procedure, suggesting the need for this guide.

5.3 Estimated in-duct sound pressure level may be obtained by measuring exit plane sound pressure levels and applying a transfer function consisting of the insertion loss through the gas path, including the insertion loss of any silencers. Significant uncertainties are associated with such a procedure, suggesting the need for this guide.

5.4 This guide purports to measure the in-duct sound pressure level directly using type 1 instrumentation per ANSI S1.4 or S1.43. It is limited, however, to the determination of the sound pressure level at the location of the port only and will include the effects of duct acoustical modes, as well as an unknown degree of turbulence and other flow related effects. Methodologies may be devised by the user to minimize such effects. As a rule, the larger the number of test ports used, the better will be the averaged data. Although not prescribed by this guide, cross-channel coherence analysis is also available to the analyst, using ports at different locations along the duct axis, which may yield improvements in data quality.

5.5 This guide is intended for application to equipment in-situ, to be applied to large fans and gas turbines having inlet or exhaust ducts whose cross sectional areas are approximately four (4) square meters, or more, and are therefore not amenable to laboratory testing. All of the field experience on the part of task group members developing this guide has been on gas turbine ducts having cross sections in excess of ten (10) square meters.

5.6 This guide has no known temperature limitations. All of the field experience on the part of task group members developing this guide has been on gas turbine ducts having temperatures between ambient and 700°C.

6. Operating Conditions

6.1 Whenever possible, equipment under test shall be operated in a mode or modes acceptable to all parties to the test. Otherwise, operating conditions must at least be monitored in order that the test results are properly qualified in terms of the parameters most likely to affect the measurements.

7. Apparatus

7.1 *Description of the Apparatus*—See section 4.1 and Figs. 1 and 2.

7.2 *Permissible Range of Anechoic Tube Diameter,* 6 to 25.4 mm (¼ to 1 in.).

7.3 *Permissible Range of Microphone Sizes*—Maximum microphone diameter is nominal 25.4 mm (1 in.). Probe microphones are permissible.

7.4 *Minimum Anechoic Tube Length*—The minimum ratio of the length of the anechoic tube to the tube inner diameter shall be one hundred (L/d > 100). Note that at low frequencies the tube connection is not anechoic. The ¼ wavelength determines the lower usable data range.

7.5 *Types of Materials*—All steel pipe fittings, and metal tube for anechoic tube are preferred. Other materials such as common garden hose could be used for the anechoic tube if it is shown to be adequate in terms of ambient noise calibration.

7.6 Use of shutoff ball valves is highly recommended, especially for hot gas applications.