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Standard Test Method for Laboratory Measurement of the Insertion Loss of Pipe Lagging Systems[1]

This standard is issued under the fixed designation E 1222; 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.

ϵ^1 NOTE—Keywords were added editorially in June 1996.

1. Scope

1.1 This test method covers the measurement of the insertion loss of pipe lagging systems under laboratory conditions.

1.2 A procedure for accrediting a laboratory for purposes of this test method is given in Annex A1.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method[2]

C 634 Terminology Relating to Environmental Acoustics[2]

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions[2]

2.2 *ANSI Standards:*

S1.4 Specification for Sound Level Meters[3]

S1.6 Preferred Frequencies and Band Numbers for Acoustical Measurements[3]

S1.11 Specification for Octave Band and Fractional-Octave-Band Analog and Digital Filters[3]

3. Terminology

3.1 *Definitions*—The acoustical terms used in this test method are consistent with Terminology C 634.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *pipe lagging system*—an arrangement of noise insulating materials used to cover a pipe to reduce noise radiating from it.

4. Summary of Test Method

4.1 Noise is produced inside a steel pipe located within a reverberation room using band-limited white noise as a test signal. The noise must be produced by a loudspeaker or acoustic driver located at one end of the pipe. Average sound pressure levels are measured within the reverberation room for two conditions, one with sound radiating from the bare pipe and the other with the same pipe covered with a lagging system. The insertion loss of the lagging system is the difference in the sound pressure levels measured with sound radiating from the bare and lagged pipe, with an adjustment for changes in room absorption due to the presence of the lagging system. The results may be obtained in a series of 100-Hz wide bands or in one-third octave bands from 500 to 5000 Hz. Using 100-Hz wide bands will improve the signal-to-noise ratio in the reverberant room. This is frequently necessary when measuring specimens having high insertion loss.

5. Significance and Use

5.1 The insertion loss of a pipe lagging system depends upon the lagging system materials, the method used to apply the materials, the pipe wall thickness, the size and shape of the bare and lagged pipe, and the mechanisms causing noise radiation from the pipe. Insertion losses measured using this test method should be used with some caution. In the laboratory, measurements must be made under reproducible conditions, but in practical usage in the field, the conditions that determine the effective insertion loss are difficult to predict and they may lead to slightly different results. Insertion losses measured with this test method can be used successfully for acoustical design purposes. Insertion losses measured with this test method are most useful for pipes and lagging systems which are similar to those used in the laboratory configuration.

5.2 This test method may be used to rank-order pipe lagging systems according to insertion loss or to estimate the field insertion loss of pipe lagging systems installed in the field.

5.3 This test method assumes that pipe wall stresses resulting from different methods of supporting the test pipe in the laboratory do not have a significant effect upon the measured insertion loss.

5.4 Pipe lagging systems typically have small insertion loss, and sometimes negative insertion loss, at frequencies below 500 Hz. The results obtained at frequencies below 500 Hz may be somewhat erratic. Sound sources used with this test method

[1] This test method is under the jurisdiction of ASTM Committee E-33 on Environmental Acoustics and is the direct responsibility of Subcommittee E33.08 on Mechanical and Electrical System Noise.

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

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

normally have a low frequency limit in the range from 300 to 500 Hz. For these reasons, the lowest band of frequencies for which results are required is centered at 500 Hz.

6. Interferences

6.1 Flanking transmission may limit the maximum insertion losses which can be reliably measured using this test method. The test pipe and reverberation room shall be constructed and arranged so as to minimize the possibility of transmission by paths other than through the test specimen. Flanking transmission should be at least 10 dB lower than the power transmitted through the test specimen into the reverberation room. Appendix X1 presents one procedure for assessing flanking transmission.

6.2 The background noise in each test band must be at least 10 dB below measured sound pressure levels for that band.

7. Apparatus

7.1 *Reverberation Room*—The sound field in the reverberation room shall approximate a diffuse field when the test specimen is in place. The requirements for the reverberation room are in Test Method C 423. The volume of the test room shall be 2000 ft^3 or greater.

7.1.1 The average sound absorption coefficients of the room, excluding sound absorption by air and the test specimen, measured in accordance with Test Method C 423, shall be less than 0.06 over the test frequency range when the test specimen is in place.

7.1.2 Diffusing devices such as rotating and stationary diffusing surfaces are useful for creating an adequate diffuse sound field.

7.2 *Pipe*:

7.2.1 *Construction*—The standard test pipe shall be at least 13 ft long and mounted horizontally within the reverberation room. It shall be a nominal 12-in. diameter carbon steel pipe with a nominal wall thickness of ¼ in.

7.2.2 Other pipes may be used but they shall have a wall thickness of at least ¼ in., a nominal diameter of at least 6 in., and shall be at least 13 diameters long.

7.2.3 *Installation*—Potential flanking transmission can be minimized if both ends of the pipe are outside of the reverberation room. For this reason, this is the preferred method of installing the pipe. Alternately, the loudspeaker end of the pipe may be located outside of the reverberation room. In this case, the other end of the pipe within the reverberation room must be carefully constructed and mounted to avoid flanking transmission. Any method of terminating the pipe may be used provided that adequately low levels of flanking transmission are achieved. It is usually necessary to cap the end of the pipe within the reverberation room with heavy structure and to vibration-isolate the pipe end from the reverberation room floor or ceiling. The cap may be a blind flange, at least twice as thick as the pipe wall, welded to the end of the pipe.

7.2.4 No solid connections may exist between the surfaces of the reverberation room and the pipe or test specimen. A flexible, nonhardening, knife grade mastic, such as available for sealing high-pressure ducts, should be used to seal the gaps where the pipe passes through walls.

7.3 *Loudspeaker*:

7.3.1 *Type*—The loudspeaker may be a horn-driver combination or a direct radiator (cone type) loudspeaker. Normally, only acoustic drivers with horns will have sufficient output for the tests when high insertion losses are being measured.

7.3.2 *Installation*—The loudspeaker shall be placed on the open end of the pipe outside the reverberation room. The horn of the loudspeaker must be structurally isolated from any contact with the pipe wall.

7.4 *Reference Sound Source*:

7.4.1 A reference sound source is needed to permit adjustments for the change in sound absorption within the reverberation room due to the lagging system.

7.4.2 The sound from the reference source shall be broadband noise without significant single-frequency components. The maximum sound power level of any single frequency component within a band should be at least 5 dB below the sound power level for that band.

7.4.3 The source level in any band shall have a maximum short-term time-variation of no greater than 2 dB measured with the slow dynamic characteristic of a sound level meter or the equivalent.

7.4.4 The source shall be physically small, with a maximum dimension of less than 2 ft.

7.4.5 The reference source may be a loudspeaker; if so, it should be driven with bands of white noise and its sound power output should be within the limits prescribed in 7.4.3.

7.4.6 A preferred reference sound source is a modified centrifugal fan, directly connected to a motor with stable speed characteristics. The sound power level of this source as a function of frequency is adequately constant for this test method.[4]

7.4.7 The source should have a resilient mounting which is suitably designed to prevent transmission of vibrations to the structure on which it is mounted.

8. Test Specimen

8.1 The test specimen shall be a pipe lagging system installed on the bare pipe following normal mounting procedure. The system should be lapped and seamed following a procedure similar to the one used in the field.

8.2 If the pipe lagging system is usually installed with a seam, the test specimen shall have at least one seam around the circumference and one longitudinal seam.

8.3 The test specimen should be sealed where it butts to the walls of the reverberation room or the capped end of the pipe. The flexible mastic used to seal gaps around the pipe is also recommended for this purpose. The mastic should not harden with age so as to cause flanking.

9. Test Signal

9.1 The loudspeaker shall be driven with bands of white noise. To avoid nonlinearities, the total sound pressure level shall not exceed 160 dB inside the pipe.

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[4] Sound sources that have been found suitable for this purpose are available from Brüel and Kjäer Instruments, Inc., 185 Forest St., Marlborough, MA 01752 (Model 4204); ILG Industries, 2850 North Pulaski Road, Chicago, IL 60641; Electric France (E.D.F.), Department Acoustique et Vibrations, 17, Av. de la Liberation, 92 Clamart, France (Model NOVACEM); and, Acculab, 3201 Ridgewood Drive, Columbus, OH 43220.

9.2 The sound pressure level in the test band on the interior of the pipe shall have a maximum short-term time-variation in any band no greater than 2 dB measured with the "slow" dynamic characteristic of a sound level meter or the equivalent. If necessary, longer time averages may be used.

9.3 *Test Frequency Bands*:

9.3.1 *Constant Bandwidth Method*—The test signal shall be contiguous 100 Hz (±10 Hz), wide bands of white noise with arithmetic center frequencies over the nominal range from 500 to 5,000 Hz. Optionally, bands centered at 300 and 400 Hz may also be used.

9.3.2 *One-third Octave-band Method*—The test signal shall be contiguous one-third octave bands of white noise at the preferred one-third octave band center frequencies from 500 to 5000 Hz. Optionally, one-third octave bands from 315 to 5000 Hz may be used.

10. Measuring Instruments

10.1 The minimum instrumentation required for this test method is as follows:

10.1.1 A monitoring microphone located inside the test pipe,

10.1.2 One or more room measurement microphones located in the reverberation room,

10.1.3 Microphone amplifiers that satisfy the requirements of ANSI S1.4 for Type 1 or better sound level meters with the exception that A and B-weighting networks are not required, and

10.1.4 A level meter, graphic level recorder, or other device from which the sound pressure level can be read or recorded. The averaging time of the instruments shall be sufficient to permit the determination of the average sound pressure level with adequate precision.

10.2 Measuring filters are required and depend upon the method selected:

10.2.1 *Constant Bandwidth Method*—Nominal 100-Hz wide constant bandwidth filters with arithmetic center frequencies consistent with the test signal frequency range.

10.2.2 *One-third Octave-Band Method*—A one-third octave filter set satisfying the requirements of ANSI S1.11 for Order 3 or higher, Type 1 or better. The nominal center frequencies of the filters shall be the same as the test signal center frequency.

10.3 A narrow band analyzer is optional. It may be useful for monitoring spectral uniformity of the sound within the pipe.

11. Procedure

11.1 Install the lagging specimen on the pipe.

11.2 Select microphone positions within the reverberation room. The locations shall be at least one-half wavelength away from any solid surface at the lowest test frequency.

11.3 Using the reference sound source, measure the average sound pressure levels in each test band within the reverberation room. Turn off the reference sound source.

11.4 Drive the loudspeaker at the end of the pipe with the test signal and measure the average sound pressure levels in each test band within the reverberation room. Measure the sound pressure levels generated by the test signal at the monitoring microphone inside the pipe.

11.5 Remove the test specimen from the pipe while maintaining the entire equipment set-up including all source and measuring instrument settings as far as practical. A precision step attenuator may be used to temporarily lower the test signal driving the loudspeaker while removing the test specimen. It is of the utmost importance to make no changes in the loudspeaker position.

11.6 Return the test signal to the previous setting.

11.7 Compare the sound pressure levels generated by the test signal at the monitoring microphone with the spectrum measured in 11.4. If the test signal, with sufficient time averaging, differs by more than 2 dB in any test band from that measured in 11.4 with the test specimen in place, begin the procedure again.

11.8 Measure the average sound pressure levels in each test band within the reverberation room. Turn the test signal off.

11.9 Repeat step 11.3 for the bare pipe.

11.10 If another specimen is to be tested, repeat all steps outlined in 11.1-11.9.

12. Calculation

12.1 In each test frequency band, calculate the insertion loss of the test specimen as follows:

$$IL = Lb - Ll - [Lbr - Llr] \quad (1)$$

where:

IL = insertion loss, dB,

Lb,Ll = average sound pressure level measured with sound radiating from the bare pipe and lagged pipe respectively, dB, and

Lbr,Llr = average sound pressure level measured with the reference sound source with the bare and lagged pipe, respectively, dB.

13. Report

13.1 Report the following information:

13.1.1 A statement, if true in every respect, that the tests were conducted in accordance with the provisions of this test method. Conformance to the relevant sections of Appendix X1 shall also be reported when applicable. Report any exceptions to this test method, including nonstandard pipes.

13.1.2 A description of the test specimen. The description should be sufficiently detailed to identify the elements that may affect the specimen's insertion loss. The specimen thickness, and the average weight per square foot shall always be reported. Wherever possible, the testing laboratory should observe and report the materials, dimensions, weight, and other relevant physical properties of the pipe lagging system components and the manner in which they are combined, including a description of fastening elements. A designation and description furnished by the sponsor of the test may be included in the report provided that they are attributed to the sponsor. The curing period, if any, and the final condition of the specimen (shrinkage, cracks, etc.,) shall be reported.

13.1.3 The method of installation of the specimen on the bare pipe including the location of support members, fasteners, and clamping devices. Laps and seams shall be carefully described. The use and type of caulking, gaskets, tape, or other sealant on joints shall be carefully described.

13.1.4 A table of insertion losses to the nearest decibel for individual test bands, including negative values. Identify any insertion loss values which are influenced by flanking transmission within 10 dB of the measured values. The data so affected shall be reported as minimum insertion losses.

NOTE 1—If results are also presented in graphical form, for the one-third octave-band method, the following formats are recommended: the abscissa length for a 10:1 frequency ratio should equal the ordinate length for 25 dB. Whenever practicable, the scales should be 50 mm for a 10:1 frequency ratio and 20 mm for 10 dB. The ordinate scale should start at 0 dB, or − 10 dB in the event of negative insertion loss data. For the constant bandwidth method, the abscissa should be a linear scale showing all test bands.

13.2 The laboratory shall make available a description of the laboratory and test setup, as well as a report on flanking transmission.

14. Precision and Bias

14.1 Neither the precision nor bias of this test method has been established. An interlaboratory test program is planned for developing a statement on precision and bias for this test method.

15. Keywords

15.1 insertion loss; pipe lagging systems

ANNEX

(Mandatory Information)

A1. LABORATORY ACCREDITATION

A1.1 Scope

A1.1.1 This annex describes procedures for accrediting an acoustical testing laboratory to perform tests in conformance with this test method.

A1.2 Referenced Documents

A1.2.1 *ASTM Standards*:

E 548 Guide for General Criteria Used for Evaluating Laboratory Competence[5]

E 717 Guide for Preparation of Accreditation Annex of Acoustical Test Standards[2]

A1.3 General Requirements

A1.3.1 The testing agency shall make available to the accrediting authority the information required by Sections 4 to 7 of Practice E 548.

A1.4 Requirements Specific To This Test Method

A1.4.1 *Physical Facilities*—The testing agency shall provide information demonstrating compliance with the provisions of this test method as follows:

Flanking transmission (6.1),
Reverberation room (7.1),
Pipe construction and installation (7.2),
Loudspeaker (7.3),
Reference sound source (7.4),
Test signal (Section 9), and
Measuring instruments (Section 10).

A1.4.2 *Measurement Procedures*—The agency shall furnish a sample report of a complete test (including raw data), showing compliance with the procedure section of Annex A2 in Test Method E 90 and the procedure section of this test method.

A1.4.3 *Repeatability and Reproducibility*—Results of repeated tests made on a particular reference pipe lagging specimen shall be reported as a demonstration of the long-term repeatability of the test procedures. Each test should include installation of the reference specimen. The record should include for each test the sound insertion losses for all standard frequencies used in the method along with the precision of each value.

A1.4.3.1 *Reference Specimen*—The reference specimen should be such that all details of construction and installation that may affect its sound insertion loss can be specified and controlled.

A1.4.3.2 To provide evidence of reproducibility in comparison with other testing laboratories, it is preferable to use a reference specimen for which test data are available from several laboratories.

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

APPENDIX

(Nonmandatory Information)

X1. FLANKING TRANSMISSION

X1.1 Scope

X1.1.1 This appendix describes a procedure which may be used to determine the maximum insertion losses that can be measured by quantifying flanking transmission.

X1.1.2 The limit on the insertion loss measurement introduced by flanking shall be investigated by installing a specimen having a very high loss and measuring the insertion loss.

X1.2 Suggested Test Specimen

X1.2.1 The suggested constituents of the test specimen are as follows (listed in order from the pipe surface outward):

X1.2.1.1 Preformed or mitered glass fiber placed directly on the pipe 100 mm of 64 to 96 kg/m^3 (4 to 6 lb/ft^3),

X1.2.1.2 A layer of 4.87 kg/m^2 (1 lb/ft^2) lead sheet placed directly on the glass fiber. The lead sheet shall be overlapped by 25 mm at seams and taped so that no seams are visible,

X1.2.1.3 A minimum air space of 50 mm,

X1.2.1.4 A separately-supported 16-gage steel enclosure with 50 mm of 64 to 96 kg/m^3 glass fiber adhered to the inner surface. This enclosure may not touch the pipe or lead sheet layer. The steel enclosure shall have 6 mm to 25 mm neoprene or foam gaskets at all seams. Bolts or rivets shall be installed through the gasket material on 150 mm centers at all seams. The steel enclosure shall be supported off the floor by means of glass fiber vibration mounts with sufficient static deflection to provide 95 % isolation efficiency at 250 Hz.

X1.2.2 The suggested test specimen shall be installed so that no metal or barrier material touches the pipe, or pipe floor mounts. A3- to 6-mm gap shall be maintained at any penetrations. The gaps shall be fully sealed using a flexible, nonhardening, knife-grade mastic such as available for sealing high-pressure ducts.

X1.3 Procedure

X1.3.1 It is imperative that all apparatus, test rooms, and equipment be installed, adjusted, and used in the same manner as for usual test specimens. In particular, the test signal fed to the loudspeaker must be the same.

X1.3.2 The insertion loss data for the suggested test specimen should be acquired using the procedure outlined in Section 11. With calculations performed in accordance with Section 12.

X1.4 Report

X1.4.1 At least once a year, the laboratory shall measure flanking transmission. The results shall be made available in a separate test report and shall be used to qualify insertion loss data on individual test specimens.