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AMERICAN NATIONAL STANDARD **METHODS FOR DETERMINING THE INSERTION LOSS OF OUTDOOR NOISE BARRIERS**

ANSI/ASA S12.8-1998

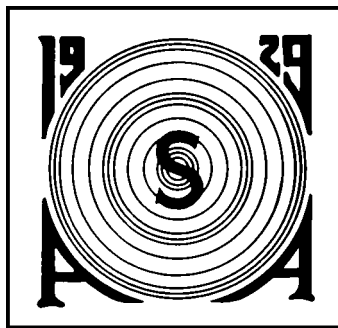
Accredited Standards Committee S12, Noise

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American National Standard

Methods for Determining the Insertion Loss of Outdoor Noise Barriers

Secretariat

Acoustical Society of America

Approved 27 April 1998

American National Standards Institute, Inc.

Abstract

This Standard presents three methods for determining the insertion loss of outdoor noise barriers. The methods are “direct” BEFORE and AFTER measurements; “indirect” BEFORE measurements at an “equivalent” site; and “indirect” predictions of BEFORE sound levels. “Indirect BEFORE measurements” and “indirect BEFORE prediction” methods require direct measurements of AFTER sound levels. Measurements of acoustical descriptors use sound sources naturally present at a site, controlled natural sound sources, or controlled artificial sound sources. Within prescribed limits, the receiver location and atmospheric, ground, and terrain conditions may be chosen based on the objectives for determination of barrier insertion loss. Examples are provided for worksheets that may be used for data acquisition and analysis.

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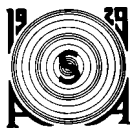
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Foreword

[This Foreword is for information only and is not an integral part of *American National Standard Methods for Determining the Insertion Loss of Outdoor Noise Barriers*, ANSI S12.8-1998.]

This American National Standard supersedes the previous version published as ANSI S12.8-1987.

This Standard contains three informative annexes.

This Standard was developed under the jurisdiction of Accredited Standards Committee S12, Noise, which has the following scope:

Standards, specifications, and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation, and control, including biological safety, tolerance, and comfort, and physical acoustics as related to environmental and occupational noise.

At the time this Standard was submitted to Accredited Standards Committee S12, Noise, for final approval, the membership was as follows:

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Working Group S12/WG6, Insertion Loss of Outdoor Noise Barriers at Sites of Interest, which assisted Accredited Standards Committee S12, Noise, in the preparation of this Standard, had the following membership:

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Suggestions for improvement of this Standard will be welcomed. They should be made in writing to Accredited Standards Committee S12, Noise, in care of the Standards Secretariat, Acoustical Society of America, 120 Wall Street, 32nd Floor, New York, New York 10005-3993, USA. E-mail: asastds@aip.org; Telephone: +1 212 248 0373; Fax +1 212 248 0146.

American National Standard

Methods for Determining the Insertion Loss of Outdoor Noise Barriers

0 Introduction

Determining the insertion loss provided by outdoor noise barriers is often difficult. In many cases, the difficulty results from the absence of sound levels measured at a site before barrier installation, or the inability to estimate accurately the “before-installation” sound levels. Lack of standard methods for determining barrier insertion loss may lead to incorrectly performed (or poorly documented) computations and prevent independent evaluation of techniques and results.

1 Scope

1.1 This Standard adopts insertion loss—the difference between acoustical levels before and after a noise-barrier installation—as the basis for evaluating the acoustical effectiveness of an outdoor noise barrier. Methods are provided to determine the insertion loss of outdoor noise barriers at selected receiver locations and under conditions of interest.

1.2 This Standard covers insertion loss determination, by measurement or by the combination of measurement and prediction, for outdoor noise barriers of all types. Sound sources at a site may be those that are naturally present, controlled natural sound sources, or controlled artificial sound sources. Preferred acoustical descriptors are time-average, A-weighted sound level, A-weighted sound exposure level, or octave-band sound pressure level. Other acoustical descriptors of the BEFORE and AFTER sound are not precluded.

1.3 Standardized receiver locations or measurement conditions are not prescribed. Measured insertion losses apply only for the stated conditions and are not to be generalized to represent other conditions, sites, receiver locations, or sound sources.

1.4 This Standard may be used for routine checking of the insertion loss of an outdoor noise barrier, or for engineering or diagnostic evaluations. The methods of the Standard may be used in situations where a barrier is to be installed, or has already been installed.

1.5 This Standard does not present methods for comparing the insertion loss of outdoor noise barriers at different sites, nor does it specifically address sound transmission loss through a barrier. While comparisons of the insertion loss of outdoor noise barriers at different sites or extrapolations to other conditions may be possible, such comparisons or extrapolations are not within the scope of this Standard.

1.6 Reliable and repeatable results may be expected when the distances between all receivers and their closest and strongest sound sources (or closest point of approach for mobile sound sources) are within 70 m. The methods of the Standard may be applied for other conditions, but the experimental uncertainties likely will increase, perhaps substantially.

1.7 This Standard presents two methods for indirectly determining the level of the BEFORE sound. The two methods are (1) by measurement at a second site that is equivalent to the desired site prior to installation of the barrier, or (2) by prediction of the BEFORE sound levels. Equivalence here is in terms of sound-source characteristics, receiver locations, and terrain, atmospheric, and ground conditions. The Standard presents principles, not procedures, for assessing sound-source, atmospheric and terrain equivalence, as well as for choosing a model to predict the level of BEFORE sound.

1.8 This Standard presents a method to determine a lower bound to the insertion loss when background noise prevents clear measurement of the source sound level at a receiver location. In many applications, reporting a barrier insertion loss for a given receiver location as “equal to or greater than X dB” is sufficient. This Standard also presents a method to determine the total experimental uncertainty associated with the barrier insertion loss.

1.9 Because of many factors affecting the sound levels at receiver locations, it may not be possible to determine the insertion loss of an outdoor noise barrier for conditions of interest.

2 Normative references

The following Standards contain provisions that, through reference in this text, constitute provisions of this American National Standard. At the time of approval by the American National Standards Institute, Inc. (ANSI), the editions indicated were valid. All Standards are subject to revision. Parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the Standards listed below. Information on the most recent editions is available from the ASA Standards Secretariat.

- [1] ANSI S1.1-1994, *American National Standard Acoustical Terminology*.
- [2] ANSI S1.4-1983 (R 1997), *American National Standard Specification for Sound Level Meters*. Amendment 1, ANSI S1.4A-1985.
- [3] ANSI S1.11-1986 (R 1993), *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters*.
- [4] ANSI S1.15-1997/Part 1, *American National Standard Measurement Microphones—Part 1: Specifications for Laboratory Standard Microphones*.
- [5] ANSI S1.26-1995, *American National Standard Method for Calculation of the Absorption of Sound by the Atmosphere*.
- [6] ANSI S1.40-1984 (R 1997), *American National Standard Specification for Acoustical Calibrators*.
- [7] ANSI S1.43-1997, *American National Standard Specification for Integrating-Averaging Sound Level Meters*.
- [8] ANSI S12.9-1988/Part 1 (R 1993), *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound—Part 1*.
- [9] ANSI S12.9-1993/Part 3, *American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound—Part 3: Short-Term Measurements with an Observer Present*.
- [10] ANSI/SAE J184a-1985, *Qualifying a Sound Data Acquisition System*.

3 Definitions

For the purposes of this Standard, the following definitions apply. Definitions for related quantities

are given in Part 1 of ANSI S12.9-1988 (R 1993) and in ANSI S1.1-1994.

3.1 AFTER. Conditions or measurements at a site of interest where an outdoor noise barrier is in place.

3.2 atmospheric equivalence. Condition that the atmosphere at the BEFORE and AFTER sites is acoustically similar in atmospheric absorption, wind, air temperature, and cloud cover.

3.3 background noise level. Sound level or sound pressure level at a reference or receiver position, without the sound source of interest in operation. Unit, decibel (dB).

NOTE – Generally, background noise level should be measured in terms of the acoustical descriptor for calculation of barrier insertion loss.

3.4 BEFORE. Conditions, measurements, or predictions at a site before installation of an outdoor noise barrier or any other site changes.

3.5 controlled artificial sound source. Sound source that is controlled in position, height above ground, output power, spectral content, and directivity.

3.6 controlled natural sound source. Test sound source taken from the population of natural sound sources.

NOTE – As an example for highway traffic, a controlled natural sound source could be one or more test trucks.

3.7 equivalent site. For receiver positions of interest, a site selected to determine BEFORE acoustical levels by the indirect measured method and having terrain, ground, atmospheric, and sound-source conditions equivalent to those at the site where an outdoor noise barrier is installed.

3.8 ground equivalence. Condition that the ground surfaces at the BEFORE and AFTER sites have the same ground-surface classification.

3.9 ground impedance. At a specified frequency, complex quotient of sound pressure by the normal component of particle velocity directed into the surface of the ground. Unit, pascal per (meter per second) [Pa/(m/s)].

3.10 insertion loss. Difference between acoustical levels before and after installation of a barrier, where the sound source, terrain, ground, and atmospheric conditions are equivalent. Unit, decibel (dB).

3.11 lower bound to insertion loss. Insertion loss when, for example, background noise levels are not measured or are too high to determine the actual insertion loss of the barrier. Unit, decibel (dB).

3.12 mean insertion loss. Arithmetic average of insertion losses determined for a given source-receiver pair by repeated measurements under equivalent conditions. Unit, decibel (dB).

3.13 partially measured insertion loss. Insertion loss determined from a predicted BEFORE and a measured AFTER acoustical level. Unit, decibel (dB).

3.14 unmasked insertion loss. Insertion loss from measured BEFORE and AFTER acoustical levels not masked by background noise. Unit, decibel (dB).

3.15 outdoor noise barrier. Structure, or structure together with other material, that potentially alters the acoustical level at a site from a BEFORE condition to an AFTER condition.

3.16 masked. Condition that occurs when the contribution of background noise is such that no adjustment for the influence of background noise is possible.

3.17 natural sound source. One or more fixed or moving sound sources naturally present or passing through a source region; typically, the source for which the barrier was installed.

3.18 receiver position. Point at which an insertion loss is to be determined.

3.19 reference position. Position at which the sound from the source is or will be minimally influenced by the barrier or planned barrier, and which will be used to monitor source sound levels.

3.20 sound source equivalence. Condition that the sound source at the BEFORE and AFTER sites is acoustically similar in sound level, spectrum, directivity, and position (in particular, the effective height of the source above the ground).

3.21 source sound level. Sound level, sound exposure level, or sound pressure level determined at a reference or receiver position with the sound source operating. Unit, decibel (dB).

3.22 sound-source position. Position at which a sound source is located.

3.23 source-receiver pair. Combination of a sound-source position and a receiver position.

3.24 terrain equivalence. Condition that the terrain at BEFORE and AFTER sites is similar in terms of the portions of the sound source visible at the receiver position (presuming absence of the barrier), sound reflections from the ground, and reflection paths from surfaces to the side or behind the receiver position.

4 Methods

Three methods for determining the insertion loss of outdoor noise barriers are presented in this Standard. The preferred method is the “direct measured” method. Alternative methods are an “indirect measured” method using *measured* BEFORE sound levels from an *equivalent site*, and an “indirect predicted” method using *predicted* BEFORE sound levels.

Choice of a method to determine the insertion loss of an outdoor noise barrier may be dictated by several factors. The factors include the objectives of the measurements, the ability to measure the sound levels before barrier installation, and the presence of sound sources in the area not related to the source of interest.

Achievement of source, terrain, ground, and atmospheric equivalence for the BEFORE and AFTER situations is important.

Figure 1 presents a flow chart illustrating the choice of the method for determination of barrier insertion loss.

4.1 Direct measured method

The direct measured method may be used only if the barrier has not yet been installed or can be removed for the BEFORE measurements.

Sound levels are measured at the same reference and receiver positions before and after installation of the barrier. For a valid determination of barrier insertion loss, the measurements shall be made with equivalent sound sources, and equivalent terrain, ground, and atmospheric conditions.

4.2 Indirect measured method

The indirect measured method applies when an outdoor noise barrier has been installed prior to any direct BEFORE measurements and it cannot be readily removed to permit such measurements. In this event, the BEFORE condition may be simulated at a site that is equivalent to the site with the barrier.

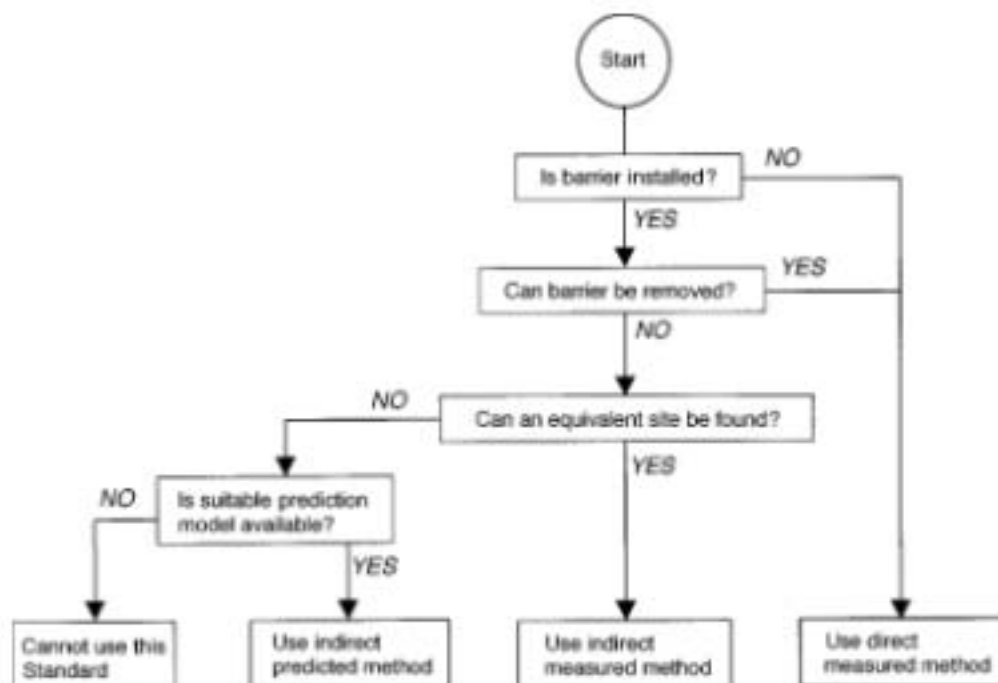


Figure 1 — Flow chart illustrating the choice of method to determine the insertion loss of an outdoor noise barrier.

4.3 Indirect predicted method

If it is not possible either to make actual BEFORE sound level measurements or to make BEFORE measurements of sound levels at an equivalent site, then BEFORE predictions of acoustical levels may be possible.

When acoustical levels are predicted, uncertainties inherent in the chosen prediction method further increase the uncertainty of the determination of insertion loss. The resulting insertion loss shall be referred to as "partially measured."

The prediction method for the BEFORE acoustical level shall conform to the following criteria:

(1) the prediction method shall consider the type of ground between the sound source and receiver, at least by accounting for differences between sound propagation over acoustically hard and soft ground (such as paved areas and grassland). Preferred prediction methods also consider the topography of the terrain between sound source and receiver.

(2) published documentation shall exist for field validation of the prediction method over the rel-

evant range of source-to-receiver distances, and for the relevant topography and type of ground surface. The documentation shall be referenced in the Test Report. The results of the validation shall be sufficient to ascribe quantitative uncertainty to the predictions. The prediction uncertainty shall be incorporated during an assessment of total experimental uncertainty.

(3) if the prediction method does not consider wind velocity and temperature gradients, the indirect predicted method shall be used only for the calm wind class specified in table 1.

Table 1 — Wind classes.

Class	Magnitude of vector component of wind velocity ^A m/s
Upwind	-1 to -5
Calm	-1 to +1
Downwind	+1 to +5

^A The vector component of wind velocity is relative to the line from the source center to the microphone.

Any prediction method that meets the above criteria may be used. However, each partially measured insertion loss carries with it any deficiencies of the prediction method. Source, receiver, and reference positions shall be modeled as precisely as possible relative to the terrain at the site of interest, within the constraints of the prediction method. Predicted BEFORE sound levels should apply for the appropriate long-term-average meteorological conditions representative of the site of interest.

5 Sound sources and source equivalence

5.1 Types of sound sources

Three types of sound sources may be used for determinations of barrier insertion loss. The resulting insertion losses shall apply only to the sound source used in the measurements, or for measurements and predictions.

Inferences of barrier insertion loss with different types or mixes of sound sources, or sources operating under different conditions, shall be substantiated in the Test Report.

5.1.1 Natural sound sources

The uncontrolled, naturally occurring sound source for which the barrier is designed is normally the best choice for the sound source.

5.1.2 Controlled natural sound sources

A controlled natural sound source should be considered when the natural sound source has changed, or is expected to change between the BEFORE and AFTER measurements and the sites are no longer equivalent.

For example, if truck flow rates at a traffic-noise-barrier site are expected to change significantly, it may be necessary to select one or several test trucks to be typical sound sources. The selected trucks are then used for controlled BEFORE and AFTER tests. Sound source equivalence shall be established for the test trucks.

5.1.3 Controlled artificial sound source

A controlled artificial sound source may be used when BEFORE and AFTER natural-sound-source equivalence cannot be established, or for preliminary testing. However, much greater technical expertise and control are required to obtain meaning-

ful results with a controlled artificial sound source than with natural or controlled natural sources.

Use of a controlled artificial sound source probably is not appropriate for a sound source distributed over a large area, such as highway traffic, or a jet or rocket engine. In such cases, a controlled natural sound source should be used.

Operating parameters of the artificial sound source shall be controlled to ensure relevance of the tests to the acoustical performance of the barrier for the natural sound source(s) being simulated. Relevance shall be documented in the Test Report.

Normally, it is only feasible to simulate an idealized approximation to the natural sound source, for example by an omnidirectional point source.

All significant sound-propagation paths between the natural sound source and the receiver position shall be covered by the simulation including those paths associated with reflection from the ground or other objects in the source and receiver regions.

The simulation shall cover the relevant components of the spectrum of the natural sound source. Sinusoidal signals may be used, but signal frequencies should be chosen to avoid interference effects.

Unless stability of the sound source is established and documented, the output of the controlled artificial sound source shall be monitored when sound levels are measured.

5.2 Sound source equivalence

For a valid determination of insertion loss, the sound sources shall be equivalent for the BEFORE and AFTER measurements. Sound source characteristics shall be sufficiently similar so as not to introduce large measurement uncertainties.

Sound source characteristics that affect insertion loss include spectral content, directivity, spatial and temporal patterns, vertical and horizontal positions, and operating conditions. In addition, for a composite of several types of sound sources, the number, type, and spatial distribution of the sources shall be considered.

It may be possible to partially or fully establish sound-source equivalence before the insertion loss measurements by analysis of previously collected or published data. In addition, it may be possible, by review of available data or by analyses conducted with appropriate prediction models,

to determine the important operational parameters that affect barrier insertion loss and to determine allowable variations in these parameters.

5.2.1 Operational parameters

During insertion loss measurements, two steps shall be followed:

- (1) key sound-source operational parameters shall be monitored and a determination made as to whether or not any monitored variations are acceptable; and
- (2) sound levels shall be monitored at a reference position.

If the variations in sound-source operational parameters are within specified limits, then the sound level at the reference position may be used in the insertion-loss calculation process. If not, then the sound sources are not equivalent and additional measurements of sound levels shall be obtained to determine insertion loss.

No single set of operational parameters is applicable to all sound sources to which this Standard applies. Appropriate parameters may be defined by trade associations, standards organizations, or government agencies.

For example, accepted parameters for the sound of traffic are average operating speeds; average hourly flow rates and spatial distribution for automobiles, medium trucks, heavy trucks; buses, and motorcycles; road gradient; and pavement type.

Allowable variations in these parameters may be established by exercising appropriate prediction models or by reviewing appropriate databases.

Operational parameters may also be developed *in situ* by observing the operational cycle of the sound source. For example, interviews of construction-machinery operators may aid in determining which operational parameters affect sound output.

Sound source parameters, operational cycle, source location, source directivity, and operating conditions shall be documented so that test conditions can be duplicated for the AFTER sound level measurements.

When a sound source is an extended composite of several more-compact individual sound sources, such as often found at a construction site, the dominant sound sources shall be determined first.

Individual sound sources that have a sound level which is 20 dB, or more, less than the total level of the sound from all sources at the site should be noted but need not be documented in detail. The type, number, location (or travel path), manufacturer, and operating parameters of the individual sound sources shall be recorded whenever possible.

5.2.2 Reference microphone position

The location for a reference microphone to monitor the sound source for equivalence in the BEFORE and AFTER tests shall:

- (1) be in a region where the outdoor noise barrier minimally influences the sound field;
- (2) be between the receiver positions and the major sound contributor in the sound source region;
- (3) be at a distance from the sound source sufficient to minimize near-field effects; and
- (4) be at a height above the ground sufficient to minimize environmental effects resulting from the atmosphere, terrain configuration, and ground reflections.

NOTE – Introduction of an outdoor noise barrier may increase sound pressure levels at the reference microphone position because of multiple reflections between the sound source and the barrier, or edge diffraction at the top of the barrier, or both.

When the outdoor noise barrier is more than 15 m from the near edge of the sound-source region, the position at least 1.5 m directly above the top of the barrier is preferred for the reference microphone.

The preferred reference microphone position illustrated in figure 2(a) shall be used unless an alternative position is required.

For most assessments of the insertion loss of outdoor noise barriers, sound levels at a reference microphone position shall not be measured for distances x less than 1.5 m as shown in figure 2(a) or 2(b).

When the distance from sound source to barrier is considered too small to neglect near-field effects, two alternatives are recommended:

- (1) when the sound source is an extended composite of several more-compact individual sound

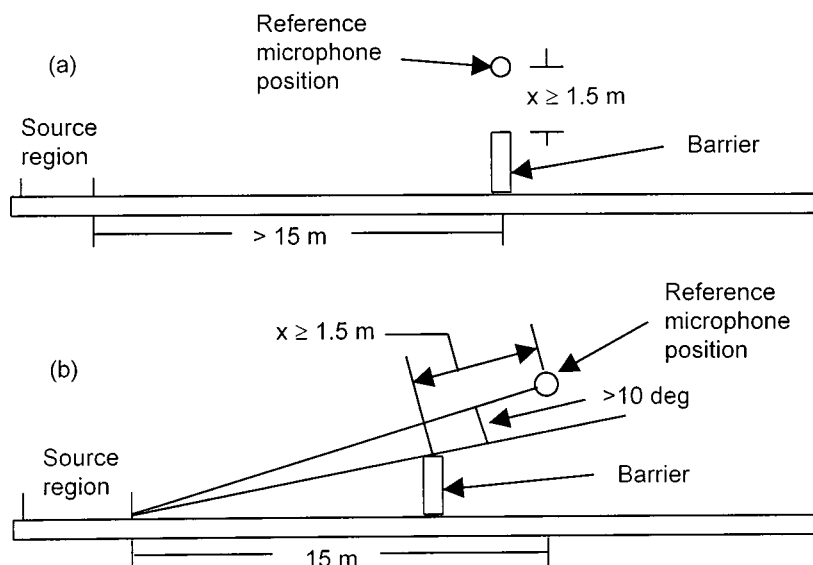


Figure 2 — Reference microphone positions.

sources, monitor and treat the individual sound sources separately, rather than together as a composite; and

(2) place the reference microphone at a distance from the sound source large enough to avoid near-field effects, but in the direct sound field. The position should be at least 10 degrees above the line segment connecting the near edge of the source region and the top of the barrier. The position should also be 15 m from the near edge of the source region as shown in figure 2(b).

When the barrier location is more than 30 m from the sound source, and, hence, probably closer to the receiver position, locate the reference microphone at a distance of 15 m from the source.

At this reference microphone position, maintain the height of the microphone so that a line from the near edge of the source region to the microphone makes an angle greater than 10 degrees with the nominal ground plane.

For this reference microphone position, the reference sound level shall not be reduced for effects of reflections and diffraction.

6 Acoustical environment

For a valid determination of insertion loss, the equivalence of terrain, ground, and atmospheric

conditions at the BEFORE and AFTER sites shall be determined and documented in the Test Report. The background noise level also shall be determined and reported.

6.1 Terrain equivalence

The terrain at two sites, presuming absence of the barrier at the AFTER site, is equivalent if the following criteria are satisfied:

- (1) The same major components of the sound source can be seen at the receiver positions for the two sites;
- (2) At each site, similar patterns for sound reflections from the ground exist between the receiver microphone and the major components of the sound source. Similarity in reflection patterns refers to:
 - (a) same number of ground reflections;
 - (b) same type of ground surface where corresponding reflections occur;
 - (c) similar reflection angles relative to the nominal ground plane at corresponding reflection points; and
 - (d) similar pathlength differences between direct and reflected sound rays.

- (3) Similar reflection paths exist from surfaces to the side of, or behind, the receiver position.

A plan view and a ground profile (elevation view) of the terrain between the sound source and receiver shall be drawn to aid in assessment of terrain equivalence.

6.2 Ground equivalence

6.2.1 Ground impedance

The equivalence of the ground at two sites may be determined by measurement of the specific acoustic impedance of the ground.

If ground impedance is not measured, then the ground surface shall be categorized, for example as paved; long grass over loose sand; short grass over packed clay; or a packed sandy dirt roadway. An equivalent site of the same ground-surface category shall be selected. When categorizing the ground surface, note that only a thin surface layer of soil is relevant, 50 mm deep at the very most.

Extreme differences in surface water content shall be avoided for ground equivalence. Avoid frozen or snow-covered ground because of its acoustical variability at different times and locations.

6.2.2 Vegetation

Vegetation at a site is usually important only insofar as it keeps the ground loose and porous. Equivalent sites shall have comparable tree density. Bushes and occasional trees may be ignored.

6.3 Atmospheric equivalence

Atmospheric conditions shall be relevant to the activities of people affected by the sound and the objectives for determination of barrier insertion loss.

BEFORE and AFTER acoustical measurements shall be restricted to similar atmospheric conditions. Major considerations are attenuation by atmospheric absorption along sound propagation paths, wind, temperature, and cloud cover. Annex A provides information on how atmospheric conditions affect sound propagation.

6.3.1 Atmospheric absorption

The level of the sound measured at a receiver position can vary because of variations in atmospheric absorption over the sound propagation

paths from a source to a receiver. At high frequencies, significant differences occur in the attenuation of sound depending on the concentration of water vapor.

For a sound source with major spectral components at frequencies greater than 3 kHz, BEFORE and AFTER measurements should be restricted to similar conditions of water vapor concentration. See ANSI S1.26-1995 for additional information.

6.3.2 Wind

Wind conditions are equivalent for BEFORE and AFTER acoustical measurements if the wind class (specified in table 1) remains unchanged. In addition, the vector components of the average wind velocity from the sound source to the microphone shall not differ by more than certain limits. The limits depend on the allowed measurement uncertainty and the distance from the sound source to the microphone.

If the uncertainty in insertion loss is to not exceed ± 1 dB for sound-propagation distances less than 70 m, the difference between the vector components of the BEFORE and AFTER average wind velocities shall not exceed 1 m/s.

If the uncertainty is not to exceed ± 0.5 dB for distances less than 70 m, at least four BEFORE and four AFTER measurements shall be made within the average wind-speed difference of 1 m/s and the insertion losses averaged.

These wind-speed limits do not apply to the calm wind class of table 1.

In any case, no acoustical measurements shall be made when the average wind speed exceeds 5 m/s, regardless of wind direction.

Attempts to measure sound levels should be avoided when there are strong winds with a small vector component in the direction of propagation, because of large uncertainties caused by turbulence and wind velocity fluctuations.

For a given set of acoustical measurements, the component of wind velocity from sound source to receiver shall be determined according to the following procedures:

- (1) monitor wind velocity (speed *and* direction) throughout each period of acoustical measurements;
- (2) note the average speed and direction;