ASA/ANSI S3.4-2007
(Revision of ANSI S3.4-2005)

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AMERICAN NATIONAL STANDARD

Procedure for the Computation of Loudness of Steady Sounds

Secretariat:

Acoustical Society of America

Approved on May 24, 2007:

American National Standards Institute, Inc.

Abstract
This document describes the divergence loss method of measurement of performance of an environment designed to provide a free sound field or free sound field over a reflecting plane. An acoustical environment is a free sound field if it has bounding surfaces that absorb all sound energies incident upon them. This is normally achieved using specialized test environments, such as anechoic or hemi-anechoic chambers. In practice, these provide a controlled free sound field for acoustical measurements in a confined space within the facility.

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Procedure for the Computation of Loudness of Steady Sounds

ANSI S3.4-2007

Accredited Standards Committee S3, Bioacoustics

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114E
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Procedure for the Computation of Loudness of Steady Sounds

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Approved: May 24, 2007

American National Standards Institute, Inc.

Abstract

This standard specifies a procedure for calculating the monaural and binaural loudness of steady sounds as perceived by listeners with normal hearing. The procedure is based on the spectra of the sounds. The possible sounds include simple and complex tones (both harmonic and inharmonic), bands of noise and mixtures of tones and noise. The spectra can be specified exactly, in terms of the frequencies and levels of individual spectral components, or approximately, in terms of the levels in 1/3 octave bands covering center frequencies from 50 to 16,000 Hz. The standard is applicable to sounds presented in free field with a frontal incidence, in a diffuse field, or listening via headphones. The procedure is available as a computer program that provides the loudness level in phons and the corresponding loudness estimate in sones. Examples of the estimates generated by the program for a variety of input spectra are presented in Annex A. The software for calculation of loudness according to ANSI S3.4-2007 is described in Annex B. It accompanies the standard for the convenience of the purchaser. Use of this software is not required for conformance.

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Foreword

[*This Foreword is for information only, and is not a part of the American National Standard ANSI S3.4-2007 American National Standard Procedure for the Computation of Loudness of Steady Sounds.*]

This standard comprises a part of a group of definitions, standards, and specifications for use in bioacoustics. It was developed and approved by Accredited Standards Committee S3 Bioacoustics, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S3 is as follows:

> *Standards, specifications, methods of measurement and test, and terminology in the fields of psychological and physiological acoustics, including aspects of general acoustics, which pertain to biological safety, tolerance and comfort.*

This standard is a revision of ANSI S3.4-2005, which was in turn a revision of ANSI S3.4-1980. Loudness is the perceived intensity of a sound (see below for definition). Loudness depends on both the acoustic properties of the sound that impinges on a listener and on the listener. This standard gives an estimate of the loudness of steady sounds as perceived by normally hearing listeners under specified conditions. The recommended procedure is based on a model of loudness perception (Moore, Glasberg, and Baer, 1997; Glasberg and Moore, 2006) that was developed from a model originally proposed by Zwicker and his co-workers (1958, 1965, 1984, 1999). Zwicker's model is part of ISO 532:1975. These models have their roots in the pioneering work of Fletcher and Munson (1933). The current procedure extends and improves the accuracy of these earlier methods. It replaces the more limited computational procedure used in the old ANSI S3.4-1980 that was based on the method proposed by S.S. Stevens (1957, 1961). Unlike the old ANSI S3.4-1980, the current standard can be applied to sounds with sharp line spectral components, e.g., transformer hum or fan noise, as well as to sounds with broadband spectra. Provided the measurement of sound pressure levels is sufficiently precise, and subject to certain restrictions specified below, the recommended procedure may also be used to estimate loudness, or loudness level, with reasonable accuracy down to near threshold levels. Moreover, it enables the loudness of complex sounds containing spectral energy below 500 Hz to be determined. The equal-loudness contours derived from this standard are in good agreement with ISO 226:2003 (see also Suzuki and Takeshima, 2004). Because loudness is a subjective quantity, the perception of which may vary among people, any calculated loudness value represents only an estimate of the average loudness as perceived by a group of individuals with normal hearing.

The changes made in this revision are: (1) A modification to the method for calculating specific loudness from excitation for center frequencies below 500 Hz to make the standard fully compatible with the provided software and with the model of Moore et al. (1997) and with its amendment by Glasberg and Moore (2006); (2) A modification to the transfer function of the middle ear, as proposed by Glasberg and Moore (2006), which allows more accurate predictions of the absolute thresholds in ISO 389-7:2005 and of the equal-loudness contours in ISO 226:2003.

The software provided with this American National Standard is entirely informative and provided for the convenience of the user. Use of the provided software is not required for conformance with the Standard.

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At the time this Standard was submitted to Accredited Standards Committee S3, Bioacoustics for approval, the membership was as follows:

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A.J. Brammer	K.D. Kryter	L.A. Wilber
A.J. Campanella	R. McKinley	W.A. Yost

Working Group S3/WG 51, Auditory Magnitudes, which assisted Accredited Standards Committee S3, Bioacoustics, in the development of this standard, had the following membership.

R.P. Hellman, Chair

A.J. Campanella	B.R. Glasberg	B. Scharf
P. Davies	T.R. Letowski	R.S. Schlauch
	B.C.J. Moore	

Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S3, Bioacoustics, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org

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American National Standard

Procedure for the Computation of Loudness of Steady Sounds

1 Scope

This standard specifies a procedure for calculating the monaural and binaural loudness experienced by listeners with normal hearing under the following conditions:

1.1. Listening conditions. The standard applies to three listening conditions: free field with a frontal incidence, diffuse field, or listening via headphones. Listening in a free field with a frontal incidence is assumed when the sound source is located at least one meter directly in front of the listener and there are no space boundaries or other surfaces that affect the sound field. The free-field condition can be achieved in an anechoic chamber or in open space. Listening in a diffuse field is assumed when the sound reaches the listener's ears from all directions with essentially the same acoustic power. The sound field in a room with hard reflective walls where the sound is reflected many times before being significantly absorbed approximates a diffuse field. Listening through headphones is assumed when the sound is delivered directly to the listener's ears through circumaural or supra-aural headphones, or insert earphones. For simplicity, the term headphones will be used hereafter to denote both headphones and earphones.

NOTE 1 The equal-loudness contour for narrow-band noise in a free field differs from that in the diffuse field, but the difference measured at 1/3-octave-band center frequencies varies from -2.0 to +4.3 decibels with the mean difference equal to only 0.8 decibels. These differences do not significantly affect calculations for broadband spectra. Nevertheless, since the loudness of a sound depends on the nature of the enclosure in which it is heard, comparative evaluations of different sources should be based on measurements all made in essentially similar enclosures or all made in a free sound field.

NOTE 2 Pressure levels in a diffuse field should be measured by means of an omnidirectional microphone located in the unobstructed sound field at the position corresponding to the center of the listener's head.

1.2 Spectrum. The computational procedure described in the standard applies to a variety of sounds including complex tones, noise bands, and mixtures of the two. The characteristics of the sounds are specified in terms of their spectra. The procedure applies to sounds with a frequency range that extends from 20 Hz to 18,000 Hz. However, the procedure may not give accurate estimates of loudness for sounds with strong components above 12,500 Hz, and perceived loudness for such sounds is likely to vary markedly across individuals.

1.3 Steady state. The procedure described in the standard applies to steady state sounds and should not be used for impulse sounds or intermittent sounds. Application to such sounds may lead to discrepancies between measured and calculated loudness levels. The magnitude of the discrepancy is related to the dynamic characteristics of the device used to determine the sound pressure levels.

2 Terms and definitions

For the purposes of this standard, the terms and definitions given in ANSI S1.1-1994 and ANSI S3.20-1995 and the following apply:

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