ANSI/ASA S12.6-2008
(Revision of ANSI S12.6-1997)

AMERICAN NATIONAL STANDARD

Methods for Measuring the Real-Ear Attenuation of Hearing Protectors

ANSI/ASA S12.6-2008

Accredited Standards Committee S12, Noise

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114 E
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Methods for Measuring the Real-Ear Attenuation of Hearing Protectors

Secretariat
Acoustical Society of America

Approved September 3, 2008
American National Standards Institute, Inc.

Abstract

This Standard specifies laboratory-based procedures for measuring, analyzing, and reporting the passive noise-reducing capabilities of hearing protection devices. The procedures consist of psychophysical tests conducted on human subjects to determine the real-ear attenuation measured at hearing threshold. Two fitting procedures are provided: Method A) trained-subject fit, intended to describe the capabilities of the devices fitted by thoroughly trained users, and Method B) inexperienced-subject fit, intended to approximate the protection that can be attained by groups of informed users in workplace hearing conservation programs. Regardless of test method, the attenuation data will be valid only to the extent that the users wear the devices in the same manner as during the tests. This Standard does not address issues pertaining to computational schemes or rating systems for applying hearing protector attenuation values (see ANSI/ASA S12.68), nor does it specify minimum performance values for hearing protectors, or address comfort or wearability features. Method A of this Standard corresponds to International Standard ISO 4869-1:1990, *Acoustics – Hearing protectors – Part 1: Subjective method for the measurement of sound attenuation*, and Method B corresponds to ISO/TS 4869-5:2006, *Acoustics – Hearing protectors – Part 5: Method for estimation of noise reduction using fitting by inexperienced test subjects*.

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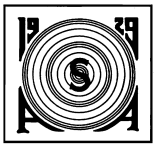

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Foreword

[*This Foreword is for information only and is not a part of the American National Standard ANSI/ASA S12.6-2008 American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors* (revision of ANSI S12.6-1997).]

This standard comprises a part of a group of definitions, standards, and specifications for use in noise. It was developed and approved by Accredited Standards Committee S12, Noise, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S12 is as follows:

> *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.*

This standard is a revision of ANSI S12.6-1997. The Method-A procedure has been modified to make it more specific and less open to interpretation, and has been re-designated as a "trained-subject fit." The Method-B procedure has also been clarified, and has been re-designated as "inexperienced-subject fit." The scope and applications have been revised accordingly.

This standard is comparable to two existing ISO Standards. Method A corresponds to ISO 4869-1:1990, *Acoustics – Hearing protectors – Part 1: Subjective method for the measurement of sound attenuation*, with the principal differences being in the number of test subjects and replications, the fitting instructions, and certain details of the electroacoustic test specifications, especially the room background noise. Method B corresponds to ISO/TS 4869-5:2006, *Acoustics – Hearing protectors – Part 5: Method for estimation of noise reduction using fitting by inexperienced test subjects*, again with similar differences as between Method A and 4869-1.

This standard does not include performance requirements for hearing protectors, nor does it specify how to utilize the attenuation values derived from testing via the methods of this standard for the prediction of protected noise exposures; computational methods and attenuation ratings are described in ANSI/ASA S12.68-2007. This standard also does not pertain to physical attenuation measurements using acoustical test fixtures or microphones mounted in human earcanals; those procedures are covered by ANSI S12.42-1995 (R2004).

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Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S12, Noise, 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.

Introduction

Background

Since the development of ANSI Z24.22-1957, real-ear attenuation at threshold (REAT) methods for the measurement of the noise reduction of hearing protection devices (HPDs) have been widely utilized and described in the literature. In subsequent years, many additional procedures have been devised and tested, and in some cases standardized, but the real-ear attenuation procedure has remained the most commonly accepted (Berger, 1986). It is generally recognized that REAT data yield the best measure of the noise reduction provided by passive level-independent devices for a specified test condition and include effects of sound transmission from flanking pathways, such as those arising from tissue and bone conduction.

A major area of contention does exist in the professional community and within the scientific literature, namely, the applicability of the laboratory-measured REAT data to real-world environments. In other words, are the data valid for application outside the laboratory? Do they provide a useful indicator of the attenuation actually attained by individual well-trained users or by groups of people wearing hearing protectors on a day-to-day basis for protection from occupational or recreational noise exposures?

Beginning in the middle 1970s and continuing up through the 2000s, studies have reported that the field-measured attenuation of HPDs was substantially less than would be predicted based upon testing conducted in conformance with the prior ANSI standards, S3.19-1974 and S12.6-1984 (Berger, Franks, and Lindgren, 1996). This divergence is especially troubling considering the importance that many hearing protector purchasers and users ascribe to published attenuation data.

Ideally, the approach to reduction of laboratory vs. real-world discrepancies would be to ensure that end users properly fit and use hearing protectors in order to improve field performance to more closely match laboratory data, keeping in mind that rarely can one hope to duplicate optimum laboratory attenuation under field conditions. Regardless, most agree that industrial hearing conservation practices must be enhanced so that better real-world HPD performance can be realized (Berger, 1992). However, it is also clear that a laboratory method of measuring hearing protector attenuation that yields data that closely correlate with existing, or even potential, field performance would be a useful predictive tool.

The Working Group responsible for this standard embarked upon a project to develop a procedure to provide more valid estimates of field performance. Various protocols were evaluated and tested via both a pilot and a full-scale interlaboratory comparison study. The results, which have been summarized and presented in three parts, provide the scientific justification for the inexperienced-subject procedure that has been incorporated in this standard (Berger *et al.*, 1998; Murphy *et al*., 2004; Royster *et al.*, 1996). Subsequently, an additional interlaboratory study evaluating six hearing protectors in six different laboratories was conducted, and the results led to refinements in the methods of ANSI/ASA S12.6-2008 as compared to the 1997 document (Murphy *et al*., 2006).

The importance of human-factors considerations

Experimenter-supervised fitting of HPDs (i.e., carefully controlled placement of the devices), which was the only option in the 1984 version of ANSI S12.6 and one of two options in the 1997 version, is intended to describe the upper limits of hearing protector performance. This procedure can be useful for developing a better theoretical understanding of how hearing protectors block sound and interface with the head or earcanals. However, such data provide inadequate insight into the performance of HPDs when real-world human-factors considerations are taken into account. Since the seal between

the HPD and the head or earcanal is such a critical determinant of the achieved attenuation, and because it is so strongly controlled by the subject and how the device is worn (especially for earplugs), human-factors considerations must be included in the laboratory model if valid field estimates are to be obtained.

In recognition of the importance of the HPD-head/earcanal interface, standardized laboratory methods of measuring hearing protector attenuation have typically involved the use of human subjects wearing the devices under test. Using human subjects as opposed to acoustical test fixtures is of great value because it provides the potential to develop a laboratory-based procedure that more closely models use conditions.

In spite of the importance of using human subjects, one must also consider that an experimenter interacting with listeners may lead to variability in measured results. The experimenter can dramatically influence the data by how s/he selects, trains, supervises, motivates, and fits the subjects—in short, by the experimenter's own preconceptions about how the HPD should be used and is expected to perform. The usefulness of the laboratory data in predicting field performance in a given application will be determined in large part by the degree of correspondence between the laboratory procedures for fitting HPDs and those found in the real world.

Definition of validity and selection of test methods

In order to create a procedure that generates "valid" data, the question has to be asked, "Valid with respect to what?" In practice, a wide range of HPD attenuation values may be observed in the workplace, from essentially no attenuation at all for devices incorrectly and inconsistently fitted by untrained users, to much higher levels of protection that may be obtained by well-trained and motivated users in workplaces with the most successful hearing conservation programs. It is unrealistic to use trained-subject fit values to estimate field performance for groups of workers in hearing conservation programs without recognition of the exceptional training under which they were obtained. Neither does it make sense to derate hearing protector performance to estimate worst-case attenuation values, since worst-case values are much more heavily influenced by factors other than the hearing protectors themselves.

The most suitable laboratory method will be dictated by the purpose to which the data will be applied. Thus, the choice made in the development of the 1997 version of this standard and retained in the current version was to provide two different but realistic fitting methods, one similar to the experimenter-supervised fitting procedure with which much of the hearing protection community has become familiar, and another for estimating representative field attenuation.

Method A of this standard, previously called "experimenter-supervised fit" and now designated "trained-subject fit," describes something close to an optimum fitting scenario that can be accomplished by a motivated and proficient user. In the current standard it allows full training and intervention by the experimenter as before, but for the actual test the subject must don the hearing protector on his or her own without assistance. The rationale is that allowing intensive individualized training immediately prior to a subject fitting the device is a reasonable reflection of the best that could be obtained in practice. The reason to not have the experimenter actually fit the device was the observation that experimenters, who vary in the way they interpret the standard and perform HPD fitting, can add substantial interlaboratory variability (Murphy *et al*., 2006). Isolating them from the actual test, to some extent, reduces this problem. Furthermore, in actual use workers and other users don hearing protectors on their own without assistance.

To estimate field performance, the Method-B approach of the 1997 standard was retained but re-designated "inexperienced-subject fit" to more clearly indicate the key feature of the procedure. Various details of the test method were refined with the aim of reducing ambiguity in interpretation of the dictates of this standard and to improving reproducibility. Method B is intended to approximate "achievable" results for workers in hearing conservation programs. Because in an inexperienced-

subject fit procedure the experimenter's input is limited, much depends upon the subjects' skill in reading and interpreting instructions, which in turn is substantially affected by their prior experience with HPDs and any previous training they may have received. The literature suggests that under such conditions, it is important to select subjects with as little prior practice and training in HPD usage as possible; otherwise, their performance on the current tests will likely be strongly influenced by their preconceptions and acquired level of skill (Berger, 1992).

It was recognized that sincerely interested and/or highly motivated *individuals* may obtain workplace attenuation values significantly exceeding laboratory inexperienced-subject data, but for most populations of occupational users, the inexperienced-subject fit estimates will be more appropriate. The validity of the estimates was assessed and substantiated by comparing laboratory-measured values arrived at using the subject-fit protocol of this standard to values for groups of users derived from more than 20 available real-world studies (Berger *et al*., 1998).

Based upon the available literature as well as the findings of the 1990s interlaboratory study that provided the foundation for this standard (Berger *et al*., 1998; Royster *et al.*, 1996), it was anticipated that Method-A fitting would result in higher mean attenuation values and lower within-test standard deviation values than Method-B results, with the effect being substantially larger for earplugs than for earmuffs because of the greater importance of fitting factors in testing insert devices. See Annex A for examples of representative data. The results of the second interlaboratory study confirmed these findings but illuminated unanticipated problems with between-laboratory variability for both Methods A and B (Murphy *et al.*, 2006). This was one of the reasons for the conversion in this current standard from experimenter-supervised to trained-subject fit for Method A, and for many of the changes that were implemented in the Method-B protocol. See Annex A for information on the precision of the Method-A and Method-B procedures.

The choice of the method will be determined by the application that the user intends. For guidance, see Clause 1.2.

Beyond laboratory testing

The inexperienced-subject fit method described in this standard was developed to approximate the real-world attenuation achieved on average by most *groups of users* participating in actual hearing conservation programs; selected individual users may well achieve higher values. Attempts to predict values of attenuation achieved by individuals will have a large degree of uncertainty. The only way to make such predictions is to utilize field test measurements on the actual users in question. For a particular workplace the best way to estimate the attenuation actually attained by employees is to measure real-ear attenuation for the workers in question (Berger, 1986), or utilize field measurement devices to evaluate a sample or, preferably, the entire workforce. Ultimately, the audiometric database for the noise-exposed employees will demonstrate whether their hearing has been protected, but this bottom-line indicator depends upon the effectiveness of the entire hearing conservation program, not hearing protector use alone (ANSI S12.13 TR-2002).

American National Standard

Methods for Measuring the Real-Ear Attenuation of Hearing Protectors

1 Scope

1.1 Scope

This standard specifies laboratory-based procedures for measuring, analyzing, and reporting the passive noise-reducing capacity of hearing protection devices. The methods consist of psychophysical tests conducted on human subjects to determine real-ear attenuation at threshold.

Two methods are provided, differing in their subject selection, training, hearing protector fitting procedures, and experimenter involvement, but corresponding in all electroacoustic and psychophysical aspects. One method, designated *trained-subject fit*, is intended to describe the upper limits of hearing protector performance for devices fitted by carefully trained users. The second method, designated *inexperienced-subject fit*, is conducted with persons with little or no experience with respect to the use of hearing protection. It approximates the attenuation that has been achieved by groups of users as reported in real-world occupational studies (Berger *et al*., 1998).

1.2 Applications

The selection of test method, trained-subject fit or inexperienced-subject fit, is based upon the intended application.

Method-A trained-subject fit will correspond most closely to tests using the prior versions of this standard, issued in 1984 and 1997, and its predecessor, ANSI S3.19-1974. Such values are useful to estimate performance for highly trained and motivated individual users, as well as in the design of hearing protectors, to provide a theoretical understanding of their performance limitations, and for routine testing for quality assurance purposes.

Method-B inexperienced-subject fit is intended to provide an approximation of the upper limits to the attenuation that can be expected on average for *groups* of occupational users. Properly trained and motivated *individuals* can potentially attain larger amounts of protection, in closer agreement with the trained-subject fit data, especially for earplugs, than the inexperienced-subject fit values found using this standard. However, inexperienced-subject fit values provide a closer correspondence to real-world performance for groups of users than do the trained-subject fit data.

Regardless of the test method that is selected, trained-subject fit or inexperienced-subject fit, the attenuation values will be applicable only to the extent that:

(a) the hearing protectors are worn in practice in the same manner as during the laboratory test;

(b) the hearing protectors are properly maintained; and

(c) the anatomical characteristics of the population of actual wearers are a reasonable match to the laboratory test subjects.