ASA/ANSI S12.68-2007
(Editorially Corrected and Republished July 2009)

Reaffirmed by ANSI September 29, 2017

AMERICAN NATIONAL STANDARD

Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn

Secretariat:

Acoustical Society of America

Approved on August 20, 2007

American National Standards Institute, Inc.

Abstract

This standard specifies three methods, in ascending order of complexity of use and potential accuracy, for the estimation of the sound pressure levels that are effective when a hearing protector is worn. The application of the procedures in turn requires an estimate of the real-ear attenuation of the device for groups of users and an estimate of the noise levels to which the users are exposed. The simplest method is the Noise Level Reduction Statistic for use with A-weighting (NRSA) that can be directly subtracted from an A-weighted sound level or sound exposure estimate. A more accurate procedure is the Noise Level Reduction Statistic, Graphical (NRSG) that requires measurements of both the A- and C-weighted sound levels or exposures, and the application of a set of graphical data. Potentially the most accurate approach is the octave-band method utilizing the octave-band real-ear attenuation and noise measurement data. Each of the simplified ratings, the NRSA and NRSG, is to be computed at both the 80th and 20th percentiles to reflect the range of performance to be expected based on the variation in the attenuation data.

ANSI/ASA S12.68-2007
(Editorially Corrected and Republished July 2009)

Reaffirmed by ANSI
September 29, 2017

Reaffirmed by ANSI
September 5, 2012

AMERICAN NATIONAL STANDARD

Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn

ANSI/ASA S12.68-2007

Accredited Standards Committee S12, Noise

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114 E
Melville, NY 11747-3177

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Acoustical Society of America
ASA Secretariat
35 Pinelawn Road, Suite 114E
Melville, New York 11747-3177
Telephone: 1 (631) 390-0215
Fax: 1 (631) 390-0217
E-mail: asastds@aip.org

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Foreword

[*This Foreword is for information only, and is not a part of the American National Standard ANSI/ASA S12.68-2007 American National Standard Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn*].

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 is a new American National Standard that pertains solely to the computation of number ratings for hearing protectors; acquisition of the data themselves is described in other ANSI standards. Though number ratings have been heretofore specified by regulation in the U.S., this is the first American National Standard method that specifies how to compute such numbers. This standard compares to ISO 4869-2, *Acoustics – Hearing Protectors – Part 2: Estimation of Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn*. Like that standard it includes three different rating methods of increasing accuracy, but unlike that document it includes a number that is suitable for direct application to A-weighted sound pressure level measurements (NRS_A), whereas the ISO document's simplest approach still requires the measurement of C-weighted sound pressure level measurements. Both standards include a multi-number rating that requires use of both A- and C-weighted sound pressure level measurements—in the ANSI document an NRS_G and in the ISO document an HML. The NRS_G is similar in application to the HML as specified in ISO 4869-2:1994; however, the two methods differ in how they are calculated. The NRS_G more accurately achieves the targeted protection rate while providing a simplified graphical presentation for ease of use. Both standards include as their most accurate descriptor an octave-band computational method identical in all aspects except that the ANSI document excludes 63 Hz from the computations since such attenuation data are not normally available and even when they are, they usually have negligible impact on the overall A-weighted noise reduction.

The standard was editorially corrected and republished in July 2009 after discovery of a typographical error in Table 2 which carried through to Equation (14). This edition contains the corrected table and equation.

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L.S. Finegold	R.J. Peppin	G.S.K. Wong

Working Group S12/WG 11, Hearing Protector Attenuation and Performance, which assisted Accredited Standards Committee S12, Noise, in the development of this standard, had the following membership.

E.H. Berger, Chair

W. Ahroon	D. Gauger	B. Mozo
A. Behar	L.D. Hager	W.J. Murphy
J.G. Casali	T.K. Madison	D. Ohlin
C. Dixon-Ernst	R. McKinley	B. Witt
	K. Michael	

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

Though there exists today, and has for many years, an American National Standard for the measurement of real-ear attenuation at threshold (ANSI S12.6), there has never been a U. S. national standard for the estimation of effective A-weighted sound pressure levels when hearing protection devices (HPDs) are worn. This standard addresses that need by specifying procedures for estimation, values suitable for labeling of HPDs, and guidelines on the accuracy that can be expected.

Many issues are involved in estimating the protection that users achieve while wearing HPDs. These include obtaining valid estimates of the hearing protector's attenuation as influenced by user training and motivation, the proportion of exposure time during which users actually wear the devices, and accurate measurements of the noise exposure in question. Perhaps of greatest concern is the issue of individual variability in the fit and performance users achieve. Even with precise computational schemes such as an octave-band analysis of the noise, the issue of variability remains critical. Once predictions are made, one can estimate the percentage of users in various noises that achieve the targeted protection values, called the protection performance, and use this metric to evaluate the accuracy of various rating systems. For example, if the goal is to protect 84% of the population to a "safe" exposure level, it is desirable to know how closely the protection performance approaches the desired value.

Numerous rating systems have been proposed in the past 30 years. Those materials were used as the basis for an extensive research project that was reviewed and approved by ANSI Accredited Standards Committee S12/WG11 (Gauger and Berger, 2004). That project expanded upon the prior published literature by introducing new concepts and new data. Methods of varying complexity were examined, from an octave-band approach to ones involving ratings used with C-weighted sound levels or exposures, from those that work with A-weighted measurements to those that are simple class or grading schemes. It became apparent that the straightforwardness of what are called A – A' ratings is appealing. Such ratings predict, by simple subtraction from the A-weighted ambient noise levels, the effective A-weighted levels (L'_A) when an HPD is worn. A – A' ratings, which by their very nature are easier to use and less prone to computational errors, are of sufficient precision for most applications considering the many sources of variability inherent in predicting protection.

An important collateral issue to the development of a rating procedure is the underlying attenuation data from which the rating is to be computed. Gauger and Berger examined various techniques, especially Methods A and B as specified in the ANSI S12.6 standard. Subsequent to publication of their report an interlaboratory study was completed (Murphy et al., 2006) and the results demonstrated differences in the repeatability and reproducibility of the two methods. Since both methods have merits and applications as discussed in ANSI S12.6 and the selection of one for labeling purposes is primarily a matter of public policy, the decision was made to incorporate both methods as options in this standard.

Various sets of representative noise data have been published since the 1950s to provide a picture of the occupational noise scene. They originated from around the globe and included industrial, military, and specialized environments. Most of the prior hearing protection analytical studies have based their work on the "NIOSH 100" (Kroes et al., 1975). Gauger and Berger assessed a variety of additional data sets to make sure that the 60-year old data from which the NIOSH 100 were selected were indeed still representative. They were, and thus those values are utilized for the most simplified of the proposed ratings. For the more complex graphical approach, data were included from specialized Air Force and aviation spectra in order to assure the suitability of the recommendations for a broader range of noises.

The basis for the research in support of this standard is the pioneering work of Dick Waugh (1976, 1984). Building upon his analytical methods allowed examination of the ratings that best met the goals of simplicity, consistency, and accuracy. What emerged were two ratings, the Noise Level Reduction Statistic for use with A-weighting (NRS_A), and the somewhat more complex and more accurate Noise Level Reduction Statistic, Graphical (NRS_G). Finally as the “gold standard” for comparison purposes and for cases in which the maximum accuracy is warranted, a classical octave-band noise-reduction computational scheme is described as a third method.

A substantial divergence in this standard from prior publications and other standards (CSA Z94.2; ISO 4869-2; SA/SNZ 1270) is the recommendation that the simplified ratings be presented as pairs of numbers in order to provide additional information about the precision of the ratings, and to supply better user guidance for labeling purposes. This pair of values describes the range of performance at the 80th and 20th percentile level; the specific meaning depends upon whether Method-A or Method-B data are utilized, as defined below:

- Method A, NRS_{A80} (80th percentile value) - the protection that is possible for *most individually trained* users to achieve or exceed.
- Method B, NRS_{A80} (80th percentile value) - the protection that is possible for *most users* to achieve or exceed.
- Method A or Method B, NRS_{A20} (20th percentile value) - the protection that is possible for *a few motivated proficient users* to achieve or exceed.

The 20th percentile number has the same meaning regardless of the procedure, Method-A or Method-B, since the results of the Murphy et al. (2006) study demonstrated that the high-performing users achieved approximately the same protection regardless of the test procedure. This was not the case for the low-performing subjects.

The rationale for the two-number approach is:

- It indicates that a range of performance is to be anticipated.
- It represents, via the range between the high and low numbers, products that offer more or less inter-subject variability.
- It diverts the attention of the buyer from a single value and the associated tendency to focus on the seeming “accuracy” of that value.
- It supports the rating of the product with a conservative number that may appear low to some observers, while still indicating a much higher level of protection that is potentially attainable when a hearing protector is fit in an exemplary manner.
- It draws attention, via the higher number, to the possibility of overprotection.
- It may also encourage more careful fitting of hearing protection, especially among consumers who are buying products for their own use, by explicitly demonstrating what exacting application of the product can achieve.

The Gauger and Berger report summarizes the rationale for the choices made in this standard and provides comprehensive recommendations on how to implement them. It included presentation of the data in a primary label [much like the existing primary label required by the U.S. Environmental Protection Agency (1979)] that incorporated a pair of NRS_A values and new explanatory wording along with supporting information.

American National Standard

Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn

1 Scope and Applications

1.1 Scope

This standard specifies a choice of three methods for use with hearing protector attenuation data to estimate the effective A-weighted sound pressure levels when a hearing protector is worn. The three methods, the Noise Level Reduction Statistic for use with A-weighting (NRS_A), the Noise Level Reduction Statistic, Graphical (NRS_G), and the octave-band method are presented in order of increasing complexity of use and potential accuracy. Furthermore, the standard specifies in the case of the NRS_A and the NRS_G that values will be presented for both the 80th and 20th percentiles, indicated as NRS_{A80} and NRS_{A20}, and as NRS_{G80} and NRS_{G20}, to reflect the range of attenuation that can be anticipated.

The NRS_A specifies an attenuation value, the Noise Level Reduction Statistic for use with A-weighting, determined from the octave-band attenuation data of a hearing protector in an ensemble of 100 representative noises, which may be directly subtracted from an A-weighted noise assessment to estimate L'_A, the effective A-weighted sound pressure level when the hearing protector is worn.

The NRS_G specifies an estimated noise level reduction value deduced from a graph (or, alternatively, an arithmetic interpolation done by a spreadsheet) that relates the protection in a given A-weighted exposure to the difference between the C- and A-weighted sound pressure levels of the noise. It requires two noise measures (A- and C-weighted), instead of the single measure (A-weighted) necessary for use with the NRS_A. The NRS_G is determined by applying the octave-band attenuation data for a hearing protector to an ensemble of 67 noises that span a broader range of spectral types than used for the NRS_A computation.

The octave-band method specifies a procedure for directly applying the octave-band attenuation data of a hearing protector to a set of octave-band measurements of the noise. The computation includes a correction that is a multiple of the standard deviation in order to adjust the prediction for the desired protection performance.

1.2 Applications

The methods of this standard are applicable to estimating either the sound pressure level or the equivalent continuous or time-weighted average sound pressure levels that are effective when hearing protectors are worn.[1] Although primarily intended for steady noise exposures, the methods are also

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[1] The estimated value represents the "effective" sound level when the hearing protector is worn, i.e., the A-weighted sound level at the head center with the listener absent (commonly estimated by the on-the-shoulder measurement with a dosimeter), minus the attenuation of the HPD. This is not the same as the sound level in the earcanal. The earcanal sound level differs from that in the sound field by the transfer function of the open ear. It cannot simply be estimated by subtracting the HPD's attenuation from the A-weighted level. However, it is the "effective" values that are required to assess noise hazard, as it is those values that are normally compared to the classical damage-risk curves and permissible exposure limits.