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Evaluating the Effectiveness of Hearing Conservation Programs through Audiometric Data Base Analysis

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Accredited Standards Committee S12, Noise

Acoustical Society of America
Standards Secretariat
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ASA Technical Report

Evaluating the Effectiveness of Hearing Conservation Programs through Audiometric Data Base Analysis

Secretariat

Acoustical Society of America

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ABSTRACT

This ASA Technical Report describes methods for evaluating the effectiveness of hearing conservation programs in preventing occupational noise-induced hearing loss by using techniques for audiometric data base analysis. The rationale is given for using the variability of threshold measurements in annual monitoring audiograms as the basis for judging effectiveness. Guidelines are discussed concerning how to select a restricted data base to which the analysis procedures will be applied. Specific procedures for data analysis are defined, and criterion ranges are given for classifying program effectiveness as acceptable, marginal, or unacceptable. Sample results for industrial audiometric data bases contributed to Working Group S12/WG12 are included as an annex for reference and illustration.

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FOREWORD

[This foreword is for information only and is not an integral part of ASA S12.13 TR - 2002 *ASA Technical Report Evaluating the Effectiveness of Hearing Conservation Programs through Audiometric Data Base Analysis*]

This ASA Technical Report is a revision of Draft American National Standard S12.13-1991, which was published for a period of trial use and comment regarding the validity and usefulness of the recommended procedures for evaluating the effectiveness of hearing conservation programs (HCPs) through audiometric data base analysis (ADBA), and later unsuccessfully balloted for approval as a full standard. The ADBA procedures described are those recommended by the members of S12 Working Group 12 (S12/WG12) based on the results from their original research in applying suggested procedures to actual audiometric data bases (see Annex C), as well as the additional experience and feedback obtained from S12/WG12 members and other interested users following publication of the draft standard.

In spite of the unsuccessful ballot to convert the draft standard to a full standard, S12 deemed the contents of the document of substantial value for the hearing conservation community, and hence decided to publish them for guidance as an ASA Technical Report. The substantive negative comments during the balloting involved the following issues:

a) the possibility that gradual hearing loss in excess of that due to aging may occur in subgroups of the population evaluated in spite of acceptable ADBA criteria results on a year-to-year basis,
b) objections to the year-to-year nature of ADBA evaluations, which intentionally provide a set of indicators with values that vary annually to reflect current HCP status changes to alert personnel to incipient problems (in contrast to a single overall indicator across a long period of time),
c) concern that an inadequate selection of restricted groups for analysis by the evaluator might lead to failure to detect that different subgroups of the HCP population may show lesser degrees of protection from noise than the group selected for analysis,
d) the derivation of the numerical ranges for the criteria,
e) the fact that this results-oriented method does not address failures of omission by the HCP (such as failure to identify and include all noise-exposed individuals in the program) or failures of implementation by the HCP (such as failure to provide annual educational programs).

The Working Group chair did not elect to pursue reversal of the negative votes because the scope of changes desired by negative voters would have fundamentally altered the nature of the document. The ADBA method was developed as a tool for evaluating HCP effectiveness in terms of audiometric data variability from year to year. Other types of methods that reflect cumulative hearing loss over time are briefly described in Annexes A and B, but the intent of this document was to describe only the ADBA method.

Publication of this ASA Technical Report has been approved by the Acoustical Society of America. This document is registered as a Technical Report in a series of publications according to the Procedures for the Registration of ANSI Technical Reports. This document is not an American National Standard and the material contained herein is not normative in nature. Comments on the content of this document should be sent to the following address:

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This ASA Technical Report 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 ASA Technical Report was submitted to Accredited Standards Committee S12, Noise, for final approval, the membership was as follows:

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When preparation of this ASA Technical Report was begun, Larry H. Royster was WG chair.

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Evaluating the Effectiveness of Hearing Conservation Programs through Audiometric Data Base Analysis

0 INTRODUCTION

0.1 Need

Hearing conservation programs (HCPs) have been implemented in occupational, military, and other settings to protect noise-exposed populations from developing occupational hearing loss, which negatively affects individuals' quality of life. For industry in the U.S.A., the Occupational Safety and Health Administration (OSHA) has promulgated regulations defining minimum standards which the employer must follow in implementing an HCP. Similar requirements also exist for the mining industry (regulated by the Mine Safety and Health Administration) and HCPs in the military. However, these regulations currently give no guidance for determining program effectiveness.

Without evaluation procedures based on objective data, it is difficult for the personnel responsible for administering the HCP to determine whether the program is actually preventing occupational noise-induced hearing loss. Several authors [5–13] have discussed the need for systematic procedures to assess whether noise-exposed populations are being adequately protected and to identify any inadequacies in the HCP. The goal of standardizing procedures for audiometric data base analysis (ADBA) is to give objective data concerning HCP effectiveness to management, to the key individual responsible for the entire HCP, and to other personnel involved in implementing the program (safety professionals, industrial hygienists, noise control engineers, audiometric technicians, fitters of hearing protectors, audiologists, medical directors, and departmental supervisors who enforce hearing protector utilization). HCP personnel need information about the program's performance to make decisions about HCP policies, to achieve and maintain adequate employee protection, to justify resource allocations, and to motivate supervisors and employees [11,12]. In addition, a method for using audiometric data to judge HCP effectiveness could be useful to regulatory compliance officers.

0.2 Rationale

Because the purpose of HCPs is to prevent occupational hearing loss, the results of monitoring audiometry for noise-exposed personnel provide the obvious test of whether the HCP has been successful. However, audiogram results cannot alert the audiologist or physician reviewer to incipient hearing loss if the threshold measurements are so variable that beginning hearing shifts cannot be identified. Likewise, unreliable data invalidate attempts to assess long-term population hearing level trends. Even if the noise-exposed population is not developing occupational hearing loss, poor quality audiometric monitoring data render the HCP ineffective because professional audiogram reviewers cannot discriminate spurious threshold shifts from real hearing changes. The employer is penalized by having to deal with follow-up actions for shift rates which are inflated by poor quality data.

This report provides procedures for evaluating HCP effectiveness based on the variability in serial monitoring audiometry for the noise-exposed population. Year-to-year audiometric variability is selected as the basis for the ADBA procedures specified in this report because it provides an immediate indication of data problems. The evaluator is alerted by the high variability to investigate whether it results from inadequate protection from occupational noise, or from poor control of audiometric testing factors. Either way, corrective actions can be taken before many individual employees develop significant threshold shifts.

0.3 Alternative Approaches

Other valid approaches using population audiometric data to judge HCP effectiveness exist, but they are not amenable to standardization because their use requires the evaluator to make case-by-case judgments rather than applying a fixed set of criterion ranges to the results. For the reader's convenience, some of these techniques are summarized in Annex A.

Annual rates of OSHA standard threshold shifts (STSs) are frequently used as a measure of HCP effectiveness, but these rates cannot be interpreted in a meaningful way without knowing relevant characteristics of both the noise-exposed population and the audiometric data. Therefore, OSHA STS rates do not provide an indicator which is amenable to standardization. Further details are provided for the reader in Annex B.

Checklist or audit approaches to evaluating HCPs are also in common use, but these approaches usually merely tally the observed completeness of a program, or its nominal regulatory compliance, without assessing the quality of the program elements that are present. Sample checklists are available which attempt to address qualitative factors [14,15]. However, the usefulness of such audits depends on the expertise of the evaluator in recognizing the difference between cursory lip service to program requirements versus meaningful implementation.

Task-based statistics regarding HCP implementation (such as the percentage of audiograms administered on time, the percentage of retests obtained promptly, the percentage of employees observed to be wearing hearing

protectors, etc.) provide information that is useful to administrators, but these data do not indicate how well employees were actually protected from noise. Likewise, exposure statistics (such as the percent of the workforce in potentially hazardous noise, or reductions in daily noise exposures) are also useful, but they do not address the effectiveness of the HCP in preventing noise-induced hearing damage for those workers who are exposed.

0.4 Brief Historical Review

Summaries of research to analyze industrial hearing data have been published [5,12,13]. The first known use of audiometric data by a regulatory agency occurred in 1971, when the North Carolina OSHA program reserved the option not to issue a noise citation to a company where workers' OSHA time-weighted average noise exposures (TWAs) exceeded 90 dBA if the company had a good safety record, had implemented a complete HCP, *and* would make available the company's audiometric records for analysis [16]. Governmental evaluation of group audiometric data is currently practiced in British Columbia, Canada, where the Worker's Compensation Board of British Columbia receives audiometric results annually from each employer, processes the records, and reports to the employer various statistics concerning the data which allow different employers' HCPs to be compared [17].

0.5 Report Development Process

The S12 Working Group 12 (S12/WG12) was reorganized during the spring of 1984 with a strong emphasis on participation by representatives of industries and organizations that would be the most likely users of any recommendations made by the committee. Working group members were selected for their experience and involvement with HCPs. To create a large data base which S12/WG12 could use for its research, all working group members with access to HCP audiometric data bases were required to make them available for study purposes. It was stipulated that only the chair and the member of S12/WG12 primarily responsible for data analysis would know the sources of the data.

As a result of the requirement for data contribution by working group members and the collection of additional industrial data bases by L.H. Royster, S12/WG12 formulated the largest known industrial audiometric data base available for research purposes in the USA. All procedures suggested by members as potentially useful analysis techniques were tested by applying them to the contributed data bases. The results from these analyses performed on behalf of the working group enabled the members to compare different techniques and develop criterion ranges for selected procedures.

S12/WG12 recommendations were published as Draft ANSI S12.13-1991, which included criterion ranges for three procedures. The research undertaken by S12/WG12 in developing their draft standard is described as Annex C, which includes summary analysis results.

Further experience with the procedures, as well as comments received from other users, led S12/WG12 to eliminate one of the draft standard procedures (standard deviation of differences in hearing threshold levels) from the current report because it proved less sensitive to data quality than the two remaining procedures, which are also simpler to use.

0.6 Benefits of ADBA

0.6.1 Enhancing Prevention of Noise-Induced Hearing Loss In occupational HCPs in the U.S.A. today, audiometry is typically conducted only for the purpose of determining if any employees have developed a standard threshold shift (STS), defined by OSHA's Hearing Conservation Amendment [18] as a change of 10 dB or more in the average of hearing levels at 2, 3, and 4 kHz in either ear from baseline values (usually with optional age corrections applied). In the U.S. military services, audiograms are reviewed to detect both OSHA STSs and another defined shift [19]. Few HCPs review audiograms to detect and follow up on other non-regulated significant hearing shifts in individuals, and very few analyze group data to evaluate program performance except by annual STS rates (see Annex A). Therefore, the potential of the audiometric data base to indicate HCP effectiveness is largely untapped.

Annual audiometry has been criticized in the literature [20–22] based on the high variability of hearing threshold measurements and the resulting difficulty in reliably detecting the small hearing shifts expected in sensitive individuals with typical daily exposures (most OSHA TWAs are less than 90 dBA). However, this criticism of audiometry is invalid if audiometric data are used to detect increased variability from temporary threshold shift in the population before the assumed related permanent hearing loss becomes detectable. In addition, if ADBA is used to identify and correct excess variability related to testing factors, then smaller shifts can be recognized. The concept of detecting high variability in the hearing threshold level measurements before permanent hearing loss develops is fundamental to ADBA.

Consider a worker who is hired and placed in the company's HCP, as shown in Figure 1. He or she may or may not be provided hearing protection devices based on the daily time-weighted average noise exposure. If the worker must develop an OSHA STS or another significant shift before we get an indication of possible HCP ineffectiveness, then it is difficult to justify the cost of audiometry which merely documents the occurrence of hearing loss. However, if ADBA procedures are used to detect and correct HCP problems early in the worker's noise exposure history, then audiometry becomes a powerful tool in preventing significant noise-induced hearing loss.

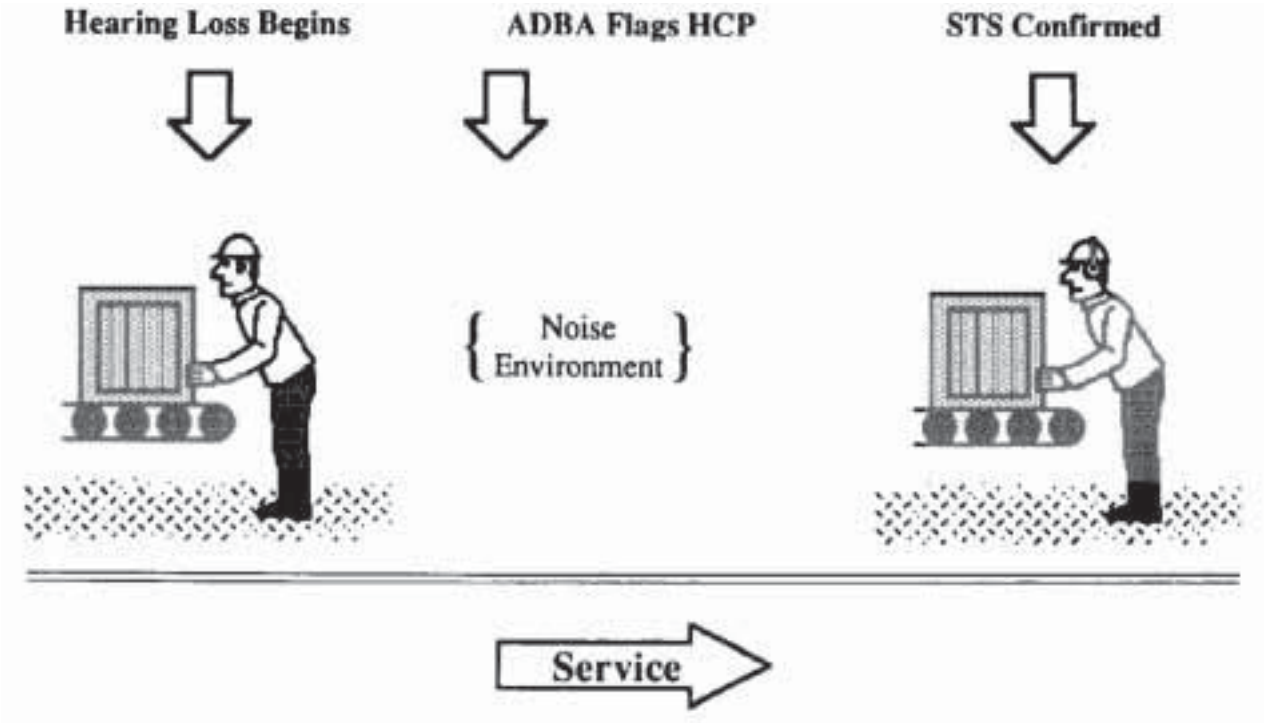

Figure 1. Sequence of events in a worker's noise exposure history showing how ADBA indicates an inadequate degree of employee protection before a confirmed OSHA STS develops.

0.6.2 Providing Cost-Effective Data for Regulatory Compliance Current federal OSHA enforcement policies may exempt an employer from implementing engineering noise controls if employees' OSHA TWA noise exposures are less than 100 dBA and an effective HCP has been established; however, there is no accepted method of making a judgment concerning program effectiveness. ADBA results could help in this decision. In the future, if OSHA implemented a method of obtaining audiometric data from employers, then compliance inspectors could use their limited time more efficiently by selectively visiting plant sites where ADBA results suggested the existence of problems in the HCP. Acceptable ADBA results for a plant could be interpreted as an overall performance indicator of an adequate program.

0.6.3 Guiding Internal Management Decisions The application of ADBA procedures provides a cost-effective method of HCP evaluation for management. If managers can determine that the HCP is ineffective, they have the opportunity to correct any problems and thereby avoid potential OSHA citations. More importantly, managers will be warned of HCP problems before many employees develop significant hearing changes which may reduce their productivity and eventually could develop into workers' compensation claims.

ADBA results not only can identify an ineffective HCP, but they also can point to the potential cause(s) of the problem. With this information, managers can make changes to prevent hearing loss. If unsatisfactory ADBA findings are similar across plant sites or departments, the existence of a shared problem or problems can be inferred. Examples include failure to enforce the use of hearing protection devices, to provide the worker with adequate instructions for fitting and wearing the hearing protection devices correctly, to allow sufficient time to obtain valid hearing threshold level measurements, or to use audiometric results to motivate employees.

In contrast, ADBA findings may show different patterns of results for population subgroups, suggesting specific problems. Examples include the relative adequacy of different hearing protection devices for the noise environment [23], differences in training for hearing protector utilization, differences in enforcement of hearing protector use, errors in audiometer calibration, or changes in audiometric methods resulting in abnormally high variability in hearing threshold level measurements.

If high variability is found to be related to testing factors rather than to noise exposure, management can take steps to improve in-house audiometry or to change mobile test service providers in order to obtain more reliable data.

In effective HCPs the total potential legal and social risk resulting from noise-induced hearing loss at the production facility would be expected to decrease over time in comparison to the risk which would have occurred for an ineffective program. The yearly ADBA results will provide objective data to show management the benefits of an effective HCP in reducing potential liability for workers' compensation by stopping the progression of occupational hearing loss.

With respect to workers' compensation claims, too often the records of companies with ineffective HCPs simply document the progression of significant hearing loss over time. If management uses ADBA procedures to guide improvement of the HCP, then records could document the overall effectiveness of the program as well as the preventive actions taken for individuals. ADBA results could provide management with information to support the quality of the company's efforts in contested compensation claims for occupational hearing loss.

0.6.4 Motivating Workers and Supervisors Some workers are more motivated by concrete data than they are by persuasive communications from management or other HCP personnel. Posting simplified summaries from yearly applications of ADBA procedures across different plant sites and/or production areas may enhance workers' interest in the HCP. If management takes the next step and uses the findings in evaluating supervisors of production areas during periodic performance appraisals, then a strong incentive is created to achieve consistent, correct use of hearing protection devices.

1 SCOPE, PURPOSE AND APPLICATIONS

1.1 Scope

This report specifies procedures for systematically assessing the effectiveness of hearing conservation programs (HCPs) in preventing noise-induced hearing loss based on the variability of regular monitoring audiometry results for noise-exposed personnel. Test-to-test variability in hearing thresholds measured in successive audiograms is used as the basis of two statistical indicators. Criterion ranges are given for the results of these indicators as applied to populations of noise-exposed personnel followed over time.

The application of the procedures specified in this report is one facet of audiometric data base analysis (ADBA), which also includes related techniques described in Annex A.

1.2 Purpose

The goal of ADBA—to evaluate the degree of protection for populations in hearing conservation programs—is complementary to the purpose of detecting hearing changes in individual noise-exposed employees. In audiogram review the records for a person are examined to detect significant cumulative hearing change from the initial or baseline audiogram and to trigger any follow-up actions needed to increase the degree of protection for that particular person. In contrast, ADBA is a separate process of evaluating group audiometric data to monitor the degree of protection provided to the noise-exposed population as a whole, or in selected subgroups such as departments or noise exposure groups. If ADBA results show undesirable trends, the follow-up action involves changes in overall HCP policies or procedures rather than changes in the treatment of individual employees [10–12].

The purpose of this report is to define objective procedures for evaluating HCP effectiveness in preventing occupational noise-induced hearing loss in a noise-exposed population through ADBA procedures which evaluate the variability of the serial audiometric data for the noise-exposed population as a whole or for selected subgroups.

The intended users of these procedures include industrial or military personnel directly responsible for HCPs, as well as related professionals providing consulting services in support of HCPs, and public health or regulatory agency personnel interested in evaluating HCP effectiveness. These personnel can use information about HCP effectiveness to reinforce good HCP implementation, or to identify deficiencies and justify program improvements, thereby increasing the degree of protection for the noise-exposed population before many individuals show significant hearing changes.

1.3 Applications

The fundamental assumptions underlying the ADBA approach to evaluating HCP effectiveness are described below. In addition, certain requirements are described that the audiometric data must meet before the approach can validly be applied.

1.3.1 Assumptions

1.3.1.1 Effective Hearing Conservation Program An effective HCP provides the noise-exposed population with adequate protection from on-the-job noise exposures so that changes in their hearing threshold levels over time are not different from those found in a properly matched control population which exhibits all of the relevant characteristics of the occupational noise-exposed population except on-the-job noise exposure. Characteristics which should be accounted for in a matched control population include age, sex, race, the incidence of ear disease, and non-occupational noise exposure.

1.3.1.2 Audiometric Variability as an Indicator The year-to-year variability in the population's hearing threshold levels as measured during approximately annual HCP audiometric evaluations is a valid indicator of the effectiveness of the HCP. For a population of noise-exposed workers who are properly protected from on-the-job noise, the year-to-year variability in their hearing threshold levels will be no larger than that for a similar population without significant occupational noise exposure. It is implied that the only way to achieve a satisfactorily low level of variability in the data base is to establish an effective HCP that prevents both temporary threshold shift and permanent occupational hearing loss [10].

The recommended ADBA procedures are based on the variability of hearing threshold level measurements between sequential pairs of audiograms, not comparison