inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 6.0

NOISE AND HEARING PROTECTORS - NEW DEVELOPMENTS

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Keywords:
HEARING PROTECTORS, COMMUNICATION, SAFE DESIGN, TESTING

ABSTRACT
Hearing protectors are designed to protect the user's hearing. But new developed hearing protectors show integrated sound restoration equipment: Ear-muffs with integrated broadcast receivers, level-dependent ear-muffs, ear-muffs with active noise reduction, ear-muffs with integrated radio communication devices, and ear-muffs to be connected to mobile phones are developed by the manufacturers. This sound restoration equipment as an additional sound source is often forgotten when hazards at the work place are analysed. For testing against the European directive 89/686/EEC [1] procedures have been established for level dependent ear-muffs, ear-muffs with integrated broadcast receivers and ear-muffs with active noise reduction. New methods are developed and proved in Europe for testing of all the other ear-muffs with integrated sound restoration equipment.

1 - INTRODUCTION

For assessing the personal noise exposure when headphones or ear-muffs with sound restoration equipment are worn two portions of the total noise exposure of the wearer's hearing have to be considered: The remaining portion of the ambient noise under the head phone or ear-muff and the portion of the additional sound restoration source inside the cup. The ambient noise is determined by well known procedures. Using the attenuation data of the ear-muff the rest level of the ambient sound effective to the wearer's hearing can be determined. The level of the sound which is restored inside the cup by the integrated loudspeakers has to be determined free or diffuse field related. For this purpose new procedures have been developed (s. ISO/DIS 11904-1 [2]).
For ear-muffs with sound restoration equipment which show multiple functional modes the testing conditions have to consider several portions of sound which contribute to the total sound exposure of the user. Ear muffs with integrated broadcast receivers and level-dependent transmission path shall be tested in both functions simultaneously. Using ear muffs with two-way communication devices not only the speech sound is transmitted but also the environmental sound. The testing of such an ear-muff requires the use of an artificial head with a mouth simulator and an environmental sound field similar to the sound field found at workplaces.
Solutions for the design, testing, and safe use of such hearing protectors have to be found in order to fulfil health and safety requirements.

2 - PERFORMANCE OF EAR MUFFS

Ear muffs are available in a couple of different function modes.
The conventional ear muff consist of a cup, a cushion and a head band. It shows a passive sound attenuation for ambient noise.
Level-dependent ear muffs are conventional ear muffs with built-in loudspeakers and microphones on the outside of the cups. The ambient sound is transmitted level-dependent by an electric-acoustic transmission path to the loudspeaker inside the cup. The volume under the cup is adjusted by a control. The sound level, under the cup generated by the loud speaker is limited within the electric-acoustic transmission path.

Ear muffs with built-in broadcast receivers have a receiver and a built-in loudspeaker for reproduction of the station received. They consist of antenna, volume control and device for tuning.
Radio ear muffs are conventional ear muffs with built-in wireless communication devices. They have an antenna, a built-in loudspeaker, a volume control and a device for selection of the radio canal. One way systems have only loudspeakers; two way systems have a microphone in addition.
Ear muffs with an audio input are conventional ear muffs with built-in loudspeaker and a connecting cable to feed in audio signals. That means additional to hifi-headphones at home they have a sound attenuation required for the ambient sound at the workplace.
Ear muffs with audio connection are conventional ear muffs with built-in loudspeaker, a built-in microphone, a volume control and an audio input and output. They can be connected for example with a mobile phone.
Ear muffs with active noise reduction (ANR) are equipped with built-in loudspeaker and an ANR-system. This system generates sound waves under the cups with opposite phase relative to the sound detected by microphones under the cups. This results in a more or less cancellation of the initial sound.

3 - APPLICATION OF SPECIAL HEARING PROTECTORS

In the following the areas of application of special − non conventional − hearing protectors are described:

- Level dependent ear muffs are used when the sound exposure often varies and when good speech recognition is required.
- Ear muffs with built-in broadcast receiver are suitable at workplaces in noise areas where monotonous tasks are carried out and serve for the motivation of the co-workers. These ear muffs are not suitable at workplaces where good speech or signal recognition is required.
- Hearing protectors with active noise reduction are suitable at workplaces, where low frequency sound with high sound pressure levels dominates.
- Hearing protectors with built-in communication devices serve for the speech communication in noise areas.

4 - HEALTH AND SAFETY ASPECTS

Aspects dealing with health and safety requirements for conventional ear muffs such as

- Materials must not affect user hygiene or health,
- Satisfactory surface conditions of all PPE parts in contact with the user's skin,
- Adjustability of the cup and cup rotation,
- Headband force and cushion pressure,
- Resistance to damage when dropped,
- Change in headband force after conditioning,
- Comparison of the sound attenuation of conditioned and non-conditioned specimen,
- Ignitability,
- Minimum sound attenuation

are well described in the standards ISO/DIS 10449.2 [3] and EN 352-1 [4].
By conventional ear muffs the sound acting at the outside of the muff is attenuated by the cup when passing it. The remaining component of the sound reaches the hearing. This component is not allowed to exceed the limit value.
All these aspects also apply to ear muffs equipped with sound restoration devices. But the acoustic situation is not tested by the determination of the sound attenuation alone.
For assessment of the risk of hearing impairment by the use of level-dependent ear muffs that sound component generated by the loudspeaker reproducing sound inside the cup has to be considered additionally beside the component transmitted trough the cup.
Also for communication ear-muffs an additional sound component − besides the remaining rest component of the ambient sound − generated by the loudspeaker inside the cup is produced. But here the level

of the reproduced sound is in general not affected by the ambient sound but by the level of the signals feed in and the transfer characteristic of sound restoration equipment.

5 - EXAMPLE FOR A NOISY WORKPLACE WITH USE OF COMMUNICATION DEVICE

As an example for the total noise exposure when communication devices are worn in noise areas the results of measurements carried out by BIA at a helicopter pilot workplace are shown: The sound level of the ambient noise for the pilot in the cockpit of a helicopter was 96 dB(A). The pilot's communication headset had an attenuation of 15 dB(A) for the cockpit sound. That resulted in a remaining component of the cockpit sound under the headset of 81 dB(A). For the second sound component, which was generated by the communication, 86 dB(A) was determined. The total sound exposure of the pilot was 87 dB(A). By this simple example it can be shown, that for the assessment of the risk of hearing impairment always the total sound exposure has to be determined: The sound attenuation of the headset was sufficient for the cockpit noise and the remaining sound component did not exceed the limit value of 85 dB(A). But actually the pilot is exposed to 87 dB(A) and the limit value is exceeded.

6 - ACOUSTIC MEASUREMENT METHODES

For the determination of the sound exposure by ambient noise at workplaces procedures are well known (s. ISO/DIS 9612.2 [5]). The measurement of the sound attenuation of (passive attenuating) hearing protectors is described in ISO 4869-1 [6]. Calculation of the rest levels under that protectors may be carried out according to ISO 4869-2 [7].
For the measurement of the sound generated by loudspeakers inside a cup of a hearing protector or for the measurement of the total sound exposure at the ears by ambient noise and restored sound inside a communication hearing protector several procedures are developed. For such measurements ISO/DIS 11904-1 [2] is most suitable. For the assessment of the risk of hearing impairment ISO/TR 4869-4 [8] cannot be used. The European experts found in the CEN Technical Committee "Hearing Protection" and all the European testing bodies authorised for testing and certification of hearing protection against directive 89/686/EEC [1] decided to use ISO/DIS11904-1 [2] instead of ISO/TR 4869-4 [8] for several reasons:

- The issue of ISO/TR 4869-4 [8] as a type 2 technical report based on the ATF (artificial test fixture, ISO 4869-3 [9]) or an unspecified HATS (head and torso simulator),
- The observed variable underestimation of sound level effective to the ear of the wearer of a sound restoration circumaural ear muff when measured using the ATF,
- The lack of specification of a suitable head simulator in ISO/TR 4869-4,
- The need for standardisation and regulation in Europe for this type of hearing protector.

For comparison of the results obtained with the two procedures described in ISO/DIS11904-1 [2] and ISO/TR 4869-4 [8] two sets of measurements have been carried out at BIA: One set with sixteen subjects and four specimen of one type of level-dependent ear muff using MIRE-technique as described in prEN 352-4 [10] and one set using ATF according to ISO/TR 4869-4 [8], attenuation data obtained with ISO 4869-1 [6], and the four specimen. The sound field used fulfilled the requirements of the L-noise described in prEN 352-4 [10]. The criterion level is the external level for which the first time the internal free field equivalent level exceeds 85 dB(A). Within the first set of measurements the criterion level was found to be 105 dB(A). In the second set it resulted in 110 dB(A). As the MIRE-technique is regarded by experts to be the reference method the procedure proposed by ISO/TR 4869-4 [8] resulted in an overestimation of the protection level of about 5 dB. That means using ATF data for the assessment of risk of hearing impairment may result in a considerable underestimation of the risk.

7 - RECOMMENDATIONS FOR SAFE DESIGN

All hearing protectors have to fulfil the same requirements as conventional hearing protectors do. That means relative to their passive sound attenuation they have to perform at least the minimum attenuation (given for example in EN 352-1 [4]) required, when additional sound sources inside the hearing protector are switched off. For communication ear muffs an agreement was found by the experts working in the CEN TC "Hearing Protection" and the group of experts representing all European notified bodies for testing hearing protectors: Communication hearing protectors for entertainment purposes, such as ear muffs with built-in broadcast receivers, must have a sound level limiter to keep the total noise exposure below

85 dB(A) in case the passive attenuation is sufficient for the noise at the workplace. If a communication hearing protector is not used for entertainment it should have also a limiter in normal case. The safe operation of the limiter has to be tested by an independent testing body (in Europe: notified body).
Within exceptional cases, where non-perception or misunderstanding of communication at noisy workplaces results in a significant risk of accidents, the sound level limiter is allowed to limit at levels above 85 dB(A) total noise exposure. Such an exceptional case are the headsets of helicopter pilots and the headsets of crew members of sea rescue services. Together with the information on the maximum allowed operation time at maximum volume per work shift a risk of hearing impairment can be excluded in these exceptional cases. If the manufacturer does not produce communication hearing protectors with sound level limiters, he has to obtain the safe use of his products by other measures to avoid the risk of hearing impairment.

8 - TESTING PROCEDURES

In 1993 for level-dependent ear muffs a proved testing procedure was described in prEN 352-4 [10]. These ear-muffs can be used at workplaces at levels below their criterion level.
Since 1994 a testing procedure using the MIRE-technique for ear muffs with built-in broadcast receivers is used in Europe. The mean value plus one standard deviation of sound levels at maximum volume are not allowed to exceed 82 dB(A) determined using sixteen test subjects. The use of these products does not give rise to any risk of hearing impairment when selected regarding a sufficient passive attenuation relative to the noise at the workplace.
In Europe for ear muffs with ANR a testing procedure using also the MIRE-technique is in use since several years. 1999 the first draft standard was produced by CEN Technical Committee "Hearing Protection".
For all the other communication ear muffs MIRE-technique should be used. For the ear muffs with multiple function modes − for example level-dependent ear muffs with built-in broadcast receiver and the equipment for connecting a mobile phone − the working group of the European notified bodies for hearing protection proposed the following procedure: Switch on all function modes at maximum volume, apply a standardised external sound field as for example described in prEN 352-4 [10], and use standardised sound fields generated by standardised mouth simulators. The products we tested up to now show facilities giving priority to special function modes − for example to the communication − while limiting effectively the sound pressure level generated inside the cup by all the function modes operating simultaneously.

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