

OBJECTIVE TESTS AND THE ASSESSMENT OF THE ACOUSTIC PROPERTIES OF EAR-PLUGS

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Ear-plug-type hearing protectors are commonly used in a noisy working environment. In a certification process of ear-plugs only sound attenuation is tested subjectively. There is no requirement of maximum variability in ear-plug insertion loss measured objectively like the requirement of maximum variability in ear-muff insertion loss. The aim of this paper is to present the methodology and the results of insertion loss measurements for ear-plugs. The measurements were carried out in the laboratory test site meeting EN 24869-3 requirements, for test signals consisting of pink noise filtered through one-third octave bands with centre frequencies of 63–8000 Hz, with a newly designed acoustic test fixture. Twenty popular models of ear-plugs (made of foam and cotton wool), with twenty samples of each model, were tested according to the worked out procedure. The mean values of insertion loss and standard deviations for each frequency band of tested ear-plugs are presented.

Key words: hearing protectors, ear-plugs, insertion loss.

1. Introduction

If the risk arising from exposure to noise in the working environment cannot be prevented with other technical means, workers should use hearing protectors. Hearing protectors should be chosen according to their attenuation, and they should be suitable for the level and spectrum of noise to which the worker is exposed. The most suitable hearing protectors ensure that the A-weighted sound pressure level of noise at the wearer's eardrum is between 5 and 10 dB lower than the action noise level [5]. The calculations of A-weighted sound pressure level under the hearing protectors are based on the sound attenuation of hearing protectors tested in a notified laboratory during a certification process. Sound attenuation is tested subjectively on sixteen listeners [6].

In a certification process of ear-muffs their acoustic properties are also tested objectively. The insertion loss of ten samples of ear-muffs is measured for the purpose of quality inspection [7]. The requirement is a minimum standard deviation of the insertion

loss which should not be greater than 4.0 dB in four or more adjacent one-third octave bands, and not greater than 7.0 dB in any individual one-third octave band [8].

In the case of ear-plugs their acoustic properties are not tested objectively during the certification process. There is no requirement of testing them for the purposes of quality inspection [9]. The aim of the project carried out in the Central Institute for Labour Protection – National Research Institute (CIOP-PIB) [1] was to investigate objectively the spread of the acoustic performance of ear-plugs – for samples of the same model – granted the certification mark. The insertion loss of the most popular models of ear-plugs made of foam and cotton was tested.

2. Methodology

Insertion loss of an ear-plug is defined as the mean algebraic difference in decibels between the sound pressure level, measured with a microphone of the acoustic test fixture, in a specific sound field under specific conditions, without and with the ear-plug placed on the test fixture.

The measurements were carried out with the methodology of insertion loss measurements for ear-muffs, according to EN 24869-3 [7]. The test sound field consisted of random incidence waves. The test signal consisted of a pink noise filtered one-third octave band. The new test fixture for the purpose of this project was worked out.

The measurements of insertion loss were carried out for nineteen models of ear-plugs made of foam and one model of ear-plugs made of cotton. Twenty brand new samples of each ear-plug model were tested.

3. Acoustic test fixture

The acoustic test fixture worked out for insertion loss measurements of ear-plugs is presented in Fig. 1. It was made of a non-magnetic metal. The acoustic coupler that simulated the ear-canal was worked out on the basis of an analysis of different known



Fig. 1. The acoustic test fixture worked out for insertion loss measurements of ear-plugs [2].

solutions [3, 4]. The nominal diameter of the measurement microphone was 1/2 inch. To equalize the statistic pressure under the ear-plug a fixed capillary tube connecting the cavity under the ear-plug to external air was used. The acoustic isolation of the test fixture complied the requirements of EN 24869-3 [7].

4. Relaxation time of foam ear-plugs

Relaxation time of foam ear-plugs is defined as a maximum time measured with a 1-minute step from the placement of the ear-plug at the acoustic test fixture to the moment when the measured one-third frequency band sound pressure level is lower than the previous measured value by at least 1 dB.

Relaxation time was tested for nineteen popular models of foam ear-plugs, with ten samples of each model. Table 1 presents the mean time of all tested ear-plugs.

Table 1. Relaxation time of the tested ear-plugs.

Relaxation time	1 min	2 min	3 min	4 min	5 min	6 min
Ear-plugs	EAR EXPRESS, EAR PUSHINS, HOWARD LEIGHT MATRIX	3M 1120, Eco Damp, HOWARD LEIGHT MAX, HOWARD LEIGHT MULTIMAX, KOYOTE K310, MOLDEX Pura-Fit 7700, MOLDEX Spark Plugs 7800		3M 1110, Bilsom 303L	EAR soft FX, EAR soft YELLOW NEONS, EAR SuperFit 36, HOWARD LEIGHT MAX Lite	EAR Classic, EAR Classic Corded, EAR Classic soft
Σ	3	7	0	2	4	3

The data presented in Table 1 show that relaxation time is different for various models of ear-plugs. One-minute relaxation time was observed for 3 models, 2-minute for 7 models, 4-minute for 2 models, 5-minute for 4 models and 6-minute relaxation time for 3 models. To standardize the procedure of insertion loss measurements 6 minutes was established as relaxation time.

5. Measurement results

The mean insertion loss and standard deviation of each tested ear-plug model is presented in graphic form in Figs. 2 and 3.

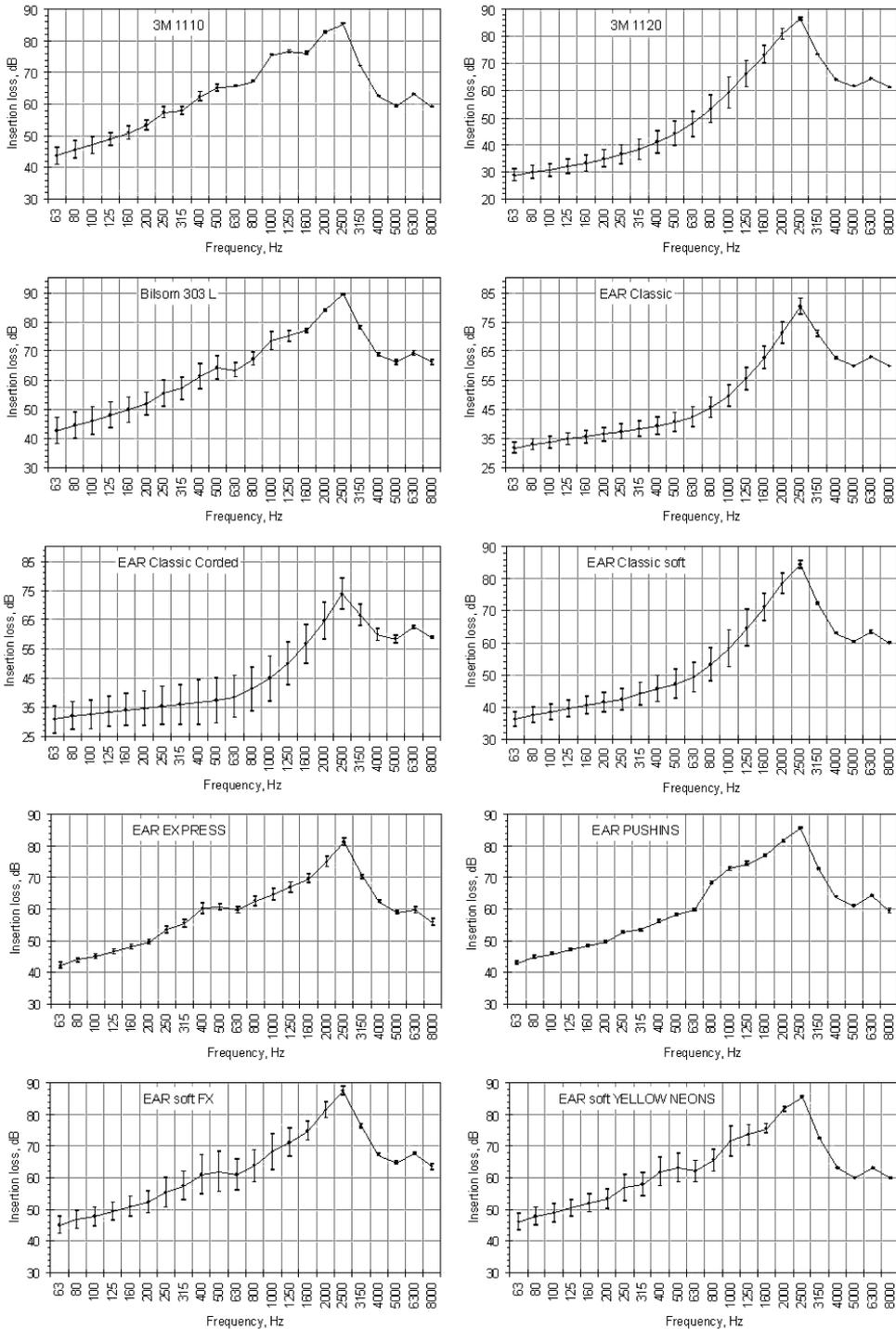


Fig. 2. Insertion loss and standard deviation of tested ear-plugs.

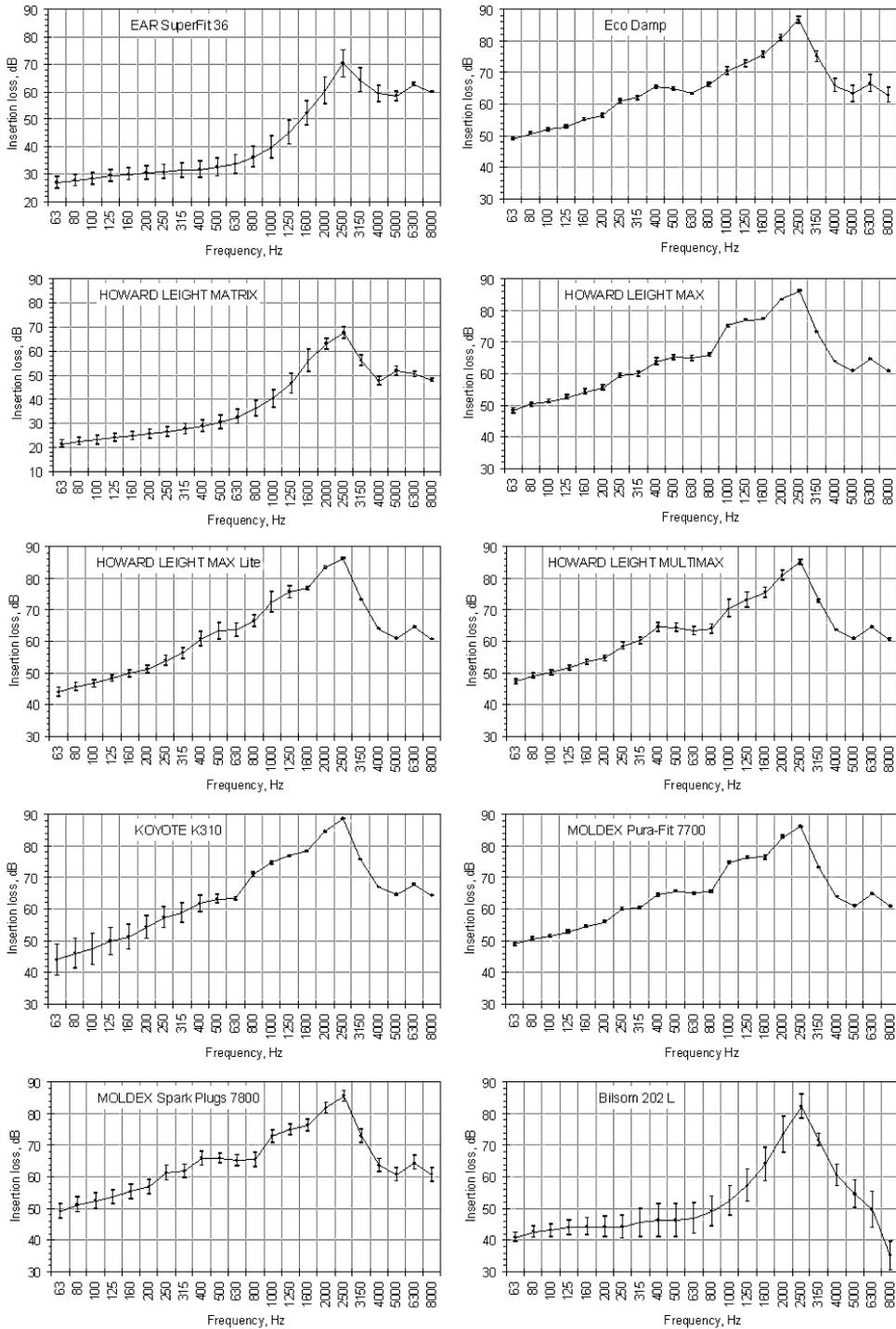


Fig. 3. Insertion loss and standard deviation of tested ear-plugs.

The data presented in Figs. 2 and 3 show the great spread of standard deviation of the measured values of insertion loss for various ear-plug models. For three models – Ear Pushins, Howard Leight Matrix and Moldex Pura-Fit 7700 – standard deviation was lower than 1.0 dB for each one-third octave band. For seven models – 3M 1110, 3M 1120, Bilsom 303L, Ear Clasic Soft, Ear Soft FX, Ear Superfit 36 and Keyote K310 – standard deviation was greater than 4.0 dB in four or more adjacent one-third octave bands. For one tested model – Ear Classic Corded – standard deviation was greater than 4.0 dB in eleven adjacent one-third octave bands, and greater than 7.0 dB in six adjacent one-third octave band.

6. Conclusions

The presented method of insertion loss measurements for ear-plugs based on the method of insertion loss measurements for ear-muffs according to EN 24869-3 is useful for an objective assessment of the acoustic properties of ear-plugs. The method can be used to investigate production spreads of the performance of ear-plugs and to investigate the change in the performance of ear-plugs with age or usage.

The results of investigations of twenty popular models of ear-plugs made of foam and cotton show that for eight of them the criterion used for the purposes of quality inspection during a certification process of ear-muffs is not met.

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