EVALUATION AND IMPROVEMENT OF THE ACOUSTICAL PERFORMANCE OF VENTED EARPLUGS

Mark Cheng[1], Murray Hodgson[1] and Orval Baskerville[2]

[1]Occupational Hygiene Program and Department of Mechanical Engineering, University of British Columbia, 3rd Floor, 2206 East Mall, Vancouver, BC V6T 1Z3

[2]Canadian Custom Protect Ear Inc., 681 - 7789 134th Street, Surrey, BC V3W 9E9

Introduction

Ear plugs are a common type of hearing protector. Those studied here were of the custom-moulded type, and were made of silicon rubber. They were either solid or were 'vented' to allow the equalization of air pressure and to reduce the attenuation of speech frequencies to allow speech to be understood. The vent consists of a small-diameter 'core' tube into which is inserted a 'filter' which further reduces the vent diameter in one or more steps. The noise-attenuation performance (insertion loss - the difference in the sound-pressure levels measured at the eardrum without and with the earplug) of earplugs is usually determined using 'subjective' REAT tests, involving human subjects, according to ANSI S3.19-1974. This paper discusses research conducted to:

- evaluate objective methods for measuring earplug performance using a dummy head;

- to model vented earplugs and improve their performance by redesigning the filter. More specifically, it was hoped to increase the insertion loss at 1000 Hz by about 2 dB.

Objective Test Method

'Objective' measurements of earplug insertion loss were made using a KUNOV dummy head with compliant ears in three environments and the results compared to existing REAT data. The environments were created by headphone presentation in an audiometric booth, and by loudspeaker presentation in a semi-diffuse sound field (conforming to ANSI S12.6-1984) and in an anechoic chamber for various angle of incidence. Fig. 1 shows some results for a vented plug. Loudspeaker presentation in the semi-diffuse field gave the best agreement with REAT results.

Vented Earplug Model

A theoretical model for predicting the insertion loss of vented earplugs inserted in an ear was developed based on theory proposed by Iberall [1] and Egolf [2, 3]. The model assumes that sound energy reached the eardrum due to transmission through the vent only. The vent, filter and earcanal were modelled as a series of rigid, cylindrical tubes terminated by an average human eardrum impedance.

Fig. 2 shows a comparison between the predicted 125-8000 Hz insertion losses of an earplug vent, and those of a vented plug as measured subjectively and objectively. At all but the lowest and highest frequencies the predicted vent insertion losses are 10 dB higher that those measured. This suggests strongly that the sound energy transmitted through the vent is significantly lower than that transmitted through the solid plug material. The obvious conclusion is that redesigning the filter in the vent will have negligible effect on earplug performance at these middle frequencies.

Earplug Redesign

The insertion losses of solid plugs with different densities of solid material were measured. Density did not substantially and consistently affect sound transmission through the solid material.

Despite coming to the conclusion that the performance of the vented earplugs studied here could not be improved by filter redesign, the prediction model was used to investigate how changes in filter dimensions would affect earplug insertion loss in the absence of significant sound transmission through the solid plug material. The prediction results demonstrated that changing the filter dimensions affects performance over a wide range of frequencies; dimensional changes do not allow performance to be tuned at individual frequencies.

References

[1] A. S. Iberall, "Attenuation of oscillatory pressures in instrument lines", *J. Res. Natl. Bur. Stand.* **45**, 85-108 (1950).

[2] Egolf et al, "Mathematical modelling of a probe-tube microphone", *J. Acoust. Soc. Am.* **61**, 200-205 (1977).

[3] Egolf et al, "Mathematical prediction of electroacoustic frequency response of in situ hearing aids", *J. Acoust. Soc. Am.* **63**(1), 264-271 (1978).

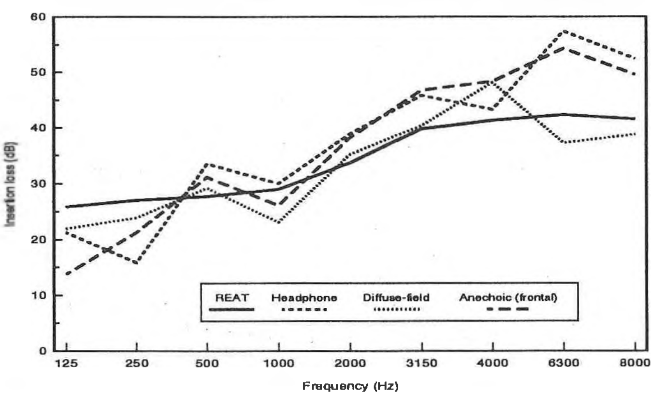

Fig. 1. Insertion loss of a vented earplug as measured 'subjectively' by REAT, and 'objectively' using a dummy head and either headphone, ANSI diffuse-field or anechoic, frontal-incidence signal presentation.

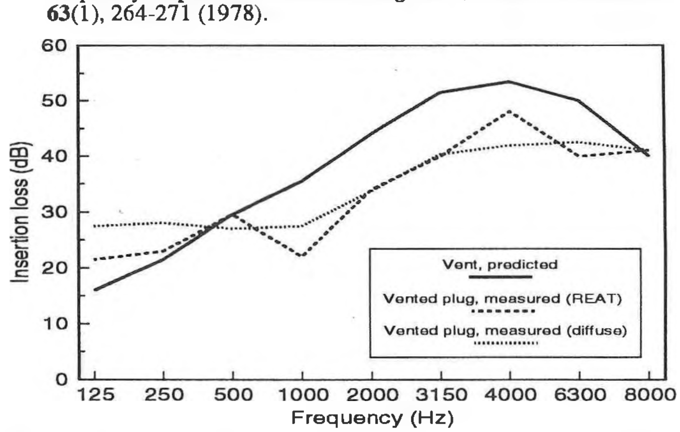

Fig. 2. Predicted insertion loss of an earplug vent, and that of a solid earplug as measured objectively.