
A Comparison Study of Foam versus Custom Silicone Earplugs Used as Part of an Intelligent Electronic Hearing Protector System

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During the development of an intelligent hearing protection and communication system the attenuation of two different earplugs were measured. Both earplugs were measured separately and in combination with earmuffs. Foam earplugs and custom-moulded silicone earplugs were both used. The hearing protection system in question is able to measure the ear canal with respect to leaks. If a leak is detected, the system will warn the user.

The measurements show that the foam plug gives higher attenuation than the silicone plug at all frequencies, but particularly at frequencies below 2 kHz. It has a steadily increasing attenuation from 30 dB – 43 dB over the frequency range 125 Hz – 8 kHz. The silicone plug attenuates around 26 dB, from 125 Hz – 1 kHz. Above this range, the attenuation increases to approximately 40 dB. With extra earmuffs added, the attenuation is 40 dB or better at all frequencies except 125 Hz, and the two plugs offer nearly identical protection.

The results show that the mean and standard deviation of the attenuation for the foam earplug is as good as for an optimally fitted earplug. In the case of the silicone earplug, the mean attenuation is comparable to a typical custom earplug, but the standard deviation is better than comparable earplug. This finding is a result of the leakage control acting as a 'supervisor' in the fitting of the earplugs.

1. INTRODUCTION

During the development of the hearing protector system now called QuietPro® (produced by Nacre),¹ SINTEF investigated its attenuation. The system is generally delivered with a foam earplug to be inserted deep into the ear canal. It is also possible to produce custom moulded silicone earplugs that can be used instead of the foam earplugs. The custom-moulded alternative was sometimes asked for by users. Custom-moulded earplugs are believed to improve user comfort. The protection level can vary, however, depending on the details of the design. The attenuation of the specific design of the custom-moulded silicone earplugs should therefore be investigated. In addition to the attenuation based on the specific design, the attenuation of the earplugs when worn in combination with an earmuff was also measured. Therefore, this study contains results from 4 states of protection: a foam earplug, a custom-moulded silicone earplug, and the same two types of earplugs when used in combination with an earmuff.

2. THE TEST CONDITIONS

The American standard of 1997 for measuring a hearing protector device (HPD) defines two types of measurements: "Method A: Experimenter-supervised fit" and "Method B: Subject fit."² These methods were the available standards at the time of the measurements. This standard was revised in 2008. The ISO standards have similar methods defined in ISO4869-1 and ISO4869-5, respectively.^{3,4} In these experimental definitions, the main difference is the interaction between the experimenter and the test subject. In the Method A experiment, the supervisor is allowed to train the subject as much as is required, and the supervisor may also inspect the insertion of the HPD. In the Method B experiment, the subject will not be instructed on how to use the hearing protectors, and the exper-

imenter is restricted to minimal interference with the subjects. It is believed that Method B gives a more realistic estimate of real world performance of a HPD.

Our test did not follow either of the two methods. We imitated Nacre's introductory course of the system to their customers in order to be as realistic as possible. This course is a short presentation of the system and its functionality, followed by some practical training guided by a supervisor. One unique feature with the system is that it employs a leakage test that is automatically performed at system power up. If the earplug is badly fitted and/or has a leak, the system will warn the user with a sound. The user is then expected to refit his or her earplug and power up again. The purpose is to ensure that the plugs are worn correctly and that the user is well protected. In this way the user is trained by the system and will learn how the device is to be inserted to get good protection. The leakage control was used throughout the experiment.

As a result, the test used in this experiment is something in between Method A and Method B. In addition the leakage control was used to warn the user of bad fittings.

2.1. The earplugs

The two earplugs are shown in Figure 1 and Figure 2. The earplugs are connected to a transducer housing at the outer end. There is a stem containing channels through the earplug. The channels connect the transducers acoustically to the ear canal. The transducers are used by the hearing protection system for sound throughput, communication, and other functions during normal operation, but they remain passive during the attenuation measurements. The foam earplugs were available in three sizes, approximately 12 mm - 14 mm in diameter.

The silicone plug is a custom-moulded earplug. In the design maximum obtainable attenuation was the main criteria. This was done by making the impressions and moulds as deep