# Validation of AHAAH

Part of the "validation" of the model is in the form of transfer functions, i.e., does the model correctly reproduce the conductive path from the free field to the eardrum, the stapes, and to displacements within the cochlea. Data exist for the human ear for the first two locations (the eardrum and stapes); but while the general form of the response of the cochlea is known for the mammalian ear, there are, understandably, no human data on the response of the inner ear. The transfer functions can be plotted by "pointing and clicking" within the model.

The model's values have been adjusted to create a proper conductive path, with the correct impedance for the human ear. The stapes displacement-to-basilar membrane displacement ratio in the mid-range of frequencies had been set to the same value as for the cat. The same equation of loss (relating auditory hazard units [AHUs] to threshold shift) was used for the human cochlea as for the cat cochlea. Up to this point, no human hearing loss data had been used in setting any values in the model.

Human data - protected hearing. As part of meeting the need for an improved damage risk criterion (DRC) for noise, the Army Medical R&D Command had conducted an extensive series of studies with human volunteers, under a contract with EG&G, known as "The Albuquerque Studies". In this work, groups of 60 subjects were exposed to impulses intended to simulate weapon impulses in the open and in one case, in a reverberant environment. On the test ear, they wore an ear muff (in one series of exposures) or an ear muff that had eight holes in its seal. Peak pressures in the free field went from the upper 170 dBs to about 195 dB. In all, 53 conditions were tested. This data set is the largest and most completely documented in existence for such exposures, especially since it included waveforms measured in the free field and under the muff(s).

The goal of the Army's program was to establish a DRC that will avoid threshold shifts 25 dB or greater (measured just after the exposure) in response to intense impulses in 95% of the exposed population. The presumption is that threshold shifts of 25 dB or less should result in minimal permanent threshold shift. Therefore, the model was set to predict threshold shift for the 95 percentile subject and the

Albuquerque waveforms were run through the model. In all but three cases, its output and the data agreed on the 95 percentile outcome. In the three cases in which there was a disagreement, the model over-predicted the hazard (was conservative, loss for 50 and 100 impulses in the fully protected 5 m condition, and three impulses in the reverberant condition). In contrast, MIL-STD-1474, the current DRC, predicted correctly in 20 instances and over-predicted hazard in the remaining 33 instances. A

prediction based on A-weighted energy predicted correctly in 13 instances and over-predicted hazard in the remaining 40 instances.

Human data - unprotected hearing. There are several reasons why there are few usable data from recent studies using human exposures with unprotected hearing. Given the fact that weapon impulses can and do produce permanent losses in hearing, there has been almost essentially no experimental work with unprotected human ears since the 1960's. In addition, the model needs a digitized waveform to process and there are few recorded pressure histories from that era. Furthermore, older studies generally ran too few subjects to permit characterization of the 95 percentile response.

However, a few analytical possibilities do exist. Work with impulse noise exposures at the former Human Engineering Laboratory with rifle and rocket impulses and three different exposures conducted by the German army with rifle impulses provided enough data to allow at least a tentative comparison with the model. One study by the U.S. Army Medical Research Laboratory using spark gap discharges also provided data that are indicative.

In the experiments with unprotected hearing, AHAAH was correct in its predictions (more than a dozen additional tests). An A-weighted energy measure under-predicted the hazard for two of the rifle impulses.

## Summary

The analyses just cited show that AHAAH has correctly predicted the onset of unacceptable hearing loss in more than 95% of the tests examined. MIL-STD-1474 has been correct 38% of the time (protected hearing only) and A-weighted energy has been correct 24% of the time for protected hearing and 30% of the time for all tests analyzed.