To: 3M™ E-A-Rfit™ Validation System Users

From: Elliott H. Berger

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Re: Presentation of the uncertainty/variability value in the 3M™ E-A-Rfit™ Validation System Software (V4.4)

This memo details changes that have been made in the presentation of the uncertainty value in Version 4.4 of the E-A-Rfit validation system measurement and report screens.

The uncertainty value, also called variability, of an E-A-Rfit validation system measurement is the result of three factors:

1. Measurement uncertainty – how closely does an E-A-Rfit validation system measurement and a corresponding real-ear attenuation at threshold (REAT) measurement agree? This can be tricky to answer since both the E-A-Rfit validation system and the REAT measurements have a variability inherent in their respective measurement processes. This variability is in fact somewhat larger for REAT since it is a subjective measurement, whereas E-A-Rfit validation system data are based on objective results (no subject response required).
2. Fit variability – regardless of how one measures a personal attenuation rating (PAR) there is an uncertainty in the fact that the next time the person fits the earplug s/he may do it differently. The PAR provides an estimate of attenuation for a given fit, but the prediction for the next fit has an associated uncertainty. E-A-Rfit validation system estimates this value based on experience in our lab-based compensation-factor studies in which we create calibration factors for our various probes. As part of these studies we get a measure of fit variability. As long as the operator conducts less than four sequential measurements on a wearer, it is this laboratory-based fit variability component that is included in the E-A-Rfit validation system uncertainty. However, if the operator takes four or more measurements for four different fittings of the hearing protector and adds them to the measurement bank, the system has sufficient data to make a useful estimate of personal uncertainty. In this case the wearer's own measured values will be used for the computation.
3. Spectrum uncertainty – whenever a single number rating is used to estimate protection there is an "error" or uncertainty as compared to the more accurate approach that would utilize all of the available spectral data for both the noise measurement and the hearing protector's attenuation. Most users wish to employ a single number, ideally one that can be subtracted from the A-weighted noise measurement and this is what the PAR provides. In so doing, the E-A-Rfit validation system PAR, or the A-weighted PAR from any other fit-test system will have a measure of uncertainty related to the hearing protector's spectral attenuation characteristics. Devices with a more uniform attenuation across frequency will have less spectral uncertainty than those who attenuation falls off substantially as frequency decreases.

The E-A-Rfit validation system presents ONLY the measurement uncertainty component of the total uncertainty on the measurement screens for the left and right ears. It is shown graphically as a horizontal bar on the Fitting Profile distribution curve on the left side of the screen. Only this one component is provided on these screens because at this stage of the measurements we are only looking at the data as one measurement at a time, so in effect there is no fit-variability component. There is also no spectral component on the measurement screens, since the principal value of the presentation of uncertainty on these screens is to provide a general idea of how reliable the PAR estimate is for that person for that fitting.

On the results screens all three uncertainty components are included and presented numerically in the Performance Outcome table and graphically on the Fitting Profile distribution chart. The magnitude of the uncertainty value is important at this point since it should be included in the prediction of the effective protected exposure when the hearing protectors are worn. The total uncertainty value is the combination of the measurement, fit, and spectral uncertainties.[1]

Only the measurement uncertainty is a function of the E-A-Rfit validation system process per se. The fit uncertainty is related to the skill of the wearer (presuming that four or more measurements were taken and banked in each ear) or to the skill of our test subjects (if less than four measurements were taken and thus the program reverted to laboratory data for estimation). The spectral uncertainty is a function of the mathematics of the single-number computation. The method used in the E-A-Rfit validation system is based upon the NRS_A as defined in ANSI S12.68-2007.

An example of the magnitudes of the uncertainties appears below. The actual values of uncertainty for each of the components will vary depending on the probe, the wearer, and the shape of the measured attenuation curve.

Measurement uncertainty	(system related)	3.8 dB
Fit uncertainty	(user related)	3.6 dB
Spectral uncertainty	(related to the computation of PAR)	4.1 dB
TOTAL uncertainty	(square root of sum of squares of the above rows)	6.6 dB

Fitting Distribution Curve (left side of the Attenuation Measurement screen)
The distribution shown here represents the range of values of well-fitted earplugs on our laboratory test subjects. Thus it gives the operator and the wearer an idea of the range of anticipated PARs under optimum conditions. Certainly not every user/employee will obtain values near the peak of the distribution curve, but falling far to the left of those values suggests either that the wearer needs additional training or that s/he should try alternative earplugs.

The curves shown are not symmetric since the best fit to the actual test data is not obtained with a standard normal distribution but with an alternative type of probability curve called a Weibull distribution.

[1] Since the spectral uncertainty is influenced by the shape of the attenuation curve as a function of frequency and since the attenuation curve may differ between the ears, the spectral uncertainty may also differ between ears, by approximately one dB. Since spectral uncertainty is part of the total uncertainty, that means that it too may differ between the two ears. This is accounted for in the computation of the overall binaural PAR uncertainty.