

## The LDL to SSPL 90 conversion dilemma

By E. Robert Libby

By comparison with the selection of gain and frequency response, the selection of SSPL 90 of a hearing aid has received little attention in hearing aid fitting. Inappropriately high SSPL 90s may, therefore, account for a substantial portion of dissatisfied hearing aid users. One only has to subtract the gain from its SSPL 90 to realize that it does not take a very intense sound in the environment to drive some aids into saturation. Dillon and Macrae<sup>3</sup> noted that under these conditions, it is possible that the shape and level of the SSPL 90 curve could be even more important than the gain curve of a hearing aid.

The patient fitted with a hearing aid whose SSPL 90 exceeds the loudness discomfort level (LDL) usually will resort to one or more of the following strategies according to Hawkins<sup>5</sup>:

- a) lower the volume control setting to a less than optimum position in anticipation of a loud signal,
- b) wear the hearing aid mainly in quiet environments or
- c) reject the hearing aid entirely.

The disadvantage of resorting to volume control changes is that the hearing aid wearer's reaction time always will lag behind the changes in signal level, causing both discomfort and loss of lower intensity level information.<sup>3</sup>

If the SSPL 90 is too low, the usable dynamic range will have been unnecessarily reduced. For an individual with a very restricted dynamic range, a low SSPL 90 setting may even cause speech in a particular frequency region always to be inaudible, irrespective of the input level or the volume control position.

As Hawkins<sup>4</sup> stated, the logic is straightforward. A hearing aid should not amplify any signal above the level at which a hearing-impaired person experiences discomfort. Therefore, the major reason for measuring the loudness discomfort level is to assist in determining the appropriate saturation sound pressure (SSPL) of a hearing aid.

Although the logic is simple, the

many criteria for discomfort have rendered such varying results that virtually any output limit could be chosen depending upon procedures and instructions.

Morgan, Wilson and Dirks<sup>9</sup> demonstrated that significantly different measurements will be obtained when LDLs are measured under 6 cm<sup>3</sup> earphones and in a sound field with conventional calibration procedures. The differences in LDL measurements can vary as much as 20-25 dB.

Unfortunately, most selection procedures recommend obtaining LDL values under earphones and then converting the HTL values to SPL, virtually ignoring the impedance differences between the 6 cm<sup>3</sup> headphones and the 2 cc coupler.

The TDH-39 earphones, usually in clinical use, are a low impedance source (acoustically speaker), while virtually every hearing aid is a high impedance source. Thus, the eardrum SPL developed by these sources can vary significantly from person to person, resulting in considerable over estimation or underestimation of the correct SSPL 90.

These problems, and the use of insert

earphones to avoid these errors, are discussed by Cox<sup>1,2</sup> and by Hawkins.<sup>4,5</sup> Until now, however, available insert earphones required large correction factors because their sensitivity and frequency response were not matched to that of the standard TDH-39 earphone.

### New developments

A new insert earphone, the ER-3A Tubeophone insert earphone, has been developed recently.<sup>7,8</sup> This earphone mimics the average response of the TDH-39 at the eardrum, so that it can be used as an audiometric earphone without requiring large correction factors (Fig. 1). More importantly, in individual cases, settings of the HL dial can be converted directly to 2 cc coupler SPLs because these insert earphones are calibrated in the 2 cc coupler. Thus, LDL can be converted directly to equivalent hearing aid SSPL 90 output without the uncertainty that goes along with the normal multi-step conversion process.

For example, assume an LDL of 95 dB HL at 1000 Hz is obtained using an ER-3A insert earphone with an audiometer specifically calibrated for that earphone. Immediately, it is known that this corresponds to 98.5 dB SPL in a 2 cc coupler, because 95 dB HL is 95 dB above the 0 dB HL reference equivalent threshold level of 3.5 dB SPL in the HA-1 2 cc coupler. This SPL can be verified quickly by simply removing the eartip from the client's ear and sealing it into a 2 cc coupler on a hearing aid test box or sound level meter.

With an audiometer that has been calibrated for an ER-3A earphone using the provisional reference equivalent threshold levels given in Table 1, the conversion from loudness discomfort level (read in HL on the audiometer dial) to 2 cc coupler SPL is accomplished by simply adding the SPL from Table 1 to the HL dial reading, just as in the example above. In this case then, the required conversion table is nothing more or less than Table 1 itself.

With an audiometer that has not been calibrated specifically for an ER-3A earphone (as when the ER-3A is used as an auxiliary to a standard

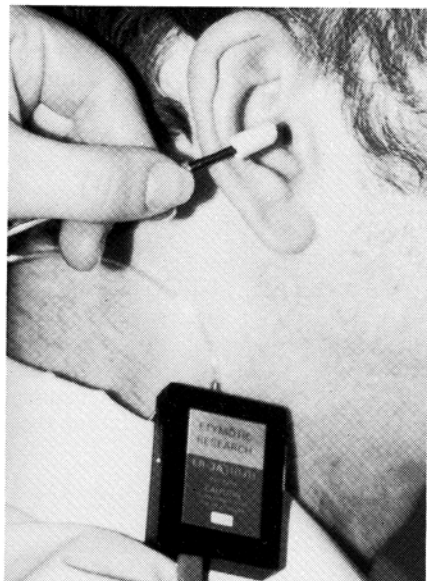


Fig. 1. ER-3A Tubeophone insert earphone with EAR™ earplug.

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TDH-39 earphone), a custom conversion table is required to show the 2 cc coupler SPL produced by this particular audiometer-earphone combination. Such a table is easily generated, as described below.

To generate a conversion table, the only equipment needed, in addition to the audiometer and ER-3A earphone, is a 2 cc coupler connected to a hearing aid test box or sound level meter so that the SPL in the 2 cc coupler can be read. (The correct 2 cc coupler, in this case, is the HA-1 coupler: the one used for ITE hearing aids or when a custom earmold is to be measured with a BTE hearing aid.)

**Preparation**—Place a foam eartip on the end of the ER-3A sound tube. Seal the eartip (using Fun-Tak, Silly Putty or similar) to the HA-1 coupler so that the bottom of the eartip is flush with the top of the 2 cc cavity volume. Plug the ER-3A earphone into the audiometer output jack, turn the audiometer attenuator dial to 90 dB (HL) and the tone switch to On.

**Recording data**—Set the audiometer frequency dial successively to 250 Hz, 500 Hz, etc. For each frequency, write down the SPL read on the hearing aid test box or sound level meter. As an example, Table 2 shows the numbers obtained on the left channel of an audiometer that was used with both TDH-39 and ER-3A earphones. (It, therefore, was not recalibrated for the ER-3A earphone.)

**The final table**—Subtract 90 dB (the audiometer dial setting) from each of the SPLs recorded above. The difference is the number of dB that should be added to the HL dial reading in order to obtain the 2 cc coupler SPL that the ER-3A will produce at that setting. As an example, the final column of Table 2 contains the conversion numbers used for the audiometer with the left ER-3A earphone.

It should be remembered that a custom conversion table, such as shown in Table 2, is required only when the audiometer has not been calibrated to the ER-3A earphone. Once the audiometer is calibrated to a given ER-3A earphone, the conversion values of Table 1 would apply.

### Instructions to patient

The instructions to the patient in order to obtain LDL are of primary importance. Instructions have an effect on the measured LDL, since they can influence the subject toward accepting extremely

Frequency in Hz	Add to HL dial to obtain 2 cc coupler SPL
250	15.5
500	8.5
750	6.0
1000	3.5
1500	2.5
2000	6.5
3000	5.5
4000	1.5
6000	-1.5
8000	-4.0

Table 1. Provisional reference equivalent threshold SPLs for ER-3A.

Frequency in Hz	Measured SPL in 2 cc coupler (90 HL dial)	Add to HL dial to obtain 2 cc coupler SPL
250	113	23
500	96	6
750	87	-3
1000	93	3
1500	94	4
2000	96	6
3000	93	3
4000	91	1
6000	76	-14
8000	88	-2

Table 2. An example of a custom conversion table.

uncomfortable stimuli or rejecting sounds which only slightly exceed their MCL.

Instructions as recommended by Hawkins,<sup>5</sup> Cox,<sup>1,2</sup> Morgan, Wilson and Dirks,<sup>9</sup> Skinner, Pascoe, Miller and Popelka<sup>10</sup> and Dillon and Macrae<sup>3</sup> can be used. The instructions of Hawkins as reported in November 1984 HEARING INSTRUMENTS are especially recommended. Although many clinicians measure LDLs with a speech stimulus, most prescription methods recommend the use of more frequency specific signals such as warble tones or narrow bands of noise. Using a speech signal may result in erroneous SSPL 90 measurements. LDLs for warble tones or narrow bands of noise centered at 250, 500, 1000, 2000, 3000 and 4000 Hz appear to provide adequate information.

Next, add the conversion number (from the table generated above) to the dial reading which gives the maximum 2 cc coupler SPL that a hearing aid should produce at that frequency in order to just reach LDL.

### Discussion

Attaining the appropriate LDL still may not solve all annoyance and discomfort problems if a peak clipping hearing aid is used, since the "spectral splatter" of the overload distortion products of a peak clipping hearing aid sometimes can turn a loud sound into an uncomfortably loud sound (not to mention the

fact that distortion simply sounds bad). The dispenser can avoid the "ear banging" of peak clipping hearing aids by choosing the softer and more pleasant sound of low distortion AGC (compression) hearing aids.

In addition, Cox<sup>1</sup> recommends adding +3 dB to arrive at a final correction to compensate for the average practice effect that occurs in LDL measurements. In other words, a first-time LDL measurement may unnecessarily restrict the SSPL 90 specification if applied directly. It is interesting to note that the common practice of adding 10 dB to the HL dial setting with TDH-39 measurements amounts to adding a final correction of approximately +4 to +8 dB to the equivalent 2 cc coupler SPL.

The well-known differences in hearing aid output, due to horns, reverse horns, dampers, etc., can be taken into account if the client's own custom earmold is used when the hearing aid SSPL 90 is measured on the hearing aid test box. The custom earmold, however, is not always available at the time the hearing aid is ordered. Experience has shown that SSPL 90 levels between 100-115 dB SPL would appear to be appropriate for most mild to moderate to moderately severe hearing-impaired individuals.

Use of the new insert earphones allows a much more accurate determination of the 2 cc coupler equivalent of LDL measurements, providing a solution to the dilemma of whether or not to use LDL to SSPL 90 conversions when the previous lack of accuracy made them only marginally useful. □

### References

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