

Contemporary Technology for Hearing Conservation Audiometric Monitoring

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Ultimately, the most important product of a hearing conservation program is the prevention of hearing loss, not the amount of hearing protection that has been purchased or whether employees are attending their annual training sessions. Audiometric testing directly reveals whether hearing losses are actually occurring in a plant. With audiometric data, we can assess overall program effectiveness, alert workers of impending hearing loss, and reveal potential employer liabilities for compensable hearing loss. Without the ability to efficiently analyze audiometric data or produce effective reports, our programs become fruitless and unproductive. Consequently, if audiometric data are such vital end-products, then effective audiometric technologies serve as the prime architect and generator of these fundamental data. These technologies, consisting of audiometers, associated peripheral hardware, and database/reporting software, deserve our consideration.

If you are now conducting audiometric tests, you may have become so comfortable with your current equipment and recordkeeping system that it might seem like "this is the way things are supposed to be." However, could it be possible that one day your management might notify you that it's time to replace the audiometer, due to age or condition (or maybe due to an increase in your workload)? If that happens, where would you turn, and what criteria would you use, to shop for replacement instrumentation and database technology? The purpose of this article is to help you recognize some criteria of features currently available in audiometric equipment and audiometric database management software. Perhaps this information might help you plan for ways to enhance your program's efficiency and effectiveness (provided that budgetary constraints aren't exceeded). Even if you don't think that you're currently "shopping" for such technology, you may find it worthwhile to consider what's changed (and what has not changed) in this element of hearing loss prevention.

The evolution of audiometric equipment to our current microprocessor-controlled audiometers has been relatively deliberate since "self-recording audiometers" were popular,

several decades ago, in military and industrial hearing conservation programs. Of the various audiometers now marketed for use in hearing conservation programs, it's reasonable to assume that there's no perfect audiometer system for all scenarios. A small, in-plant HC program may require a basic audiometer, with fewer features than are needed by a service that uses mobile vans to support multiple companies in different cities. Basic manual audiometers can cost between \$600 and \$1,500, while microprocessor audiometers can cost approximately \$1,500 to \$5,500, depending on options ordered. But price shouldn't serve as the only criterion for audiometer equipment selection. A choice of audiometer and peripherals will be influenced by obvious issues like the number of employees needing tests, protocols used in the plant for audiometry and professional review of audiometric data, and capital operating resources.

As shown in Table I (on page 5), several other considerations can be applied when choosing a new audiometer system. These considerations are intended to help spark questions that can be discussed with the equipment manufacturer or your equipment provider (e.g., someone affiliated with the National Association of Specialty Equipment Dealers, or NASED) about your needs. Since CAOHC doesn't intend to endorse any particular product or vendor, only general features will be addressed here, not specific manufacturers or models.

NEW DEVELOPMENTS IN AUDIOMETRIC HARDWARE

If your audiometric data will be saved electronically for analysis and reporting (see the discussion on audiometer software, later in this article), an interface with a computer becomes important. This link may be via a standard wired connection (e.g., RS-232, USB cable or Firewire), or even with wireless communication (up to 30 feet from the computer). In any case, consider how the data can be transferred to the computer, as well as how the audiometer can access data from previous tests in the database. If the level of activity requires testing more than one person simultaneously, it will be important that the audiometers can link to a controller and

Table 1: Hardware considerations when purchasing a microprocessor audiometers.

MICROPROCESSOR AUDIOMETER CONSIDERATION	SPECIFIC QUESTIONS
<i>Interface to a computer</i>	Are direct connections to a computer and database software available? Can data be transferred electronically from (or to) your audiometer?
<i>Interface to other audiometers</i>	If needed, how can audiometer test more than one person simultaneously?
<i>Manual entry of data (e.g., /D, thresholds)</i>	Is the method of data entry (keyboard or touch screen) appropriate for your situation?
<i>Manual audiometry option</i>	How easily (intuitively) is manual audiometry performed?
<i>Audiogram storage</i>	Can audiograms and data be stored on the audiometer (if testing is done in remote areas)?
<i>Recognition of errors (e.g., person responds too often)</i>	Does microprocessor audiometer recognize errors (and how many)? Does it alert the operator (and how)?
<i>Duration of microprocessor-driven test</i>	With standard protocol, how long does it take to test typical person?
<i>Microphone</i>	Is there a talk-over mike? If so, is it mounted on audiometer's console or on headset?
<i>Instructions</i>	Are recorded instructions available? If desired, are instructions available in languages other than English?
<i>Choice of test protocol</i>	Can you change protocols (e.g., first ear tested, include 8 kHz)?
<i>Price range</i>	Does the cost fit your business plan?
<i>Calibration of earphones</i>	Does audiometer hold calibration data for comparison with daily listening checks? Does audiometer recognize if earphones are different than the set used in calibration?
<i>Portability</i>	Can the unit be transported to other locations (if needed)? What does unit weigh?
<i>Printer capability</i>	Does system have an internal printer? Require an external printer? Allow use of both?

to the computer. Some audiometers allow entry of identifying information (e.g., employee name and ID number, previous baseline data, and responses to questions about histories) with full-size keyboard entries. While others use touch-sensitive screens or keypads for alpha-numeric entries. Of course, it may not be feasible (or necessary) to always link the audiometer and computer. If the testing is done onsite at the plant, you may find it far more efficient to just transport the audiometer to the location and leave the computer in your office or clinic for later interconnections. If that's the case, your audiometer's internal memory can be a real asset. Audiometers can store audiometric data from a few dozen records to over a thousand audiograms. Depending on the software you choose, you can then have access to these records when the employees arrive for hearing testing. Later, the new audiometric records and data can be downloaded to the overall database at your convenience (e.g., when you've returned home from your trip). Some units even operate on battery power, should your location be so remote.

A microprocessor-driven audiometer's basic advantage has been that these units can be programmed to apply standard audiometric testing rules, without an operator (although NOT without oversight of the Occupational Hearing Conservationist, or OHC). For instance, when an employee depresses the response button when no tone is present or has an excessive number of false positive responses, microprocessor audiometers can stop the test and alert the OHC of the problem, providing the option to reinstruct or abort the test. CAOHC's requirements to learn manual audiometry are based, in part,

on the concept that such problem tests can be efficiently expedited onsite by switching to manual audiometric testing. Some audiometers will integrate the manually-determined threshold with thresholds from other frequencies, to complete the record. Moreover, if multiple tests are being conducted but don't all end at the same time, the audiometer operating system can be programmed to continue presentations of a test signal to those who finished quickly, until all have completed the test. Some microprocessor audiometers have a talk-over circuit so that the OHC can communicate with the tested employee (e.g., "Your test is completed. Do not remove your earphones, but sit and wait quietly"). Some models use digital signal processors to play pre-recorded sound files with instructions in languages (sometimes a dozen or more) other than English. This feature may be a real boost to the success of your program, if your employees do not possess strong English skills. Up to 25 customized test questions can be created and used with some audiometers.

While it might seem intuitive that all audiometers use a standard audiometric (e.g., the Hughson-Westlake) technique, ask your vendor about how hearing thresholds are determined by a specific audiometer. This can affect the duration of the test and (more importantly) the validity of the hearing thresholds. Some audiometers allow changes in the default protocols (choice of OSHA, Canadian or other criteria), should the Professional Supervisor and OHC desire.

As described in Table 1, you can also consider other audiometer options like set up and customization, calibration

of more than one set of earphones (and even recognition that an unrecognized set of earphones has been used), portability (e.g., weight and convenience factors), biological checks, printers (built-in or peripheral), and audiogram backups.

NEW DEVELOPMENTS IN AUDIOMETRIC DATABASE SOFTWARE

An OHC who supports a small program, with only a few dozen noise-exposed employees, can quickly appreciate the frustrations of calculating Standard Threshold Shifts without support of automation

(e.g., to track baselines and use age corrections). Table 2 provides some specific considerations and questions related to audiometric database management software that can be applied to designing your own (should you choose to take on that task) or when shopping for a program that has been commercially prepared (and undergone troubleshooting to clear out bugs). While relatively few audiometer systems are being marketed (and once introduced, don't change dramatically for a few years), audiometer software technologies are quite diverse and can be customized. This variety is, logically, intended to meet specialized needs of the users.

As shown in Table 2, some of the features of the software extend the capabilities of the audiometer (e.g., storage of audiograms), while other features greatly exceed functions available on the audiometer itself. Filtering out sources for audiometric software is a bit more complicated than contacting an audiometer equipment vendor, since software developers can range from those with proprietary links tied to a specific audiometer to independent vendors who aim to support multiple lines of audiometers. In some cases, the hearing conservation database software is part of a larger occupational health care system. It's possible to locate software vendors via the National Hearing Conservation Association, your NIOSH point of contact, or (of course) Google searches.

When considering software options, you may find that the conditions of purchase are linked to

a license agreement that might allow only one plant's database to be maintained. If needed, though, a more comprehensive combination of databases can be maintained (for instance, when a consultant is reviewing audiograms from multiple sites). Your vendor may limit the number of separate locations that can be maintained, as well as the number of OHCs and reviewers who can be simultaneously using the software.

One clear advantage of an electronic database is how it maintains records of calibration data, OHC certifications,

Table 2: Considerations when choosing audiometric database software

AUDIOMETER SOFTWARE CONSIDERATION	SPECIFIC QUESTIONS
<i>Audiogram storage</i>	Is capacity adequate for audiogram database?
<i>Database platform</i>	Is platform proprietary? Windows-based or DOS?
<i>Modules</i>	Is software dedicated to hearing conservation or a module of larger occupational health system?
<i>Software licensing</i>	How many users may use license and/or can use system simultaneously?
<i>Price range</i>	Is software's price fixed, negotiable, based on use of services, or based on amount of purchase?
<i>Initial purchase</i>	What products and services are provided with the initial cost and for how long? What happens after that?
<i>Daily calibration or functional check</i>	Are audiometer checks required before any testing is done? Does system prompt user to perform check?
<i>Employee notification forms</i>	How does the software support employee notification of STS? Does the employee notification provide all OSHA-required elements? What additional information is also provided?
<i>Reporting capabilities</i>	Can reports be customized for user specifications? Can the user configure reports? Will the software company include report configuration services with purchase, or will such service require additional fees? Are a variety of reports available?
<i>Maintenance fee</i>	How are upgrades, maintenance and customer/technical support handled after initial coverage is over? If through a maintenance agreement, what is the cost?
<i>Other costs</i>	Is there a charge for training in, and implementation of, the software? Any other additional charges?
<i>Professional review</i>	Is a professional review service available, or provided with the product? If available are such review services required? If review services are used, what is the turn-around time (to receive results)?
<i>OSHA 300 Log</i>	Will the software generate your OSHA 300 log and automatically flag workers for inclusion?
<i>Baseline revision</i>	Are baseline revisions handled using NHCA Guidelines or other criteria? Does software revise baseline automatically, or is revision made only after professional input?
<i>Medical referral</i>	What criteria generate a medical referral? (AAO-HNS or other?) Do questions relate to physical symptoms (dizziness, fullness, tinnitus, pain)? How is a record cleared so that it doesn't continue to appear as needing a medical referral?
<i>Additional notes</i>	Does software include data fields to document other notes and findings that could affect hearing test results or compliance with the hearing conservation program (e.g., illness, non-use of HPDs, cerumen impaction)?
<i>Data back up</i>	How does the software handle audiometric data "back-ups"? Are back-ups done automatically? How often? Is the source of back-ups secure?
<i>Technical support</i>	How accessible is technical support? How will the vendor address your problem (e.g., by phone, remote connection, site visit etc.)? Is there a toll free number or email access to technical support?
<i>Written reports (in non-English language)</i>	Can notification forms be printed in languages other than English?
<i>Data conversion</i>	How are data from previous software handled? Is there a fee to convert data to work with the new software?
<i>Multimedia</i>	Is an interactive demonstration available to preview product?
<i>Web-based</i>	If the application is web-based, how are security and accessibility issues handled?

daily functional check data, patient medical histories, noise exposure records, medical referrals, and other data for documentation and quality control. Currently, software options can offer (to some degree, more or less) an abundant amount of documentation, as shown in Table 2. Moreover, reports can be generated (either from an established set or customized) to indicate medical referrals, STS rates, trends, and reports of hearing loss among individuals, shops, or companies. As indicated in the table, you may find that the software company might charge an additional fee for customizing reports (or for allowing you to generate ad-hoc reports). You may also consider other software options (listed in Table 2) like capabilities to generate individual letters to employees (in languages other than English, if needed), flagging workers who have triggered an OSHA-recordable hearing loss or medical referral, or documentation of other notes (e.g., cerumen impaction) that might be relevant for the Professional Supervisor (PS) who reviews your data. Don't forget that the recommendation of the PS is required for problem audiograms, including decisions re baseline revision. Although the software might offer an "alert" re a need for baseline revision, the PS may override the revision alert if warranted. Don't trust the software to drive your hearing conservation program; use a knowledgeable PS (with the scope of practice outlined at www.caohc.org/professional_supervisor/scope_of_practice.php).

org/professional_supervisor/scope_of_practice.php). Your PS will also be especially concerned about how your audiometer software can convert audiometric data (either by import or export functions), so be sure to coordinate your decision processes with your PS. While the effectiveness of your audiometric testing program benefits markedly from good recordkeeping, it's important to tailor your efforts to best use time and resources effectively. As Daniel 1. Boorstin once said, "Technology is so much fun but we can drown in our technology." Designers of audiometric equipment and audiometric database management technologies are aware of our need to be efficient, yet thorough. As you contemplate your future needs in this area, feel free to shop around, express your specific needs and coach the vendors who are earnestly seeking to develop technologies that contribute to our required jobs in hearing loss prevention.

The opinions expressed are neither those of the National Space Biomedical Research Institute nor of the National Institute for Occupational Safety and Health.