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Case Studies: Transient Sounds Through Communication Headsets

Dawn Tharr Column Editor

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Transient Sounds Through Communication Headsets

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Reported by Randy L. Tubbs and John R. Franks

Introduction

The National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation at an air traffic approach control tower. There was concern that air traffic control (ATC) specialists may be exposed to noise greater than 85 decibels on an A-weighted scale [dB(A)] over an 8-hour time-weighted average period from their communication headsets as a result of brief, loud tones transmitted intermittently through the headset receivers. A compression unit that would limit the intensity of these tones had been designed by an outside firm and had been installed at the radar screen positions prior to the NIOSH site visit. The survey was designed to determine if the compression units were effective in reducing sounds that reached the controllers' earpieces and if any permanent hearing damage had occurred in the population of ATC specialists.

Investigators from NIOSH measured noise levels from the communication systems used by the ATC specialists while the noise compression unit was inserted into the communication line, as well as when the unit was removed and uncompressed signals were allowed to reach the headset receiver. Also, ambient background noise measurements were made in the controllers' work area. Interviews were conducted with any ATC specialists from the day and afternoon shifts who wished to speak to a NIOSH investigator. Finally, NIOSH obtained the annual audiometric tests for the ATC specialists over the last 3 years, a copy of the Occupational Safety and Health Administration (OSHA) Log of Federal Occupational Injuries and Illnesses, and an unused compression unit and communication headset that could be further tested in the NIOSH laboratory.

Laboratory analysis of the headset receiver and the compression unit showed that the controllers could be exposed to uncompressed signals with equivalent free field noise levels of up to 104 dB(A), but that the compression units functionally reduced the exposure to a safe listening level. Analysis of the audiometric records did not reveal any systematic occupational hearing loss in the population of controllers, even though over 75 noise incidents had been recorded on the injuries and illnesses log.

Background

The ATC tower handles air traffic at an eastern U.S. international airport. The controllers are responsible for aircraft approaches and for planes leaving the airport until they reach a location out of the region, where they are handed off to other control centers. The darkened room where the controllers work contains four radar screens, a supervisor's station, and a computer printer that records flight numbers and flight plans for both inbound and outbound aircraft.

The communication system in the control tower relies upon head-worn microphone/receiver sets. The body of the earpiece is shaped to fit over the ear and held in place by an ear hook. The microphone is located in the body of the piece and is coupled to the mouth by a rigid tube. The receiver is coupled to the ear with flexible plastic tubing that ends at an olive-shaped universal tip. The tip, available in six sizes, is attached to flexible tubing that is inserted into the ear.

The flight controllers were concerned that the signal levels they received from the communication system through the headset receiver were of sufficient intensity to cause hearing loss from long-term use. They were also concerned that when the communication system became unstable and oscillated (creating feedback), the tone could cause instantaneous hearing loss due to its extremely high level. Tests determined that feedback occurs during three different scenarios: (1) if two or more aircraft simultaneously transmit communications on the same radio frequency, (2) if ATC specialists from other locations attempt to communicate with personnel at this control tower and are improperly using a headset in very close proximity to a loudspeaker, and (3) if the telephone company test signal is accidentally transmitted over the telephone land lines. Feedback tones were described by employees as loud, squealing, shrieking, piercing, hissing, or shrill, and as persisting from 1 second to 5 minutes. In an effort to prevent the controllers from receiving high intensity speech or feedback, electronic compression units, designed by an outside electronics firm, were purchased and put into the signal path. While these compression units prevented extremely high levels of signals, controllers complained that they reduced the loudness of the speech, making it more difficult to understand.

Methods

Noise Evaluation

To capture speech and other signals from the headset receiver, it was necessary to record the signals delivered to the system as they would be under normal operating conditions. A junction box was made that allowed signals going to the receiver set to also be recorded to digital audio tape (DAT; model SV-255, Panasonic) without changing the signal level delivered to the headset receiver. The input impedance of the DAT recorder was high (>10 kOhms) so that the line signal impedance was unaffected at 600 Ohms (Z). The DAT recorder was calibrated so that a system signal of 0 decibel volume units (dB VU; 1.0 V rms at 600 Z = 0 dB VU) to the receiver module was equal to −20 dB VU on the DAT. The DAT recorder had a dynamic range of 90 dB, so that it could accurately record signals ranging in levels from +20 to −70 dB VU (100 V rms to 100 nV).

Recordings of normal air-to-ground and ground-to-air communications were made for two conditions: the electronic compression unit out of the system with normal communication traffic, and the electronic compression unit in the system with normal communication traffic. Recordings of tones were also made with the compression unit in and out of the communications circuit.

In the laboratory, the DAT recordings were played through the sample headset receiver sent to NIOSH, complete with ear tip to the artificial ear of a head and torso simulator (KEMAR). The playback system was maintained at 600 Z so that playback voltages corresponded to recorded voltages. The signals were analyzed to provide readings of integrated maximum output, integrated minimum output, and integrated average output with a real-time spectrum analyzer.

Area noise samples in the controllers' work space were made with a Larson-Davis Laboratories model 800B precision integrating sound level meter. Octave-band measurements at consecutive center frequencies of 31.5 Hz to 16 kHz were made at the supervisor's counter, located in the center of the room behind the controllers' radar screens. Octave measurements were made with the sound level meter integrating the sound energy over 1-minute periods.

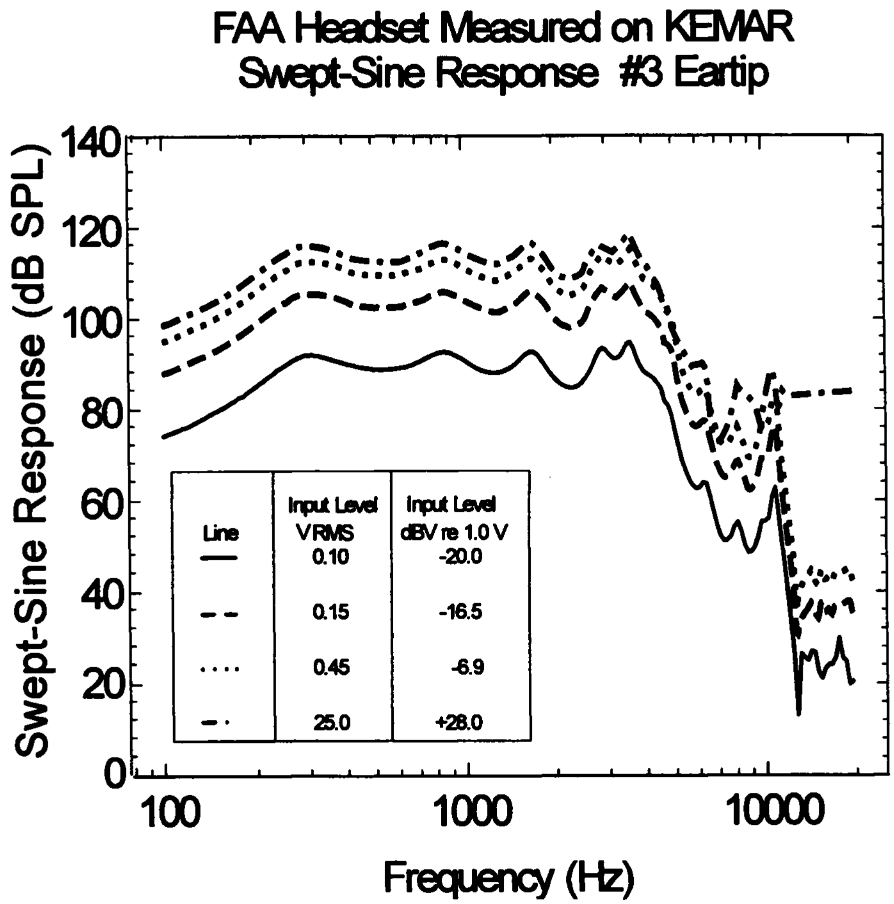

FIGURE 1. Output characteristics of the AT&T microphone/receiver module coupled to the artificial ear. All input voltages at 600 Z; sound pressure levels shown in dB SPL at plan of artificial eardrum.

Medical Evaluation

During the site visit, ATCs from the day and afternoon shifts were given the opportunity to meet in private with a NIOSH investigator to discuss any tone incidents they may have experienced. NIOSH investigators also requested copies of OSHA logs for tone incidents in 1993, 1994, and 1995. Finally, the last 3 years of audiometric examinations given in conjunction with the annual medical exams for all of the ATCs were requested so that analyses of their hearing abilities could be conducted. The hearing requirements for the ATC specialists are verified by pure-tone, air conduction audiometric examinations. The controller must have hearing levels at 500, 1000, and 2000 Hz that do not exceed 25 dB in their worse ear or 20 dB in their better ear. If employees are unable to meet the requirements for at least one ear, then they are reviewed by the medical staff on a case-by-case basis.

Results

Communication Headset Evaluation

The headset receiver is made by Plantronics for AT&T and is sold as model KS22915-L7. A belt-worn module has an on/off switch and cabling that is plugged into the controller's console. A wire runs from the belt-worn module to a microphone/receiver module that fits over the ear. The module is symmetrical and may be worn over the right or left ear. A microphone tube extends from the module so that its opening may be placed just to the side of the mouth. There is a nubbin on the bottom of the module that will accommodate a length of Tygon® tubing attached to an ear tip that is placed in the ear canal. The module is worn over the ear. There are six sizes of ear tips, labeled 1 (smallest) to 6 (largest). The olive-shaped ear tips resemble a premolded, no flange earplug with a hole in the center through which the tubing passes.

There is no volume control for this system. The signal level reaching the ear is regulated by the controller's console. The unit has an operating impedance of 600 Z. This makes calibrating and describing the unit's input signal levels simpler because 1 V at 600 Z equals 0 dB VU. As seen in Figure 1, the unit has a very wide frequency response from 100 to 5000 Hz.

Its acoustic output at −20 dB VU peaks at 96 dB SPL at 3500 Hz. The curve is smooth, showing only the resonance characteristics of the tubing connecting the receiver to the ear tip. At 0 dB VU (1 V rms at 600 Z), the unit produces a peak sound level of 106 dB SPL at 3500 Hz. The unit is capable of handling input voltages beyond 25 dB VU, but its output is limited to 116 dB SPL by the electromechanical characteristics of the receiver. The free-field equivalent A-weighted sound level to 116 dB SPL measured in the ear simulator is 104 dB(A). Thus, it is possible for the AT&T KS22915-L7 to produce sound levels that are hazardous to hearing. Current NIOSH recommendations are that exposure to sound levels of 104 dB(A) be limited to 6 minutes or less over an entire 8-hour work period.[1,2]

Compression Unit Analysis

To limit the output of the receiver module so that it would not produce high level sound, an electronic compression system was introduced. The unit, the Personal Hearing Protector model 1 (PHP unit), was manufactured to be used specifically at the facility. The PHP unit has balanced 600-Z input and output impedances and is described as providing output limiting so that signals cannot exceed a set amount. The PHP units observed by NIOSH investigators were set to limit the output to −14 dB VU or equivalent to a diffuse sound field level of 80 dB(A). The output levels captured on tape the day of the sampling were generally low enough not to be considered as hearing hazards with the PHP unit in or out of the system. Recordings with the PHP unit out of the system provided maximum equivalent diffuse sound field levels of 84 dB(A), while with the PHP unit in operation, the maximum equivalent diffuse sound field level was 80 dB(A), consistent with the PHP setting.

The signals for which there were the most complaints were referred to as "tones" by personnel. These tones are the consequence of feedback caused by phase-locking the communication system and the subsequent oscillation at the frequency of highest output. The tones were reported as occurring most often when a microphone switch was left open by a pilot who was also receiving a message from the flight controller. The tones could also be generated when the controllers were talking via telephone lines with controllers in other facilities. Acoustic phase-locking must occur for acoustic feedback to be generated. None of the simulated tones generated during the site visit were intense enough to be hazardous.

The PHP unit is described as a compressor. If such were the case, upon testing it would show unity gain (output equals input) until it reached the compression point, after which there would be no increase in output level from further increase in input level. With the unit set to −14 dB VU, the PHP unit should have shown unity gain up to −14 dB VU and then should have shown no more increased output as the input signal was increased from −14 to +20 dB VU. Figure 2 shows input/output (I/O) curves for the PHP unit with no compression (0 dB VU), with moderate compression set to −14 dB VU, and with maximum compression (−20 dB VU).

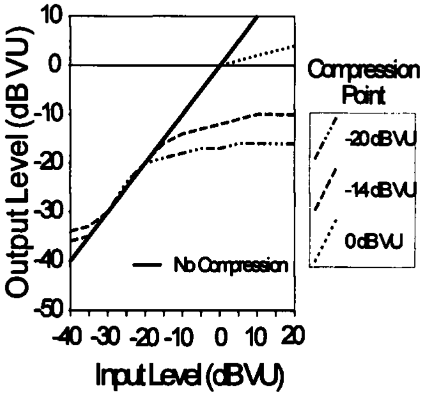

FIGURE 2. I/O functions for AT&T receiver. Shown are curves for PHP compressor unit settings of −20, −14 (present setting), and 0 dB VU. Also shown is the function for a noncompressed system with linear gain.

The I/O curves depict a device that certainly is a compressor; above the compression knee it appears to have a 10:1 compression ratio. Below the knee the unit shows unity gain. However, the PHP unit tested had a noise floor of about −33 to −35 dB VU depending on the compression setting. The result of the noise floor is to restrict the usable dynamic range of the PHP unit.

Control Room Noise Analysis

The octave-band sound levels were made in the controllers' work area. The sound energy at each octave-band center frequency was integrated over a 1-minute period during normal ATC activities. The results are shown in Figure 3.

The average (L_{eq}) octave-band levels ranged from 52 to 71 dB, with the greatest energy measured at 125 Hz. Noise criteria for occupied interior spaces (NCB curves) have been devised to limit noise to levels where satisfactory speech intelligibility is obtained.[3] These criteria were devised through the use of extensive interviews with personnel in offices, factories, and public places, along with simultaneously measured octave-band sound levels. The interviews consistently showed that people rate noise as troublesome when its speech interference level is high enough to make voice communication difficult. The recommended space classification and suggested noise criteria range for steady background noise heard in various indoor occupied activity areas are shown in Table 1.

When the sound levels in the controllers' work area are compared to the balanced noise criteria, the controllers' sound environment is near the NCB-60 criteria, which have been designated as meeting the sound requirements for workshops and garages. However, the NCB-60 criterion is the maximum level recommended in areas where speech or telephone communication is necessary.

Medical and Self-Reported Workplace Evaluation

Both the day and afternoon shifts at the ATC facility were staffed by eight ATC

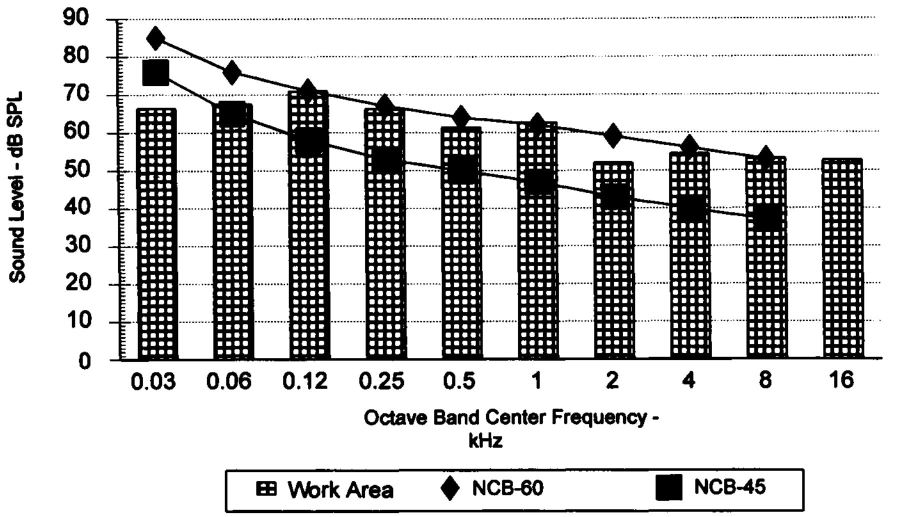

FIGURE 3. Octave-band sound levels in control room compared to balanced noise criterion curves.

TABLE 1. Recommended Space Usage for Balanced Noise Criteria Range in Occupied Indoor Areas

Type of Space and Acoustical Requirements	NCB Curve
Concert halls, opera houses, and recital halls	10–15
Large auditorium large drama theaters, and large churches	Not to exceed 20
Small auditoriums, small theaters, small churches, music rehearsal rooms, large meeting and conference rooms, or executive offices	Not to exceed 30
Bedrooms, hospitals, residences, apartments, hotels	25–40
Private or semi-private offices, small conference rooms, classrooms, libraries	30–40
Large offices, reception areas, retail shops and stores, cafeterias, restaurants	35–45
Lobbies, laboratory work spaces, drafting and engineering rooms, general secretarial areas	40–50
Light maintenance shops, industrial plant control rooms, office and computer equipment rooms, kitchens, and laundries	45–55
Shops, garages	50–60[A]
Work spaces where speech or telephone communication is not required	55–70

[A]Levels above NCB-60 are not recommended for any office or communication situation.

specialists and one supervisor. NIOSH investigators were able to interview 9 of a possible 16 controllers who volunteered to discuss their experiences with any tone incidents. All interviewed employees had at least one occurrence with a tone incident; most had been severe enough to warrant a completion of a Federal Employee's Notice of Traumatic Injury and Claim for Continuation of Pay/Compensation (form CA-1). Several of the reported exposures caused pain and ringing (tinnitus) in the employee's affected ear for hours in some cases and for up to 3 days in other cases. All but one employee reported that they were informed by their physician that no hearing damage had occurred. However, one ATC specialist noted that he wears a hearing aid as a result of a tone incident.

The interviewed employees were not convinced that the noise compression units were an optimal fix for the tone problem. They reported that the PHP unit would lower the intensity of the communications, but that sometimes the noise compression was too much. They would be unable to hear radios clearly and would have to request pilots to repeat their radio traffic. In some instances, the ATC specialists reported that the PHP unit would be by-passed to get around these poor listening conditions. Of the controllers who responded to a question about the plastic, olive-shaped earpiece of the radio headset, over 80 percent said that it was uncomfortable or only tolerable. However, when the plastic earpiece was replaced with a foam earpiece (ACS Contour Lx Ear Tiplet, model 0008-LX-00), the ATC specialists found it unbearable and went back to the olive-shaped earpiece.

The management at the control tower supplied NIOSH investigators with data which they had collected that documented any loud tone exposures for the calendar years 1993 to 1995. A total of 76 incidents were included in the information. Over one-half of the incidents included a CA-1 form that the employee completed in conjunction with the exposure. However, the OSHA logs for these same years had a total of 35 reported occurrences for loud tones in one of the ATC specialists' ears. Three of the 35 notations resulted in a lost-time case injury.

During the interviews, the employees reported that they were required to receive an annual physical examination near their birthday to maintain their eligibility for employment as an ATC specialist. Audiometric testing is included in the examination, and the ATC specialists must meet the hearing requirements referenced earlier. Many of the employees reported that even though they had been regularly tested, they were not given copies of the hearing tests or a detailed explanation of their hearing ability and how it had possibly changed over the years of testing. NIOSH investigators requested audiometric data for the ATC specialists. A total of 57 records were forwarded to NIOSH for analysis. These records included the last three audiometric examinations that the employees had received during the years 1993 to 1996. Only four individuals who were noted on the OSHA Log of Federal Occupational Injuries and Illnesses did not have audiometric data in the medical records. Because the headset receiver used by the ATC specialists had an earpiece in only one ear, it was speculated that if the tone incidents were a permanent hazard to hearing, then the damage would be seen more in one ear when compared with the individual's other ear. Thus, the hearing data for the last recorded examination were classified as better ear or worse ear before they were analyzed. During this classification, six records were removed from the analysis because of irregularities in the test results. One physician who administered audiometric examinations recorded hearing data down to single numbers (e.g., 1, 7, 16) rather than the routine practice of recording zeros and fives (e.g., 5, 20, 25) as is conventionally practiced in audiometry. These irregularities brought the validity of the data into question and they were therefore removed from the group that was statistically analyzed.

Two ATC specialists had audiometric examinations where their worse ear exceeded the American Medical Association's (AMA's) low fence average of 25 dB at the test frequencies 500, 1000, 2000, and 3000 Hz, which is calculated to determine hearing impairment.[(4)] To determine if this finding was a trend for the population of controllers, the last audiometric examinations for the 51 ATC specialists were separated into the better and worse ear simply by adding the total hearing level (HL) values for the left and right ears. The ear with the highest total was classified as the worse ear. The mean HL values for the employees' better and worse ears are plotted in Figure 4 for the

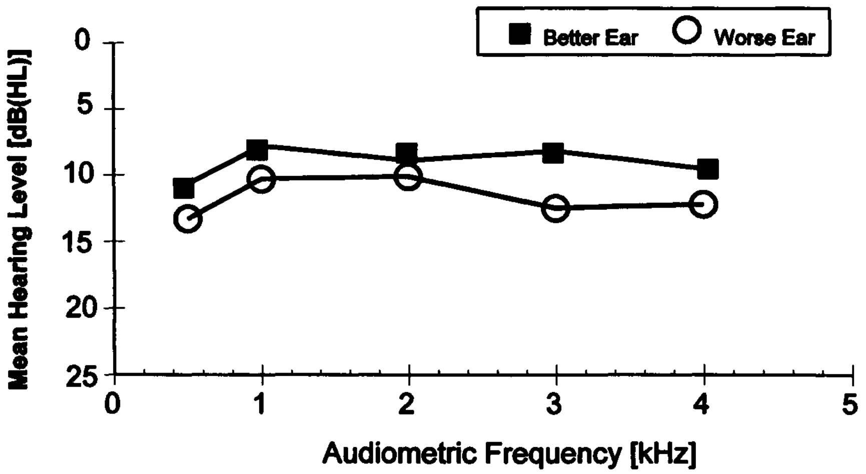

FIGURE 4. Better ear versus worse ear: last audiometric examination.

pure-tone frequencies of 500, 1000, 2000, 3000, and 4000 Hz.

The mean values are within 5 dB of each other when comparing better and worse. The values are also less than the lower fence of hearing impairment (25 dB). For an additional analysis, the hearing data were further limited to male employees because only four female ATC specialists were included in the audiometric testing. The 47 males had a mean age of 39.4 years (SD = 4.2 years). Thus, the average hearing levels for these employees were directly compared to the age-effect data in the American National Standard S3.44-1996 for 40-year-old males from an unscreened population in an industrialized society (Annex B).[5] The 10th, 50th, and 90th fractiles for the population and the mean Federal Aviation Administration data are graphed in Figure 5.

The hearing ability of the ATC specialists is very similar to the 50th fractile (median) comparison population that has no occupational noise exposure.

The audiometric data were also reviewed from a hearing conservation program effectiveness perspective using the American National Standards Institute (ANSI) S12.13 percent better or worse sequential (%BW).[6] This metric uses the percent of the population which shows a 15-dB shift toward either the better hearing or the worse hearing at any test frequency in either ear between two sequential audiograms (%BW). In the audiograms that covered 1993 to 1994, %BW equaled 7.7 percent; for 1994 to 1995, %BW equaled 15.7 percent; and for 1995 to 1996, %BW equaled 18.4 percent. Even though this metric is increasing instead of decreasing over the three years that were examined, all three of the comparisons fall within the acceptable criterion range of 25 percent or less. An indication that the audiograms may not have been as accurate as possible is the number of audiograms that had the same HL value for all of the tested frequencies in both ears. Over the 153 audiometric examinations reviewed by NIOSH investigators, a total of 30 tests (19.6%) had identical HLs at the ten test frequencies.

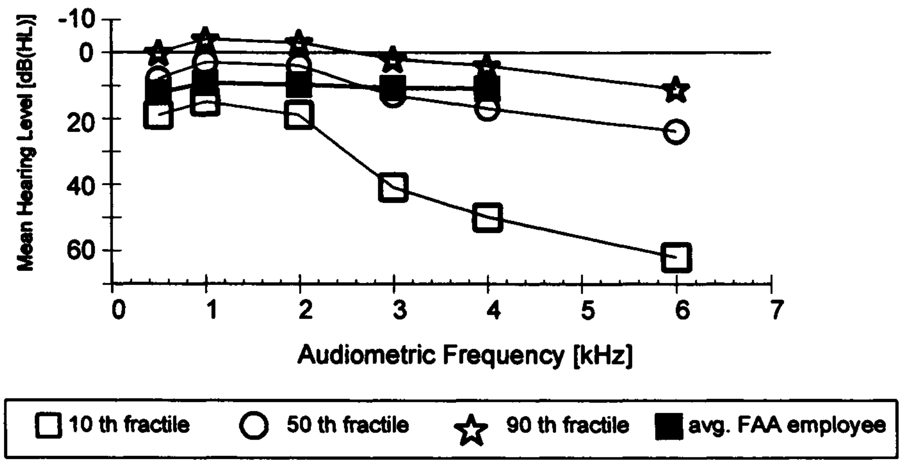

FIGURE 5. Male audiometric data compared to ANSI, annex B, 40 years data.

Discussion

The results of the noise analyses show that it is very possible that a feedback signal (tone) could drive a headset receiver to its maximum output, giving the wearer a short blast at 116 dB SPL [equivalent field level of 104 dB(A)]. For this to happen, the console would need to be set at full volume, there could be no compression unit in the line, and the feedback signal would have to originate from an environment where both a microphone and a loudspeaker were close enough to each other to start the feedback oscillations. In this case, the receiver module would not be in the feedback loop; rather, it would delivering the monitored feedback signal to the wearer. The PHP unit that was installed at the workstations, however, is effective at controlling the high intensity feedback signal down to a safe listening level. Once the signal is above the noise floor of the unit, the PHP provides unity gain up to the compression set level and then a 10:1 compression ratio over the remainder of the dynamic range of the communication systems.

The present setting of the PHP unit to −14 dB VU provides too much compression. At −14 dB VU, the PHP unit is limiting output sounds to 80 dB(A) or less. The background noise level of the PHP unit is around −32 dB VU; the noise is always present and audible. The speech that the controllers need to hear must have an equivalent diffuse sound field level of between 62 and 80 dB(A). They complain that when the PHP unit is used, the level of signal they need to hear is too soft and that there is too much background noise.

The audiometric test data for the group of ATC specialists indicate that they have not been exposed to noise of a sufficient level and duration to cause occupational hearing loss. The difference between the better and worse ear for the

51 controllers is negligible, and the group compares to an unscreened population that has not been exposed to occupational noise. For the two individual ATC specialists who exceeded the AMA lower fence of 25 dB, one appears to have a loss more indicative of conductive hearing problems than of a sensorineural loss. The other individual does exhibit a hearing loss pattern that is consistent with noise exposure. However, it is impossible to ascertain the exact cause of the loss from the limited data obtained in this evaluation.

The audiometric tests do point to a problem with the consistency and validity of the data which can impact the usefulness of the program. The increase in the percent of people who have excessive variability in their annual hearing tests, the hearing tests that show no differences in HL over all test frequencies, and the recording of data in a manner that is not consistent with good audiometric practices are examples of a medical test program that needs reevaluation.

The ambient noise levels in the controllers' work space are high enough to interfere with communications in the area. This less than optimum listening environment is coupled with the ATC specialist's headset that also limits the communication signal. Although the headset receiver has a frequency range from 100 to 5000 Hz, the signals provided to it by the radio and telephone communication systems are limited to a narrower range of 300 to 3000 Hz. This frequency range was determined to be the optimum range for speech understanding in the late 1920s, when bandwidths were being set for telephone systems. Speech passed through this narrow frequency response range does not sound natural, is of low fidelity, and is difficult to understand in the presence of background noise.

Conclusions

Feedback signals, or tones, generated by the communications system at the ATC tower are capable of reaching levels of 116 dB SPL at the ear of the ATC specialist, which equates to a free-field noise level of 104 dB(A). The NIOSH recommended exposure limit limits worker exposure to this noise level to 6 minutes or less during the work shift. The model 1 PHP that has been developed for this facility is capable of reducing the feedback signal to a safe listening level. However, too much compression has been set on the PHP units, which causes the communication signals to be too soft to be heard over the background noise of the units and the work area. Several controllers reported that the PHP units are bypassed because of this.

Analysis of the hearing examinations of the controllers does not indicate that permanent hearing damage has been inflicted upon this group of employees as a result of occupational noise exposure. The analysis of the output function of the headset receivers used by the ATC specialists does show a low fidelity characteristic that, coupled with the moderately high ambient background noise measurements made in the work space, leads to problems in understanding speech signals fed through them. Finally, the review of the audiometric data revealed some deficiencies in the testing program that reflect on the validity of the hearing tests given to the controllers.

Recommendations

The results of the evaluation of the ATC specialists show that a health hazard to controllers' hearing does not exist for the current employees. There were, however, some situations discovered during the evaluation that can be changed to improve the working conditions and the medical testing program. The following recommendations are offered to alleviate the problems uncovered during the NIOSH evaluation at this facility.

1. At −14 dB VU, the PHP unit is limiting output sounds to 80 dB(A) or less. The speech that the controllers need to hear must have an equivalent diffuse sound field level of between 62 and 80 dB(A). They complain that when the PHP unit is used, the level of signal they need to hear is too soft and that there is too much background noise. Acceptance of the PHP units could be improved by raising the setting to −9 dB VU. This will still provide a safe setting, would make the signal sound louder, and would increase the speech to noise ratio so that speech understanding could be enhanced.
2. The PHP unit is only one type of limiting circuitry. A second type of limiter is the zener diode. The zener diode can be placed in the receiver module in the line going to the receiver and can be selected to peak clip any line voltage above a selected level. A zener diode is immediate in response, costs little, does not require power, and does not raise the noise floor of the system. Zener diodes are used in other communication systems sold by AT&T and Plantronics.
3. The narrow bandwidth of the speech signal is also part of the problem. To overcome the narrow bandwidth, the controllers increase the intensity of the signal. When they are protected from high signal levels by the PHP unit, they complain because they can't make the signal loud enough to be clearly heard. If controllers were provided a system that employs the full spectrum of speech, from at least 100 to 6000 Hz, they would not be so concerned with making the speech louder. As changes in the communication systems in use are made, equipment that meets this wider bandwidth specification should be sought.
4. Controls to reduce the ambient noise levels in the controllers' work area should be pursued. The octave-band noise data collected at the facility seem to show that voices add a great deal to the background noise. The use of barriers or partitions between workstations may reduce the amount of background conversations that interfere with the controllers' ability to hear the radio and telephone signals. Also, the addition of acoustical materials on hard surfaces in the room should reduce the noise reflecting off of these surfaces, which would lower the overall background noise.
5. The present headset receiver unit is coupled to the controller's ear canal by an ear tip that comes in six sizes. Most of these sizes do not exactly fit the controllers' ears and so they must use the best of the selection. A custom earmold can be coupled to the receiver unit as well. The custom earmold would provide the advantages of sealing the listening ear from outside noises, such as speech from other controllers, and delivering a signal that is clearer and more stable than is now possible.
6. The audiometric tests furnished to NIOSH for analysis indicate that the hearing test program lacks consistency between the providers of the audio-

metric examinations. Also, many of the hearing test results were of questionable accuracy because the same hearing levels were reported at all test frequencies, or hearing level values were not recorded according to standard audiometric procedures. Professional guidelines established to ensure that accurate and valid hearing tests are obtained during the annual medical examination given to the ATC specialists should be followed.[7]

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Editorial Note: Randy L. Tubbs is with the Hazard Evaluation and Technical Assistance Branch and John R. Franks is with the Physical Agents Effects Branch of NIOSH. More detailed information on this evaluation is contained in the Health Hazard Evaluation Report No. 96-0184-2663 available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800) 35-NIOSH; fax (513) 553-8513.