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Federal Aviation Administration — Bradley Airfield
Windsor Locks, Connecticut

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a request from health and safety management for the Federal Aviation Administration's (FAA) New England Region to conduct a health hazard evaluation (HHE) at the Bradley Airfield Air Traffic Approach Control Tower. The request followed an Occupational Safety and Health Administration (OSHA) citation and notification of penalty to the Federal Aviation Administration for failure to monitor workers' noise exposures. 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 (TWA) period from their communication headsets. OSHA suggested that NIOSH be contacted to make the measurements to determine the level of noise exposures.

On October 8–9, 1996, investigators from NIOSH visited Bradley Airfield to measure noise levels from the communication systems used by the ATC specialists while a noise compression unit was inserted into the communication line, as well as when the unit was removed and unattenuated 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 shift who wished to speak to a NIOSH investigator. Finally, NIOSH obtained the annual audiometric tests for the ATC specialists assigned to Bradley Airfield over the last three years, a copy of the OSHA Log of Federal Occupational Injuries and Illnesses, and an unused compression unit that could be further tested in the NIOSH laboratory. Laboratory analysis of the headset receiver and the compression unit showed the controllers could be exposed to equivalent free field noise levels up to 104 dB 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 at Bradley Airfield, even though over 75 noise incidents had been recorded on the injuries and illnesses log.

The results of the evaluation lead NIOSH investigators to conclude that a hazard to the hearing of the ATC specialists does not exist. However, there were deficiencies noted in the manner in which the compression unit was used and in the hearing tests given to the controllers. There was also a moderately high level of background noise in the work area that could possibly interfere with speech intelligibility. Recommendations to alleviate these deficiencies are given in the last section of this report.

Keywords: SIC 9621 (Regulation and Administration of Transportation Programs), air traffic control operations – government; noise; radio headsets; compression circuits; noise–limiting circuits; audiometric testing; hearing conservation program.

TABLE OF CONTENTS

INTRODUCTION

In May 1996, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Federal Aviation Administration's (FAA) Office of Occupational Health and Safety in Burlington, Massachusetts. The request concerned reported loud tone bursts and static that air traffic control (ATC) specialists experience on an intermittent basis through their radio headsets or telephone landlines at the controller's radar screen located at Bradley Airfield in Windsor Locks, Connecticut. These incidents had been reported as early as 1994 at Bradley Tower. From November 3, 1995, to March 20, 1996, the Occupational Safety and Health Administration (OSHA) conducted an inspection at the facility and issued citations on April 8, 1996. One of the citations was for lack of a noise exposure monitoring program where information indicated that the employees may be exposed to noise exceeding an 8–hour time–weighted average (TWA) of 85 dB(A). The OSHA area office gave the FAA the option of requesting a NIOSH HHE to measure the noise exposures through the headsets.

A headset was sent to NIOSH in Cincinnati, Ohio, for examination and analysis prior to the health hazard evaluation (HHE) site visit. Researchers in the Physical Agents Effects Branch, Division of Biomedical and Behavior Science determined input/output functions for the headset over a wide frequency range and also determined the equipment necessary to collect the relevant noise data at Bradley Airfield. On October 8–9, 1996, researchers from NIOSH performed a site visit at Bradley Airfield's Air Traffic Control Tower (TRACON) to collect noise data from the headsets used by the controllers at their work positions. On the first day of the survey, an opening conference was held with representatives from the FAA, the National Air Traffic Controller's Association (NATCA), and the OSHA Hartford, Connecticut office. On the second day, several recordings of radio and telephone communications were made at an unmanned radar position along with octave band sound levels of background noise in the control room. Additionally, interviews were conducted with ATC specialists from the day and afternoon shifts about their experiences with loud tones or static that they encountered in their job. Audio tapes of several tone incidents recorded by the FAA from the master tape of control tower communications were given to NIOSH investigators to analyze in our laboratory. Finally, an unused noise compression unit that had been purchased by the FAA to limit the sound levels transmitted to the controller's headset was given to NIOSH researchers for further analysis and characterization. Copies of the U. S. Department of Labor Log of Federal Occupational Injuries and Illnesses for Bradley TRACON and the audiometric examinations for the past three years for all controllers was requested by NIOSH and received from the FAA for analysis.

BACKGROUND

The TRACON facility at Bradley Airfield handles air traffic at Bradley International Airport (BDL) serving the Hartford, Connecticut area. The controllers are responsible for aircraft approaches to BDL 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 FAA tower relies upon head–worn microphone/receiver sets. The body of the ear piece is shaped to fit over the ear, 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 is available in six sizes that are attached to flexible tubing that is inserted into the ear. Figure 1 shows a schematic of the microphone/receiver module along with a schematic of the Tygon® tubing and the ear piece.

The concerns of the flight controllers were that the signal levels they receive from the communication system through the headset receiver were of sufficient volume to cause hearing loss from long–term use and that when the communication system became unstable and oscillated (feedback), the tone could cause instantaneous hearing loss due to its extremely high level. The FAA 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 BDL and are improperly using a headset in very close proximity to a loud speaker, and, (3) the accidental transmission of a telephone company test tone over the telephone landlines. Tones were described by employees as loud, squealing, shrieking, piercing, hissing, or shrill, and that they persisted from one second up to five minutes. In an effort to prevent the controllers from receiving high intensity speech or feedback, electronic compression units 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 and made 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 under normal conditions. A junction box was made that allowed signals going to the receiver set to also be recorded on digital audio tape (DAT; Panasonic Model SV–250). The input impedance of the DAT recorder was high so that the line signal remained at 600 ohms (Z). The DAT recorder was calibrated so that a system signal of 0 decibel volume units (dB VU; 1.0 volt rms @ 600 Z) to the receiver module was equal to –20 dB VU on the DAT. The DAT recorder has a dynamic range of 90 dB, so that it could accurately record signals ranging in levels from +20 dB VU to –70 dB VU.

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 sent to NIOSH by the FAA, complete with ear tip to the artificial ear of a head and torso simulator (KEMAR). The signals were analyzed to provide readings of integrated maximum output, integrated minimum output, and integrated average output with a real–time acoustic 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 Hertz (Hz) to 16 kilohertz (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.

Medical Evaluation

During the site visit, FAA air traffic controllers from the day shift and afternoon shift were given the opportunity to meet with a NIOSH investigator to discuss any tone incidents which they may have experienced. The unstructured interviews were conducted in a private office at Bradley Airfield. NIOSH investigators also requested that the FAA furnish copies of OSHA logs for tone incidents in 1993, 1994, and 1995. Finally, the last three years of audiometric examinations given in conjunction with their annual medical exams for all of the air traffic controllers assigned to Bradley Airfield were requested so that analyses of their hearing abilities could be conducted. These data were forwarded to NIOSH in February 1997.

EVALUATION CRITERIA

Noise–induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise–induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[1] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise–induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[2]

The A–weighted decibel [dB(A)] is the preferred unit for measuring sound levels to assess worker noise exposures. The dB(A) scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. Because the dB(A) scale is logarithmic, increases of 3 dB(A), 10 dB(A), and 20 dB(A) represent a doubling, tenfold increase, and 100–fold increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[3] specifies a maximum permissible exposure limit (PEL) of 90 dB(A) for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dB(A) for no more than 4 hours, to 100 dB(A) for 2 hours, etc. Conversely, up to 16 hours exposure to 85 dB(A) is allowed by this exchange rate. NIOSH, in its Criteria for a Recommended Standard,[4] proposed a recommended exposure limit (REL) of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. The NIOSH 1972 criteria document also used a 5 dB time/intensity trading relationship in calculating exposure limits. However, in 1995, NIOSH changed its official recommendation for an exchange rate of 5 dB to 3 dB.[5] The American Conference of Governmental Industrial Hygienists (ACGIH®) also changed its Threshold Limit Value (TLV®) in 1994 to a more protective 85 dB(A) for an 8–hour exposure, with the stipulation that a 3 dB exchange rate be used to calculate time–varying noise exposures.[6] Thus, a worker can be exposed to 85 dB(A) for 8 hours, but to no more than 88 dB(A) for 4 hours or 91 dB(A) for 2 hours.

The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

Dose = 100 X (C1/T1 + C2/T2 + ... + Cn/Tn),

where Cn indicates the total time of exposure at a specific noise level and Tn indicates the reference duration for that level as given in Table G–16a of the OSHA noise regulation.[4] During any 24–hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation has an additional action level (AL) of 85 dB(A); an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o).

Finally, the OSHA noise standard states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. However, in 1983, a compliance memorandum (CPL 2–2.35) directed OSHA compliance officers not to cite employers for lack of engineering controls until workers' TWA levels exceed 100 dB(A), so long as the company has an effective hearing conservation program in place. Even in TWA levels in excess of 100 dB(A), compliance officers are to use their discretion in issuing fines for lack of engineering controls.

The OSHA regulation is designed to prevent hearing losses from exposures to intense noise levels. However, lower intensity noise can be disruptive in the workplace. Interference with speech and disruption of office activities are possible results of unwanted noise. The noise can interfere with the efficiency and productivity of the office staff and can be detrimental to the occupants' comfort and sense of well–being. Noise criteria for occupied interior spaces (NCB curves) have been devised to limit noise to levels where satisfactory speech intelligibility is obtained.[7] 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.

The FAA has hearing requirements for its ATC specialists which are verified annually 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 the employee is unable to meet the requirements for at least one ear, then they are reviewed by the FAA medical staff on a case–by–case basis.

RESULTS

Noise 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 #13 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 which are labeled "1" as the smallest and "6" as the 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 volt at 600 Z equals 0 dB VU. As seen in Figure 2, 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 volt rms @ 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. 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.

In order 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 for the FAA to be used specifically at the Bradley 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 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 signal for which there were the most complaints was referred to as "tones" by the FAA 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 dB VU to +20 dB VU. Figure 3 shows input/output 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). 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 upon the compression setting. The result of the noise floor is to restrict the usable dynamic range of the PHP unit.

The octave–band sound levels in the controllers' work area were made during the morning of October 9, 1996. The sound energy at each octave band center frequency was integrated over a 1–minute period during normal air traffic control activities. The results are shown in Figure 4. The average (L_{eq}) octave band levels ranged from 52 to 71 dB, with the greatest energy measured at 125 Hz. When the sound levels in the work area are compared to the balanced noise criteria, the controllers' sound environment is near the NCB–60 criteria which has been designated as meeting the sound requirements for work shops and garages (Table 1).

Medical Evaluation

Both the day shift and afternoon shift at the Bradley TRACON facility were staffed by eight ATC specialists and one supervisor. NIOSH investigators were able to interview nine 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 employees' affected ear for hours in some cases and up to three 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 notes that he wears a hearing aid as a result of a tone incident.

The interviewed employees were not convinced that the noise compression circuits (black boxes) were an optimal fix for the tone problem. They reported that the black box 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 black box 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% 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 they went back to the olive–shaped earpiece.

The management at Bradley Airfield supplied NIOSH investigators with data which they had collected that documented any loud tone exposures for the calendar years 1993–1995. 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 FAA hearing requirements. 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 from the FAA for the ATC specialists at BDL. 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 1993–1996. 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 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 to 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 for the FAA 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 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 low fence average of 25 dB at the test frequencies 500, 1000, 2000, and 3000 Hz that is calculated to determine hearing impairment.[8] In order to determine if this finding was a trend for the population of controllers at Bradley Airfield, 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 5 for the 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 (s.d. = 4.2 yrs.). 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).[9] The 10th, 50th, and 90th fractiles for the population and the mean FAA data are graphed in Figure 6. 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 ANSI S12.13 percent better or worse sequential (%BW).[10] This metric uses the percent of the population which shows a 15–dB shift either toward the better hearing or the worse hearing at any test frequency in either ear between two sequential audiograms. In the audiograms that covered

1993–1994, 7.7% exceeded the %BW; for 1994–1995, 15.7% exceeded the %BW; and for 1995–1996, 18.4% of the tests exceeded the %BW. 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% 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 hearing levels at the 10 test frequencies.

DISCUSSION

The results of the noise analyses show that it is very possible that a feedback signal (tone) could drive a receiver module to its maximum output, giving the wearer a short blast at 116 dB SPL [equivalent field level of 104 dB (A)]. In order 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 deliver the monitored feedback signal to the wearer. The Personal Hearing Protector (PHP) unit that the FAA has 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 dBVU; the noise is always present and is 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 assigned to Bradley Airfield 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 who have 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 rather than 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 re–evaluation.

The ambient noise levels in the controllers' work space are high enough to interfere with communications in the area. The NCB–60 criterion is the maximum level recommended in areas where speech or telephone communication is necessary. 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 1920's when band widths 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 Bradley Airfield 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. The NIOSH REL limits worker exposure to this noise level to 6 minutes or less during the workshift. The Model 1 Personal Hearing Protector 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 by the FAA 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 assigned to Bradley Airfield 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 assigned to Bradley Airfield 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 the FAA 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 zenier diode. The zenier 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 zenier diode is immediate in response, costs little, does not require power, and does not raise the noise floor of the system. Zenier diodes are used in other

communication systems sold by AT&T and Plantonics and the FAA specifications could be written to incorporate them.

3. The narrow band width of the speech signal is also part of the problem. In order to overcome the narrow band width, 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 at Bradley Airfield are made, equipment that meets this wider bandwidth specification should be sought by the FAA.

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 work stations 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 audiometric examination service to the FAA. 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. The FAA should follow professional guidelines established to ensure that accurate and valid hearing tests are obtained during the annual medical examination given to the ATC specialists.[11]

7. The FAA should continue the practice of logging all feedback (tone) incidents that the controllers experience. This generates a written record of the problem that can be forwarded to management personnel responsible for the communication system and show how any corrections to the system and equipment affect future noise exposures to the employees.

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TABLE 1

Recommended Space Usage for Balance Noise Criteria Range
in Occupied Indoor Areas

Bradley Airfield
Windsor Locks, Connecticut
HETA 96–0184

Type of Space and Acoustical Requirements	NCB Curve
Concert halls, opera houses, and recital halls	10 – 15
Large auditoriums, 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 semiprivate 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*
Work spaces where speech or telephone communication is not required	55 – 70

* Levels above NCB–60 are not recommended for any office or communication situation.

Figure 1

Diagram of AT&T microphone/receiver ear piece and tubing/ear tip assembly.

Bradley Airfield
Windsor Locks, Connecticut
HETA 96–0184

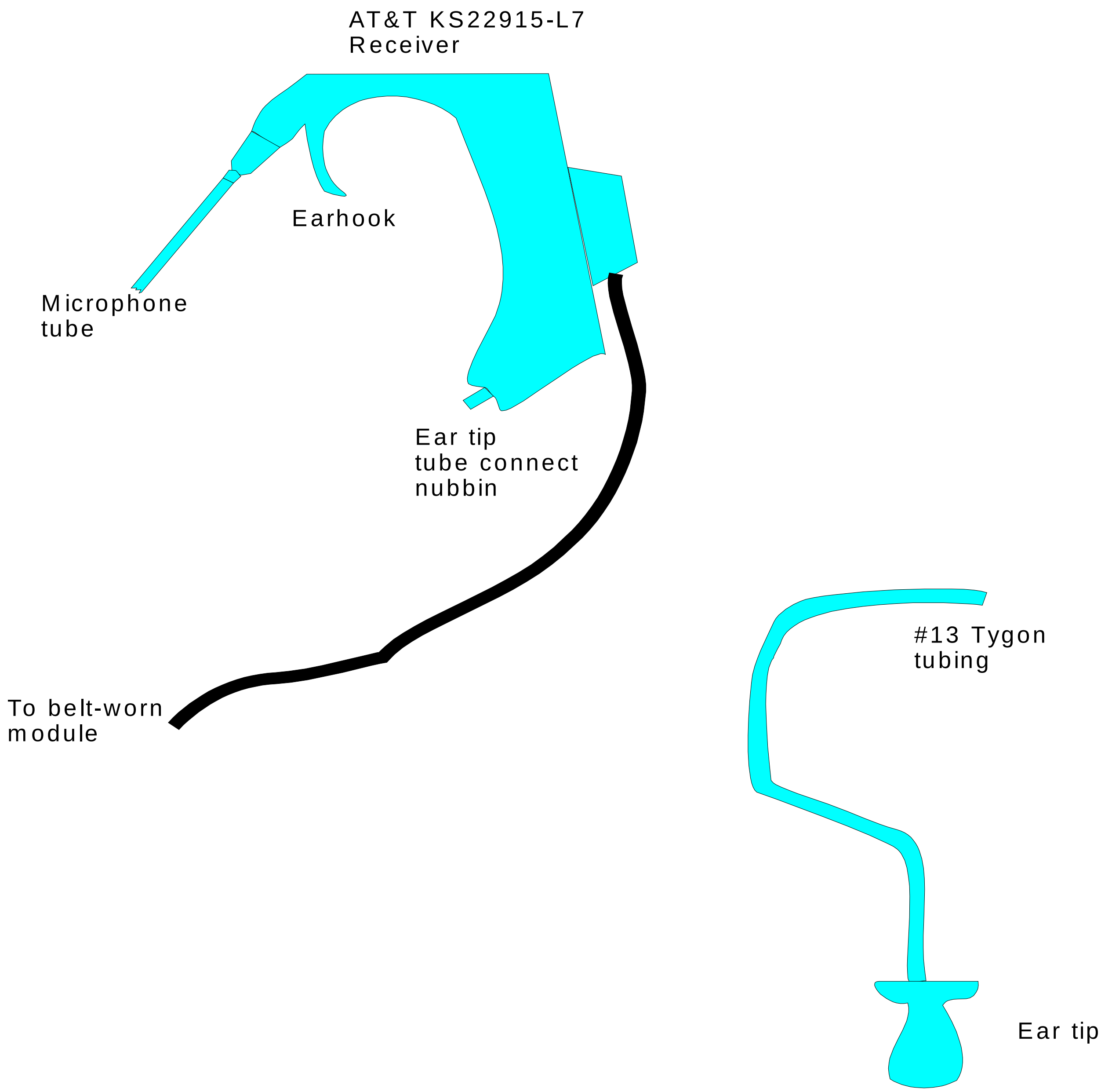

Figure 2

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 plane of artificial eardrum.

Bradley Airfield
Windsor Locks, Connecticut
HETA 96–0184

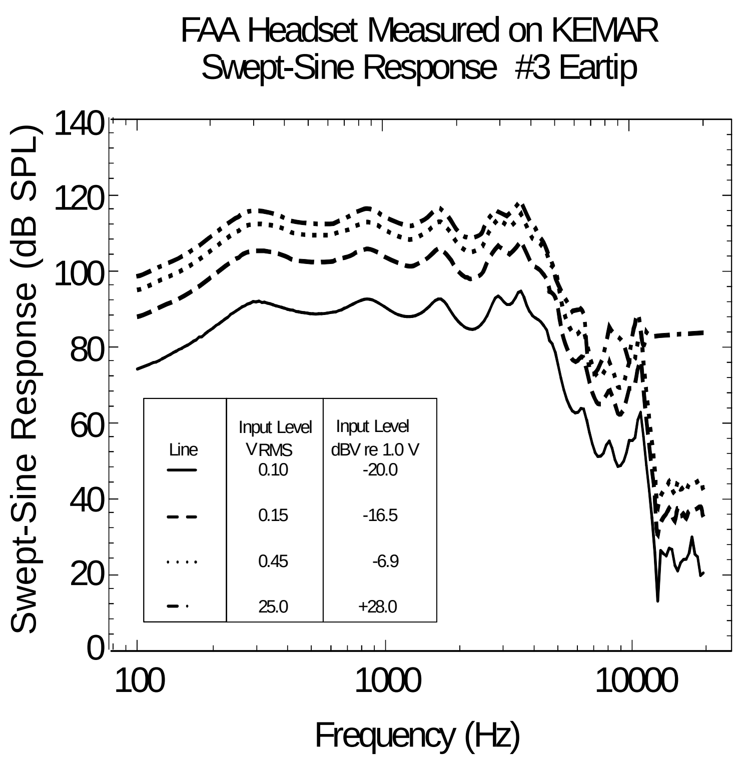

Figure 3

Input/Output (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 function for a non–compressed system with linear gain.

Bradley Airfield
Windsor Locks, Connecticut
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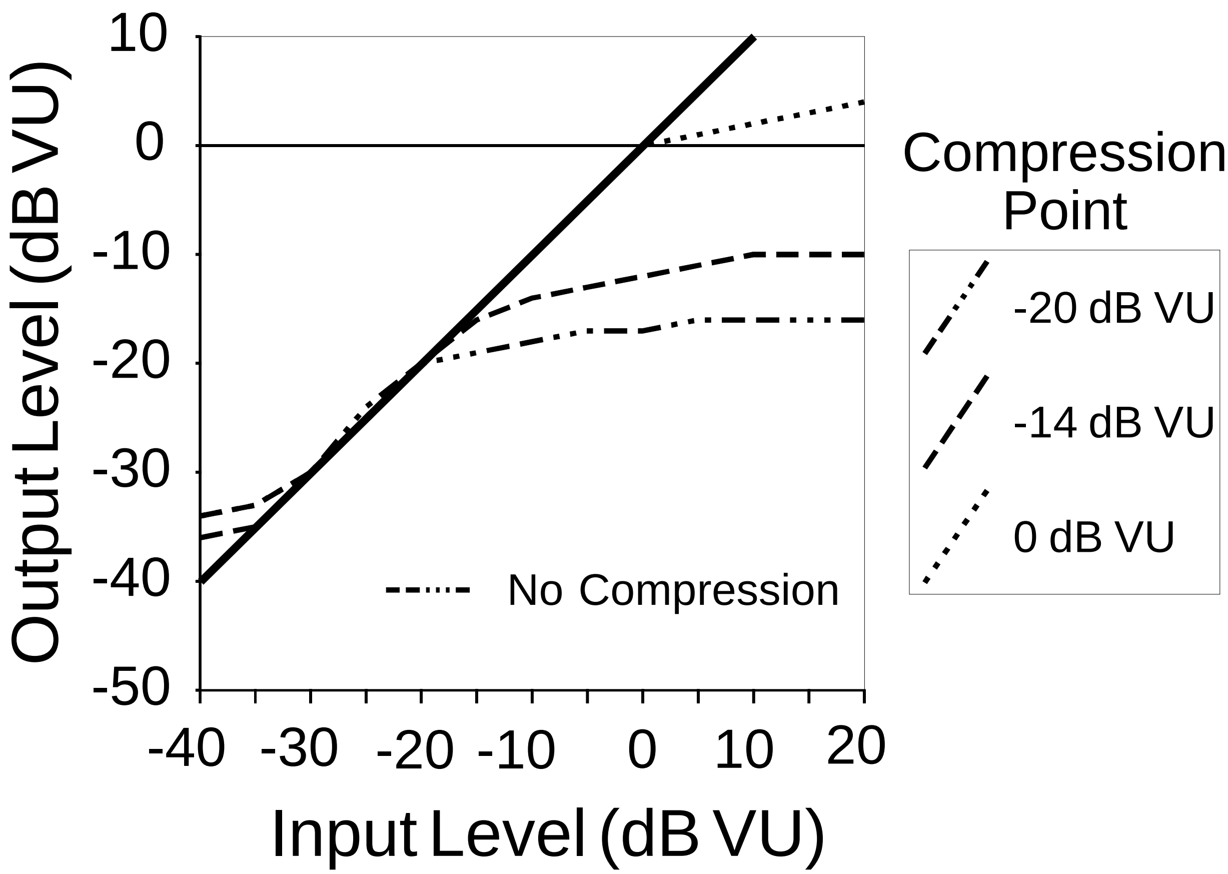

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