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The Crown
U.S. Hot Rod Monster Truck and Motocross Show
Cincinnati, Ohio

J. Clinton Morley, M.S.
Teresa A. Seitz, M.P.H., C.I.H.
Randy L. Tubbs, Ph.D.

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Clint Morley, Teresa Seitz, and Randy Tubbs, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Ron Hall, Mike King, Greg Kinnes, Rob McCleery, Dino Mattorano, and Kevin Roegner. Analytical support was provided by Ardith Grote. Desktop publishing was performed by Ellen Blythe. Review and preparation for printing was performed by Penny Arthur.

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SUMMARY

In response to a request from Nederlander Arena Management, National Institute for Occupational Safety and Health (NIOSH) investigators conducted a health hazard evaluation (HHE) at the Crown Coliseum during the U.S. Hot Rod Monster Truck and Motocross Show in Cincinnati, Ohio. NIOSH investigators conducted personal and area air monitoring on January 23 and 24, 1998, to evaluate exposures to carbon monoxide (CO) and volatile organic compounds (VOCs), and to measure noise levels.

Personal monitoring was conducted on two ushers and two security personnel during each show. The monitoring was conducted over the course of the 4-hour work shifts. Monitoring was also conducted to assess typical crowd exposures to CO and noise during the 2 ¼ hour shows. The monster trucks burn methanol and do not have exhaust suppression systems, while the motorcycles burn a mixture of high octane gasoline and racing engine oil and are equipped with exhaust suppression systems and noise silencers.

Peak concentrations of CO exceeded the NIOSH ceiling concentration of 200 parts per million (ppm) in two of the eight personal air samples. The sample collected on a roaming security guard had one isolated peak at 340 ppm; the sample collected on an usher in the west elephant gate area recorded 13 peaks in excess of the NIOSH criterion. The CO concentrations ranged from 22 to 49 ppm when averaged over the course of the approximately 4-hour sampling period. When averaged over the course of a typical 8-hour work day (assuming no CO exposure for the non-sampled period), the CO concentrations ranged from 12 to 24 ppm. None of the personal air samples exceeded the NIOSH 8-hour time-weighted average (TWA) Recommended Exposure Limit (REL) of 35 ppm; however, the sample collected on the usher in the west elephant gate (24 ppm) was near the American Conference of Governmental Industrial Hygienists (ACGIH®) 8-hour TWA Threshold Limit Value (TLV®) of 25 ppm.

The Occupational Safety and Health Administration (OSHA) action level for implementing a hearing conservation program was exceeded in all but one instance for the four employees surveyed, and the NIOSH REL for noise was always exceeded. It is difficult to predict what the average noise exposure is for these employees. Although monster truck shows are not held routinely at this facility, employees may be exposed to high levels of noise at other events such as rock concerts and hockey games, and to substantial levels of noise from the crowds as was seen during this survey.

The spectators at the monster truck show were exposed to average noise levels from 95 to 100 dB(A) and to short-term CO concentrations exceeding the Cincinnati Safety Department's criterion and other health-based criteria intended to protect members of the general public.

The NIOSH evaluation found that some of the employees were exposed to carbon monoxide concentrations exceeding the NIOSH ceiling criterion, but below the 8-hour TWA-REL. Monster truck shows are not routine events; thus, prevention of acute effects in workers resulting from short-term CO exposures is of primary concern in this situation. The NIOSH REL for noise was always exceeded for these workers on both days, and in all but one case, the OSHA action level for hearing conservation program implementation was exceeded. Recommendations are made to minimize CO and noise exposures to workers and spectators through use of engineering and administrative controls, and in the case of noise exposures, through use of hearing protection devices. Recommendations are also made for additional CO and noise monitoring, as well as for employee training and public education and awareness about noise and carbon monoxide exposures.

Keywords: SIC 7999 (Amusement and Recreation Services, Not Elsewhere Classified), monster truck, motocross, carbon monoxide, CO, noise, exhaust, internal combustion engine, coliseum.

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INTRODUCTION

On January 16, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at The Crown Coliseum, Cincinnati, Ohio, from a representative of Nederlander Arena Management. The request asked NIOSH to assess carbon monoxide (CO) levels within the arena during the U.S. Hot Rod Monster Truck and Motocross Show on the evenings of January 23 and 24, 1998. NIOSH investigators conducted personal and area air monitoring during both shows to evaluate air concentrations of carbon monoxide, formaldehyde, and volatile organic compounds, as well as to measure noise levels.

BACKGROUND

The Crown Coliseum has a seating capacity of 12,000 for the monster truck and motocross show. Five monster trucks participated in the show on both nights. The monster trucks burn methanol and do not have exhaust suppression systems. The motorcycles burn 100+ octane gasoline with two-cycle, racing engine oil mixed at a 32:1 ratio. The motorcycles have exhaust suppression systems equipped with silencers to reduce noise and exhaust emissions. The shows started at 8:00 p.m. and lasted until approximately 10:15 p.m., with a 15 minute intermission.

The Crown management indicated that the arena is ventilated by four exhaust fans on the ground level, each rated at 30,000 cubic feet per minute (CFM), and four exhaust fans at the catwalk level, each rated at 22,000 CFM. The four ground-level fans located on the east and west ends of the arena (two on each side) draw air through their respective "elephant" gates and exhaust it outside. The four catwalk level exhaust fans are located in the top corners of The Crown. One exhaust fan, located directly above sections 236 and 237 in the northwest corner of the arena, was not operating. Twelve air handling units (AHUs) located at the catwalk level, each rated at 22,000 CFM, and four AHUs at the concourse level, each rated at 8,000 CFM, provide supply air to the facility. The AHUs are equally spaced to provide uniform supply ventilation throughout the arena. These AHUs were designed to use 30-70% recirculated air, depending upon the inside and outside air temperatures. NIOSH investigators were informed that the set points of the AHUs would be overridden to provide 100% outside air during the monster truck event. Ten downdraft fans, each rated at 10,000 CFM are mounted on the catwalk rafters directly above the floor of the arena.

Assuming that all operable fans were running at maximum capacity, the ventilation system could provide 296,000 CFM of supply air and exhaust 208,000 CFM of air to the outside. However, one exhaust fan was out of service, so the maximum amount of exhaust air was 186,000 CFM. If all fans are operating at maximum capacity, the arena is under positive pressure. Considering an arena volume of 6 million cubic feet and an exhaust air flow rate of 186,000 CFM, the estimated air change rate in the coliseum (assuming perfect air mixing) was approximately two air changes per hour (ACH). The calculation could also be done using the volume of supply air, for a total air change rate of approximately three ACH.

METHODS

Carbon Monoxide

Four Nederlander Arena Management employees wore Toxilog Atmospheric Monitors (Biosystems Inc., Middlefield, CT) with CO sensors during the shows on January 23 and 24, 1998. Four additional Toxilog CO monitors were used during each show to assess spectator exposures. Four NIOSH investigators were positioned in general crowd areas around the arena. For short time periods (generally less than 15 minutes), the NIOSH investigators moved around the arena wearing the CO monitors to simulate what might occur when spectators left their seats to obtain refreshments or take breaks. The Toxilog monitors were calibrated in the laboratory

according to the manufacturer's recommendations prior to use in the field.

The Toxilog monitors are direct-reading instruments with data logging capabilities. The instruments were operated in the passive diffusion mode, with a one-minute sample interval. As configured, the monitors store the maximum CO concentration detected during the one-minute sampling interval (approximately two measurements are made per second) and this concentration is used in calculating time-weighted average (TWA) and short term exposure limit (STEL) concentrations. The monitors provide an 8-hour TWA concentration by taking the sum of the one minute CO concentrations and dividing this value by 480 (the number of minutes in 8 hours). Thus, for sampling periods less than 8 hours, zero exposure is assumed for the non-sampled time period. NIOSH investigators calculated one-hour TWAs for the time periods 8:14 p.m. to 9:14 p.m. and 9:15 p.m. to 10:15 p.m. by taking the sum of the one minute CO readings during the time interval and dividing this value by 60. The monitors also provide 15-minute STEL concentrations which are running averages; that is, after the first 15 CO concentrations are stored, a 15-minute STEL is calculated from the average of these values, and every minute thereafter, a new STEL is calculated considering the 15 most recent measurements (i.e., the first measurement drops out). The stored data was downloaded to a personal computer using the manufacturer's software and then converted to a Microsoft Excel file for graphical presentation of the data.

Noise

Quest® Electronics Model M-27 Noise Logging Dosimeters were worn by four Nederlander Arena Management employees on January 23 and January 24, 1998. The noise dosimeters were attached to the wearer's belt and a small remote microphone was fastened to the wearer's shirt at a mid-way point between the ear and the outside of the employee's shoulder. Four additional noise dosimeters were used during each show to assess spectator exposures to noise as described above for the CO monitors. The four NIOSH investigators responsible for the CO monitors were also responsible for the noise dosimeters. At the end of the show, the dosimeters were removed and paused to stop data collection. The information was downloaded to a personal computer for interpretation with QuestSuite computer software. The dosimeters were calibrated before and after the show according to the manufacturer's instructions.

Formaldehyde

Five area air samples for formaldehyde were collected on silica gel cartridges coated with 2,4–dinitrophenylhydrazine. Formaldehyde and other volatile organic compounds are possible fuel combustion products. The air samples were analyzed in accordance with NIOSH Method 2016 (with modifications).[1] However, results of the analysis of two field blanks submitted along with the samples revealed unexpectedly high concentrations of formaldehyde. Thus, the analytical results for the air samples cannot be reported with confidence and are not included in this report.

VOCs

Three area air samples for volatile organic compounds (VOCs) were collected during each show using thermal desorption tubes containing three beds of sorbent materials (Carbopack Y, Carbopack B, and Carboxen 1003). On the 23rd, two thermal tube samples were collected inside the arena on the lower level and one thermal tube sample was collected in the vending corridor surrounding the arena on the concourse level. On the 24th, two thermal tube samples were collected inside the arena on the lower level and one thermal tube sample was collected in the arena on the upper level.

Air samples for VOC analysis were collected at a flow rate of 0.05 liters per minute. The samples were thermally desorbed and analyzed using a gas chromatograph equipped with a mass selective detector in accordance with NIOSH method 2549.[1] This screening method allows for the identification

of VOCs present in very small quantities (generally the parts per billion range); however, it does not provide quantitative results.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Carbon Monoxide

CO is a colorless, odorless, tasteless gas that can be a product of incomplete combustion of organic materials, including fuels. Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with hemoglobin. Blood has an estimated 210–250 times greater affinity for CO than oxygen, thus the presence of CO in the blood can interfere with oxygen uptake and delivery to the body. Once absorbed into the bloodstream, the half–life of CO is approximately 5 hours.

Symptoms of acute CO poisoning include headaches, rapid breathing, nausea, weakness, dizziness, and confusion.[5] If the exposure level is high, loss of consciousness may occur without other symptoms. Death may result from depression of the functions of the brain, or if there is underlying coronary artery disease, from heart attacks. Because CO remains in the blood for several days, there may be a gradual increase in body levels of CO over the course of a work week.

Many epidemiologic studies have been conducted to evaluate the long term health effects associated with exposures to low concentrations of CO. Of particular concern is the suspected relationship between CO and arteriosclerotic heart disease, cardiovascular disease (CVD), and ischemic heart

disease (IHD). Some studies have shown a correlation between occupational exposure to CO and arteriosclerotic heart disease mortality.[6,7] Although there is evidence in the literature of an association between CVD and occupational CO exposure, an epidemiologic review of the literature in 1989 concluded that there is still need for further and better review of this issue before a conclusive statement can be made.[8] A 1994 study of CVD among foundry workers indicated that exposure to CO increased the risk of CVD morbidity and mortality. This was primarily attributed to increases in IHD.[9] Although some studies do show an association between CVD and CO exposure, the scientific community continues to be divided on this issue, and further research continues.

The etiology of CVD from occupational exposure to CO is not fully understood; however, some studies have shown that the development of arteriosclerosis and coronary lipid deposition can be enhanced by arterial hypoxia.[10,11] CO exposure can induce partial arterial hypoxia, depending upon the level and duration of exposure.

The body compensates for hypoxic stress due to CO exposure by increasing cardiac output, thereby increasing blood flow to specific oxygen–demanding organs (the brain, the heart). This ability may be limited by pre–existing heart or respiratory diseases that inhibit increased cardiac output. Of particular concern is the pregnant worker, whose endogenous carboxyhemoglobin level can be elevated three fold[12] and whose oxygen consumption is 15–25% higher than normal. Additionally, the mother's blood may have 20–30% reduced oxygen carrying capacity due to lower hemoglobin levels.[13] Exposure to CO can increase the carboxyhemoglobin level in the fetus's blood above the endogenous levels. Additionally, the developing fetus does not have the ability to compensate for hypoxia through increases in cardiac output.[12] A well–established relationship exists between smoking and low fetal birth weight; CO is suspected to be one of the primary causes.

Occupational Exposure Criteria

In 1972, NIOSH published a criteria document recommending that occupational exposures to CO be maintained to a level that will not induce an increase in carboxyhemoglobin level greater than 5%.[14] NIOSH established an REL for CO of 35 ppm as a TWA for up to an 8–hour workday, and a ceiling concentration of 200 ppm which should not be exceeded at any time during the workday. The NIOSH criteria were established to prevent acute CO poisoning, protect against harmful myocardial alterations from carboxyhemoglobin levels in excess of 5%, and to protect against adverse behavioral effects from exposure to low levels of CO.

The current OSHA PEL for CO is 50 ppm as an 8–hour TWA.[4] In 1996, ACGIH revised its TLV for CO to 25 ppm as an 8-hour TWA.[15] ACGIH recommends that occupational exposure to CO be based upon exposure levels that will maintain shifts in blood carboxyhemoglobin levels to less than 3.5%. This 3.5% carboxyhemoglobin criteria was established "to minimize adverse neurobehavioral changes, and to maintain cardiovascular exercise capacity."[15] The ACGIH recommendation also provides "a margin of safety for individuals particularly susceptible to the adverse effects of CO exposure, including pregnant workers (i.e., the fetus) and those with chronic heart and respiratory disease."[15]

Other Health Criteria

Because individuals in the general population may have physical impairments that interfere with normal oxygen delivery to the tissues (e.g., emphysema, anemia, coronary artery disease), the occupational exposure limits noted above should not be used for interpreting general population exposures since they would not provide the same degree of protection as they do for the healthy worker population.

The Cincinnati Safety Department requires a pubic assembly permit for indoor events where internal combustion engines are used. This permit specifies that CO levels will be maintained below a 15-minute

TWA-STEL of 35 ppm, and a ceiling concentration of 200 ppm CO for any two consecutive samples.[16] The permit specifies that CO measurements are to be made every five minutes until the facility has been vacated. If concentrations exceed the 35 ppm TWA, then readings shall be taken at 2.5 minute intervals and mitigation measures shall be implemented until levels drop below 35 ppm. The CO exposure criteria specified in the permit were developed by a consensus committee that included physicians and toxicologists from the University of Cincinnati College of Medicine, staff of the Cincinnati Health Department, staff of the Cincinnati Safety Department, and former Coliseum management. The intent was to protect members of the general public who attend indoor sporting events where internal combustion engines are used.

The Environmental Protection Agency (EPA) has promulgated a National Ambient Air Quality Standard (NAAQS) for CO. This standard requires that ambient air contain no more than 9 ppm for an 8-hour average, and 35 ppm for a 1-hour average.[17] The NAAQS for CO was established to protect "the most sensitive members of the general population (i.e., individuals with ischemic heart disease)"[17] by maintaining increases in carboxyhemoglobin to less than 2.1%. Ambient air is defined by the EPA as outside air; however, due to the unique nature of this event, where the exposed population includes the general public, the NAAQS is an appropriate guideline.

CO limits in residential indoor air have been established in Canada. These limits include acceptable short-term exposure ranges (ASTERs) for CO of $\leq$25 ppm as a 1-hour average, and $\leq$11 ppm as an 8-hour average.[18] These guidelines were established to prevent increases in carboxyhemoglobin levels greater than 1.5%, to protect sensitive individuals, such as those with cardiovascular, cerebrovascular, and peripheral vascular diseases, fetuses, the newborn, pregnant women, and individuals living at high altitude.[18]

Noise

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.[19] 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 Hertz (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.[20]

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

$$\text{Dose} = 100 \text{ X } (C1/T1 + C2/T2 + ... + C_n/T_n),$$

where C_n indicates the total time of exposure at a specific noise level and T_n indicates the reference duration for that level as given in Table G-16a of the OSHA noise regulation. 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.

NIOSH, in its Criteria for a Recommended Standard,[22] and the ACGIH,[3] propose exposure criteria of 85 dB(A) as a TWA for 8 hours, 5 dB less than the OSHA standard. The criteria also use a more conservative 3 dB time/intensity trading relationship in calculating exposure limits. 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.

RESULTS

Carbon Monoxide

Employee Exposures

Personal CO monitoring was conducted on two ushers and two security guards on January 23 and 24, 1998. A summary of the CO exposure data is presented in Table 1; the data are graphically displayed in Figures 1 through 8.

On January 23, peak exposures to CO exceeded the NIOSH ceiling concentration of 200 ppm in personal breathing zone air samples collected on a roaming security guard and an usher. The 340 ppm CO peak recorded by the monitor on the roaming security guard (Figure 7) was an isolated event that occurred between 10:05 and 10:15 p.m, the time of the championship monster truck event. As shown in Figure 1, the monitor on the usher working at the west elephant gate recorded 13 peaks exceeding 200 ppm. There were five periods in which these peaks were recorded, ranging in duration from about 2 to 6 minutes.

As shown in Table 1, the maximum 15-minute STELs recorded by the personal CO monitors ranged from 57 to 156 ppm. NIOSH, OSHA, and ACGIH have not established STEL criteria for occupational CO exposures. CO concentrations expressed as TWAs over the sampling period ranged from 22 to 49 ppm. When averaged over the course of a typical 8-hour work shift (assuming no CO exposure for the non-sampled period), the CO concentrations ranged from 12 to 24 ppm. While none of the 8-hour TWAs exceeded the applicable occupational exposure limits, the sample obtained on the usher in the west elephant gate on the 23rd had a concentration of 24 ppm, just slightly below the 25 ppm TWA established by ACGIH.

Although the personal breathing zone air samples were not collected for the purpose of monitoring compliance with the Cincinnati Safety Department permit (which specifies that monitoring be conducted in a specific area and in a particular manner), Figure 1 indicates that the sample collected on the usher in the west elephant gate would exceed the peak CO criterion of 200 ppm (for two consecutive samples). In addition, as shown in Table 1 and Figures 1 through 8, the Cincinnati Safety Department 15-minute STEL criterion for CO would be exceeded in all personal air samples.

A separate CO measurement was taken behind an idling monster truck whose engine was revved. The peak CO concentration was 678 ppm, with an ensuing 15-minute STEL of 112 ppm. This indicates that employees working close to the Monster Trucks or conducting maintenance, repair, etc. can be exposed to high peak and short term concentrations of CO.

Crowd Exposures

One of the CO monitors malfunctioned on the 23rd and 24th; therefore, data were obtained from only three of the four crowd samples on each night, for a total of six CO monitoring events. A summary of the CO exposure data is presented in Table 2; the data are graphically displayed in Figures 9 through 14.

Although the crowd air samples were not collected for the purpose of monitoring compliance with the Cincinnati Safety Department permit, Figure 13 indicates that the crowd sample collected in the west lower level on January 24 recorded consecutive CO peaks exceeding the 200 ppm peak exposure criterion. There were no peak exposures greater than 200 ppm on the 24th. In addition, as shown in Table 2 and Figures 9 through 14, the 15-minute STEL criterion for CO of 35 ppm would be exceeded in all crowd air samples. Table 2 lists the maximum STEL recorded during each sampling period.

The one-minute CO peaks were averaged over the one hour period from 8:14 p.m. to 9:14 p.m. and from 9:15 p.m. to 10:15 p.m. for comparison with the EPA NAAQS. The 35 ppm 1-hour TWA criterion was exceeded in all six CO spectator samples. Although not shown in Table 2, the EPA NAAQS of 9 ppm as an 8-hour TWA would be exceeded in all CO samples.

Noise

Employee Exposures

Noise dosimeters were worn by two ushers and two security personnel on January 23 and 24, 1998. The meters were placed on the employees generally 60 to 90 minutes before the beginning of the show (8:00 p.m.), and they wore them until 10:30 - 11:00 p.m., when the meters were paused and the data transferred to a computer. The results of the noise dosimeter survey are shown in Figures 15-22. The employees were exposed to average noise levels during the show that ranged from 88 to 94 dB(A) when analyzed with a 5-dB exchange rate. When the data were averaged with a 3-dB exchange rate, the noise levels ranged from 94 to 99 dB(A) (Table 3). If one compares the employees' noise exposures to the OSHA and NIOSH noise criteria, then the sampling period must be extended to a full eight hours and the noise exposure during the extension must be assumed to be effectively quiet. Table 3 shows these comparisons in the columns labeled TWA. While the OSHA noise PEL was not exceeded for any employee, in all but one instance, the values exceed the OSHA AL for hearing conservation program implementation. The NIOSH REL was always exceeded for these workers on both survey days.

The employees were subjected to short periods of relatively high noise exposures each evening. The figures show that these high exposures would occur 5 - 7 times during the show. It should be noted that the individual values plotted on the graphs are the result of a one-minute integration of sound levels measured 16 times per second. The maximum dB(A), slow-response values reported in Table 3 are the highest individual readings captured for use in

this integration. Even before the show began, the employees were exposed to crowd noise of 85 - 90 dB(A), which adds to their overall noise dose.

Crowd Exposures

Four additional noise dosimeters were used by NIOSH investigators on each of the survey nights in an attempt to simulate the noise exposures experienced by spectators attending the show. The results of these measurements are given in Table 4. Since the people who pay to watch the monster truck show are not employees, only the average noise exposures measured from one-half hour before to the end of the show are reported for the two different exchange rates. The values for the crowd areas ranged from 92 to 95 dB(A), and from 97 to 100 dB(A), when calculated according to a 5 dB and 3 dB exchange rate, respectively. The maximum dB(A), slow-response measurements were also high, exceeding 120 dB(A) in all cases.

Volatile Organic Compounds

The major compounds identified in the area VOC samples were methanol, ethanol, acetonitrile, toluene, isooctane, xylene, butane, and pentanes. Other compounds identified included formaldehyde, C_3-C_{15} alkanes, trimethylbenzenes, perchloroethylene, siloxanes, and traces of acrolein. A comparison of the chromatograms from samples collected in the different areas and on the two days of sampling did not reveal any significant qualitative differences. Many of the substances identified are either products of fuel combustion or components of the fuels.

Ventilation

The ventilation conditions in the arena were different on January 23 and 24. On the 23rd, the 10 downdraft fans were not used. Additionally, the 16 AHUs reportedly recirculated 50% of the air until approximately 9:00 p.m., at which time it was recognized that the initial steps taken to provide 100% outside air were not sufficient. NIOSH investigators were later informed that at approximately 9:00 p.m. the computer set points were overridden and the 16 AHUs were providing 100% outside air.

On the 23rd, at approximately 8:53 p.m., CO levels were sufficiently high that the Cincinnati Division of Fire required that arena managers pursue CO abatement measures. The concourse level doors were opened on both ends of the arena, and an 8-minute break from racing was taken at this time. The final monster truck race occurred from 9:00 until 9:05 p.m., at which time the first half of the show was completed and the 15-minute intermission began. During the intermission, the concourse level doors were left open and the CO concentration in the arena decreased substantially. This decrease in CO concentration is apparent in Figure 1. At 9:20 p.m., the show resumed and the concourse level doors were left open until about 9:43 p.m. At 9:49 p.m., CO levels were again sufficiently high that the Cincinnati Division of Fire required arena managers to take CO abatement measures. A 15-minute break from vehicle operations was taken at this time. By 10:04 p.m. the CO levels had decreased, and the final monster truck race began.

On the 24th, the 10 downdraft fans located directly above the arena floor were turned on to help prevent hot vehicle exhaust from rising to the top of the arena. Additionally, the 16 AHUs that supply air to the arena were reportedly supplying 100% outside air during the entire event. The concourse level doors remained closed throughout the event, and no unscheduled breaks were taken.

DISCUSSION AND CONCLUSIONS

CO concentrations exceeded the NIOSH ceiling REL in two of the eight air samples collected on the ushers and security guards. Both of these samples were collected on January 23, 1998. For the roaming security guard, the elevated CO concentration was an isolated event, but for the usher in the west elephant

gate, 13 CO peaks exceeding the 200 ppm criterion were recorded. The maximum 15-minute STELs were generally higher on the 23rd than the 24th. However, when averaged over the course of the sampling period, the mean CO concentrations for the four employee samples were 32 ppm on the 23rd and 30 ppm on the 24th. None of the air samples exceeded the 8-hr TWA criteria established by NIOSH, OSHA, and ACGIH. However, the air sample obtained on the usher had an 8-hour TWA of 24 ppm, just slightly below the ACGIH TLV of 25 ppm. It should be noted, however, that employees would not be exposed to such CO concentrations on a daily basis since monster truck shows and other events where internal combustion engines are present are not routine events. Therefore, prevention of acute effects in workers resulting from short-term CO exposures is of primary concern.

Despite the use of downdraft fans and provision of 100% outside air during the entire show on January 24 (as compared with only part of the show on the 23rd), all of the samples had 15-minute STEL concentrations exceeding the Cincinnati Safety Department criterion of 35 ppm. In addition, even when averaged over the course of 1 hour, the average CO concentrations exceed 35 ppm. Thus, these concentrations also exceed the EPA ambient air quality criterion for CO and the Canadian residential indoor air quality guideline. While the EPA and Health Canada criteria are not enforceable in this situation, they are mentioned because, like the Cincinnati Safety Department criteria, they were developed to protect members of the general public from the deleterious effects of short-term CO exposures. Members of the public who may be at greater risk include pregnant women (and fetuses), persons with chronic heart and respiratory diseases, and individuals with anemia.

Noise exposure to both employees and spectators at The Crown was relatively high during the performances. The OSHA AL for hearing conservation was exceeded in all but one instance for the four employees surveyed, and the NIOSH REL was always exceeded. However, the work shift of these employees is somewhat unique. The time that the ushers and security personnel spent at the monster truck show was much less than the typical 8-hour workday. Their day was closer to four hours. Also, The Crown does not book monster truck shows five days a week, 52 weeks a year. There are other sporting events, concerts, and product shows that have very different noise exposures associated with them. Thus, it is difficult to predict, based on one 2-day event, what the average noise exposure is for these employees.

Even though employees do not have typical noise days, Nederlander Arena Management should be aware of the high noise exposures associated with the different kinds of entertainment that is presented at this venue. It is well known that rock concerts produce high levels of noise. The horn that sounds when a goal is scored by the home team at the hockey games is also a source of loud noise exposure to the employees. The crowds themselves also generate substantial levels of noise, as evidenced in the dosimeter results reported in this evaluation. Nederlander Arena Management needs to document all of the workers' noise exposures in order to make informed decisions on the kinds of hearing conservation programs that should be offered to their employees.

From a public health perspective, Nederlander Arena Management and local public health agencies should evaluate their responsibility in informing and educating the public about the potential noise and CO exposures that they could encounter during the time spent at events. The crowds at the monster truck show were found to be exposed to average noise levels from 95 to 100 dB(A), depending on the exchange rate used to calculate the exposures, and to short-term CO concentrations exceeding limits intended to protect members of the general public. In addition, research has shown that simultaneous exposure to CO can increase the harmful effects of noise.[23,24,25] Controlling noise at the source, making hearing protection devices available, and providing educational materials about noise, CO, and their adverse effects are measures that Nederlander Arena Management and public health agencies should consider.

RECOMMENDATIONS

Based on the measurements and observations made during the evaluation, NIOSH investigators offer the following recommendations to reduce exposures to employees and the public at The Crown.

1. Carbon monoxide exposures of workers and spectators should be reduced. Nederlander Arena Management should explore options for reducing CO exposures, including the use of engineering controls (such as increased ventilation and/or the reduction of CO emissions through engine tuning or emission control devices), and administrative controls (such as increasing the number and/or length of breaks, and changing the schedule of the events to take advantage of more favorable outdoor air temperatures that would allow the possible use of natural ventilation to supplement the mechanical ventilation system).

2. Strict adherence to the Cincinnati Safety Department permit should be enforced. Although CO concentrations exceeding those specified in the permit were exceeded on both nights of the show, appropriate interventions were not always taken.

3. Additional CO monitoring beyond that required by the Cincinnati Safety Department permit should be performed during future events to confirm that interventions used to reduce CO levels in The Crown are effective. The permit requires limited monitoring in a designated area. As shown in this report, CO concentrations can vary considerably, depending on the location of the sampler. The use of additional CO monitors to document conditions in several areas throughout the arena would help assure that representative areas are covered.

4. Employees should be educated about the health effects associated with exposure to CO and noise and should be made aware of their role in minimizing such exposures. They should also be informed about management efforts being made to reduce CO and noise exposures.

5. More noise monitoring is needed for the employees of Nederlander Arena Management. This evaluation has shown that noise overexposures can occur for this type of event. Other events may also involve high noise levels. Both the 8-hour TWA criteria and the actual noise levels for those events need to be documented. This becomes very important if employees work additional hours for Nederlander Arena Management at The Crown or other jobs where noise may be a concern.

6. If it is determined that Nederlander Arena Management employees are exposed to several events where noise is a problem, management should implement a hearing conservation program that at least meets the requirements of the OSHA hearing conservation amendment (29 CFR 1910.95).[21] Other sources for defining effective hearing conservation programs are also available.[26,27,28]

7. If the noise exposure assessment indicates that hearing protection devices are warranted for employees, then some of the newer devices on the market should be investigated. For employees who must hear communication signals as part of their job, there are linear ear plugs available that distort these sounds less than ordinary ear plugs. For individuals who must stay in contact with others through radio communications, there are custom ear mold speakers that reduce background noise and, using compression circuitry, do not allow radio signals to exceed pre-set sound levels. For events like this monster truck show, employees should be wearing some type of hearing protection device.

8. Public education and awareness about noise, CO, and their combined effects should be made available to the audience and to the potential audience. The use of one-page fliers, information booths on the mezzanine level, and public address announcements before the beginning of the event can be used to inform those attending the event so that they are able to make informed decisions about their risks of possible health effects. Because this may be too late for those who have already purchased tickets to make such a decision, consideration should also be

given to providing such information in announcements and advertising, and by ticket sellers.

9. Hearing protection devices should be made available to the audience if they choose to wear them. Users should also be informed that the fitting instructions are printed on the packaging of the devices. Nederlander Arena Management may also want to make available persons who are competent in training people on how to properly fit hearing protectors.

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Table 1
Carbon Monoxide Concentrations in Personal Breathing Zone Air Samples
U.S. Hot Rod Monster Truck and Motocross Show at The Crown
Cincinnati, Ohio
HETA 98–0093

Personnel & Location	Sampling Date	Sampling Time (min)‡	Carbon Monoxide Concentration (ppm)			
			Peak	Max STEL	TWA sampling period	TWA 8-hr†
Usher West Elephant Gate	1/23/98	236	327	156	49	24
	1/24/98	220	159	80	34	16
Usher East Concourse Level	1/23/98	229	71	61	28	13
	1/24/98	218	85	60	28	13
Security North Concourse Level	1/23/98	272	172	57	22	12
	1/24/98	236	92	65	27	13
Security Roamer	1/23/98	257	340	94	31	16
	1/24/98	242	77	64	29	15

Evaluation Criteria		Carbon Monoxide Concentration (ppm)			
		Ceiling	STEL	TWA	8-hr TWA
Occupational Exposures:	NIOSH REL	200	NA	NA	35
	OSHA PEL	NA	NA	NA	50
	ACGIH TLV	NA	NA	NA	25
Other:	Cincinnati Safety Department	200/2 cs	35	NA	NA

Notes:

ppm	parts per million
Peak	Highest concentration of CO recorded during the show.
Max STEL	Maximum 15-minute Short Term Exposure Limit recorded during the show.
TWA	Time Weighted Average
NA	Not Applicable
cs	consecutive samples
‡	The show began at 8:00 p.m., the first trucks began racing about 8:15 p.m., the show ended around 10:15 p.m.
†	The 8-hr TWA assumes no carbon monoxide exposure for the non-sampled period (approximately 4 hours).

Table 2
Spectator Exposures to Carbon Monoxide
U.S. Hot Rod Monster Truck and Motocross Show at The Crown
Cincinnati, Ohio
HETA 98–0093

Location	Sampling Date	Carbon Monoxide Concentration (ppm)			
		Peak	Maximum STEL	1-hour TWA ‡ 8:14 - 9:14 p.m.	1-hour TWA 9:15 - 10:15 p.m.
Crowd East Lower Level Seating	1/23/98	87	66	49	46
	1/24/98	75	65	42	47
Crowd North Lower Level Seating	1/24/98	118	77	62	57
Crowd South Lower Level Seating	1/23/98	191	103	71	68
Crowd West Lower Level	1/23/98	246	126	55	80
Upper Level	1/24/98	99	77	52	50

Evaluation Criteria	Carbon Monoxide Concentration (ppm)			
	Peak	15-minute	1-hour TWA	1-hour TWA
Cincinnati Safety Dept.	200/ 2 cs	35	NA	NA
USEPA NAAQS	NA	NA	35	35
Health Canada Residential Indoor Air Quality Guideline	NA	NA	25	25

Notes:

ppm	parts per million
Peak	Highest concentration of CO recorded during the show.
Max STEL	Maximum 15-minute Short Term Exposure Limit recorded during the show.
TWA	Time Weighted Average
cs	consecutive samples
NA	Not Applicable
‡	The show began at 8:00 p.m., the first trucks began racing about 8:15 p.m. the show ended around 10:15 p.m.

Table 3
Employees' Personal Noise Exposures
US Hot Rod Monster Truck and Motocross Show at The Crown
HETA 98-0093

Personnel & Location	Sampling Date	Sampling Time (min)	Noise Levels [dB(A)]				
			L_{osha} [TWA]	L_{niosh} [TWA]	L_{avg}	L_{eq}	Maximum
Usher West Elephant Gate	1/23/98	235	87.2	94.9	92.3	98.0	124.5
	1/24/98	221	88.0	95.3	93.5	98.6	125.3
Usher East Concourse Level	1/23/98	230	87.8	93.9	93.1	97.1	121.9
	1/24/98	219	86.6	93.1	92.3	96.5	121.9
Security North Concourse Level	1/23/98	271	84.3	91.4	88.4	93.8	122.6
	1/24/98	236	86.5	92.6	91.6	95.7	124.5
Security Roamer	1/23/98	255	87.1	93.8	91.6	96.5	122.3
	1/24/98	243	87.3	93.0	92.2	95.9	124.1

Notes:

L_{osha} TWA	Eight hour exposure assuming no noise during non-sampled period using 5dB exchange rate.
L_{niosh} TWA	Eight hour exposure assuming no noise during non-sampled period using 3 dB exchange rate.
L_{avg}	Average noise level over the sampling period using 5 dB exchange rate.
L_{eq}	Average noise level over the sampling period using 3 dB exchange rate.
Maximum	Highest dB(A), slow-response value recorded during sampling period.

Table 4
Area Crowd Noise Exposures
US Hot Rod Monster Truck and Motocross Show at The Crown
HETA 98-0093

Personnel & Location	Sampling Date	Noise Levels [dB(A)]		
		L_{avg}	L_{eq}	Maximum
Crowd East Lower Level Seating	1/23/98	93.2	97.9	125.3
	1/24/98	93.0	97.5	121.5
Crowd North Lower Level Seating	1/23/98	91.7	96.7	122.3
	1/24/98	93.4	97.6	121.9
Crowd South Lower Level Seating	1/23/98	93.7	98.4	125.6
	1/24/98	93.9	99.3	124.9
Crowd West Lower Level	1/23/98	95.1	99.5	124.5
Upper Level	1/24/98	93.5	98.3	124.1

Notes:

L_{avg} Average noise level over the sampling period using 5 dB exchange rate.
L_{eq} Average noise level over the sampling period using 3 dB exchange rate.
Maximum Highest dB(A), slow-response value recorded during sampling period.

Figure 1
Carbon Monoxide Concentrations on Usher in West Elephant Gate
The Crown
January 23, 1998

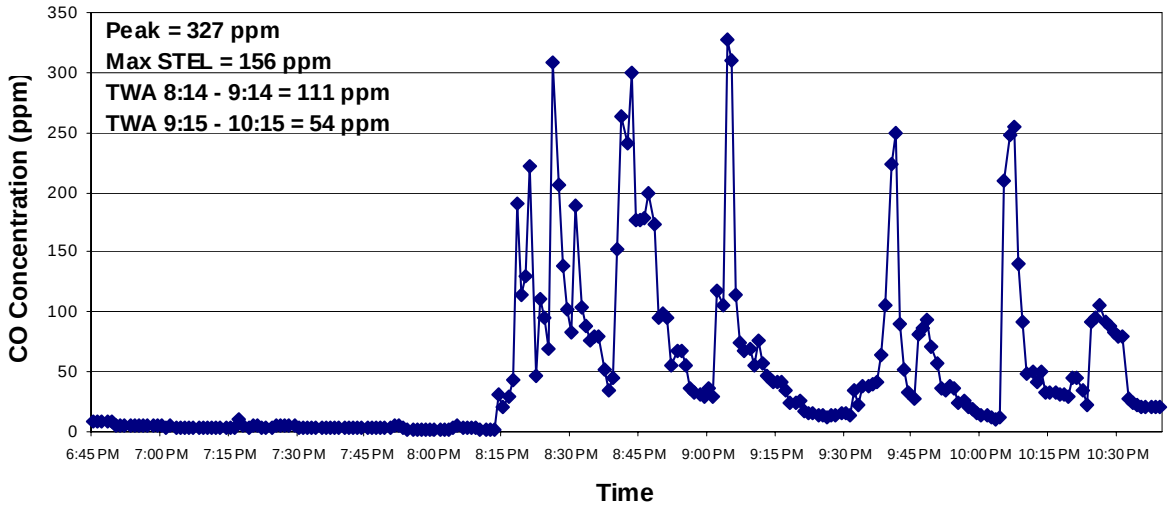


Figure 2
Carbon Monoxide Concentrations on Usher in West Elephant Gate
The Crown
January 24, 1998

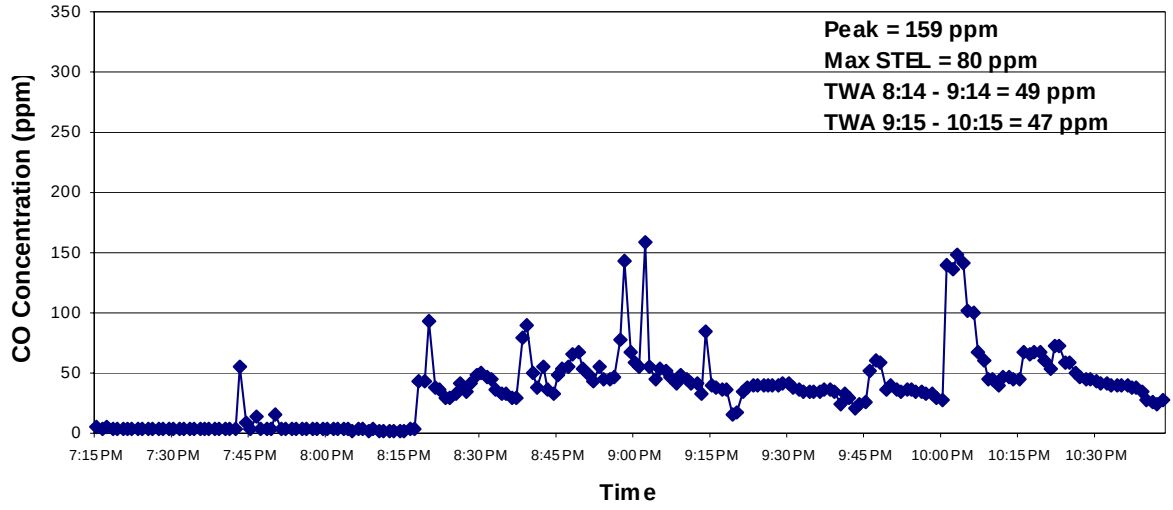


Figure 3
Carbon Monoxide Concentrations on Usher in East Concourse Level
The Crown
January 23, 1998

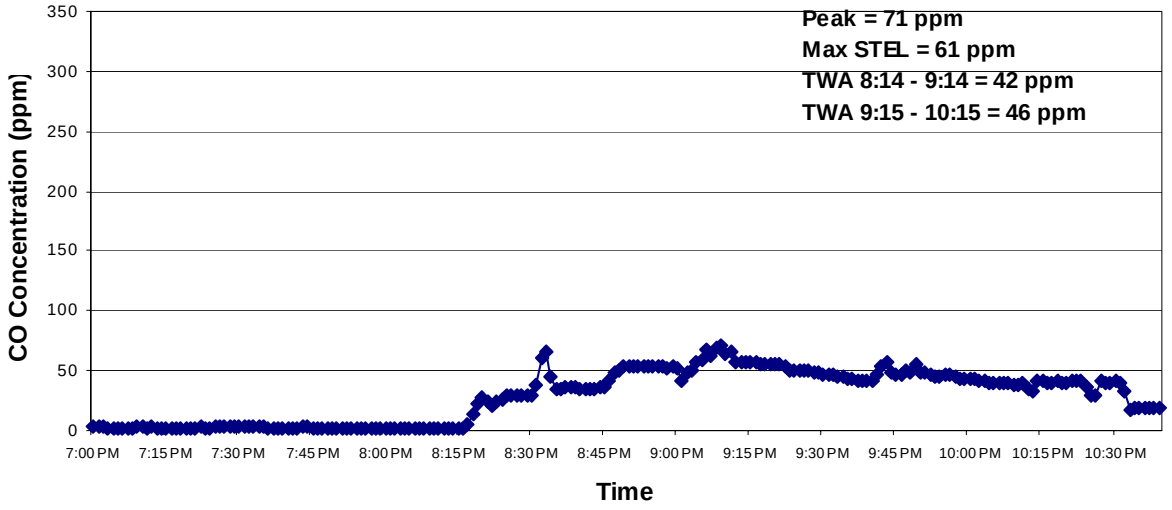


Figure 4
Carbon Monoxide Concentrations on Usher in East Concourse Level
The Crown
January 24, 1998

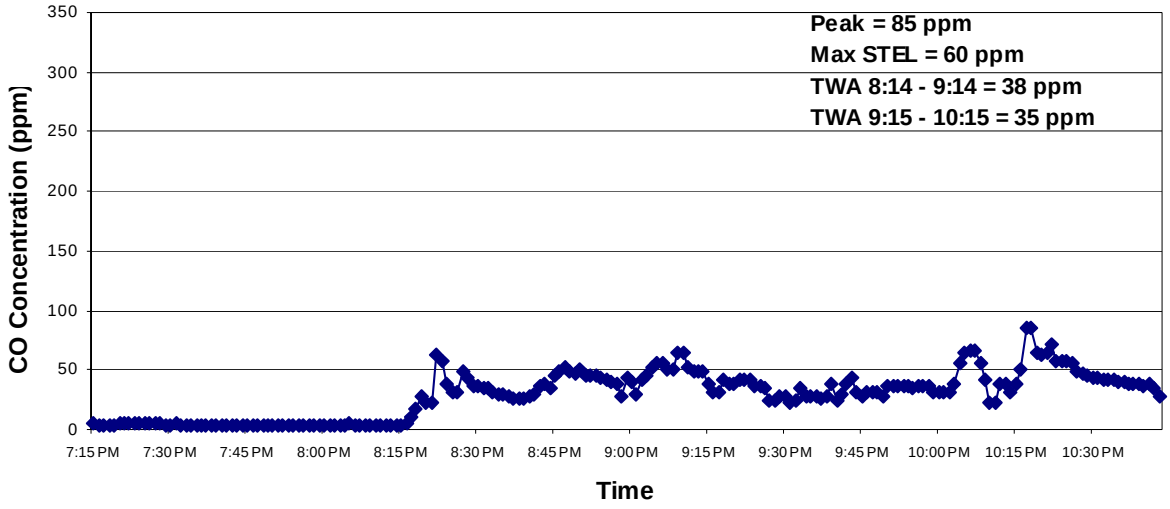


Figure 5
Carbon Monoxide Concentrations on Security in North Concourse Level
The Crown
January 23, 1998

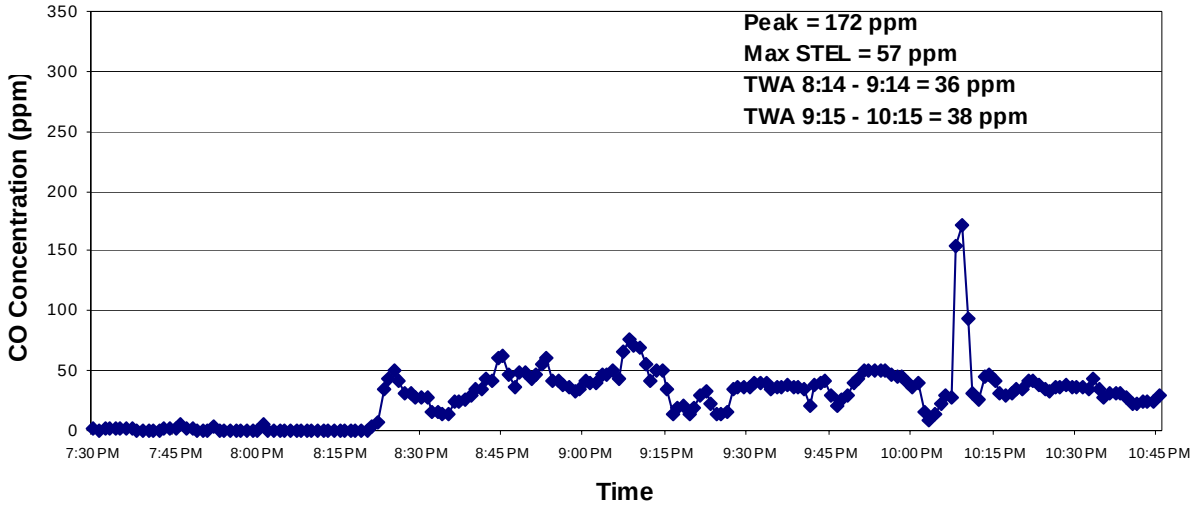


Figure 6
Carbon Monoxide Concentrations on Security in North Concourse Level
The Crown
January 24, 1998

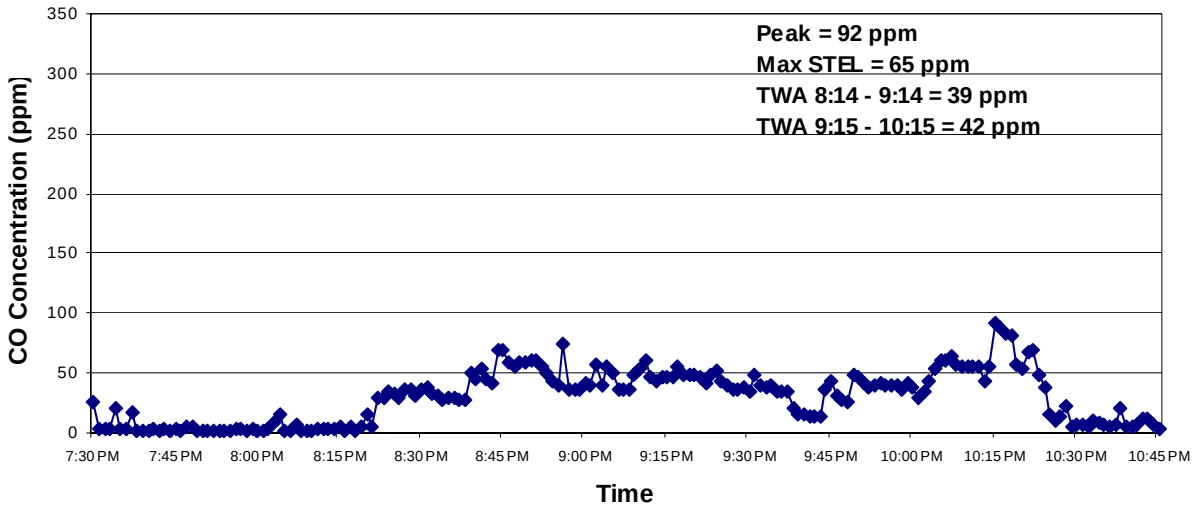


Figure 7
Carbon Monoxide Concentrations on Security (Roamer)
The Crown
January 23, 1998

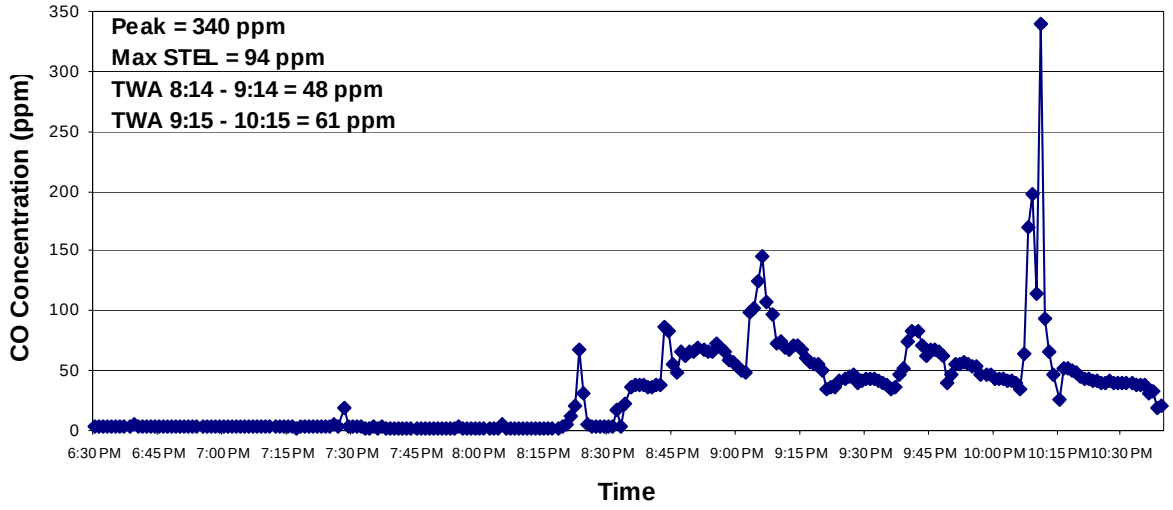


Figure 8
Carbon Monoxide Concentrations on Security (Roamer)
The Crown
January 24, 1998

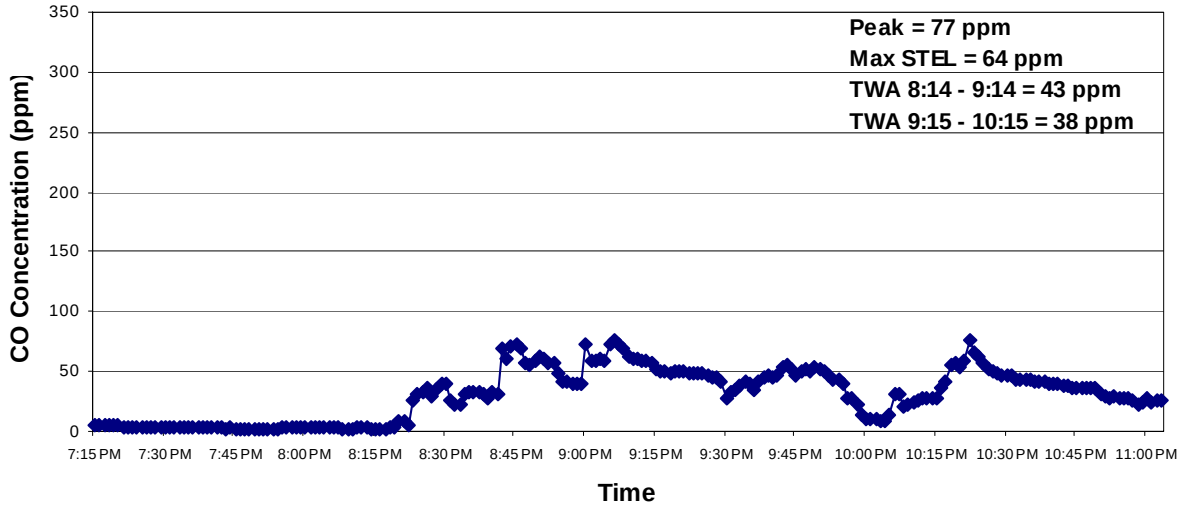


Figure 9
Carbon Monoxide Concentrations - East Lower Level Seating
The Crown
January 23, 1998

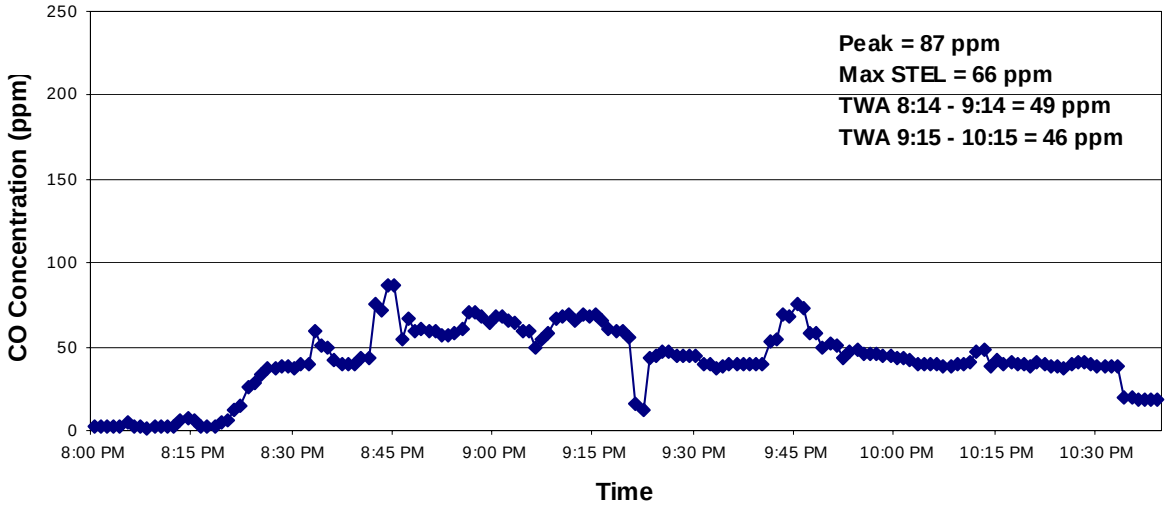


Figure 10
Carbon Monoxide Concentrations - East Lower Level Seating
The Crown
January 24, 1998

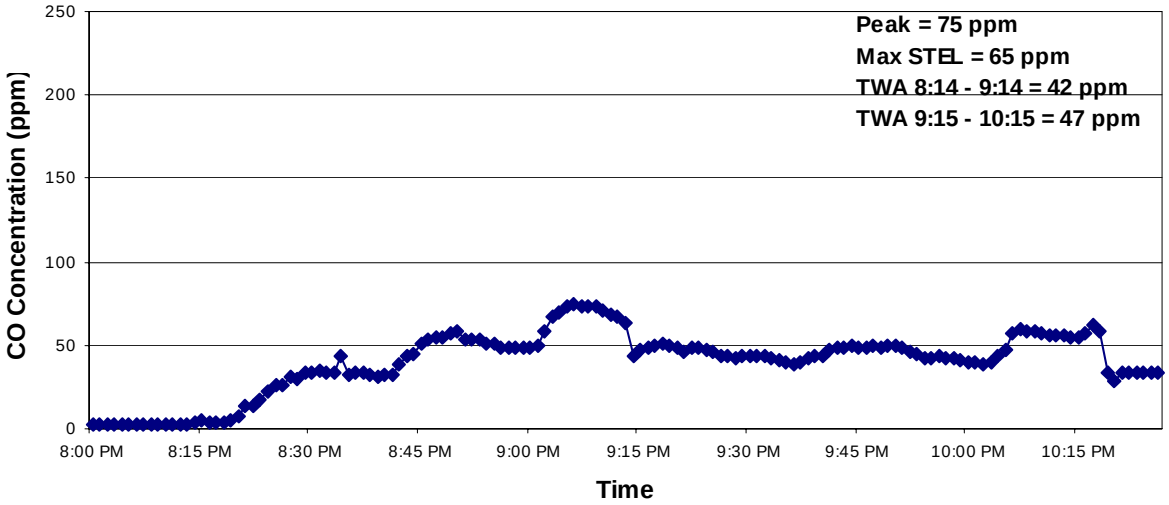


Figure 11
Carbon Monoxide Concentrations - South Lower Level Seating
The Crown
January 23, 1998

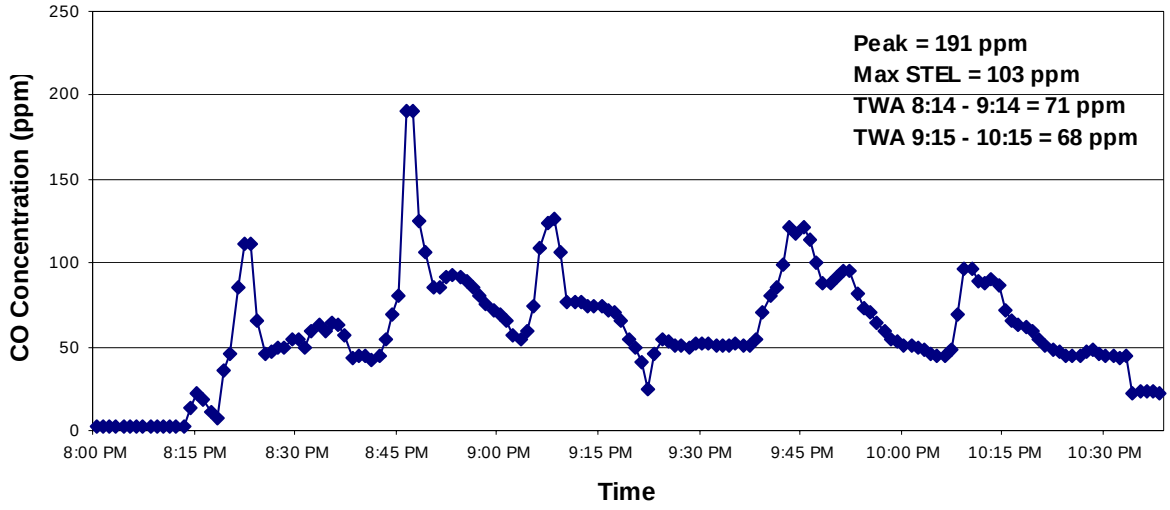


Figure 12
Carbon Monoxide Concentrations - North Lower Level Seating
The Crown
January 24, 1998

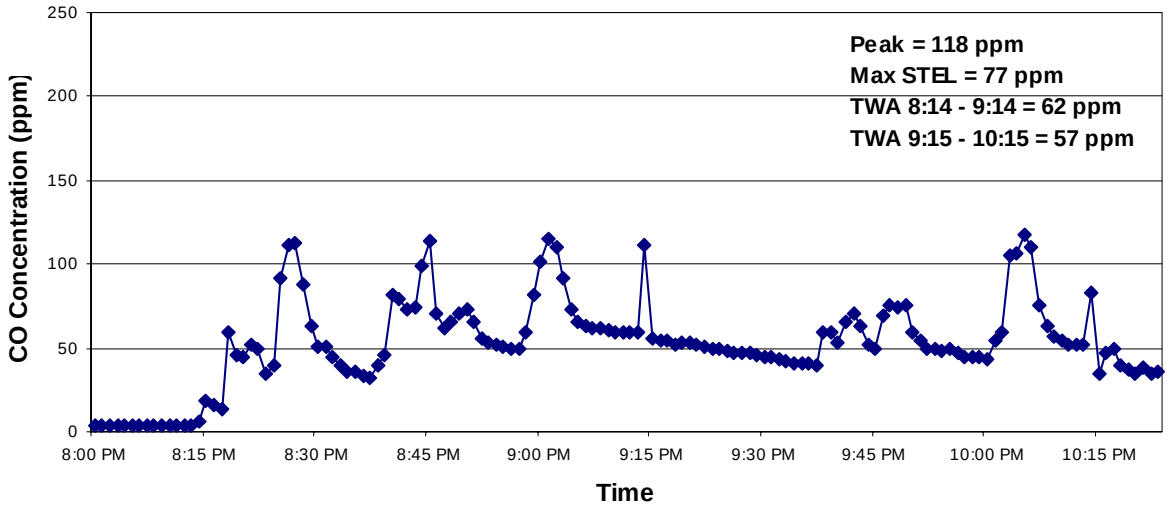


Figure 13
Carbon Monoxide Concentrations - West Lower level Seating
The Crown
January 23,1998

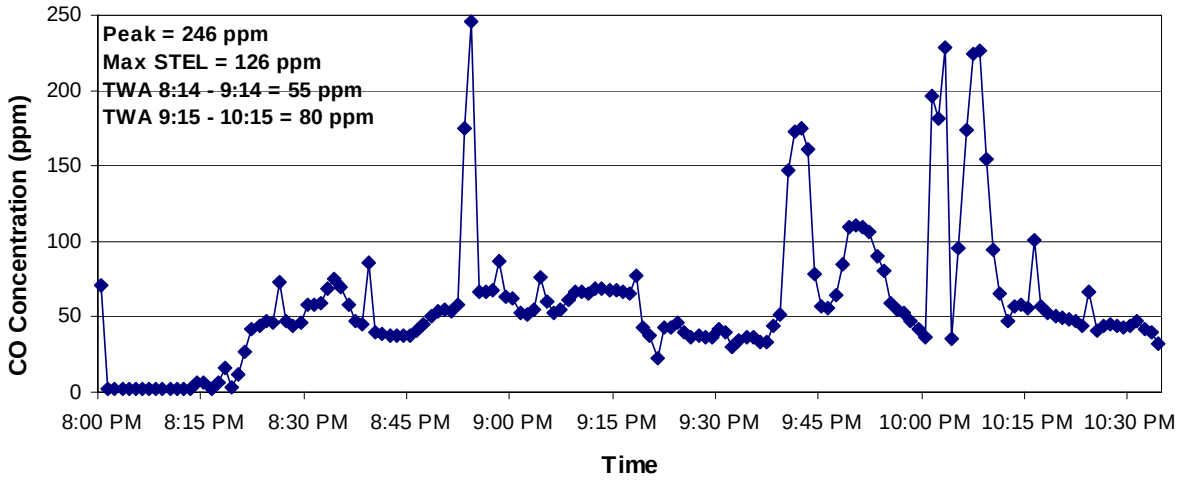


Figure 14
Carbon Monoxide Concentrations - West Upper Level Seating
The Crown
January 24, 1998

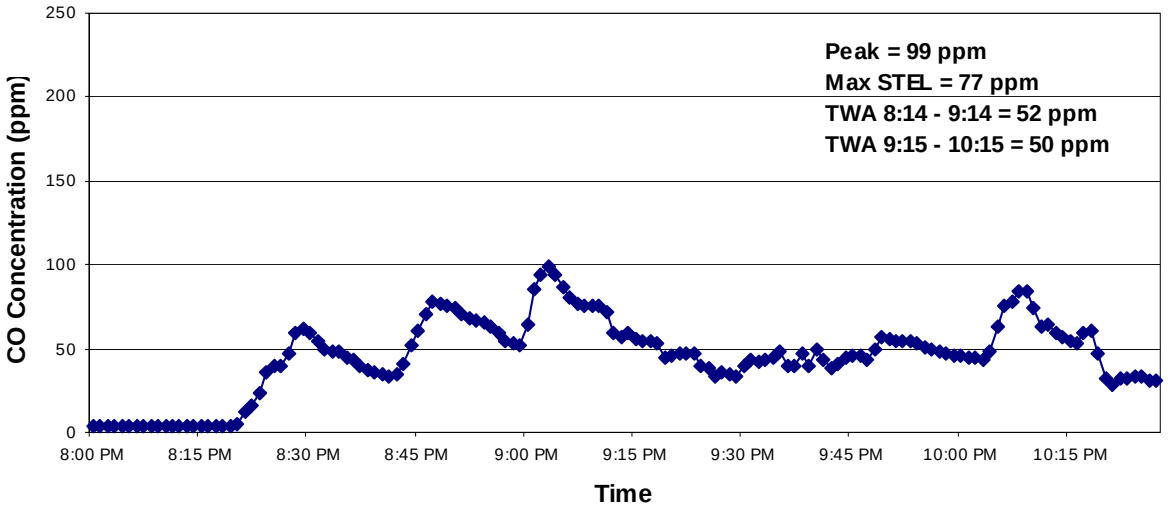


Figure 15
Personal Noise Levels - Usher West Elephant Gate
The Crown
January 23, 1998

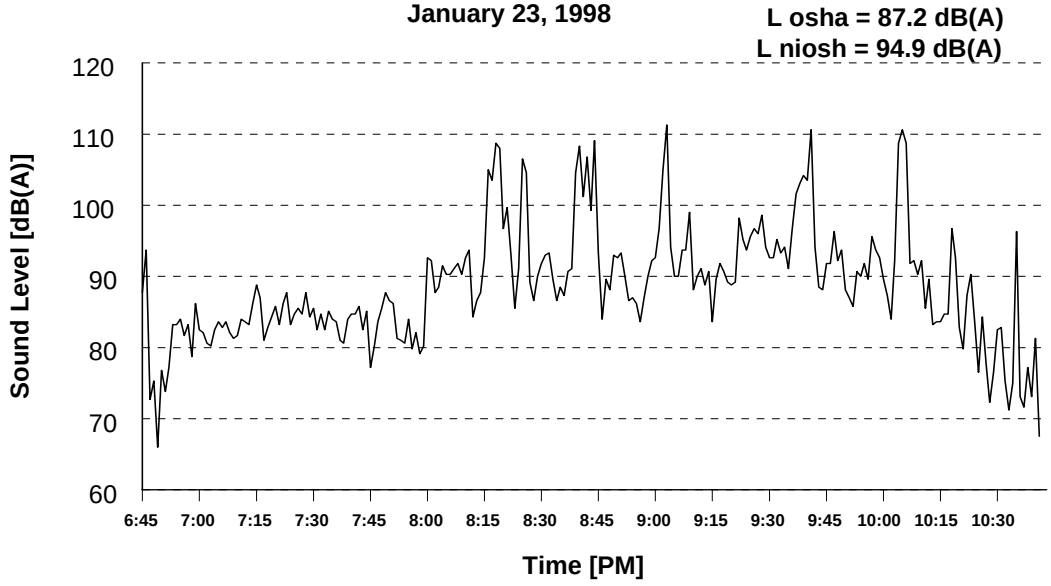


Figure 16
Personal Noise Levels - Usher West Elephant Gate
The Crown
January 24, 1998

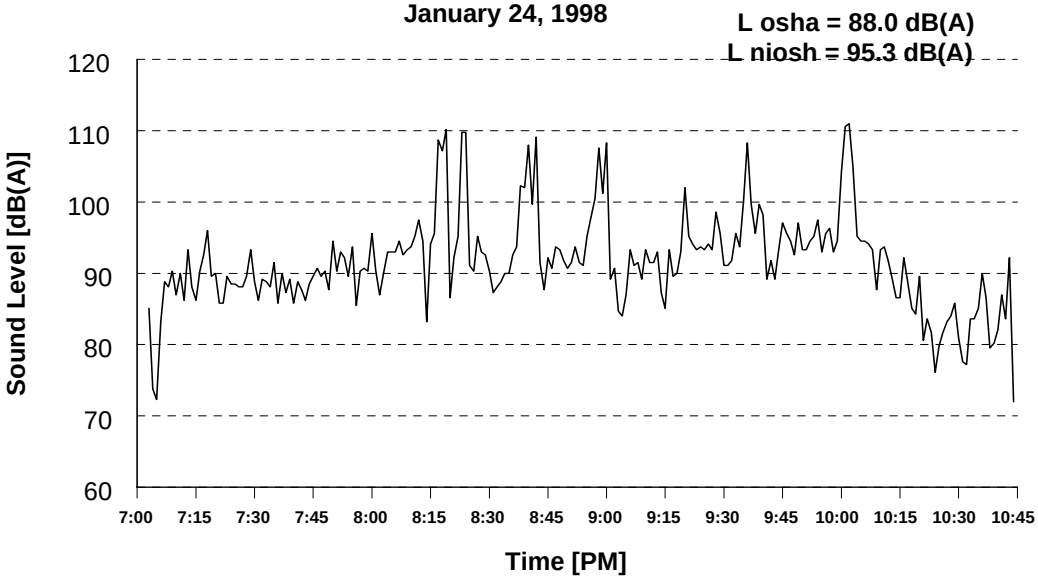


Figure 17
Personal Noise Levels - Usher East Concourse Level
The Crown
January 23, 1998

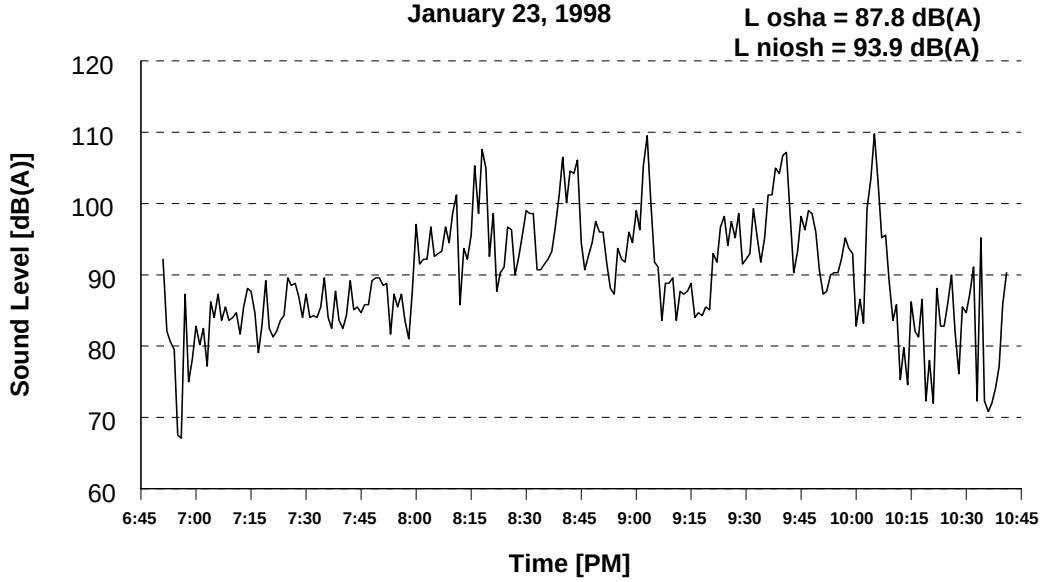


Figure 18
Personal Noise Levels - Usher East Concourse Level
The Crown
January 24, 1998

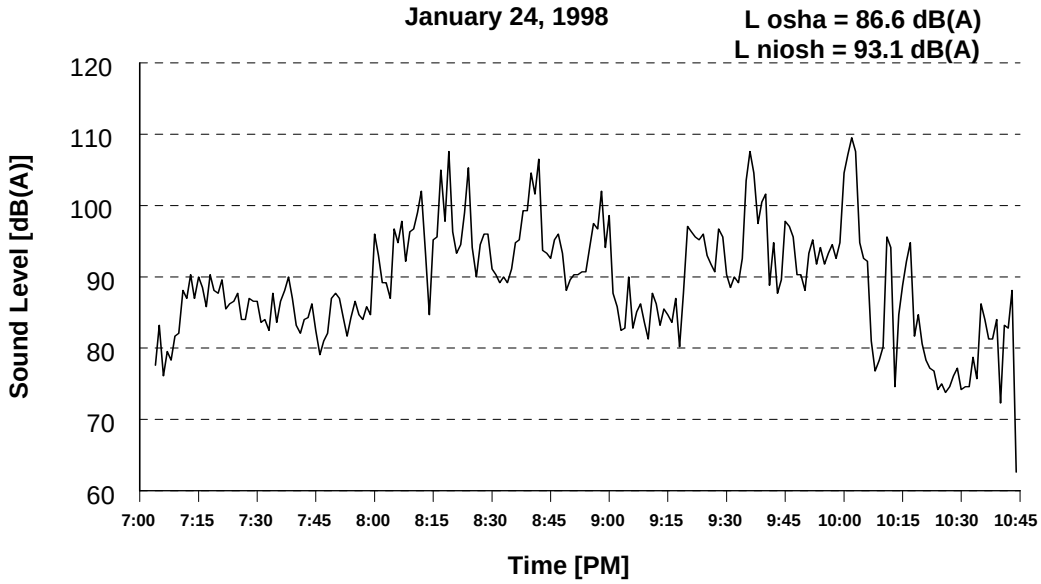


Figure 19
Personal Noise Levels - Security North Concourse Level
The Crown
January 23, 1998

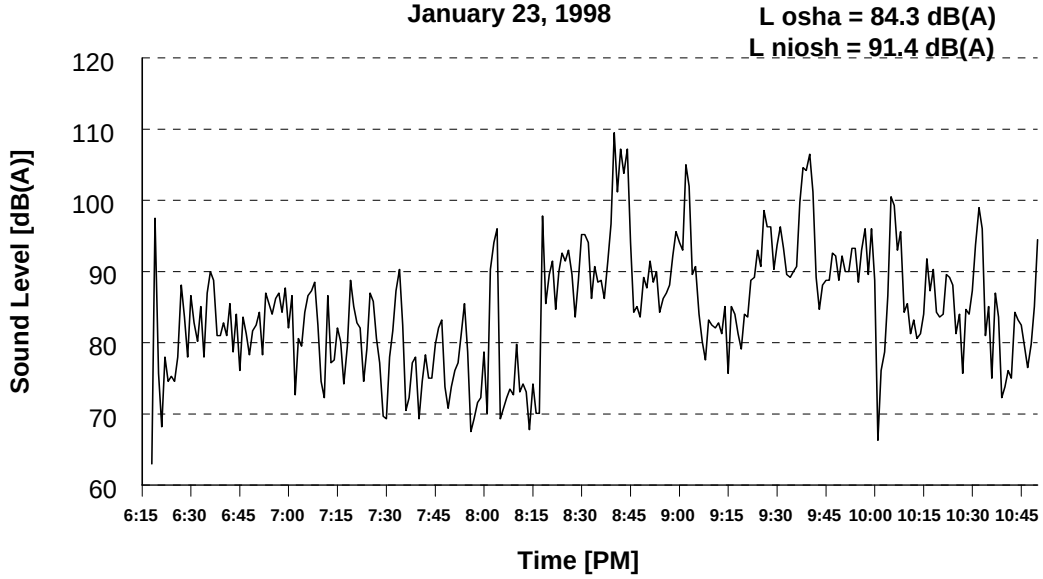


Figure 20
Personal Noise Levels - Security North Concourse Level
The Crown
January 24, 1998

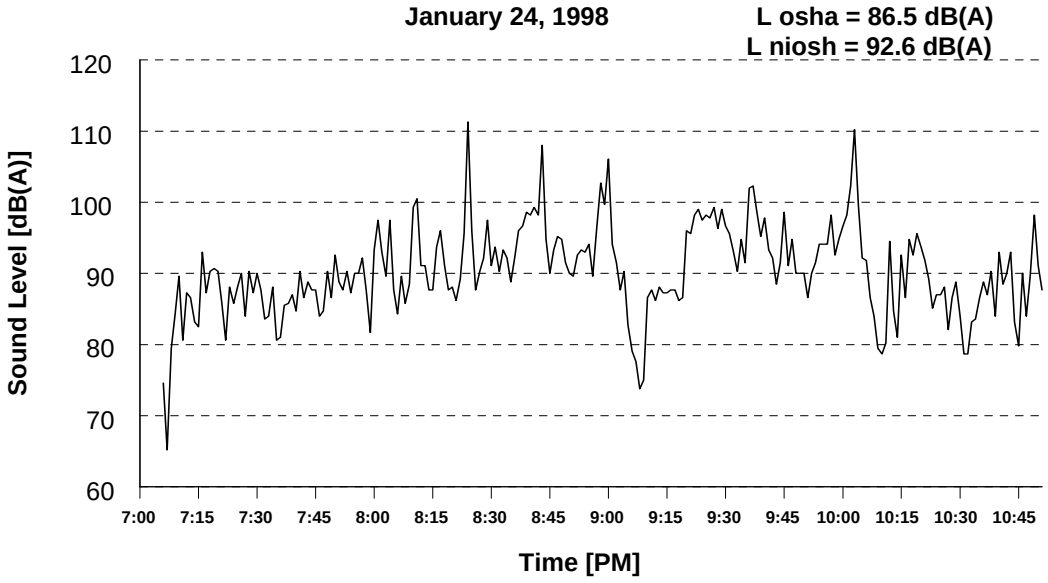


Figure 21
Personal Noise Levels - Security (Roamer)
The Crown
January 23, 1998

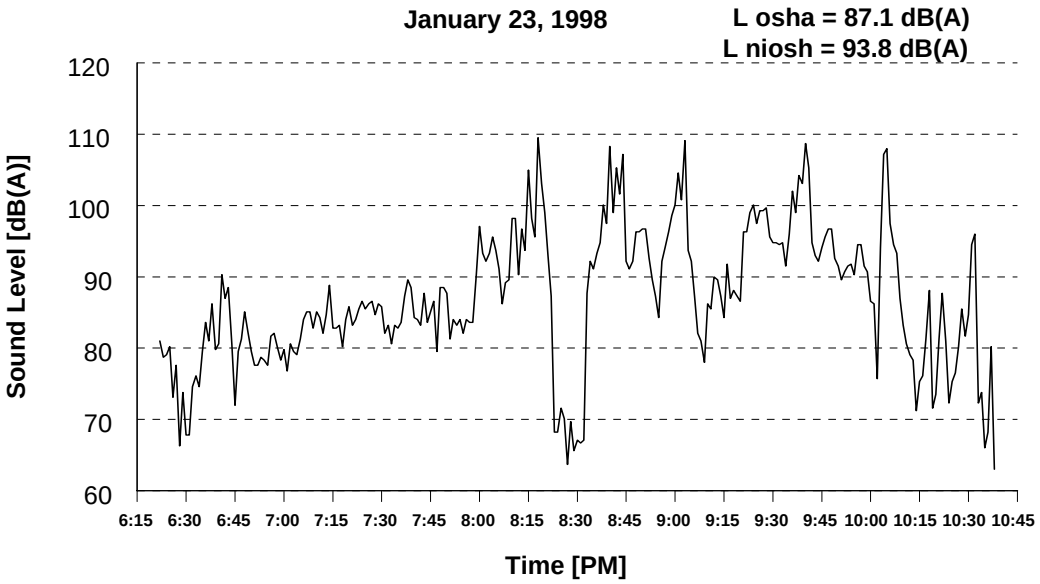
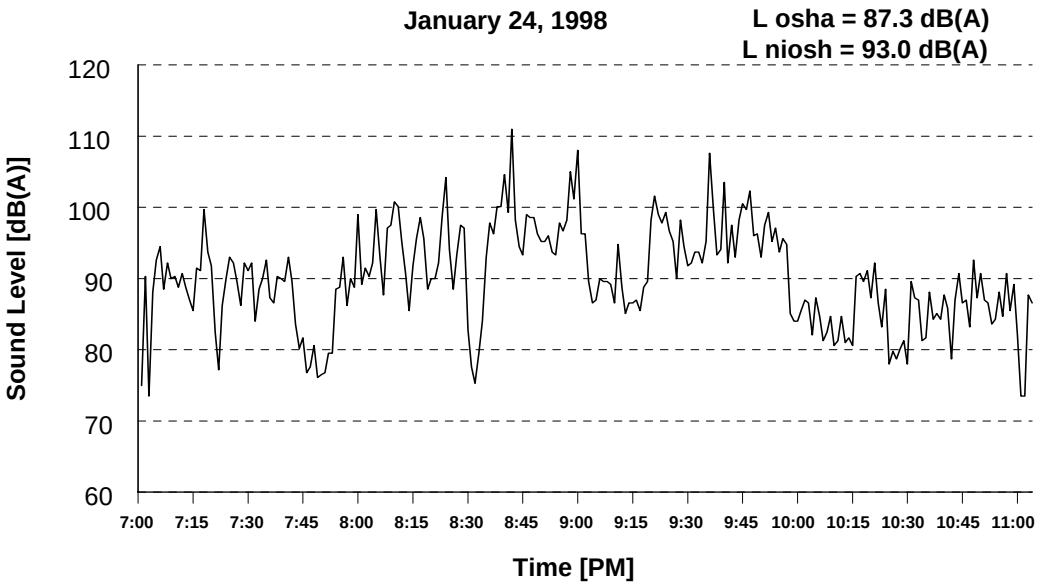


Figure 22
Personal Noise Levels - Security (Roamer)
The Crown
January 24, 1998



For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4676)
or visit the NIOSH Homepage at:
http://www.cdc.gov/niosh/homepage.html

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