HETA 2000–0110–2849
Human Performance International, Inc.
Charlotte, North Carolina

Kristin K. Gwin, M.S.
Kenneth M. Wallingford, M.S., C.I.H.
Thais C. Morata, Ph.D.
Luann E. Van Campen, Ph.D.

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. As in this situation, HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by NIOSH. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) 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.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Kristin K. Gwin and Kenneth M. Wallingford of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS) and Thais C. Morata and Luann E. Van Campen, of Engineering and Physical Hazard Branch (EPHB), Division of Applied Research and Technology (DART). Field assistance was provided by Lisa Delaney (DSHEFS), Chuck Kardous and Ronald Kovein (DART). Analytical support was provided by Data Chem Laboratories. Desktop publishing was performed by Ellen Blythe and Robin Smith. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at Human Performance International, Inc. and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Health Hazard Evaluation Report 2000–0110–2849
Human Performance International, Inc.
Charlotte, North Carolina
June 2001

Kristin K. Gwin, M.S.
Kenneth M. Wallingford, M.S., C.I.H.
Thais C. Morata, Ph.D.
Luann E. Van Campen, Ph.D.

EXECUTIVE SUMMARY

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) collaborated with the Division of Applied Research and Technology (DART) within NIOSH to conduct a pilot research study evaluating occupational exposure to noise and potential ototoxic agents, such as solvents, metals, and asphyxiants, among a stock car racing team. The purpose of the study was to evaluate exposures to noise and ototoxic agents for their potential combined effect on occupational hearing loss. The exposure assessment included two site visits to the racing team's race shop and two site visits to a racetrack, which represented the worst case exposure scenario due to its small size, steep banking, and high grandstand configuration.

An initial site visit was conducted at the professional stock car race team's shop on January 19 and 20, 2000. Air samples were collected to qualitatively and quantitatively identify ototoxic chemicals and other organic compounds. Full-shift and half-shift carbon monoxide (CO) measurements were also collected. Sound pressure levels were measured for the tasks that generated the greatest amount of noise. Noise dosimetry was then conducted to give full-shift personal noise exposures for at least one employee from each job description related to assembling the race car. A follow-up site visit was conducted at the racing team's race shop on February 9, 2000. Full-shift air samples were collected for organic solvents in the paint and body shop areas. A short-term air sample was also collected for lead and 26 other metals and minerals next to a tungsten inert gas (TIG) arc welding station. Noise dosimetry was performed on three workers.

Concentrations of toluene, acetone, perchloroethylene, xylenes, styrene, C_7-C_8 alkanes, and methylene chloride at the race shop were either not detectable or extremely low, and well below any relevant occupational exposure criteria. Mean CO concentrations were well below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 50 parts per million (ppm), the NIOSH Recommended Exposure Limits (REL) of 35 ppm, and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 25 ppm. The peak concentrations, although elevated, did not exceed the 200 ppm NIOSH ceiling REL. The short-term air sample collected for metals near a welding station revealed no detectable concentrations, with the exception of manganese (which was less than 20% of it's most stringent exposure criteria of 1 milligram per cubic meter of air (mg/m^3) as an 8-hour-time weighted average [TWA]).

Sound pressure levels for individual job tasks ranged from 58 to 103 decibels, A-weighted [dB(A)]. While the OSHA PEL of 90 dB(A) for an 8-hour TWA was never exceeded, in two instances the values exceeded the OSHA action level (AL) of 85 dB(A) for hearing conservation implementation. The NIOSH REL of 85 dB(A) for an 8-hour TWA was exceeded for five of the nine measured jobs. Only three of the workers (21%) were observed wearing ear plugs during their work shift.

An initial site visit was conducted at Bristol Motor Speedway in Bristol, Tennessee, on March 24 and 25, 2000. Air samples were collected for organic compounds, CO, and lead during the race. Although isopentane, C_8 alkanes (isooctane, dimethylhexanes, trimethylpentanes), and toluene were the major compounds detected, the amounts of even these compounds were insufficient to quantify. Mean CO concentrations were well below all evaluation criteria. Air samples collected for lead revealed either non-detectable, or extremely low concentrations, well below the occupational exposure criteria. Noise measurements were performed on both practice and race days (March 24 and 25, 2000, respectively) which included sound level meter measurements and noise dosimetry conducted in and around the pit area, as well as inside the race car. Both the OSHA PEL and NIOSH REL were exceeded in every instance with average noise levels above 100 dB.

A follow-up site visit was conducted at Bristol Motor Speedway in Bristol, Tennessee, on August 25, 2000, to measure CO and perform more noise dosimetry. Full-shift mean CO concentrations in some locations exceeded the PEL, REL, and TLV of 39 ppm, 19 ppm, and 27 ppm, respectively, after they were adjusted for a 10⅓-hour day. Peak CO concentrations exceeded the NIOSH recommended ceiling limit of 200 ppm in three of the five sampling locations during the practice period. Peak concentrations in two of the three locations where measurements were collected over the full day also exceeded 200 ppm. Noise dosimetry and sound level meter measurements were also conducted. Both the OSHA PEL and NIOSH REL were exceeded in every instance.

Based on the environmental data collected during this pilot study, exposures to potentially ototoxic agents are not high enough to produce an adverse effect greater than that produced by the high sound pressure levels alone. Carbon monoxide levels, however, occasionally exceeded all evaluation criteria at the race track evaluated. In addition, noise exposures occasionally exceeded the OSHA PEL at the team's race shop and exceed all evaluation criteria at the race track evaluated. Recommendations are included to reduce exposures to potentially ototoxic agents that have the likelihood of producing high short-term exposures and to control noise exposures through the use of appropriate strategies (such as wearing hearing protection with a high enough noise reduction rating [NRR] to provide adequate attenuation).

Keywords: 7948 (Racing, Including Track Operation), professional stock car series racing, race shop, race track, noise, ototoxic agents, solvents, lead, carbon monoxide

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Noise and Substances such as Solvents, Metals, and Asphyxiants Among a Stock Car Racing Team

Two research groups from the National Institute for Occupational Safety and Health (NIOSH) conducted a pilot study evaluating occupational exposure among a stock car racing team to noise and substances such as solvents, metals, and asphyxiants (also called ototoxic agents), which can damage hearing. We wanted to evaluate both noise and ototoxic agents for their potential combined effect on occupational hearing loss. We made two site visits to the racing team's race shop and two site visits to a race track.

What NIOSH Did

- We took air samples for 26 different types of metals and minerals at the race shop and at the race track.
- We took air samples for organic solvents at the race shop and at the race track.
- We tested for carbon monoxide (CO) at the race shop and at the race track.
- We measured noise levels.

What NIOSH Found

- Race shop workers had brief exposures to high concentrations of CO, but their full day exposures were low.
- Team members at the race track were exposed to CO levels above the NIOSH ceiling limit of 200 parts per million.
- Metals, minerals, and solvents were either not detected or very low.
- Noise levels for most race shop jobs that we checked were above the NIOSH recommended exposure limit REL).
- Noise levels at the race track were above NIOSH recommended exposure limits.
- Only three race shop workers were seen wearing hearing protection.
- The crew and driver at the race track did wear communication equipment, but we felt it was not good for hearing protection.

What the Race Shop Can Do

- Welding areas should be surrounded with shielding curtains, and welders should wear gloves and arm protection.
- Use protective gloves when handling any solvents and acids.
- Make sure that exhaust vents go outside of the race shop.
- Clean and/or replace the air filters used in shop vacuums on a regular basis.
- Clean or replace any respirators that are used by the painters, and also start a respiratory protection program.

What the Race Team Can Do

- Wear protective gloves when refueling the car in the pit.
- Turn off gasoline-powered engines when they are not needed to reduce CO.
- Check noise levels more often, and check the hearing of race teams yearly.
- Teach the race team about health effects from noise and CO exposure.
- Try to increase the number and/or length of breaks during race weekends to reduce noise exposures to team members.

What To Do For More Information:

We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report # 2000-0110-2849

TABLE OF CONTENTS

INTRODUCTION

High performance automobile racing has a strong record of safety innovations and practices. Despite this safety culture, noise and chemical exposures have not been empirically measured and are unregulated by race sanctioning bodies. Moreover, the effects of these agents on hearing, communication, and job performance are unknown. Most high performance auto racing crews and drivers wear some type of hearing protection device (HPD), but there is no published scientific documentation of noise levels. Anecdotal reports describe engine levels of 125 to 140 decibels (dB), which exceed the pain threshold.[1,2,3,4] Also described are complaints of ear ringing, an inability to hear important sounds, muffled hearing, and dizziness for hours to a day following a race.

Potentially hazardous chemical exposures involved with high performance automobile racing include: organic solvents, carbon monoxide (CO), lead, and other metals. Published literature indicates that exposure to these compounds has been associated with neurobehavioral disorders, and visual and auditory dysfunction.[5,6,7,8]

The significant noise issues, as well as combined effects of noise, chemicals, heat, and vibration, not only represent potential health risks, but also possible detriments to effective occupational communication and performance.[9] Some non-auditory noise effects reported in the literature are physiologic changes, fatigue, increased reaction time, reduced concentration, and irritability. Improved noise reduction could result in improved performance of the driver and crew members hearing preservation, and consequently safer racing conditions.

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) collaborated with the Division of Applied Research and Technology (DART) within NIOSH to conduct a pilot research study evaluating occupational exposure to noise and potentially ototoxic agents, such as solvents, metals, and asphyxiants for a stock car racing team. The purpose of the study was to evaluate exposures to noise and ototoxic agents for their potential combined effect on occupational hearing loss. The study was performed in conjunction with Human Performance International, Inc. (HPI), a group contracted by high performance race teams to deliver performance enhancement programs for the driver and crew members. HETAB's responsibility was to conduct an exposure assessment with the exception of the noise component, which was concurrently investigated by DART. The exposure assessment included two site visits to the race team's shop, and two site visits to a racetrack, representing the worst case exposure scenario due to its small size, steep banking, and high grandstand configuration.

On January 19–20, 2000, NIOSH investigators conducted an initial assessment at a professional stock car race team's shop. A follow-up site visit was conducted at the race shop on February 9, 2000. Site visits were also conducted at Bristol Motor Speedway in Bristol, Tennessee, on March 25 and August 25, 2000, during professional stock car races. Environmental monitoring at both the race shop and the racetrack included sampling for organic solvents, lead and other metals, CO, and noise.

BACKGROUND

Building Description

The professional stock car race team's shop is a large, one-story building with approximately 15,000 square feet (ft^2) of indoor floor space. The shop is divided into two main areas; the set-up area and the fabrication area. The set-up area consists of the front lobby, enclosed offices, the break room, restrooms, the parts room, and the gear/suspension room. The remaining set-up area is a large open space where the finished bodies of the cars are stored. This is also where the mechanics install the suspension, engine, and drive line in the cars. The fabrication area is a large room in the rear of the building consisting of a paint/body shop with an enclosed paint booth, a machine shop, metal working area, and storage area. The remaining area is a large, open space where the car is fabricated to meet specific dimension requirements established and enforced by professional stock car racing officials. The set-up and fabrication area are separated by a wall with two large swinging doors at either end of the building. Ducted return is used in the set-up and office areas; however, the fabrication area relied on dilution ventilation. The garage doors are opened throughout the day for loading and unloading purposes, thus allowing for a supply of outdoor air.

The gear/suspension room, located off the set-up area, is where the various suspension components are prepared for installation under the car. This room houses an axle assembly table, a hydraulic press, a Blastpro® glove box, axle and gear case racks, and two Safety Kleen® parts cleaning stations (one each for dirty and clean parts).

The machine shop section of the fabrication area consists of a lathe, boring mill, three grinding machines, a large and small belt sander, two drill presses, a sheet metal saw, a cutoff saw, a large band saw, and a pipe bender. The actual fabrication area consists of two level floors where the cars are assembled, a sheet metal roller, cutter, and bender, and metal inert gas (MIG) and tungsten inert gas (TIG) welding stations. There are two large garage doors at either end of the fabrication area where the finished race cars are taken in and out of the building.

The paint/body shop within the fabrication area consists of a storage area, an enclosed paint booth, and a body shop. The storage area houses the painting supplies (stored in explosion proof paint cabinets), a sink, and a Safety Kleen® laquer thinner cleaning station. The enclosed paint booth has approximately 4,000 ft^2 of floor space. The body shop is an unenclosed area next to the paint booth. A work bench, storage cabinet, and Spraybake® local exhaust unit are located there.

Ventilation

Gear/Suspension Room

The Blastpro® glove box in the gear/suspension room is an enclosed sandblasting process. Gloves (where arms are placed) extend into the enclosed box to allow for manipulation of the metal that is being sandblasted. Aluminum, brass, bronze, steel, magnesium, and other non-ferrous metals are sandblasted, using glass shot as the abrasive material, so that lubricants will better adhere to the metal. The glass shot is recycled through the cyclone to separate out particulates and reused until it gets dirty. The Blastpro® uses 12 rubberized canvas bag filters (6' x 4") for filtration. After filtration, the air is exhausted directly outside the building through an exhaust duct.

Every two weeks the debris and metal dust residue is shaken from the bottom of the filters. The residue falls into a pan placed beneath the filters. It is discarded through a baffled hood, which exhausts directly outside. The Blastpro® is serviced every six months when the bag filters are removed, shaken outside, and then cleaned using a high-efficiency particulate air (HEPA)-vacuum.

Fabrication Area and Machine Shop Area

Welding is conducted at various locations throughout the fabrication area. Local exhaust ventilation (LEV) is not utilized to capture welding fumes, and no type of shielding is used to isolate the welding stations from the rest of the fabrication area.

Cutting fluids and cooling oils are not used on any of the machining tools, with the exception of the lathe. Although there is no LEV at the lathe, use of the lathe was reported by the suspension assemblist to be very infrequent.

Paint/Body Shop Area

The sealer, paint, and polyurethane coats are applied to the race car inside the enclosed paint booth. Supply air is ducted into the booth through the ceiling. The exhaust is located near the floor, on the wall opposite the door. The consultant that installed the booth reported that it was designed to run at 10,000 cubic feet per minute (cfm). Four rows (four filters in one row) of Airflow Tech AFR-1 supply filters are located on the ceiling of the booth extending from the door to one-half the length of the booth. Twelve exhaust filters manufactured by IRP® filter the air before it is exhausted directly outside the building. Supply filters are changed every six months and the exhaust filters are changed monthly.

The unenclosed Spraybake® exhaust unit is used when the body of the car is sanded and when the body filler and epoxy coat are applied in the body shop area. The filtered supply air (two Viledon® R2 filters) is delivered from an overhead duct and the exhaust is located against the garage wall. Exhausted air is filtered prior to either being exhausted outside, or recycled through the supply/exhaust system. The vent damper is manually adjusted and was reported to be positioned, on average, to exhaust 50% of the recycled air. The consultant that installed the Spraybake® reported that it was designed to pull air at a rate of 6,000 cfm. The intake filters are changed every six months and the exhaust filters are changed monthly.

Description of Monitored Processes

Welding

Solvents and acids are used to clean and remove grease and oxides from metal parts before they are welded. Muratic acid is used on steel and stainless steel, while Weld-O®, which contains hydrofluoric acid, is used to prep aluminum. The solvents are applied to the parts using a toothbrush. It was reported to NIOSH investigators by one of the fabricators that, on average, welding is performed for a total of 3 hours per day, in 5–15 minute intervals. Argon gas is used as the shielding gas during TIG welding, and an argon/carbon dioxide mix is used as the shielding gas during MIG welding.

Sanding and Painting

After body filler is applied to the race car, the body of the car is sanded by hand or using an electric sander to smooth out the surface. This process takes approximately two hours. After the body filler is allowed to set, the body of the car is resanded. This takes another six to seven hours and occurs in the body shop area directly under the Spraybake®. A HEPA-filter dust mask is worn by the employee during sanding operations.

After the initial grinding process is finished, the car, or individual parts that are being painted, are brought into the paint booth. With the exhaust fans turned on, primer is applied to the body. Once the primer is allowed to dry (approximately 30 minutes), the sealer is applied and allowed to dry for approximately 20 minutes. The first coat of paint is then applied. Each coat of paint is allowed to dry for approximately 20 minutes before the next coat is applied. Each color is applied separately, with two or more coats of each color being applied. According to the painter, on average, the entire painting process takes approximately two hours, but can vary depending on the number of coats that have to be applied. The polyurethane clear-coat is the final coat applied. The car is then baked in the paint booth for approximately 1½ hours. The paint booth heaters are fueled by a propane furnace. While the heater is on, the exhaust fans are turned off.

In between each coat of primer, sealer, or paint that is applied, the painter leaves the paint booth to clean the paint gun in a Safety Kleen® laquer thinner bath that is located directly adjacent to the paint booth. After cleaning, the primer or paint is mixed and poured into the paint gun. Coveralls and an organic vapor cartridge half-face respirator are worn inside the paint booth. The respirator is removed when the painter exits the paint booth, and is not worn while the paint gun is cleaned, or while the paint is mixed. The painter reported that the respirator filters are changed every two months and the respirator is discarded when it gets dirty. It was not cleaned on a daily basis after use. A chemical solutions glove was occasionally worn while cleaning the paint gun in the laquer thinner bath and while mixing paint.

Race Track Description

Bristol Motor Speedway, also known in the stock car racing community as the world's fastest half-mile, is a 0.533 mile oval track with 36° banking. In 1999, seats were added to increase its capacity from 71,000 to approximately 135,000. Grandstand seating extends upward around the track, creating a bowl-like configuration. During the warm summer months, temperature inversions often occur in the mountains at night, creating stagnant air conditions in the valleys. The temperature inversion simulates a blanket-like effect over the track. Its location in the mountains of Bristol, Tennessee, along with the track configuration and recommendation from HPI and the race team, led NIOSH investigators to believe that this track would represent a worst-case exposure scenario during the night race on August 25, 2000.

During the initial site visit to the track on March 24 and 25, 2000, racing events took place over two days. Haulers transporting the race cars were allowed to enter the infield area of the track and park in their respective position (decided by overall points standing) on Thursday, March 23. On Friday, March 24, the practice period and first round of qualifying for positions 1–25 took place. On Saturday, March 25, the second round of qualifying for positions 26–36 took place in the morning. During qualifying each car ran two laps around the track. The fastest of the two was used to rank the pole position of the driver for the race. If the driver did not post a fast enough lap time to qualify for position 1–25 on the first day, he could either qualify the second day for position 26–36, or keep his time from the first day and see if it was fast enough to qualify for one of the remaining positions. After qualifying, the race car inspections were performed. A total of 43 cars started the Cheez-It 250 stock car race in the afternoon. This included seven provisional spots for teams that did not qualify on either day. Provisional spots were awarded by professional stock car racing officials based on the overall points standing of the team.

During the follow-up site visit to the track on August 25, 2000, all of the stock car racing events were combined into one day of activities. The race car haulers were allowed to enter the infield of the track on Thursday, August 24. Inspection of the cars also took place that afternoon. On Friday, August 25, the garages opened and practice took place from 10:30 a.m. to 12:30 p.m. Qualifying for pole positions 1–36 took place from approximately 3:30 p.m. to 4:40 p.m. After qualifying, the cars were impounded (no further adjustments were allowed to be made). At approximately 5:30 p.m., final adjustments were allowed to be made on the cars before lineup began at 6:00 p.m. The Food City 250 professional stock car race began at approximately 7:04 p.m., with a total of 43 cars on the racetrack. The cars were lined up in two rows (side-by-side) according to each driver's qualifying position (this included the 36 qualifying positions and 7 provisional spots given to teams which did not qualify).

Job Descriptions

At any given time, there were 14 full-time workers employed by the professional stock car racing team NIOSH evaluated. Approximately 80% of the workers had been involved with the racing industry for a minimum of 10 years, but not necessarily with the same team due to a high employee turnover rate. On average, employees worked six days a week for approximately 12 hours a day, including 1 hour for lunch. During the racing season (February through November) work hours vary depending on the race schedule and how much time is needed to prepare the car for the next race. In the year 2000 professional stock car racing season, there were 32 races which occurred over a period of 39 weeks, including seven weekends off. The majority of the races took place on Saturday (four took place on Friday evening and four took place on Sunday afternoon). Seven employees were taken to the track for three days to help set-up the car for practice and qualifying, and five others (the remaining members of the pit crew) arrived on the day of the race. There were a total of seven people that comprised the pit crew, two of which were full-time employees. Refer to the Appendix for a description of each full-time position and the number of employees at each position within this particular racing team's organization.

METHODS

Initial Site Visit to Race Shop

Chemical Exposure Assessment

On January 19, 2000, a total of six full-shift general area (GA) air samples for organic solvents were collected simultaneously on both thermal desorption and charcoal tubes. Samples collected on the thermal desorption tubes were used as a qualitative screen to identify ototoxic chemicals and other major organic compounds. Samples collected on the charcoal tubes were analyzed quantitatively for specific compounds based on the qualitative screening. Quantitative results were obtained for the following analytes: acetone, n-hexane, toluene, total xylenes, styrene, trichloroethylene, perchloroethylene, and total hydrocarbons. "Total hydrocarbons" is the sum of all peaks detected minus the individually requested analytes (acetone, n-hexane, toluene, total xylenes, styrene, trichloroethylene, and perchloroethylene). On January 20, 2000, a total of four half-shift GA air samples were collected in the same manner and quantitatively analyzed for the same analytes. Full-shift, 8-hour samples were collected in the gear/suspension area and in the fabrication area. Half-shift, 5-hour samples were collected in the fabrication area.

Air samples collected on thermal desorption tubes using a battery-powered air sampling pump calibrated at a flowrate of 0.05 liters per minute (L/min), were thermally desorbed in a Perkin-Elmer ATD 400 automatic thermal desorption system. The thermal unit was directly interfaced to an HP6890A gas chromatograph with an HP5973 mass selective detector (TD-GC-MSD). Air samples were also collected on coconut shell charcoal tubes using battery powered air sampling pumps calibrated to provide a volumetric flowrate of 0.2 L/min. The charcoal tubes were desorbed with 1.0 milliliter (mL) of carbon disulfide and analyzed by a HP5890A gas chromatograph equipped with a flame ionization detector (GC-FID). Analysis was performed according to NIOSH methods 1003, 1022, 1300, 1500, 1501, and 1550, with modifications.[10,11,12,13,14,15] "Total hydrocarbons" was quantitated against a heptane standard.

Full- and half-shift area CO measurements were collected with Biosystems, Inc. Toxi Ultra® personal CO monitors equipped with electrochemical sensors. The Toxi Ultra monitors were placed next to the area air samples during both days of sampling. These monitors instantaneously measure CO concentrations in a range of 0-500 parts per million (ppm) and were set to record concentrations every minute. Data was stored in an internal data logger and later downloaded to a computer. Calibration of these monitors was accomplished before and after sampling according to the manufacturer's specifications.

Qualitative airflow measurements were performed using ventilation smoke tubes to determine airflow patterns throughout the race shop. These measurements also determined whether areas were maintained under positive, negative, or neutral pressures. Airflow measurements were made at all entrances to the race shop, restroom entrances, and at the paint booth entrances.

Noise Exposure Assessment

Noisy tasks were identified and their sound pressure levels measured using a Quest model 1800 sound level meter. Job descriptions and noise level measurements were used to plan the noise dosimetry for each subject. Dosimetry involves continuous noise measurement by a small dosimeter worn by the individual. 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. Those who worked at the same job during their entire shift wore the noise dosimeter for 4 to 10 hours. The results were used to estimate their 8-hour noise dose, to compare their exposure to recommended exposure limits. Workers who performed tasks in different locations wore the noise dosimeter during their full shift (10 hours). Noise dosimetry was conducted with Quest model M-27 dosimeters. Both the Occupational Safety and Health Administration (OSHA) and NIOSH recommended limits and exchange rates were used in these evaluations. The exchange rate describes the relationship between time of maximum permissible exposure and sound level. In this case, they vary in an inversely proportional manner so that as the sound level increases, the time of maximum permissible exposure decreases, and vice versa. At the end of the sampling period, the dosimeters were removed and paused to stop data collection. The measurements stored in the internal datalogger were later downloaded to a computer for interpretation. The dosimeters were calibrated before and after use according to manufacturer specifications.

Follow-up Site Visit to Race Shop

Chemical Exposure Assessment

On February 9, 2000, a total of 11 full-shift GA air samples for organic solvents were collected on charcoal tubes (individual analytes were chosen based on a chemical inventory of the paint booth/body shop area). Samples were obtained inside the paint booth, on a cart just outside the paint booth, on a table in the paint mixing and storage area, and on a table in the body shop area adjacent to the paint booth. The sampling protocol was designed to measure exposures inside the paint booth and in adjacent areas because it was determined that the greatest potential for ototoxic chemical exposures would originate from the paints, varnishes, and thinners.

The charcoal tubes were quantitatively analyzed for the following analytes: acetone, methylene chloride, naphthas, ethyl benzene, epichlorohydrin, perchloroethylene, total xylenes, styrene, toluene, 1,1,1-trichloroethane, and n-butyl acetate. One full-shift personal breathing zone (PBZ) sample for the paint/body shop employee was also collected on charcoal tubes and quantitatively analyzed for toluene, 1,1,1-trichloroethane, n-butyl acetate, total xylenes, styrene, ethyl benzene, epichlorohydrin, and perchloroethylene. In addition, a thermal desorption tube and charcoal tube were placed side-by-side in the paint booth to obtain a GA air sample for qualitative and quantitative analysis to identify and quantify any ototoxic chemicals not targeted in the sampling protocol. Major constituents detected in the qualitative screen were subsequently analyzed on the charcoal tubes and included the following: ethyl acetate, toluene, xylenes, butyl acetate, and C_7-C_8 total hydrocarbons. Total C_7-C_8 hydrocarbons were determined by taking the sum of all peaks that were detected in this range minus toluene (an individually requested analyte also in this range).

Air samples were collected on coconut shell charcoal tubes at a nominal flowrate of 0.05 or 0.01 L/min and on the thermal desorption tubes at 0.1L/min. In order to avoid breakthrough on the charcoal tubes, they were routinely changed throughout the day before maximum volumes (outlined in the NIOSH methods) could be achieved. The charcoal tubes were desorbed with 1.0 mL of carbon disulfide and screened by GC-

FID. Analysis was performed according to NIOSH methods 1550, 1450, 1501, and 1457, with modifications.[14,15,16,17] "Total hydrocarbons" was quantitated against a heptane standard. The thermal desorption tubes were thermally desorbed in the same manner as previously described and analyzed by GC-MSD.

Real-time area air samples for toluene were collected on Drager® detector tubes. Air was pulled through the tube using a hand pump. Ten strokes were used for a detection range of 5 ppm to 80 ppm. Each measurement took approximately five minutes. A color change from white to pale brown was used as an indicator and corresponded to the toluene concentration present in the air. Xylene (all isomers) and benzene were also indicated with the same sensitivity. The discoloration in the presence of p-xylene is violet, and yellowish-green when benzene is present.

A short-term GA air sample was collected for 27 metals and minerals next to the TIG welding machine during operation. This sample was collected on a 0.8-micrometer (µm) pore size, 37-millimeter (mm) diameter, cellulose ester membrane (CEM) filter, using a battery-powered air sampling pump calibrated at a flowrate of 1.0 L/min. Analysis was performed according to NIOSH method 7300, using an inductively coupled plasma (ICP) emission spectrometer.[18]

Noise Exposure Assessment

Noise dosimetry was performed on three workers during the follow-up visit, for a period of 9 hours as previously described. Both the OSHA and NIOSH criteria and exchange rates were used for this evaluation.

Initial Site Visit to Race Track

Chemical Exposure Assessment

On March 25, 2000, three GA air samples were collected on thermal desorption tubes during the 1 hour and 48 minute Cheez-it 250 professional stock car series race at Bristol Motor Speedway in Bristol, Tennessee. The air samples were collected at two sites within the pit, and on the team's race car hauler behind the pit. A qualitative screen was performed by thermal desorption and GC-MSD analysis to identify the presence of any organic solvents.

Three short-term GA air samples were also collected for lead (at the same locations listed above) during the race. Lead sampling was conducted because the fuel used in the race cars is a 110-octane leaded gasoline. Air samples were collected on 0.8-µm pore size, 37-mm diameter, CEM filters, using battery-powered air sampling pumps calibrated at a flowrate of 3.0 Lpm. Air samples were analyzed according to NIOSH method 7082 and 7105, using flame atomic absorption spectroscopy and graphite furnace atomic absorption spectroscopy, respectively.[19,20] The minimum detectable concentration (MDC) and minimum quantifiable concentration (MQC) (calculated according to the laboratory assigned limit of detection [LOD] and limit of quantitation [LOQ]) were 7.7 micrograms per cubic meter (µg/m^3) and 20.5 µg/m^3, respectively, for method 7082, and 0.13 µg/m^3 and 0.51 µg/m^3, respectively, for method 7105.

CO measurements were collected during the race (at the same locations where the MCE filters and thermal desorption tubes were placed) using Biosystems, Inc. Toxi Ultra personal CO monitors. The monitors were set to record CO concentrations every minute and store the data in an internal datalogger. The data was later downloaded to a computer.

Noise Exposure Assessment

Noise measurements were performed on both practice and race days (March 24 and 25, 2000, respectively). Sound level meter area measurements were conducted to estimate noise exposure in the pit area, where the pit crew works.

Additionally, dosimeters were worn by NIOSH field staff (positioned by the team's race car hauler), and were also placed in the pit area on the tool box. One dosimeter was attached to a roll bar inside the race car to estimate the driver's exposure during practice.

Follow-up Site Visit to Race Track

On August 25, 2000, a total of nine personal and GA air samples were collected for CO at Bristol Motor Speedway. Of these nine samples, two personal and three GA air samples were collected for the full day (approximately 11½ hours). In addition, two GA air samples were collected during the practice period from 10:30 a.m. to 12:30 p.m., and two GA air samples were collected during the night Food City 250 professional stock car series race from approximately 7:00 p.m. to 9:00 p.m. The Biosystems, Inc. Toxi Ultra CO monitors were set to record CO concentrations every minute, with the exception of the monitors used to collect data during the practice period and race, which were programmed to record at 5 second intervals. The data was stored in an internal datalogger and later downloaded to a computer.

Sound level measurements were conducted in the pit area, as previously described. Also, a dosimeter was worn by a NIOSH researcher who positioned himself by the team's race car hauler.

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 increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[21] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[22] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).[23] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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 STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term. A STEL is a 15-minute TWA exposure that should not be exceeded at any time during the workday. The ceiling values that NIOSH recommends is a level that should not be exceeded at any time.

Organic Solvents

The term "organic solvents" refers to a group of volatile compounds or mixtures that are relatively stable chemically and that exist in the liquid state at temperatures of approximately 0° to 250°C (32° to 482°F). Common organic solvents are classified as aliphatic hydrocarbons, cyclic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons, ketones, amines, esters, alcohols, aldehydes, and ethers.[24] Many common solvents often exist as mixtures or blends of chemical compounds (e.g., Stoddard solvent and thinners).[25,26]

Organic solvents are used for extracting, dissolving, or suspending materials such as fats, waxes, and resins that are not soluble in water. The removal of the solvent from a solution permits the recovery of the solute intact with its original properties.[27] Solvents are used in paints, adhesives, glues, coatings, and degreasing/cleaning agents, and in the production of dyes, polymers, plastics, textiles, printing inks, agricultural products, and pharmaceuticals.[25,26]

Exposure to organic solvents can occur through inhalation of the vapors and absorption through the skin. Acute effects from exposure to high concentrations of solvents often include anesthesia, central nervous system (CNS) depression, impaired motor function, respiratory arrest, unconsciousness, and death. At lower concentrations, symptoms of dizziness, headaches, fatigue, lightheartedness, weakness, poor concentration, and mucous membrane irritation may occur.

Chronic effects that have been reported among some workers exposed to organic solvents include peripheral neuropathies, organic affective syndrome, and mild chronic toxic encephalopathy. Organic affective syndrome is characterized by fatigue, memory impairment, irritability, difficulty in concentration, and mild mood disturbance. Mild chronic toxic encephalopathy is manifested by sustained personality or mood changes such as emotional instability, diminished impulse control and motivation, and learning capacity. The extent to which chronic neurotoxicity is reversible remains to be established.

Three organic solvents that were identified in the initial qualitative screening and are known to have ototoxic effects were targeted in this study. A discussion of their specific health effects and exposure criteria are included below.

Toluene

Toluene is a colorless, aromatic organic liquid containing a six carbon ring (a benzene ring) with a methyl group (CH_3) substitution. It is commonly used in the manufacture of paints, lacquers, adhesives, rubber, and in rotogravure printing and leather tanning. It is also used as a raw material in the synthesis of organic chemicals, dyes, detergents, and pharmaceuticals. Inhalation and skin absorption are the major occupational routes of entry. Toluene causes acute irritation of the eyes, respiratory tract, and skin. Since it is a defatting solvent, repeated or prolonged skin contact will remove the natural lipids from the skin which can cause drying, fissuring, and dermatitis.[28,29]

The main effects reported with excessive inhalation exposures to toluene are CNS depression and neurotoxicity.[29] Studies have shown that subjects exposed to 100 ppm of toluene for six hours complained of eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication (narcosis).[30,31,32] No symptoms were noted below 100 ppm in these studies. There are a number of reports of neurological damage due to deliberate sniffing of toluene-based glues resulting in motor weakness, intention tremor, ataxia, as well as cerebellar and cerebral atrophy.[33] Recovery is complete following infrequent episodes, however, permanent impairment may occur after repeated and prolonged glue-sniffing abuse. Exposure to extremely high concentrations of toluene may cause mental confusion, loss of coordination, and unconsciousness.[34,35]

Originally, there was a concern that toluene exposures produced hematopoietic toxicity because of the benzene ring present in the molecular structure of toluene. However, toluene does not produce the severe injury to bone marrow characteristic of benzene exposure as early reports suggested. It is now believed that simultaneous exposure to benzene (present as a contaminant in the toluene) was responsible for the observed toxicity.[22,28,36]

Evidence from animal research indicates that toluene has a deleterious effect on the rat and mouse auditory system, and a synergistic effect (i.e., the total effect is greater than the sum of the individual effects) in combination with noise.[37,38] Studies conducted with printing workers reported that toluene exposure has been associated with evoked auditory potential abnormalities and increased prevalences of audiometric hearing loss.[39,40,41,42] Biological determinants of toluene, in blood[40] or urine,[42] were found to be associated with the auditory outcomes (i.e., elevated auditory thresholds with increased toluene levels).

The OSHA PEL for toluene is 200 ppm for an 8-hour TWA. The NIOSH REL for toluene is 100 ppm for up to a 10-hour TWA. NIOSH has also set a recommended STEL of 150 ppm for a 15-minute period. The ACGIH TLV is 50 ppm for an 8-hour exposure. The TLV carries a skin notation, indicating that cutaneous exposure contributes to the overall absorbed inhalation dose and potential systemic effects.

Xylene

Xylene is a colorless, flammable organic liquid with a molecular structure consisting of a benzene ring with two methyl group (CH_3) substitutions. Xylene is used in paints and other coatings, and as a raw material in the synthesis of organic chemicals, dyes, and pharmaceuticals.

The vapor of xylene has irritant effects on the skin and mucous membranes, including the eyes and respiratory tract. This irritation may cause itching, redness, inflammation, and discomfort. Repeated or prolonged skin contact may cause erythema, drying, and defatting, which may lead to the formation of vesicles. At high concentrations, repeated exposure to xylene may cause reversible damage to the eyes.[29]

Acute xylene inhalation exposure may cause headache, dizziness, incoordination, drowsiness, and unconsciousness.[36] Previous studies have shown that concentrations from 60 to 350 ppm may cause giddiness, anorexia, and vomiting.[29] At high concentrations, exposure to xylene has a narcotic effect on the CNS, and minor reversible effects on the liver and kidneys.[29,36,43]

In rats, aromatic solvents including xylene seem to affect auditory sensitivity mainly in the mid-frequency range.[44,45] Outer hair cells are the primary targets within the Organ of Corti. Therefore, xylene must be considered an ototoxic chemical agent.

Historical accounts of hematopoietic toxicity as a result of xylene exposure are likely due to the high concentration of benzene contamination in xylene prior to 1940. These effects previously reported are no longer associated with contemporary xylene exposure.[36,46,47]

The current OSHA PEL, NIOSH REL, and ACGIH TLV for xylene are 100 ppm over an 8- to 10-hour TWA. In addition, OSHA and NIOSH have published STELs for xylene of 150 ppm averaged over 15 minutes.

Styrene

Styrene is a colorless liquid with a strong odor at room temperature. It is highly flammable and can be a significant fire hazard. Styrene is readily absorbed by the respiratory and gastrointestinal systems and by the skin. Exposures to styrene have caused CNS depression; subjective complaints including headache, fatigue, sleeplessness, nausea, malaise, difficulty in concentrating, and a feeling of intoxication. Decrements in balance, coordination, and manual dexterity tests have also been reported, in addition to slower reaction times and abnormal electroencephalograms (EEGs).

Styrene has been well characterized in terms of acute toxicity. Exposure to styrene vapors at relatively low concentrations can cause immediate irritation of the eyes and respiratory system. At higher concentrations, the vapor is a narcotic and can cause disorientation, confusion, and loss of consciousness. Skin contact with liquid styrene causes drying and inflammation, and may result in dermatitis or rash.

The health effects associated with long-term exposure are less well known. Long-term exposure at high concentrations may affect the nervous system, respiratory system, liver, and skin. Recently, there have been some studies that suggest a link between styrene exposure and cancer. However, the evidence for carcinogenic effects is relatively weak and NIOSH does not currently classify styrene as a human carcinogen.

Animal experiments shed light on the ototoxicity of styrene.[44,45,48,49,50,51] Styrene exposure can cause a permanent and progressive damage to the auditory system of the rat. Styrene has been shown to be a more potent ototoxicant than toluene, and to have a synergistic effect when presented in concert with noise or ethanol.[52,53]

Early human field studies assessing the effects of styrene on auditory function identified only minimal effects of the solvent on pure-tone thresholds.[54,55,56] More recently, the effects of styrene were investigated in male workers exposed in factories that produced plastic buttons or bathtubs.[57,58] Although both noise levels and styrene concentration in air were within limits recommended by several international agencies, high frequency hearing thresholds were elevated in workers exposed for 5 years or more. This effect was associated with styrene concentrations in air and mandelic acid concentrations in urine.

Based on acute and chronic health effects, OSHA has set a PEL of 50 ppm as an 8-hour TWA. OSHA has also issued a STEL of 100 ppm for an exposure duration of 15 minutes. The NIOSH REL is 50 ppm for a 10-hour day and 40-hour work week. A ceiling limit, or maximum peak exposure, of 100 ppm is also recommended along with a warning to avoid skin contact. NIOSH recommendations are based on nervous system effects, respiratory irritation, and suspected adverse reproductive effects. The ACGIH recommends 20 ppm for an 8-hour TWA and 40 ppm for a STEL. The TLV also includes a notation that styrene is "identified by other sources as a suspect or confirmed human carcinogen."[22]

Lead

Exposure to lead occurs via inhalation of lead-containing dust and fume, and ingestion from contact with lead-contaminated surfaces. Absorbed lead accumulates in the body in the soft tissues and bones. Lead is stored in bones for decades, and may cause health effects long after exposure ceases as it is slowly released in the body. Symptoms of lead poisoning include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[29,59,60] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility, reduced sex drive in both sexes, and impotence. Lead exposure is especially devastating to fetuses and young children due to potentially irreversible toxic effects on the developing brain and nervous system.

Experimental studies on the auditory effects of lead exposure have been conducted with monkeys, and the findings reflected elevated pure-tone thresholds,[61] abnormal distortion product otoacoustic emissions (DPOAEs), abnormal auditory brain stem evoked responses, but normal middle latency evoked responses.[62,63] Hitherto, no investigations have been reported looking at the combined exposure between lead and noise.

Findings from studies on human populations exposed to lead in their work environment reported associations between lead exposures and hearing disorders. Abnormal auditory brainstem responses[64,65,66,67] and auditory event-related potentials[68,69] have been significantly correlated with blood lead levels.

In the OSHA lead standards for general industry and construction, the PEL for airborne lead is 50 µg/m^3 (8-hour TWA), which is intended to maintain worker blood lead levels (BLLs) below 40 micrograms per deciliter (µg/dL); medical removal is required when an employee's BLL reaches 50 µg/dL.[70,71] NIOSH has concluded that the revised 1978 NIOSH REL of 100 µg/m^3 for up to an 8-hour TWA does not sufficiently protect workers from the adverse affects of exposure to inorganic lead.[72] NIOSH intends to analyze the feasibility of developing a REL that would provide better protection for workers. NIOSH has conducted a literature review of the health effects data on inorganic lead exposure and finds evidence that some of the adverse effects on the adult reproductive, cardiovascular, and hematologic systems, and on the development of children of exposed workers can occur at BLLs as low as 10 µg/dL.[73] For example, fetal exposure to lead is associated with reduced gestational age, birthweight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.[60] At BLLs below 40 µg/dL, many of the health effects would not necessarily be evident by routine physical examinations, but represent early stages in the development of disease. In recognition of this, voluntary standards and public health goals have established lower exposure limits to protect workers and their children. The ACGIH TLV for airborne lead is 50 µg/m^3 as an 8-hour TWA, with worker BLLs to be controlled to $\leq$30 µg/dL.

Carbon Monoxide

CO is a colorless, odorless, tasteless gas which has approximately the same density as air. It is produced by incomplete combustion of organic fuels. Common sources of this gas are cigarette smoke, which contains approximately 4% CO, automobile exhaust, which contains from 0.5-10%, and various industrial processes.[74] CO is classified as a chemical asphyxiant because it binds with the hemoglobin molecule to form carboxyhemoglobin, interfering with the oxygen carrying capacity of the blood and resulting in a mild to severe state of tissue hypoxia. The amount of carboxyhemoglobin formed is dependent on concentration and duration of CO exposure, ambient temperature, health, and metabolism of the individual. Exposure to a constant air concentration of CO results in a constant COHb level after an equilibration period of some hours, the time required being inversely proportional to the CO concentration.[74] CO is eliminated substantially unchanged by pulmonary excretion, with less than 1% oxidized by metabolic processes to carbon dioxide. The half-life of carboxyhemoglobin in resting adults at sea level is 4–5 hours.[74] The formation of carboxyhemoglobin is a reversible process. Recovery from acute poisoning usually occurs without sequelae unless tissue hypoxia was sever enough to result in brain cell degeneration.

The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[29]

It has been shown in a number of studies that COHb concentrations of 10% or less adversely affect a person's ability to perform complex tasks as well as strenuous manual labor.[75] Blood COHb concentrations of 5–10% may aggravate pre-existing heart disease, while concentrations of 15–25% often cause dizziness and nausea. Initially the victim is pale; later the skin and mucous membranes may be cherry-red in color. Loss of consciousness occurs at about the 50% carboxyhemoglobin level and levels which exceed 50% saturation are considered life-threatening.

Experimental studies have demonstrated the potentiation of noise-induced hearing loss by CO exposure in rats.[76,77] In those studies, broad band noise exposure alone and CO exposure alone did not produce a permanent auditory threshold shift, but there was significant auditory impairment when CO was presented simultaneously with noise.

More recently, specific experiments have been carried out to determine the relationships between noise exposure and CO concentration on potentiation of noise induced hearing loss (NIHL) in pigmented rats. These studies may be helpful in undertaking risk assessment analyses. The results of experiments recently reported show a linear relationship between CO concentration and extent of potentiation of NIHL.[78,79] Statistically significant elevations in NIHL are observed with CO exposures of 500 ppm and higher, yet benchmark concentration analyses suggest that much lower CO concentrations are able to potentiate NIHL in rats. The question of how much lower the CO concentration needs to be to yield potentiation of NIHL is dependent in part upon selection of criteria for determining what the benchmark effect should be. Based on the recent evidence, a lower bound to the benchmark dose of CO for potentiation of NIHL of 195–320 ppm was predicted.[78,79] Adjustment of this benchmark by a factor of 10 would place the reference concentration within the permissible range of human workplace exposure. Moreover, the experimental results obtained when a limited number of daily repeated exposures were employed, suggest increased risk of potentiation with repeated exposures to CO and noise. This suggests the need to consider additional adjustments in developing a reference concentration for CO in the presence of noise. One potential weakness in our determination of a benchmark concentration for CO reflects the fact that the noise exposure conditions selected in the CO dose-response study are not optimal for producing potentiation by CO. Thus, the current estimated benchmark dose might still be high.

The predicted benchmark concentration at which CO exposure potentiates NIHL far exceeds permissible exposure levels for CO. In the United States, the Environmental Protection Agency permits ambient exposure levels of 9 ppm averaged over 24 hours and 35 ppm averaged over one hour. For work environments, the standards by OSHA are 50 ppm averaged over an 8-hour workday, with a peak level of 200 ppm. The ACGIH recommends an 8-hour TWA TLV of 25 ppm. The NIOSH REL for CO is 35 ppm for up to a 10-hour TWA exposure. The REL is designed to protect workers from health effects associated with COHb levels in excess of 5%.[80] NIOSH also recommends that a ceiling limit of 200 ppm CO never be exceeded any time during the workday.

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 NIHL results from damage to sensory hair cells of the inner ear (cochlea) and cannot be treated medically.[81] 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, NIHL is insidious. Typically, it begins to develop at 4000 or 6000 Hertz (Hz) (the human 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 500 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.[82]

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)[83] specifies a maximum 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:

$$\text{Dose} = 100 \times (C1/T1 + C2/T2 + ... + Cn/Tn),$$

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. 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 8-hour 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,[84] and the ACGIH[22] proposed 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 exchange rate 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, etc.

RESULTS

Initial Site Visit to Race Shop

Chemical Exposure Assessment

Multiple solvents, consisting mostly of aliphatic hydrocarbons, were detected on the thermal desorption tubes. The most predominant compounds were C_7 alkanes and toluene. Other solvents detected by qualitative analysis included, acetone, isopropanol, perchloroethylene, xylenes, methoxypropanol, methyl propanoic acid esters, trichloroethylene, butyl acetate, propylene glycol methyl ether acetate, benzyl alcohol, hexane, butyl cellosolve, limonene, styrene, methanol, and methylene chloride. Table 1 shows the quantitative results for the 8-hour full-shift area air samples collected on January 19, 2000. Table 2 shows the results for the 5-hour half-shift area air samples collected on January 20, 2000. Quantitative results and the calculated MDCs and MQCs for each analyte (based on the laboratory assigned LODs and LOQs) are listed in Table 1 and Table 2. The MDC and MQC were calculated using an average total sample volume of approximately 98 liters (L) for the full-shift samples and 63 L for the half-shift samples. The concentrations of each solvent were converted from milligrams per cubic meter (mg/m^3) to ppm for direct comparison to OSHA's and ACGIH's 8-hour TWA and NIOSH's 10-hour TWA exposure standard. The solvents chosen for quantitative analysis were either not detected or were detected in extremely low levels, well below any relevant occupational exposure criteria.

In addition, Table 1 and 2 show the mean and peak CO concentrations for both the 8-hour and 5-hour GA air samples collected on January 19 and 20, 2000, respectively. The mean concentrations were well below the OSHA PEL of 50 ppm, the NIOSH REL of 35 ppm, and the ACGIH TLV of 25 ppm. The peak concentrations in two locations within the fabrication area, although elevated, did not exceed the 200 ppm ceiling limit recommended by NIOSH.

Qualitative smoke tube tests indicated that the race shop entrances were maintained under a slight positive pressure with respect to the outdoor environment. The restrooms were maintained under negative pressure with respect to the set-up area. Smoke tube tests at the paint booth's large entrance (where the body of the race car is brought in) indicated a good seal when the ventilation was in operation. The entrance was maintained under a very slight positive pressure with the exhaust fans operating and door slightly ajar, so that particulates and other contaminants would not enter the paint booth and contaminate the paint job if the door is opened while the paint is drying. The smaller, side door entrance (where the painter enters and exits) was under negative pressure. Small openings around a window in the booth, as well as along the walls, were under negative pressure indicating that when the ventilation is used contaminants can not escape the paint booth.

Noise Exposure Assessment

The work routine of the crew (including duration of specific tasks) is highly variable, both within and between days. In such circumstances it is valuable to identify the tasks that may contribute to excessive noise exposures. The sound pressure levels of the tasks which produced the loudest noises were measured and are displayed in Table 3. The employees were subject to short periods of relatively high noise exposures each day. Mean sound pressure levels in the race shop ranged from 58 to 103 dB(A). Only three of the workers (21%) were observed wearing ear plugs during their work shift.

Noise dosimeters were worn by three workers on each day of the initial visit. On January 19, 2000, the meters were placed on employees at the beginning of their work shift (8 a.m.) and worn until the end of their shift (between 6:00 p.m. and 6:45 p.m.), when the meters were paused and the stored data downloaded to a computer. On January 20, the workers wore the dosimeters from 7:00 a.m. to 11:35 a.m. The results of the noise dosimeter survey (histograms) are shown in Figures 1 through 5. NIOSH recommended limits and exchange rates (85 dBA and the 3-dB exchange rate) were used in these figures, and are indicated as L_{NIOSH}. It should be noted that the individual values plotted on the graphs are the result of one-minute integrations of sound pressure levels measured 16 times per second.

Table 4 provides a comparison of the results obtained with the 3 and the 5-dB exchange rates. While the OSHA PEL of 90 dB(A) for an 8-hour TWA was never exceeded, the values exceeded the OSHA AL of 85 dB(A) (8-hour TWA) for hearing conservation implementation in two instances. The NIOSH REL of 85 dB(A) for an 8-hour TWA was exceeded for five of the nine measured jobs.

Follow-up Site Visit to Race Shop

Chemical Exposure Assessment

Table 5 provides the full-shift GA air samples for the following organic solvents collected on February 9, 2000: acetone, methylene chloride, naphthas, ethyl benzene, epichlorohydrin, perchloroethylene, total xylenes, styrene, toluene, 1,1,1-trichloroethane, and n-butyl acetate. Analysis revealed extremely low solvent concentrations that were well below the occupational exposure criteria.

A wide variety of solvents were identified on the thermal desorption tube that was placed inside the paint booth. Major compounds identified in qualitative analysis were toluene, actone, isopropanol, methyl ethyl ketone (MEK), ethyl acetate, C_7-C_8 alkanes (possibly a VM&P type naphtha), methyl isobutyl ketone (MIBK), butyl acetate, xylene, propylene glycol, methyl ether acetate, methyl amyl ketone (MAK), butyl propionate, and ethyl ethoxy propionate. Other compounds detected, some at trace levels, included butanol, isopropyl acetate, styrene, hexyl acetate, alkyl benzenes, methyl methacrylate, butyl cellosolve acetate, limonene, benzaldehyde, methylene chloride, methyl acetate, ethanol, methanol, methoxy propanol, and phenol. From these compounds, ethyl acetate, toluene, xylenes, butyl acetate, and C_7-C_8 total hydrocarbons were quantitatively analyzed. Solvent concentrations and C_7-C_8 total hydrocarbons were extremely low and well below the exposure criteria.

Real-time measurements indicated concentrations of toluene ranging from 6 ppm to 20 ppm. Xylene and benzene were not detected on the Drager tubes. Measurements were taken during the mixing of primer and paint, while a sealant coat was being applied to the hood, and while the Safety Kleen® lacquer thinner bath was running for approximately 30 seconds while the paint gun was being cleaned. The highest readings were detected while the Safety Kleen® bath was running.

The short-term GA air sample collected for metals near a TIG welding station in the fabrication shop revealed no detectable concentrations, with the exception of manganese. However, the detected concentration (0.012 mg/m^3) was less than 20% of the most stringent exposure criteria (1 mg/m^3 as an 8-hour TWA).

Noise Exposure Assessment

Noise dosimeters were worn by three workers on February 9, 2000. The meters were placed on employees at the beginning of their work shift (8:46 a.m.) and worn until the end of their shift (7:10 to 7:26 p.m.), when the meters were paused and the data downloaded to a computer. Table 4 provides a comparison of the results obtained with the 3 and the 5-dB exchange rates. The results of the noise dosimeter survey (histograms) with individual values are not available because of technical problems that resulted in data loss during download.

Initial Site Visit to Race Track

Chemical Exposure Assessment

Qualitative analysis from three GA air samples collected on thermal desorption tubes on March 25, 2000, during the Bristol Motor Speedway Cheez-It 250 professional stock car series race identified various organic solvents. The major compounds identified were isopentane, C_8 alkanes (isooctane, dimethylhexanes, trimethylpentanes), and toluene. Other compounds detected included various C_4-C_9 alkanes, benzene, perchloroethylene, xylene, butyl cellosolve, alkyl benzenes, naphthalene, and limonene. However, the amounts of even the major compounds identified were insufficient to quantify.

The three GA air samples collected for lead during the race revealed non-detectable concentrations after the first analysis was performed. The more sensitive method of analysis, performed subsequently, identified the highest concentration of lead to be 5 $\mu g/m^3$, well below the occupational exposure criteria.

Table 6 shows the mean and peak CO concentrations collected during the afternoon race on March 25, 2000. The mean concentrations were well below the OSHA PEL of 50 ppm, the NIOSH REL of 35 ppm, and the ACGIH TLV of 25 ppm. These criteria are all 8-hour TWAs. The mean concentrations for the race were determined over a period of 1 hour and 48 minutes, and thus cannot be directly compared to the exposure standards. The peak concentrations measured during the race did not exceed the 200 ppm STEL recommended by NIOSH.

Noise Exposure Assessment

Sound level meter measurements were made on each day of the race weekend (March 24 and 25, 2000). Additionally, noise dosimeters were worn by two NIOSH researchers positioned by the team's race car hauler in the infield area of the track on each day of the race weekend. The remaining dosimeters were placed on the crew's tool box and inside the stock car for one of the practice periods. The dosimeters were turned on at the beginning of the day (around 8:30 a.m.) and measurements were recorded in an internal datalogger until the end of the day (approximately 5 p.m.). The dosimeters were then paused and the stored data downloaded to a computer. The results of the noise dosimeter survey (histograms) are shown in Figures 6 through 12. It should be noted that the individual values plotted on the graphs are the result of one-minute integrations of sound levels measured 16 times per second. Both the OSHA PEL and the NIOSH REL were exceeded in every instance with average noise levels above 100 dB.

Follow-up Site Visit to Race Track

Chemical Exposure Assessment

Table 7 shows the area air sampling results for CO that were collected on August 25, 2000, at Bristol Motor Speedway. The mean and peak concentrations logged in three locations (on top of the race car hauler and on the left and right side of the toolbox located in the pit) are given for the practice period (10:30 a.m. to 12:30 p.m.), qualifying (3:35 p.m. to 4:40 p.m.), and the Food City 250 professional stock car series race (7:04 p.m. to 8:53 p.m.). The mean and peak CO concentrations are also given for the entire day (approximately 10 hours and 20 minutes; 10:30 a.m. to 8:53 p.m.) in these same locations. Mean and peak CO concentrations recorded on CO monitors that were placed on a speaker post by the pit and in the race car are only given for the practice period. The full-shift mean CO concentration collected on the left side of the toolbox in the pit exceeded the PEL, REL, and TLV of 39 ppm, 19 ppm, and 27 ppm, respectively, after they were adjusted for a 10⅓-hour day. The full-shift mean CO concentration collected on the right side of the toolbox exceeded the adjusted REL and TLV. Peak CO concentrations exceeded the NIOSH recommended ceiling limit of 200 ppm in three of the five locations where measurements were collected during the practice period. Peak concentrations in two of the three locations where measurements were collected over the full day also exceeded 200 ppm.

Table 7 also gives the personal CO air sampling results that were collected on August 25, 2000. Mean and peak CO concentrations are given for the practice period, qualifying, the Food City 250 professional stock car series race, and the entire day from arrival at the track's infield through the end of the race (approximately 11 hours and 30 minutes; 9:30 a.m. to 8:53 p.m.). The full-shift mean concentrations did not exceed any of the occupational exposure criteria after they were adjusted for an 11½-hour day. None of the peak concentrations exceeded NIOSH's ceiling limit of 200 ppm.

Noise Exposure Assessment

Noise dosimeters were worn by a NIOSH researcher positioned by the team's race car hauler in the infield area of the track on August 25, 2000. Dosimeters were also positioned on the crew's tool box. The dosimeters were turned on at the beginning of the day (approximately 8:30 a.m.) and measurements were recorded in an internal datalogger until the end of the race (approximately 8:50 p.m.). The dosimeters were then paused and the stored data downloaded to a computer. The results of the noise dosimeter survey are represented in histograms shown in Figures 13 and 14. Both the OSHA PEL and NIOSH REL were exceeded in every instance.

DISCUSSION

Chemical Exposures

Air sampling at the evaluated team's race shop and the race track revealed that organic solvent concentrations and levels of lead and other metals were either not detected, or were extremely low and well below any occupational exposure criteria.

CO levels never exceeded the 8-hour TWA exposure criteria, or the NIOSH recommended ceiling limit at the race shop; however, peaks up to 117 ppm were recorded while the gas-powered forklift was in use. The forklift was used to unload heavy equipment from a truck and move it into the garage. Once the forklift was turned off, CO levels returned to a range of 0 to 7 ppm within minutes. The owner of the racing team reported that the forklift was infrequently used, and when used it was only for short periods of time. Therefore, opening the garage door while the forklift is in use should supply an adequate amount of fresh air to ventilate the area and reduce peak exposures.

CO measurements taken during the day race at Bristol Motor Speedway on March 25, 2000, could not be compared to 8-hour TWA exposure criteria because the duration of the race was less than two hours. However, none of the measurements exceeded the NIOSH ceiling limit of 200 ppm. A trend was observed between peak CO concentrations and some of the laps which were run under the yellow caution flag. Laps run under caution during the middle of the race corresponded with higher CO peak concentrations as compared with laps run under caution during the beginning or end of the race, or laps run under normal conditions. During pit stops cars are refueled, tires are changed, and adjustments are made to the car. Generally, the majority of pit stops are taken during laps run under the caution flag that occur during the middle of the race when fuel and/or new tires are needed. Also, the timing of pit stops is strategically important in terms of the driver's track position. Because of this, cars generally pit together to either keep from losing positions, or to possibly gain positions. Thus, it is likely that CO generated from vehicle exhaust would be detected in higher concentrations when a greater number of cars pit.

CO measurements taken during the entire day at Bristol Motor Speedway on August 25, 2000, revealed 8-hour mean concentrations and peak concentrations in the pit that exceeded both the 8-hour TWA exposure criteria (after adjustment for a 10⅓-hour day) and the NIOSH ceiling limit. When mean and peak concentrations were broken down by each individual event, the greatest concentrations occurred during the practice period. Peak concentrations recorded at both locations in the pit (235 ppm and 458 ppm) and in the race car (202 ppm) exceeded NIOSH's ceiling limit, a level that NIOSH recommends never be exceeded. The lowest levels occurred on top of the team's race car hauler, the farthest location from the track and pit.

Concentrations recorded during the qualifying period were the next to lowest observed throughout the day. The lowest concentrations observed occurred during the night race. Neither event had peak concentrations that exceeded NIOSH's ceiling limit. It was unexpected that the lowest CO levels were observed during the night race. It had been hypothesized that a temperature inversion, which typically occurs in the valleys during warm nights, would create a blanket-like effect over the track that would hinder dilution ventilation. This occurrence would trap CO fumes inside the track and result in a measurable increase in CO levels. However, the levels measured at night during the race as compared with those measured throughout the day, indicate that either a temperature inversion did not occur, or the inversion did not have as great an effect on the CO levels as originally suspected.

The highest CO concentrations observed during practice are most likely due to gasoline-powered engines used by the teams to power electrical generators during this period. Generators are used to power tools which are used to make adjustments to the race car. Generally, on practice days, the generators begin running when the team sets-up at the track and continue running throughout the day until the race. During practice, all drivers are allowed on the track at the same time and can pit whenever they choose to allow adjustments to be made to the car based on its handling and performance. During practice, the driver for the team NIOSH evaluated completed approximately two to five laps around the track before returning to the pit so adjustments could be made. The gasoline-powered engine is left running throughout this period because adjustments are a continuous process. It is probable that the high peaks and mean concentrations that occurred during the practice period can be attributed to both the CO generated from the cars and the CO generated from the gasoline-powered engines. This is also corroborated by the location of the CO monitor which recorded the highest mean and peak concentrations during practice. This particular monitor was located on the left side of the toolbox, adjacent to the running engine.

Although the highest peak CO concentrations recorded during personal sampling did not exceed NIOSH's recommended ceiling limit, the results followed the same trend observed in the area samples. The highest concentrations occurred during the practice period. The greatest peak concentration out of the two samples occurred just after practice began, while the NIOSH investigator wearing the CO monitor was around the toolbox in the pit area checking the area samples. This also suggests that CO produced by the gasoline-powered engines resulted in elevated concentrations.

None of the CO measurements recorded during qualifying or the night race exceeded NIOSH's ceiling limit. However, during the race two distinct peaks were recorded at approximately 7:45 p.m. and 8:06 p.m. on all five monitors located on the toolbox in the pit area. The peaks recorded at 7:45 p.m. on the left side of the toolbox ranged from 18 ppm to 40 ppm, whereas the peaks recorded on the right side of the toolbox ranged from 26 ppm to 27 ppm. The peaks recorded at approximately 8:06 p.m. on the left side of the toolbox ranged from 19 ppm to 24 ppm, and on the right side from 27 ppm to 31 ppm. With the exception of the CO peaks recorded on the left side of the toolbox at 7:45 p.m., the remaining peak concentrations only differed by 1 to 5 ppm, indicating uniform area CO exposures around the pit area. The highest CO peaks observed during the race coincide with the evaluated team's pit stops. The higher CO peaks may also correspond to caution laps during the middle of the race when many cars simultaneously make pit stops. Thus, the trend seen during the night race seems to follow that seen during the day race. CO from the vehicle exhaust produces peak concentrations during pit stops that are greater than the concentrations observed during the remainder of the race.

Noise Exposures

Noise exposures were evaluated at the racing team's race shop through noise dosimetry and sound pressure level measurements of noisy tasks. Despite noise levels above 85 dBA being observed in several instances, worker exposures were limited at these levels. TWA exposures for four workers were below the 8-hour/85 dBA NIOSH REL, while five were exposed to levels that exceeded the REL. The OSHA AL for hearing conservation was exceed for two individuals. However, the work and exposure characteristics of the workers in this environment are rather unique. Their work routines vary daily until the car is completed. Nevertheless, because of the noisy nature of the tasks they perform, attention should be given to hearing loss prevention. Currently, the only measure adopted by the evaluated team is to make hearing protectors available for those that request it. A task-based exposure assessment method (T-BEAM) might be indicated, considering their exposure patterns. The evaluation has shown that overexposure to noise can occur, and to better assess their hearing loss prevention needs measurements should be conducted during different time periods.

The need for hearing loss prevention is more apparent during race weekends. For the crew, the daily allowable noise dose is exceeded within five minutes of the start of the race. The crew and driver participate in races (which are usually arranged in two to three day periods) almost every weekend during the 9-month season. About a third of the mechanics (5) that work in the race shop, also travel to the different tracks to work at the races. Noise exposures at the race track were extremely high, ranging from 104 to 114 dB(A), and always exceeded the OSHA PEL and NIOSH REL. In addition, the crew often stays in the pit area during their breaks and as a result are continuously exposed. The hearing protection devices currently used by the crew and driver at the race track often incorporate communication systems and do not provide the needed attenuation, with a derated noise reduction rating (NRR) of 18 dB (using the NIOSH method described in the Occupational Noise Exposure: Criteria for a Recommended Standard, 1998).[84]

Attention needs to be given to the hearing protection devices that are offered to workers in the race shop and at the race track. The selected hearing protector must be capable of keeping the worker's noise exposure at the ear below 85 dBA. Because a worker may not know how long a given noise exposure will last, or what additional noise exposure he or she may incur later in the day, it may be prudent to wear hearing protectors whenever working in areas where hazardous noise levels can occur. Workers and supervisors should periodically ensure that the hearing protectors are fitted properly, worn correctly, and provide adequate protection for the noise levels occurring in the areas in which they are worn. Workers that are not required to use a communication set at the race track should consider using double protection. Those who must stay in contact with others using communication devices should investigate newer devices and alternative systems. Linear ear plugs and custom ear mold speakers that reduce background noise with compression circuitry are currently available. The EarTalk[85] system, a combination of a hearing protector and a communication device, developed by NIOSH and customized for the stock car racing application, was tested with the studied crew and successfully demonstrated in a visit to the race shop.

CONCLUSIONS

Based on the environmental data collected during this pilot study, it does not appear that the personal exposures to potentially ototoxic agents are high enough to produce an adverse effect greater than that produced by the high sound pressure levels alone. Carbon monoxide levels, however, occasionally exceeded all evaluation criteria at the race track evaluated. In addition, noise exposures occasionally exceeded the OSHA PEL at the team's race shop and exceed all evaluation criteria at the race track evaluated. Recommendations are included to reduce exposures to potentially ototoxic agents that have the likelihood of producing high short-term exposures and to control noise exposures through the use of appropriate strategies (such as wearing hearing protection with a high enough NRR to provide adequate attenuation).

RECOMMENDATIONS

Based on the measurements and observations made during the evaluation, NIOSH investigators offer the following recommendations to reduce exposures at stock car race shops and race tracks.

1. Welding done at the welding station should be isolated with a shielded curtain. The welder should wear gloves and arm protectors to prevent burns from UV radiation.

2. The Spraybake® should be separated from the rest of the fabrication area to minimize the migration of dust from sanding operations into other areas. A curtain pulled around three sides of the car (leaving the end closest to the exhaust fans open) would reduce migration of dust and increase the efficiency of the exhaust ventilation.

3. Butyl rubber gloves should be worn when using muriatic acid or Weld-O®, which contains hydrofluoric acid, to prep the metal before welding. Butyl rubber will protect against permeation for at least four hours against hydrofluoric acid and at least eight hours against muriatic acid. Due to the short duration required to prep the metal, butyl rubber gloves would supply adequate protection.

4. Polyethylene/ethylene vinyl alcohol gloves should be worn when using the Safety Kleen® heavy duty lacquer thinner bath (located in the paint shop) to protect against the following skin absorbers: toluene, n-butyl alcohol, and methyl alcohol.

5. The exhaust mounted at the top of the Safety Kleen® heavy duty lacquer thinner bath, which is supposed to vent directly outside, should be connected and made operational to minimize exposure to solvent fumes. The lacquer thinner contains methylene chloride and perchloroethylene, two confirmed animal carcinogens.

6. Any materials contaminated with kerosene, gasoline, detergents, mineral spirits, or chlorinated solvents should not be cleaned in the Safety Kleen® lacquer thinner bath.

7. The filter in the wet/dry shop-vac, used in the fabrication area to clean dust resulting from grinding and sanding operations, should be cleaned after each use and changed on a routine basis before the filter becomes loaded. This will prevent dust from becoming re-entrained in the air during cleaning operations.

8. The organic vapor cartridge half-mask respirator worn by the painter should be cleaned and properly stored after each use to prevent contamination inside the mask as required by OSHA 1910.134. A respirator protection program should be implemented at the race shop in accordance with OSHA 1910.134.[86]

9. CPF 3™, Tychem 10 000™, or other suitable material gloves should be worn when refueling the car in the pit to prevent skin absorption of tetraethyl lead.

10. The gasoline-powered engines should be turned off when they are not needed to reduce the generation of carbon monoxide at the racetrack during practice periods.

11. More noise monitoring and regular annual audiometric screening are needed for the employees of race teams for their work performed in the race shop. If it is determined that the crew members are overexposed to noise in the race shop, management should implement a hearing conservation program that at a minimum meets the requirements of the OSHA hearing conservation amendment (29 CFR 1910.95).[83]

12. Administrative controls (such as increasing the number and/or length of breaks taken in reduced noise areas) should be considered during race weekends to reduce noise exposures.

13. Employees should be educated about the health effects associated with exposures 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.

REFERENCES

1. Lindemann J, Brusis T [1985]. Do racing drivers undergo the risk of noise deafness? Laryng Rhinol Otol 64:476-480.

2. DiSorga R [1991]. Thunderous motor sports. ASHA. Sept:64.

3. Alexander R [1996]. Why don't racing associations provide hearing protection? Occupl Health Safety 10:21.

4. Brasseaux J [1996]. Hearing protection at 10,000 RPMs. OSHA Week:37.

5. Odkvist L, Bergholtz L, Ahlfeldt H, et al. [1982]. Otoneurological and audiological findings in workers exposed to industrial solvents. Acta Otolaryngologica Suppl 386:249-251.

6. Odkvist L, Arlinger S, Edling C, et al. [1987]. Audiological and vestibulo-occulo-motor findings in workers exposed to solvents and jet-fuel. Scand Audiol 16:75-84.

7. Rybak L [1992]. The effects of chemicals. Otolaryngol Head Neck Surg 106:677-686.

8. Morata T [1999]. Preventing hearing loss in the workplace: risks from chemical exposures. OH Forum, Occupational Hygiene Association of Ontario 22:12-13.

9. Suter A [1992]. Communication and job performance in noise: a review. ASHA Monogr Nov:1–84.

10. NIOSH [1994]. Hydrocarbons, halogenated: method no. 1003. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

11. NIOSH [1994]. Trichloroethylene: method no. 1022. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

12. NIOSH [1994]. Ketones I: method no. 1300. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–13.

13. NIOSH [1994]. Hydrocarbons, BP 36–126°C: method no. 1500. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

14. NIOSH [1994]. Hydrocarbons, aromatic: method no. 1501. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

15. NIOSH [1994]. Naphthas: method no. 1550. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

16. NIOSH [1994]. Esters I: method no. 1450. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

17. NIOSH [1994]. Ethyl Acetate: method no. 1457. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

18. NIOSH [1994]. Elements: method no. 7300. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

19. NIOSH [1994]. Lead: method no. 7082. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

20. NIOSH [1994]. Lead: method no. 7105. In: Eller PM, ed. NIOSH Manual of Analytical Methods. 4th rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

21. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92–100.

22. ACGIH [2000]. 2000 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

23. CFR [1997]. Code of Federal Regulations. OSHA 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

24. NIOSH [1987]. Current Intelligence Bulletin 48: organic solvent neurotoxicity. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 91–108.

25. WHO, Nordic Council of Ministers [1985]. Organic solvents and the central nervous system, EH5. Copenhagen, Denmark: World Health Organization and Nordic Council of Ministers.

26. Parrish C [1983]. Solvents, industrial. In: Grayson M, Eckroth D, Mark H, Othmer D, Overberger C, and Seaborg G, eds. Kirk-Othmer encyclopedia of chemical technology. Volume 27. New York, New York: John Wiley & Sons, Inc.

27. Considine D, ed. [1976]. Van Nostrand's scientific encyclopedia. 5th ed. New York, NY: Van Nostrand Reinhold Company.

28. NIOSH [1973]. Criteria for a recommended standard: occupational exposure to toluene. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73–11023.

29. Hathaway G, Proctor, N, Hughes, J [1996]. Proctor and Hughes' Chemical hazards of the workplace. 4th ed. New York, NY: Van Nostrand Reinhold.

30. WHO [1981]. Recommended health-based limits in occupational exposure to select organic solvents. Geneva: World Health Organization, Technical Report Series No. 664.

31. Benignus V [1981]. Health effects of toluene: a review. Neurotoxicology 2:567–568.

32. Anderson I, et al. [1983]. Human response to controlled levels of toluene in six-hour exposures. Scand J Work Environ Health 9:405–418.

33. EPA [1983]. Health assessment document for toluene. NTIS. Washington, DC: Environmental Protection Agency.

34. Bruckner J, Peterson R [1981]. Evaluation of toluene and acetone inhalant abuse I. Pharmacology and pharmacodynamics. Toxicol Appl Pharmacol 61:27–38.

35. Bruckner J, Peterson R [1981]. Evaluation of toluene and acetone inhalant abuse II. Model development and toxicology. Toxicol Appl Pharmacol 61:302–312.

36. NIOSH [1975]. Criteria for a recommended standard: occupational exposure to xylene. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 75–168.

37. Morata T, Nylon P, Johnson A, et al. [1995]. Auditory and vestibular functions after single or combined exposure to toluene: a review. Arch Toxicol 69:413–443.

38. McWilliams M, Chen G, Fechter L [2000]. Low-level toluene disrupts auditory function in guinea pigs. Toxicol Appl Pharmacol 15;167(1):18–29.

39. Abbate C, Giorgianni C, Munao F, Brecciaroli R [1993]. Neurotoxicity induced by exposure to toluene. An electrophysiologic study. Int Arch Occup Environ Health 64(6):389–92.

40. Vrca A, Karacic V, Bozicevic D, et al. [1996]. Brainstem auditory evoked potentials in individuals exposed to long-term low concentrations of toluene. Am J Ind Med 30(1):62–6.

41. Morata T, Dunn D, Kretschmer L, et al. [1993]. Occupational exposure to organic solvents and noise: effects on hearing. Scand J Work, Environ Health, 19(4):245–254.

42. Morata T, Fiorini A, Fischer F, et al. [1997]. Toluene-induced hearing loss among rotogravure printing workers. Scand J Work, Environ Health 23:289–298.

43. NIOSH [1977]. Occupational diseases: a guide to their recognition. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77–181.

44. Pryor G, Rebert C, Howd R [1987]. Hearing loss in rats caused by inhalation of mixed xylenes and styrene. J Appl Toxicol 7(1):55–61.

45. Crofton K, Lassiter T, Rebert C [1994]. Solvent-induced ototoxicity in rats: an atypical selective mid-frequency hearing deficit. Hear Res 80:25–30.

46. Von Burg R [1982]. Toxicology updates. Xylene. J Appl Toxicol 2:269–271.

47. Ellenhorn M, Barcelous D [1988]. Medical toxicology: diagnosis and treatment of human poisoning. New York, NY: Elsevier, 1000–1001.

48. Yano B, Dittenber D, Albee R, Mattsson J [1992]. Abnormal auditory brain stem responses and cochlear pathology in rats induced by an exaggerated styrene exposure regimen. Toxicol Pathol 20:1–6.

49. Mäkitie A [1997]. The ototoxic effect of styrene and its interaction with noise. University of Helsinki, Finland, Thesis.

50. Loquet G, Campo P, Lataye R [1998]. Ototoxicité du styrène chez le rat. Proceedings of the 66th Congress of the Physiology in Lyon. Arch Physiol Biochem 106 (suppl.):151.

51. Campo P, Loquet G, Blachère V, Roure M [1999]. Toluene and styrene intoxication route in the rat cochlea. Neurotox Toxicol 21(4):427–34.

52. Lataye R, Campo P, Loquet G [2000]. Combined effects of noise and styrene exposure on hearing function in the rat. Hear Res 139:86–96.

53. Loquet G, Campo P, Lataye R, Cossec B [2000]. Combined effects of an exposure to styrene and ethanol on the auditory function in the rat. Hear Res 148(1–2):173–80.

54. Muijser H, Hoogendijk E, Hooiisma J [1988]. The effects of occupational exposure to styrene on high frequency thresholds. Toxicology 49:331-40.

55. Möller C, Ödkvist L, Larsby B, et al. [1990]. Otoneurological findings in workers exposed to styrene. Scand J Work Environ Health 16(3):189–94.

56. Sass-Kortsak A, Corey P, Robertson J [1995]. An investigation of the association between exposure to styrene and hearing loss. Ann Epidemiol 5(1):15–24.

57. Morioka I, Kuroda M, Miyashita K, Takeda S [1999]. Evaluation of organic solvent ototoxicity by the upper limit of hearing. Arch Environ Health 54(5):341–6.

58. Morioka I, Miyai N, Yamamoto H, Miyashita K [2000]. Evaluation of combined effect of

organic solvents and noise by the upper limit of hearing. Ind Health 38(2):252–7.

59. Hernberg S, et al. [1988]. Lead and its compounds. In: Occupational medicine. 2nd ed. Chicago, IL: Year Book Medical Publishers.

60. Landrigan P, et al. [1985]. Body lead burden: summary of epidemiological data on its relation to environmental sources and toxic effects. In: Dietary and environmental lead: human health effects. Amsterdam: Elsevier Science Publishers.

61. Rice D [1997]. Effects of lifetime lead exposure in monkeys on detection of pure tones. Fund Appl Toxicol 36(2):112–8.

62. Lasky R, Maier M, Snodgrass E, et al. [1995]. The effects of lead on otoacoustic emissions and auditory evoked potentials in monkeys. Neurotoxicol Teratol 17(6): 633–644.

63. Lilienthal H, Winneke G [1996]. Lead effects on the brain stem auditory evoked potential in monkeys during and after the treatment phase. Neurotoxicology and Teratology 18(1):17–32.

64. Discalzi G, Capellaro F, Bottalo L, et al. [1992]. Auditory brainstem evoked potentials (BAEPs) in lead-exposed workers. Neurotoxicol 13(1):207–9.

65. Discalzi G, Fabbro D, Meliga F, et al. [1993]. Effects of occupational exposure to mercury and lead on brainstem auditory evoked potentials. Int J Psychophysiol 14:21-25.

66. Farahat T, Abdel-Rasoul G, El-Assy A, et al. [1997]. Hearing thresholds of workers in a printing facility. Environ Res 73:189–192.

67. Wu T, Shen Y, Lai J, et al. [2000]. Effects of lead and noise exposures on hearing ability. Arch Environ Health 55(2):109–14.

68. Araki S, Murata K, Yokoyama K, Uchida E [1992]. Auditory event-related potential (P300) in relation to peripheral nerve conduction in workers exposed to lead, zinc, and copper: effects of lead on cognitive function and central nervous system. Am J Ind Med 21(4):539–47.

69. Araki S, Sato H, Yokoyama K, Murata K [2000]. Subclinical neurophysiological effects of lead: A review on peripheral, central, and autonomic nervous system effects in lead workers. Am J Ind Med 37(2):193–204.

70. CFR [1997]. Code of Federal Regulations. OSHA lead standard for general industry. 29 CFR, Part 1910.1025. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

71. CFR [1997]. Code of Federal Regulations. OSHA construction industry lead standard. 29 CFR, Part 1926.62. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

72. 62 Fed. Reg. 206 [1997]. National Institute for Occupational Safety and Health: occupational exposure to inorganic lead: request for comments and information.

73. Sussell A, et al. [1998]. Protecting workers exposed to lead-based paint hazards: a report to Congress. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98–112. January 1998–revised with minor technical change.

74. Randall C [1980]. Biological monitoring methods for industrial chemicals. Davis, California: Biomedical Publications.

75. Coburn R, Allen E, Ayres S [1977]. Carbon Monoxide. Washington, DC: National Academy of Sciences.

76. Young J, Upchurch M, Kaufman M, Fechter L [1987]. CO exposure potentiates high frequency auditory threshold shifts induced by noise. Hear Res 26:37–43.

Safety and Health, DHHS (NIOSH) Publication No. 98–126.

77. Fechter L [1989]. A mechanistic basis for interactions between noise and chemical exposure. Arch Comp Environ Studies 1:23–28.

78. Fechter L, Chen G, Rao D, Larabee J [2000]. Predicting exposure conditions that facilitate the potentiation of noise-induced hearing loss by carbon monoxide. Toxicol Sci 58(2):315–23.

79. Rao B, Fechter L [2000]. Increased noise severity limits potentiation of noise induced hearing loss by carbon monoxide. Hear Res 150(1–2):206–14.

80. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73–11000.

81. Ward W [1986]. Anatomy & physiology of the ear: normal and damaged hearing. Chapter 5. In: Berger EH, Ward WD, Morrill JC, Royster LH, eds. Noise & hearing conservation manual. 4th ed. Akron, OH: American Industrial Hygiene Association, pp 177–195.

82. Suter A [1978]. The ability of mildly hearing-impaired individuals to discriminate speech in noise. Washington, DC: U.S. Environmental Protection Agency, Joint EPA/USAF study, EPA 550/9–78–100, AMRL–TR–78–4.

83. CFR [1992]. Code of Federal Regulations. OSHA 29 CFR 1910.95. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

84. NIOSH [1998]. Criteria for a recommended standard: occupational noise exposure (revised criteria 1998). Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98–126.

85. Kardous, Chucri [1998]. EARTALK-hearing protector and communication system. Chapter 28. In Prasher D, Luxon L, Pyykko I, eds. Advances in Noise Research, Volume 2, Protection Against Noise, London, Whurr Publishers, Ltd, pp 183-188.

86. CFR [1997]. Code of Federal Regulations. OSHA respiratory protection standard. 29 CFR, Part 1910.134. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Table 1

Full-Shift Area Air Sample Results – Initial Site Visit
Race Shop, Charlotte, North Carolina
January 19, 2000

Compound	Airborne Concentration (ppm)			OSHA PEL[d] (ppm)	ACGIH TLV[d] (ppm)	NIOSH REL[e] (ppm)	Minimum Detectable Concentration (ppm)	Minimum Quantifiable Concentration (ppm)
	Gear Room[a]	Fabrication Area[b]	Fabrication Area[c]					
Acetone	0.07	0.08	0.08	1000	500	250	0.01	0.04
Carbon Monoxide	0.5/6.0[f]	3.8/105[f]	3.6/91[f]	50	25	35/200[g]	NA[h]	NA
n-Hexane	0.19	0.32	0.32	500	50	50	0.003	0.008
Hydrocarbons (Total)[i]	4.4	2.8	2.8	500	400[l]	85	0.02	0.05
Perchloroethylene	Trace[j]	ND[k]	ND	100	25	Ca[m]	0.03	0.10
Styrene	ND	ND	ND	100	20	50	0.02	0.10
Toluene	1.4	1.1	1.1	200	50	100	0.003	0.008
Trichloroethylene	0.09	0.01	0.01	100	50	25 (Ca)	0.004	0.01
Xylenes (Total)	0.09	0.05	0.06	100	100	100	0.005	0.02

[a] Sample located in the gear/suspension room by a Safety Klean® parts cleaning station
[b] Sample located in the fabrication area near a TIG welding station
[c] Sample located adjacent to the painting booth
[d] 8-hour time-weighted average
[e] 10-hour time-weighted average
[f] Mean concentration/peak concentration
[g] NIOSH REL/Ceiling (not to be exceeded)
[h] NA = not applicable
[i] Hydrocarbons (total) is the sum of all detected compounds minus acetone, n-hexane, perchloroethylene, styrene, toluene, trichloroethylene, and xylenes (total)
[j] Trace = >minimum detectable concentration <minimum quantifiable concentration
[k] ND = non-detectable (<minimum detectable concentration)
[l] TLV for heptane (used as the standard when quantitating "total hydrocarbons"
[m] Ca = potential occupational carcinogen

Table 2

Half-Shift Area Air Sample Results - Initial Site Visit
Race Shop, Charlotte, North Carolina
January 20, 2000

Compound	Airborne Concentration (ppm)		OSHA PEL[c] (ppm)	ACGIH TLV[c] (ppm)	NIOSH REL[d] (ppm)	Minimum Detectable Concentration (ppm)	Minimum Quantifiable Concentration (ppm)
	Fabrication Area[a]	Fabrication Area[b]					
Acetone	Trace[e]	ND[f]	1000	500	250	0.02	0.07
Carbon Monoxide	4.0/84[g]	5.6/117[g]	50	25	35/200[h]	NA[i]	NA
n-Hexane	0.27	0.22	500	50	50	0.006	0.01
Hydrocarbons (Total)[j]	4.2	3.9	500	400	85	0.03	0.08
Perchloroethylene	ND	ND	100	25	Ca[k]	0.05	0.16
Styrene	Trace	Trace	100	20	50	0.04	0.15
Toluene	1.6	1.6	200	50	100	0.003	0.013
Trichloroethylene	0.02	0.02	100	50	25	0.006	0.02
Xylenes (Total)	0.08	0.08	100	100	100	0.007	0.03

[a] Sample located adjacent to the body shop
[b] Sample located near the engine testing station
[c] 8-hour time-weighted average
[d] 10-hour time-weighted average
[e] Trace = >minimum detectable concentration <minimum quantifiable concentration
[f] ND = non-detectable (<minimum detectable concentration)
[g] Mean concentration/peak concentration
[h] NIOSH REL/Ceiling (not to be exceeded)
[i] NA = not applicable
[j] Hydrocarbons (total) is the sum of all detected compounds minus acetone, n-hexane, perchloroethylene, styrene, toluene, trichloroethylene, and xylenes (total)
[k] Ca = potential occupational carcinogen (NIOSH recommends that the airborne concentration be reduced to the lowest feasible level)

Table 3

Sound Pressure Levels During Selected Work Tasks
Race Shop, Charlotte, North Carolina
January 19 and 20, 2000

Date	Job Title	Location	Task	Sound Pressure Level (dBA)			
				Mean[a]	Min[b]	Max[c]	L_{NIOSH}[d]
1/19/2000	Public Relations	Office	Administrative	57.9	41.8	66.2	51.8
1/19/2000	Team Owner	Office	Administrative	59.8	49.0	69.2	58.0
1/19/2000	Fabricator	Fabrication Area	Operating Band Saw	74.8	66.3	98.9	90.6
1/19/2000	Fabricator	Fabrication Area	Operating Pneumatic Grinder	92.2	71.2	97.8	93.0
1/19/2000	Fabricator	Fabrication Area	Sanding and Grinding	85.3	42.6	87.6	83.9
1/19/2000	Fabricator	Fabrication Area	Sanding and Grinding	78.9	78.2	87.9	84.7
1/19/2000	Fabricator	Fabrication Area	Bending Sheet Metal	75.0	77.0	82.0	72.0
1/19/2000	Fabricator	Fabrication Area	Operating MIG Welder	84.2	82.3	97.9	86.7
1/19/2000	Fabricator	Fabrication Area	Operating TIG Welder	80.6	71.9	81.3	89.3
1/19/2000	Fabricator	Fabrication Area	Operating TIG Welder	71.2	70.8	74.2	72.4
1/19/2000	Fabricator	Fabrication Area	Operating TIG Welder	74.0	69.3	85.8	70.1
1/19/2000	Fabricator	Fabrication Area	Operating Hand Drill	67.1	65.2	93.7	82.8
1/19/2000	Fabricator	Fabrication Area	Operating Pneumatic Wrench	94.3	69.2	98.4	90.9
1/19/2000	Fabricator	Fabrication Area	Operating Cut-Off Saw	72.7	71.9	90.7	94.7

Table 3 (Continued)

Sound Pressure Levels During Selected Work Tasks
Race Shop, Charlotte, North Carolina
January 19 and 20, 2000

Date	Job Title	Location	Task	Sound Pressure Level (dBA)			
				Mean[a]	Min[b]	Max[c]	L_{NIOSH}[d]
1/19/2000	Fabricator	Fabrication Area	Operating Cut-Off Saw	94.1	73.4	102.7	96.0
1/19/2000	Fabricator	Fabrication Area	Operating Band Saw	71.6	71.2	86.9	85.0
1/19/2000	Paint and Body	Body Shop	Operating Hand Grinder	74.0	69.0	84.0	80.0
1/19/2000	Fabricator	Fabrication Area	Operating Bench Grinder	87.7	75.7	92.9	89.3
1/19/2000	Fabricator	Fabrication Area	Sanding and Grinding	89.9	67.1	96.3	90.8
1/19/2000	Fabricator	Fabrication Area	Operating Hard Disk Grinder	93.7	79.4	97.8	94.7
1/19/2000	Fabricator	Fabrication Area	Operating Orbital Sander	92.6	91.1	100.8	98.2
1/19/2000	Fabricator	Fabrication Area	Operating Pneumatic Saw	88.0	81.0	97.0	93.0
1/19/2000	Fabricator	Fabrication Area	Using Compressed Air Hose	95.4	71.0	99.9	90.6
1/19/2000	Fabricator	Fabrication Area	Using Compressed Air Hose	96.2	88.3	99.6	97.1
1/19/2000	Fabricator	Fabrication Area	Using Compressed Air Hose	83.1	81.6	90.2	87.7
1/19/2000	Fabricator	Fabrication Area	Operating Millermatic Welder	71.8	66.6	86.8	79.8
1/19/2000	Fabricator	Fabrication Area	Operating Millermatic Welder	78.2	76.3	88.7	84.6
1/19/2000	Suspension Assembly	Gear/Suspension Room	Checking Rear Axle Alignment	69.9	51.9	82.7	68.7
1/20/2000	Fabricator	Fabrication Area	Vacuuming	78.7	56.6	88.4	86.5

Table 3 (Continued)

Sound Pressure Levels During Selected Work Tasks
Race Shop, Charlotte, North Carolina
January 19 and 20, 2000

Date	Job Title	Location	Task	Sound Pressure Level (dBA)			
				Mean[a]	Min[b]	Max[c]	L_{NIOSH}[d]
1/20/2000	Paint and Body	Inside Paint Booth	Painting	95.2	94.4	96.3	95.1
1/20/2000	Paint and Body	Inside Paint Booth	Painting	96.7	95.2	97.1	96.1
1/20/2000	Paint and Body	Paint Mixing Area	Painting Clean-Up	82.1	81.3	82.4	81.9
1/20/2000	Paint and Body	Body Shop	Sanding and Grinding	72.7	71.6	76.8	72.8
1/20/2000	Paint and Body	Body Shop	Operating Orbital Sander	97.1	94.8	97.0	98.2
1/20/2000	Mechanic	Outdoors	Engine Testing and Tuning	102.8	101.0	107.3	104.4

[a] Average (mean) sound pressure level during specified task

[b] Minimum sound pressure level during specified task

[c] Maximum sound pressure level during specified task

[d] Average (mean) noise level during the specified task using a 3 dB exchange rate

Table 4

Personal Noise Exposures
Race Shop, Charlotte, North Carolina
January 19 and 20, and February 9, 2000

Job Title	Sampling Date	Sampling Time (min)	Sound Pressure Level (dBA)		
			L_{OSHA} TWA[a]	L_{NIOSH} TWA[b]	Peak
Suspension Assembly	1/19/2000	600	74.5	82.4	139.1
Crew Chief	1/19/2000	650	78.3	82.7	143.2
Mechanic/ Jackman	1/19/2000	640	76.9	82.8	145.5
Engine Tuner	1/20/2000	301	82.9	94.7	138.0
Fabricator	1/20/2000	354	74.9	88.6	145.5
Fabricator	1/20/2000	259	86.9	97.7	130.1
Mechanic	2/9/2000	628	86.2	88.9	142.8
Mechanic	2/9/2000	644	82.2	88.1	145.5
Painter	2/9/2000	628	73.8	79.6	136.1

[a] L_{OSHA} TWA = Eight hour exposure assuming no noise during non-sampled period using 5dB exchange rate/90 dB threshold

[b] L_{NIOSH} TWA = Average noise level over the sampling period using 3 dB exchange rate

Table 5

Full-Shift Area Air Sample Results - Follow-Up Site Visit
Race Shop, Charlotte, North Carolina
February 9, 2000

Compound	Airborne Concentration (ppm)				OSHA PEL[e] (ppm)	ACGIH TLV[e] (ppm)	NIOSH REL[f] (ppm)	Minimum Detectable Concentration (ppm)	Minimum Quantifiable Concentration (ppm)
	Paint Booth[a]	Paint Booth[b]	Paint Mixing[c]	Body Shop[d]					
Acetone	0.96	3.8	4.7	0.98	1000	500	250	0.009	0.026
n-Butyl Acetate	0.15	0.06	0.29	0.05	150	150	150	0.003	0.007
Epichlorohydrin	Trace [g]	ND[h]	ND	ND	5.0	0.5	Ca [i]	0.008	0.023
Ethyl Benzene	0.20	0.03	ND	0.02	100	100	100	0.003	0.007
Methylene Chloride	ND	ND	ND	ND	25	50	Ca	0.045	0.180
Naphthas	32	2.6	7.6	2.7	100	none	100	0.025	0.064
Perchloroethylene	ND	ND	ND	ND	100	25	Ca	0.008	0.029
Styrene	ND	ND	ND	ND	100	20	50	0.134	0.470
Toluene	0.72	0.74	3.0	0.66	200	50	100	0.003	0.008
1,1,1-Trichloroethane	0.04	0.03	0.07	0.02	350	350	350	0.006	0.017
Xylenes (Total)	0.50	0.11	0.33	0.07	100	100	100	0.006	0.019

[a] Sample located inside the paint booth
[b] Sample located just outside the paint booth door
[c] Sample located in the paint storage and mixing area
[d] Sample located in the body shop area
[e] 8-hour time-weighted average
[f] up to 10-hour time-weighted average
[g] Trace = >minimum detectable concentration <minimum quantifiable concentration
[h] NA = not applicable
[i] Ca = potential occupational carcinogen (NIOSH recommends that the airborne concentration be reduced to the lowest feasible level)

Table 6

Carbon Monoxide Sample Results During the Cheez-it® 250 Professional Stock Car Race
Bristol Motor Speedway, Bristol, Tennessee
March 25, 2000

Sample Location	Carbon Monoxide Concentration (ppm)			
	Mean[a]		Peak	
Pit Toolbox (Left Side)	14		55	
Pit Toolbox (Right Side)	12		31	
Top of Race Car Hauler Elevator	13		52	
Carbon Monoxide Evaluation Criteria (ppm)	OSHA PEL[b]: 50	ACGIH TLV[b]: 25	NIOSH REL[c]: 35/C[d]: 200	IDLH[e]: 1200

[a] Mean carbon monoxide concentration during the 1-hour, 48-minute stock car race
[b] 8-hour time-weighted average
[c] 10-hour time-weighted average
[d] C = Ceiling concentration not to be exceeded
[e] IDLH = Immediately dangerous to life and health

Table 7

Carbon Monoxide Sample Results During the Food City 250 Professional Stock Car Race
Bristol Motor Speedway, Bristol, Tennessee
August 25, 2000

Sample Location	Carbon Monoxide Concentration (ppm)							
	Practice		Qualifying		Race		Full Day	
	Mean	Peak	Mean	Peak	Mean	Peak	Mean	Peak
Top of Race Car Hauler	14	33	16	32	11	24	15	40
Pit Toolbox (Left Side)	157	458	10	41	5.2/5.7/5.7	26/19/40	86	835
Pit Toolbox (Right Side)	76	235	11	118	5.8/7.7	27/33	35	235
Pit Light Standard	32	126	-	-	-	-	-	-
Race Car Interior	36	202	-	-	-	-	-	-
Personal 1	20	151	15	42	12	41	14	151
Personal 2	6.8	30	4.4	19	7.6	25	5.7	40
Carbon Monoxide Evaluation Criteria (ppm)	OSHA PEL[a]: 50		ACGIH TLV[a]: 25		NIOSH REL[b]: 35/C[c]: 200		IDLH[d]: 1200	

[a] 8-hour time-weighted average

[b] 10-hour time-weighted average

[c] C = Ceiling concentration not to be exceeded

[d] IDLH = Immediately dangerous to life and health

Figure 1

Personal Noise Levels - Race Shop/Crew Chief
January 19, 2000

L_{NIOSH} = 82.7 dB(A)

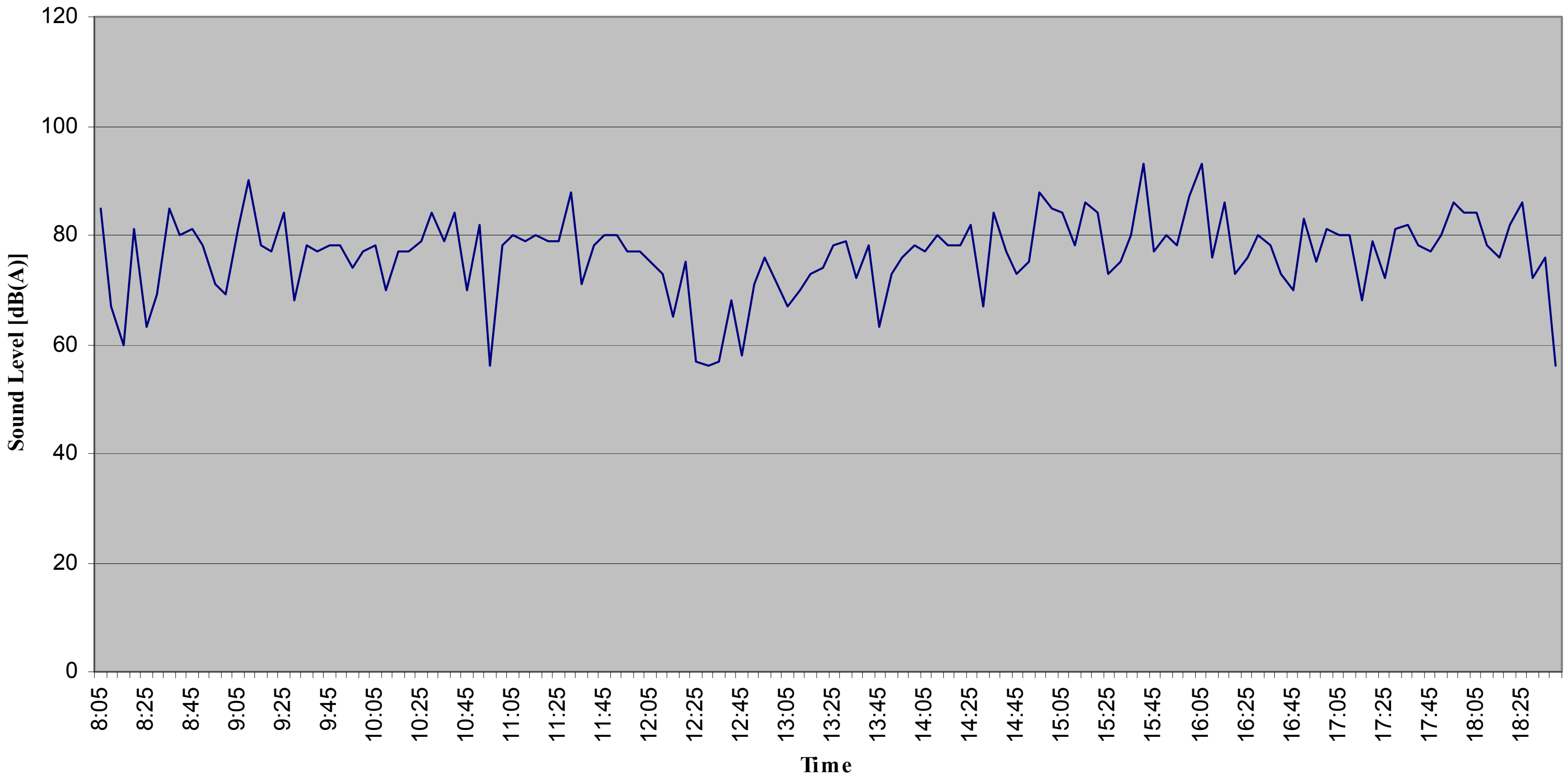


Figure 2

Personal Noise Levels - Race Shop/Suspension Assembly
January 19, 2000

L_{NIOSH} = 82.4 dB(A)

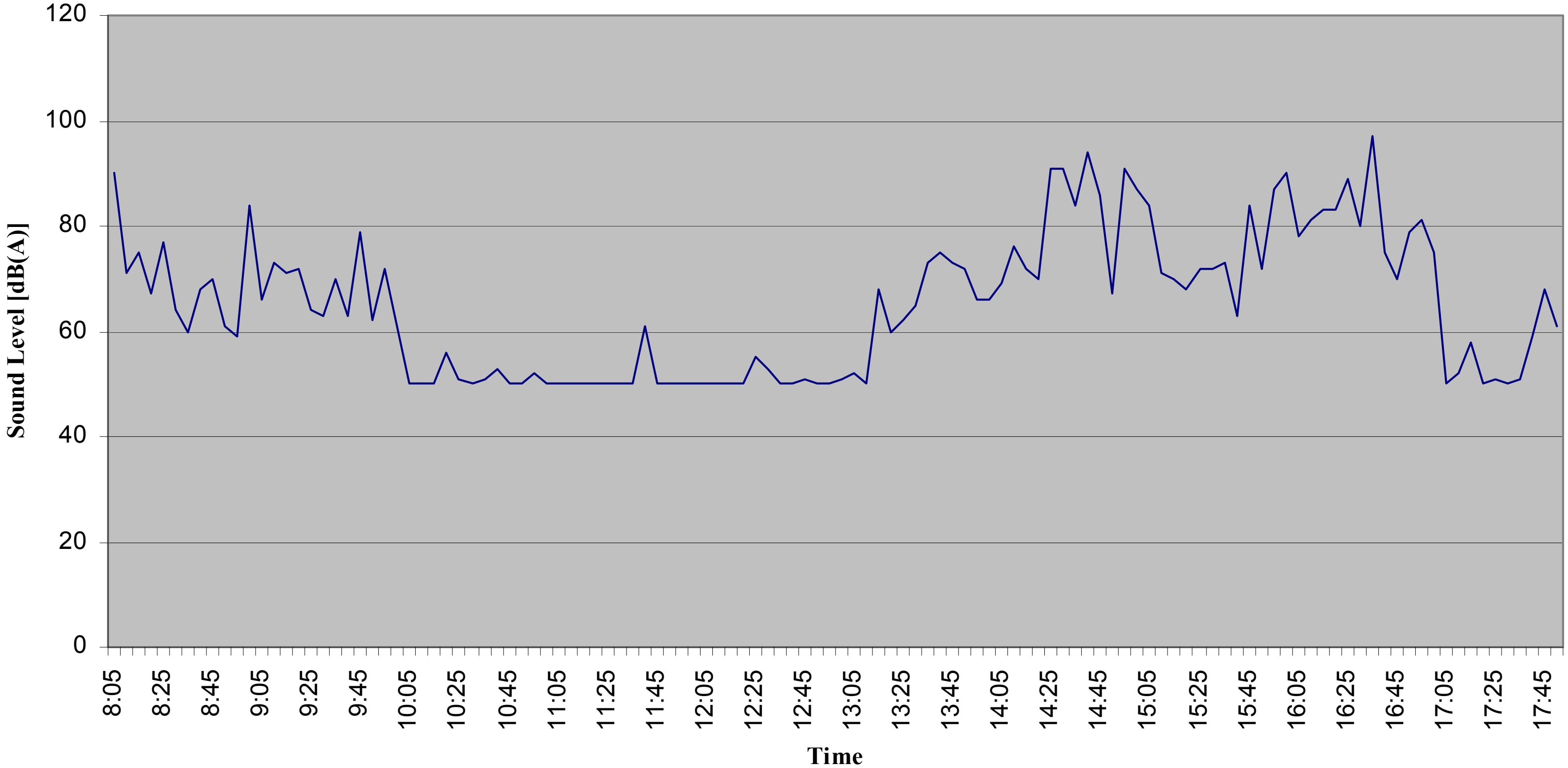


Figure 3

Personal Noise Levels - Race Shop/Mechanic
January 19, 2000

L_{NIOSH} = 82.8 dB(A)

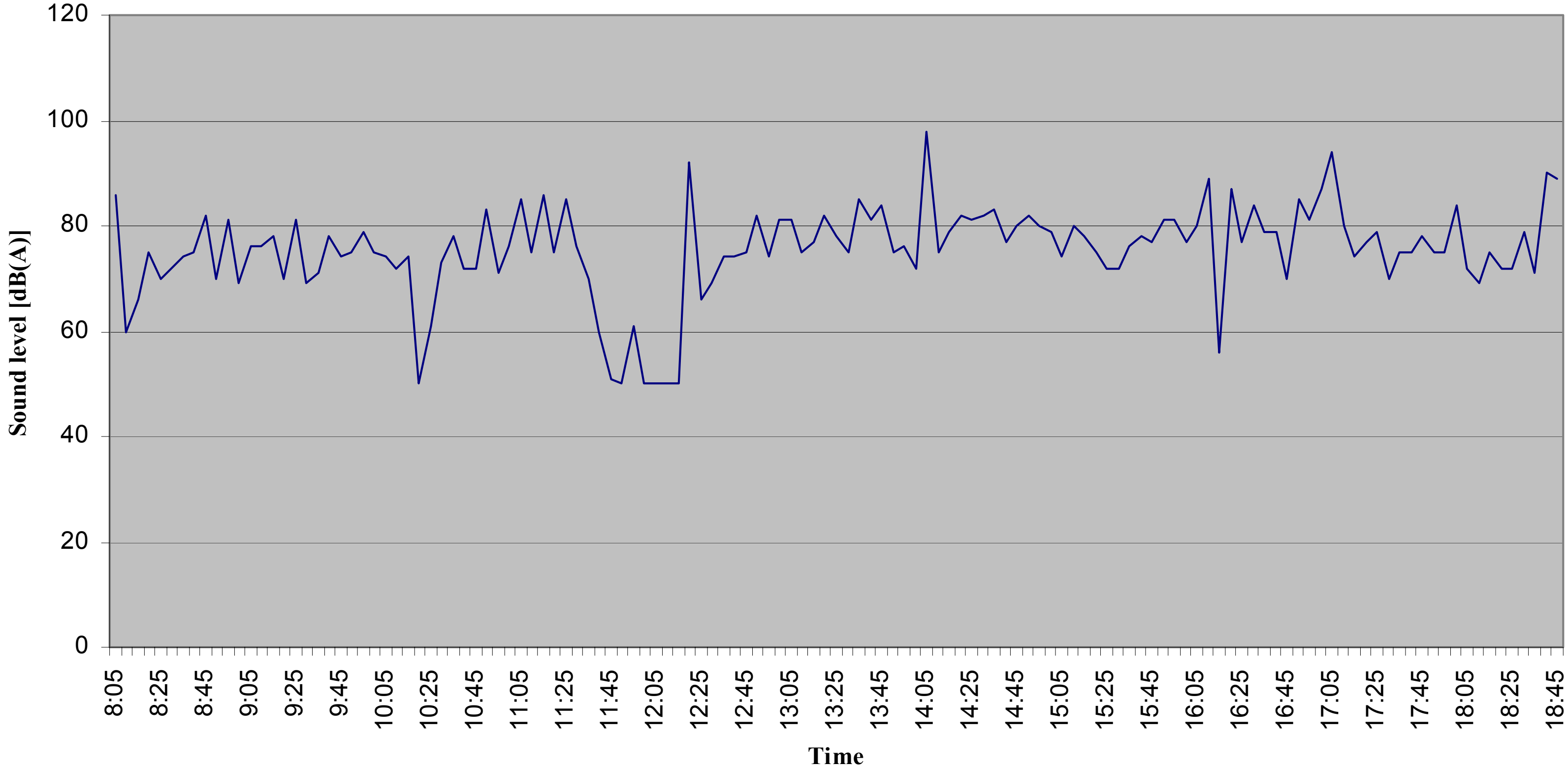


Figure 4

Personal Noise Levels - Race Shop/Fabricator (Welding)
January 20, 2000

L_{NIOSH} = 97.7 dB(A)

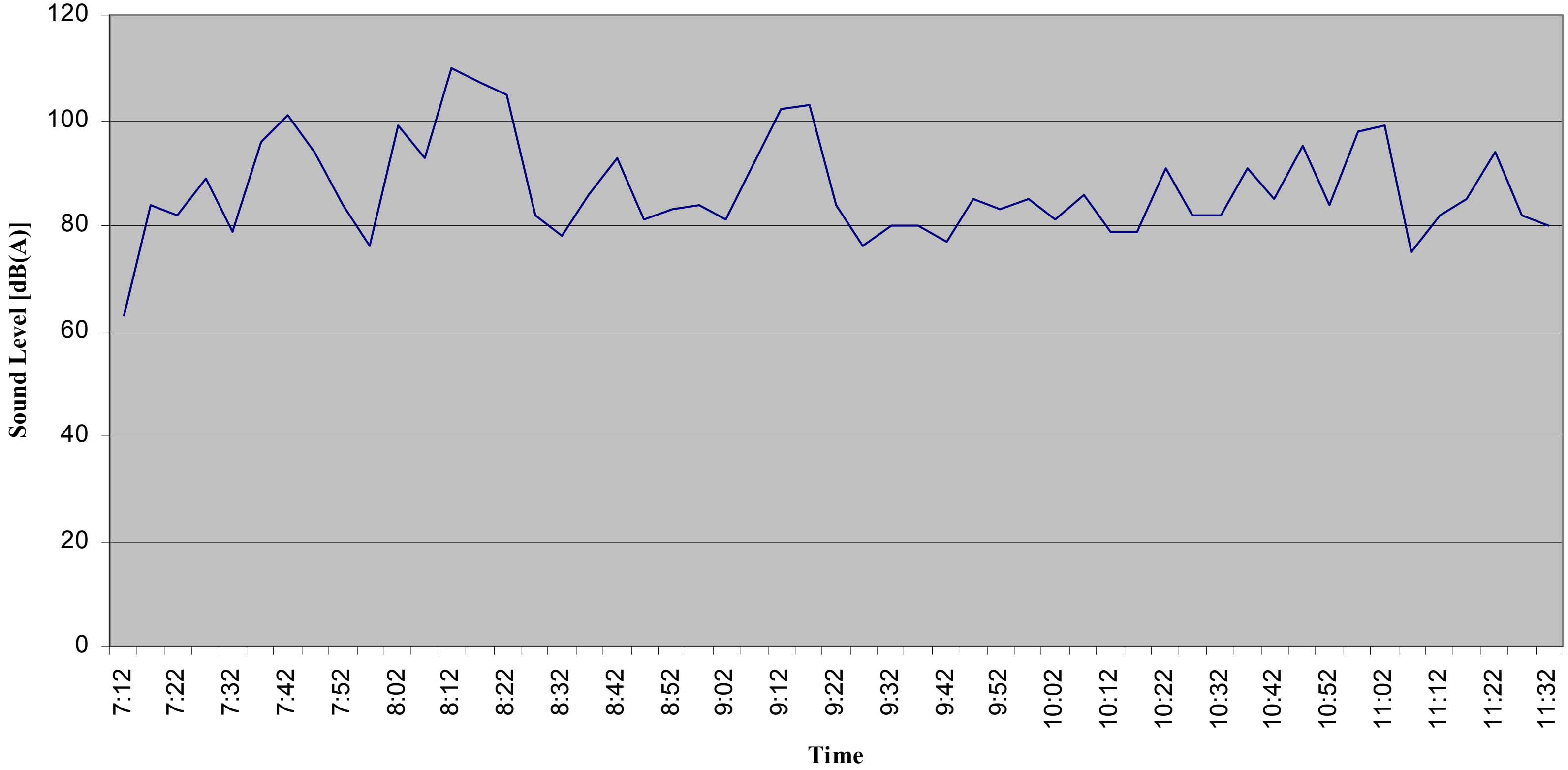


Figure 5

Personal Noise Levels - Race Shop/Fabricator
January 20, 2000

L_{NIOSH} = 88.6 dB(A)

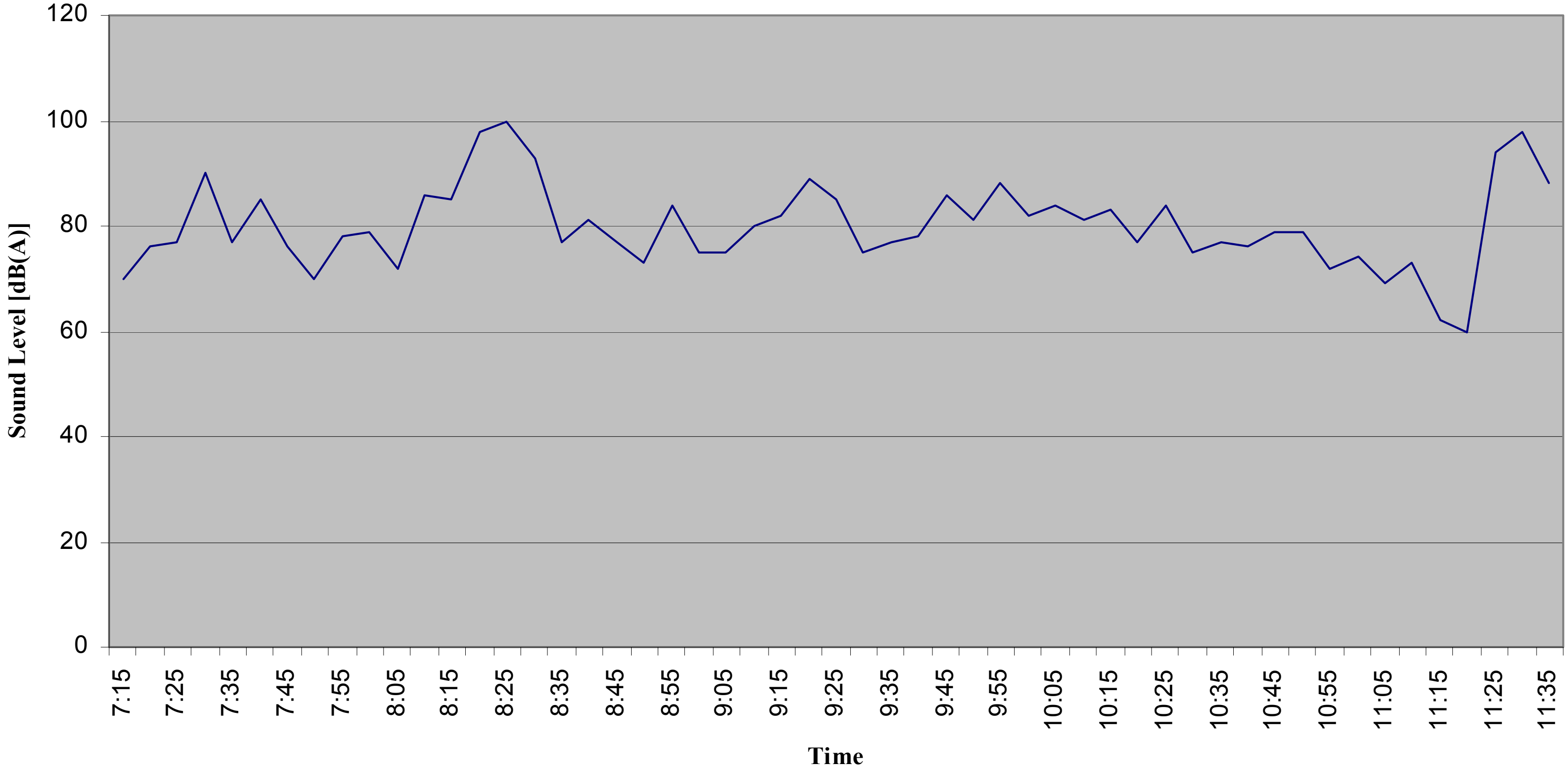
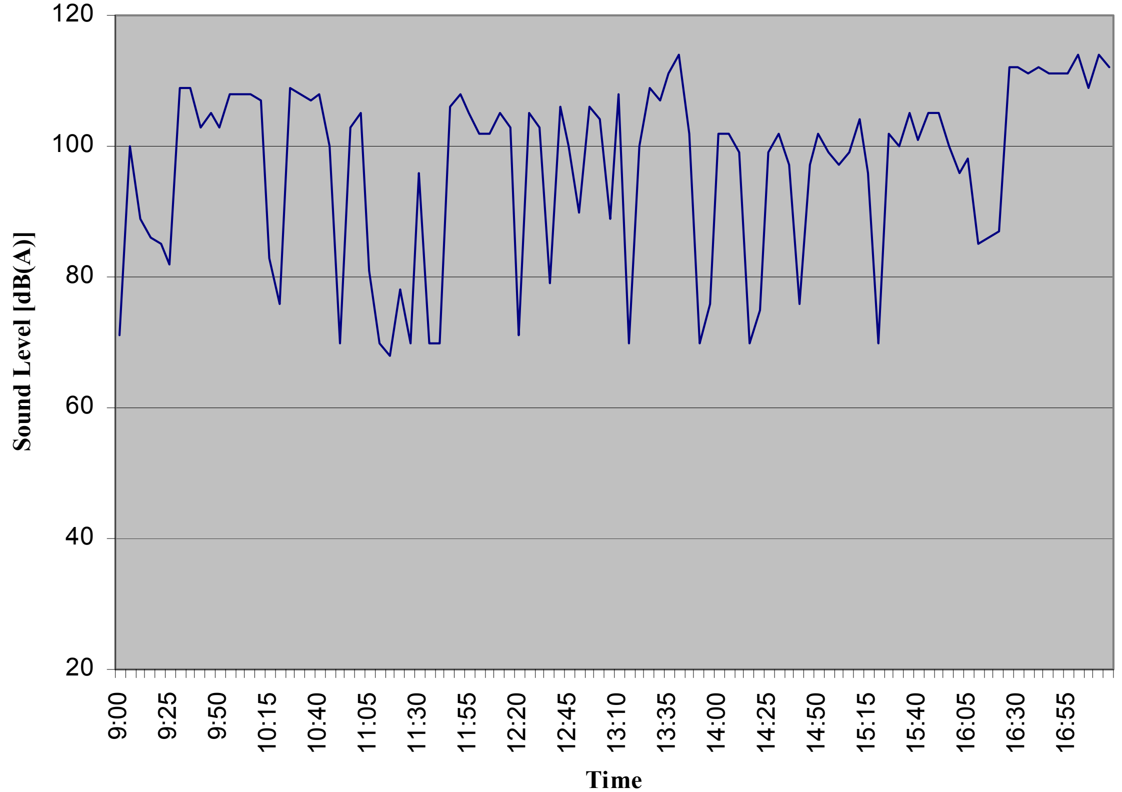


Figure 6

Personal Noise Levels - Race Track/Near Team's Race Car Hauler
March 24, 2000

L_{NIOSH} = 106.2 dB(A)

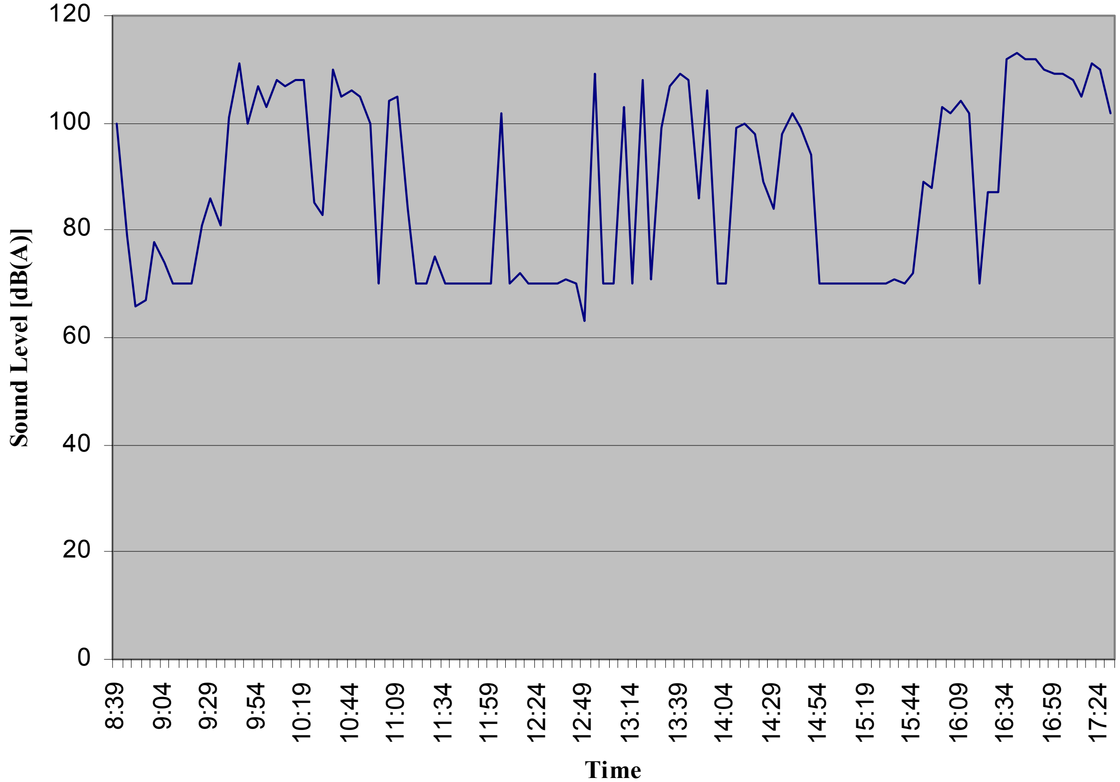


Activity: Time
Practice (10-12 cars): 9:30 to 11:00
Qualifications (1 car): 11:00 to 12:00
Practice (10-12 cars): 12:00 to 13:30
Qualifications (1 car): 13:30 to 14:30
Practice (10-12 cars): 14:30 to 16:30
"Happy Hour" (33-43 cars): 16:30 to 17:30

Figure 7

Personal Noise Levels - Race Track/Near Team's Race Car Hauler
March 24, 2000

L_{NIOSH} = 104.5 dB(A)

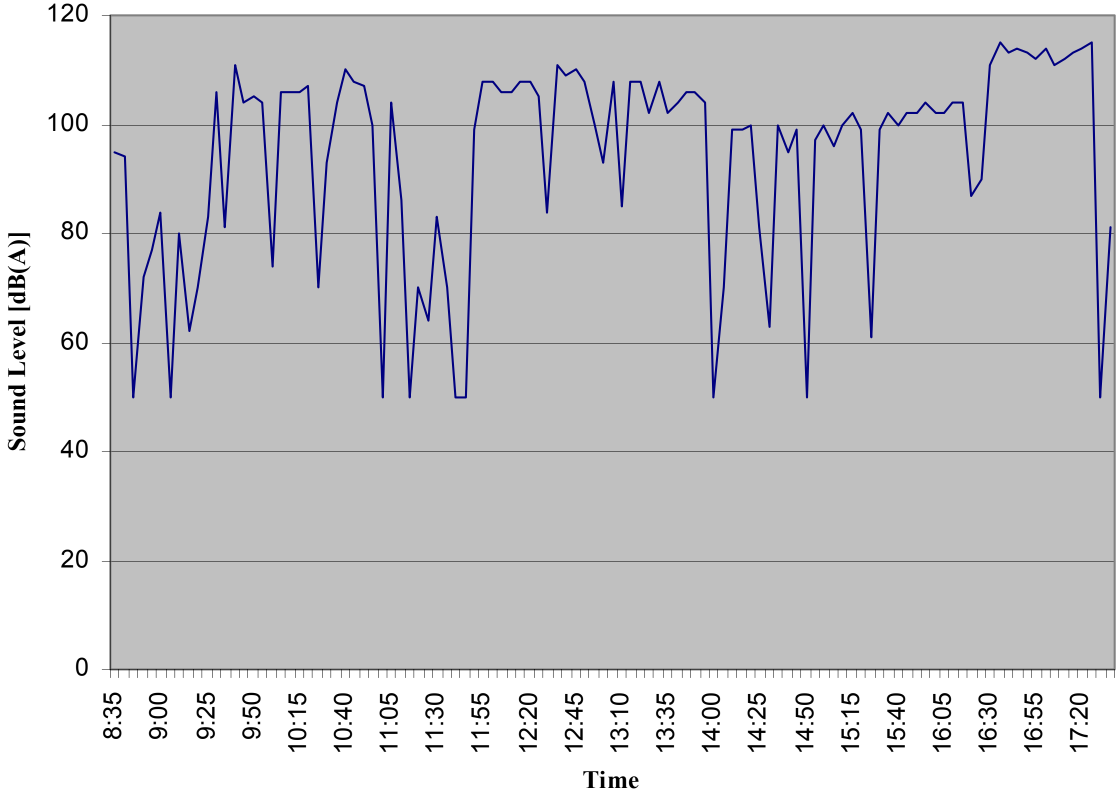


Activity: Time
Practice (10-12 cars): 9:30 to 11:00
Qualifications (1 car): 11:00 to 12:00
Practice (10-12 cars): 12:00 to 13:30
Qualifications (1 car): 13:30 to 14:30
Practice (10-12 cars): 14:30 to 16:30
"Happy Hour" (33-43 cars): 16:30 to 17:30

Figure 8

Personal Noise Levels - Race Track/Near Pit Area
March 24, 2000

L_{NIOSH} = 107.2 dB(A)



Activity: Time
Practice (10-12 cars): 9:30 to 11:00
Qualifications (1 car): 11:00 to 12:00
Practice (10-12 cars): 12:00 to 13:30
Qualifications (1 car): 13:30 to 14:30
Practice (10-12 cars): 14:30 to 16:30
"Happy Hour" (33-43 cars): 16:30 to 17:30

Figure 9

Personal Noise Levels - Race Track/Inside Stock Car (Practice)
March 24, 2000

L_{NIOSH}=114.4 dB(A)

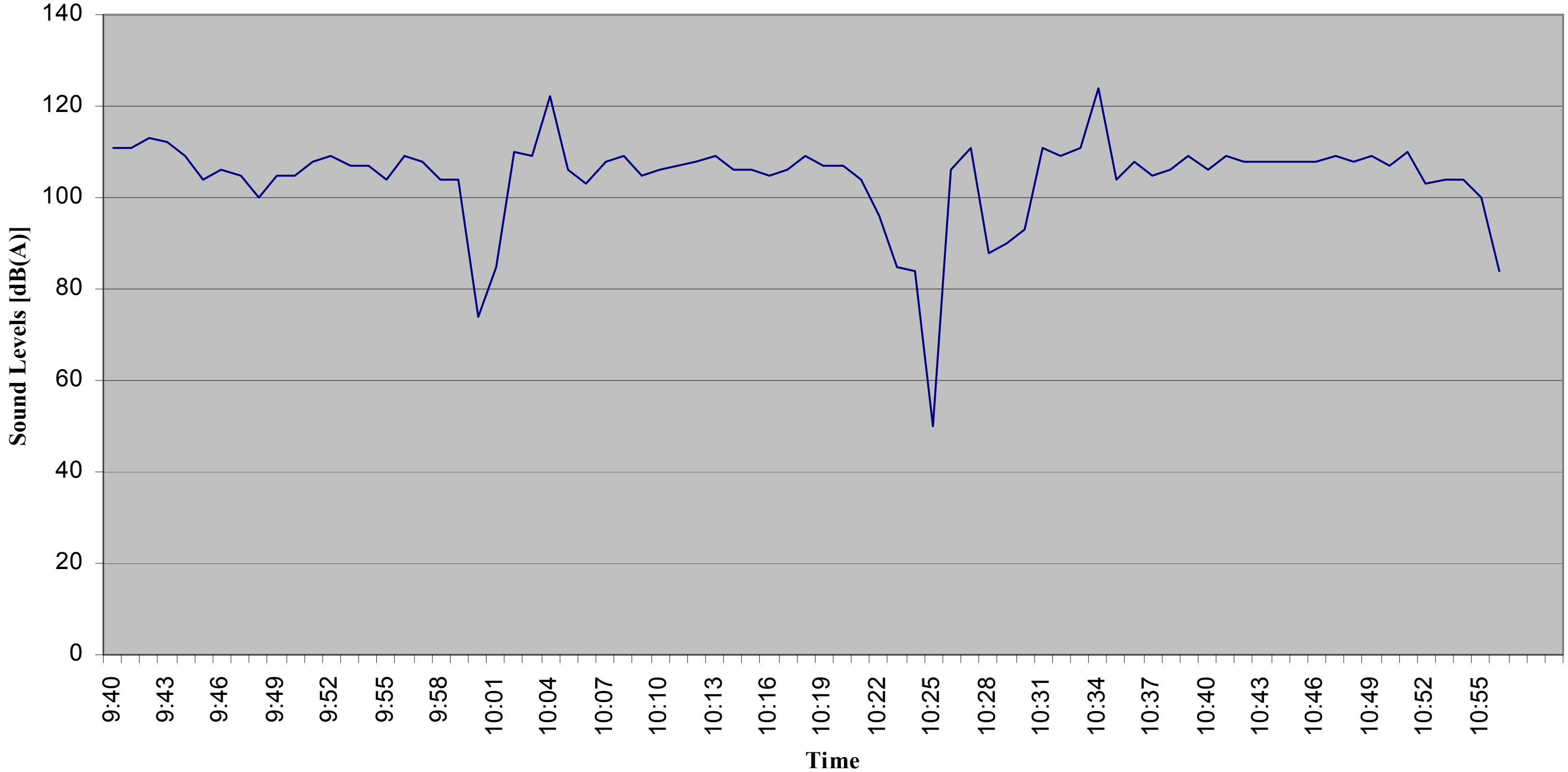
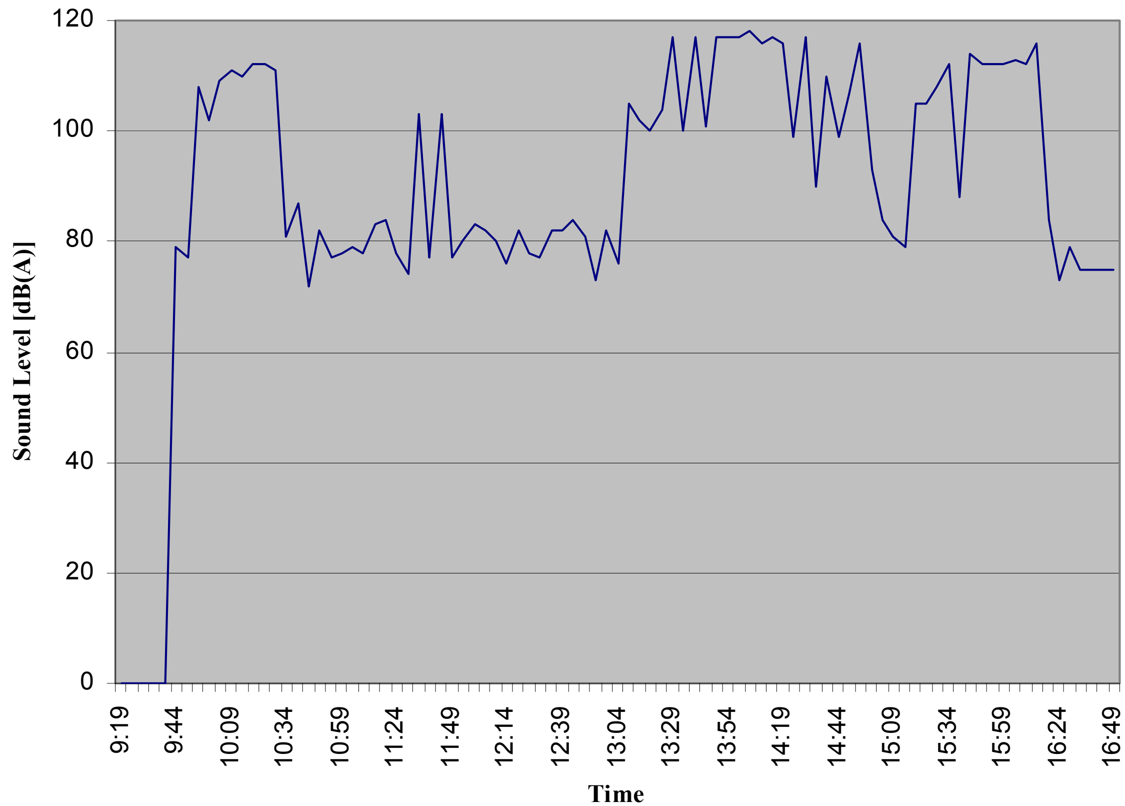


Figure 10

Personal Noise Levels - Race Track/Near Team's Race Car Hauler
March 25, 2000

L NIOSH=107.2 dB(A)

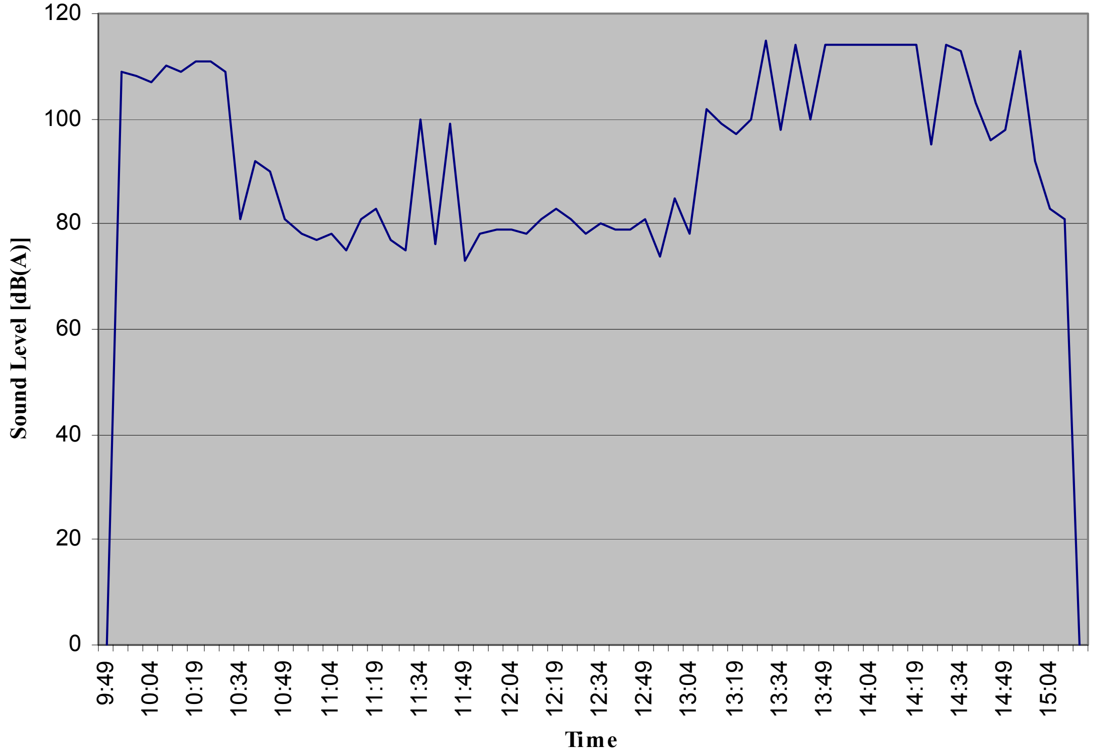


Activity: Time
Practice (10-12 cars): 9:50 to 11:00
Qualifications (1 car): 11:00 to 13:00
Race (43 cars): 13:04 to 15:00
"Happy Hour" (33-43 cars): 15:15 to 16:20

Figure 11

Personal Noise Levels - Race Track/Pit Area On Tool Box
March 25, 2000

L_{NIOSH} = 107.7 dB(A)

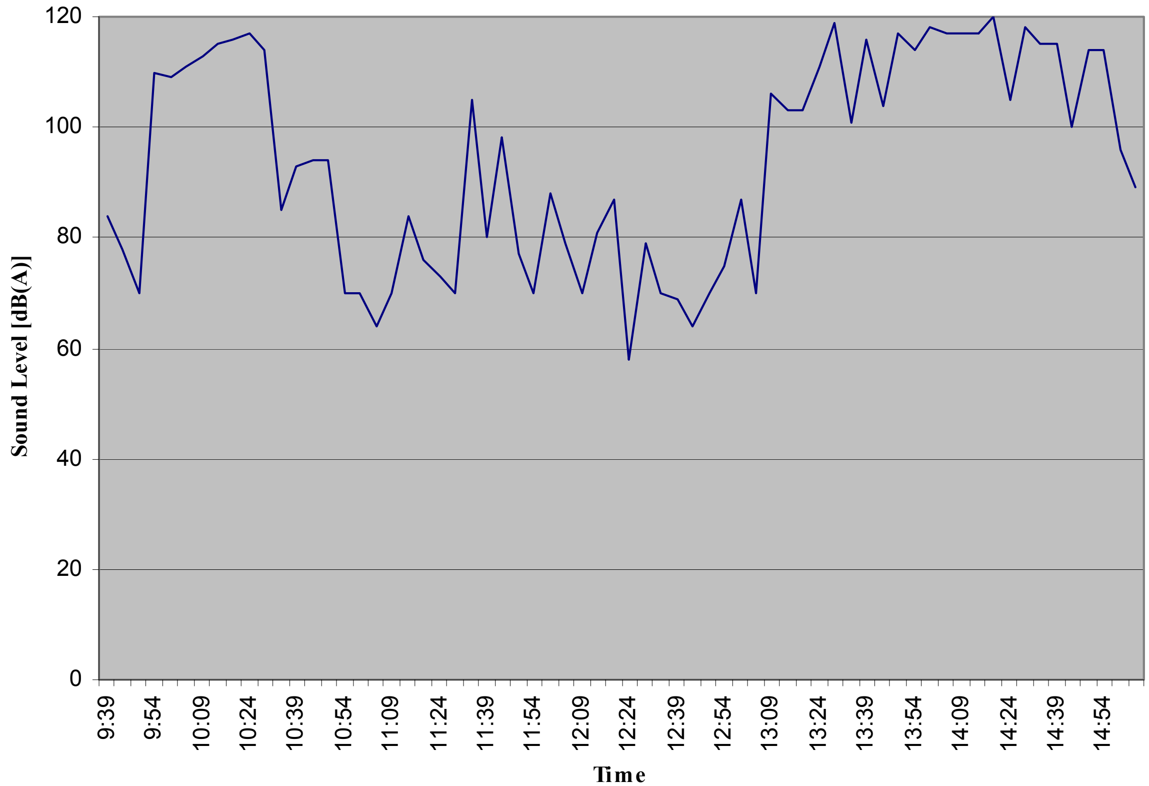


Activity: Time
Practice (10-12 cars): 9:50 to 11:00
Qualifications (1 car): 11:00 to 13:00
Race (43 cars): 13:04 to 15:00

Figure 12

Personal Noise Levels - Race Track/Near Team's Race Car Hauler
March 25, 2000

L_{NIOSH} = 111.5 dB(A)



Activity: Time
Practice (10-12 cars): 9:30 to 11:00
Qualifications (1 car): 11:00 to 13:00
Race (43 cars): 13:04 to 15:00

Figure 13

Personal Noise Levels - Race Track/Near Team's Race Car Hauler (Practice and Qualifying)
August 25, 2000

L_{NIOSH} = 114.2 dB(A)

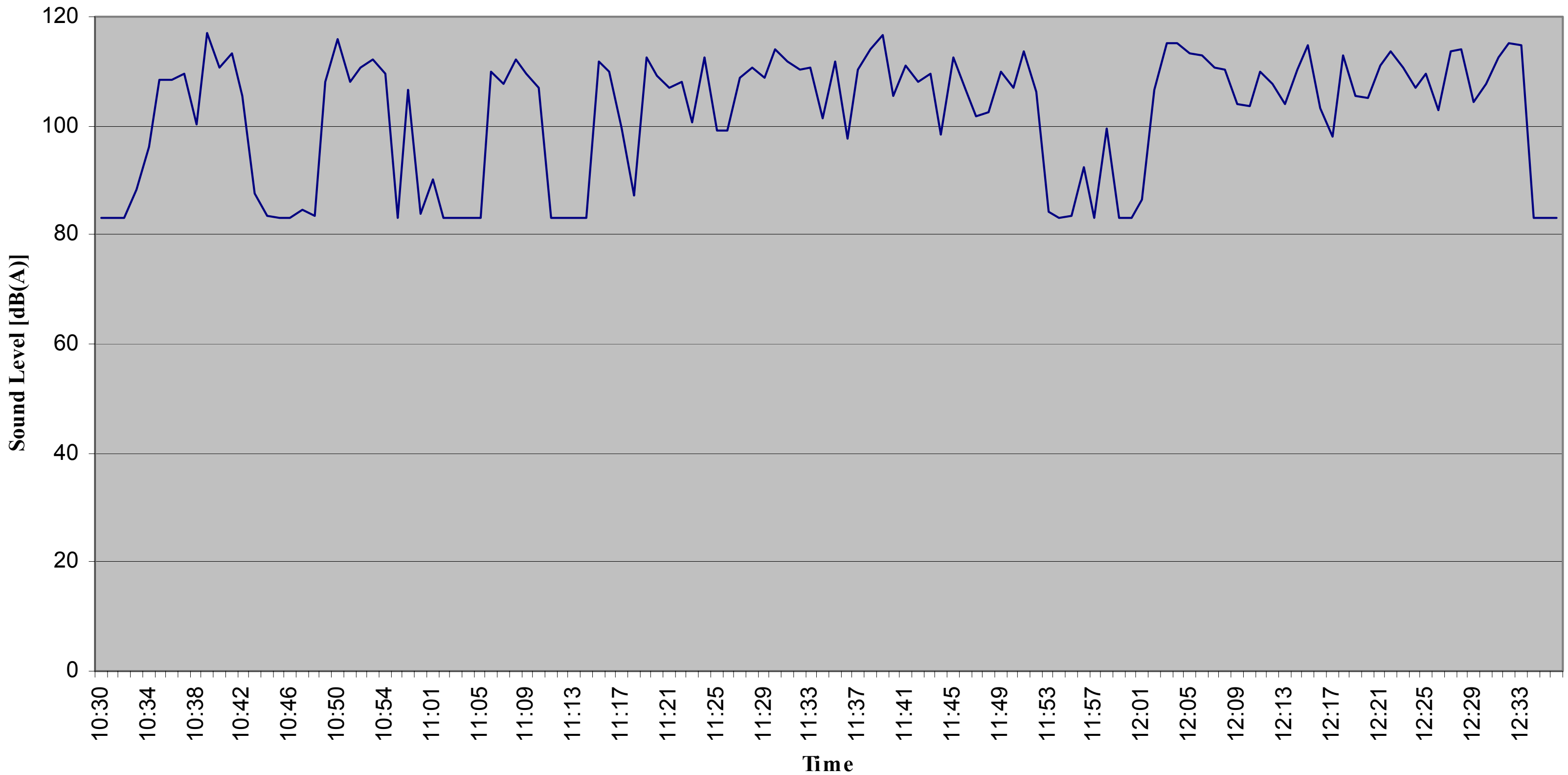
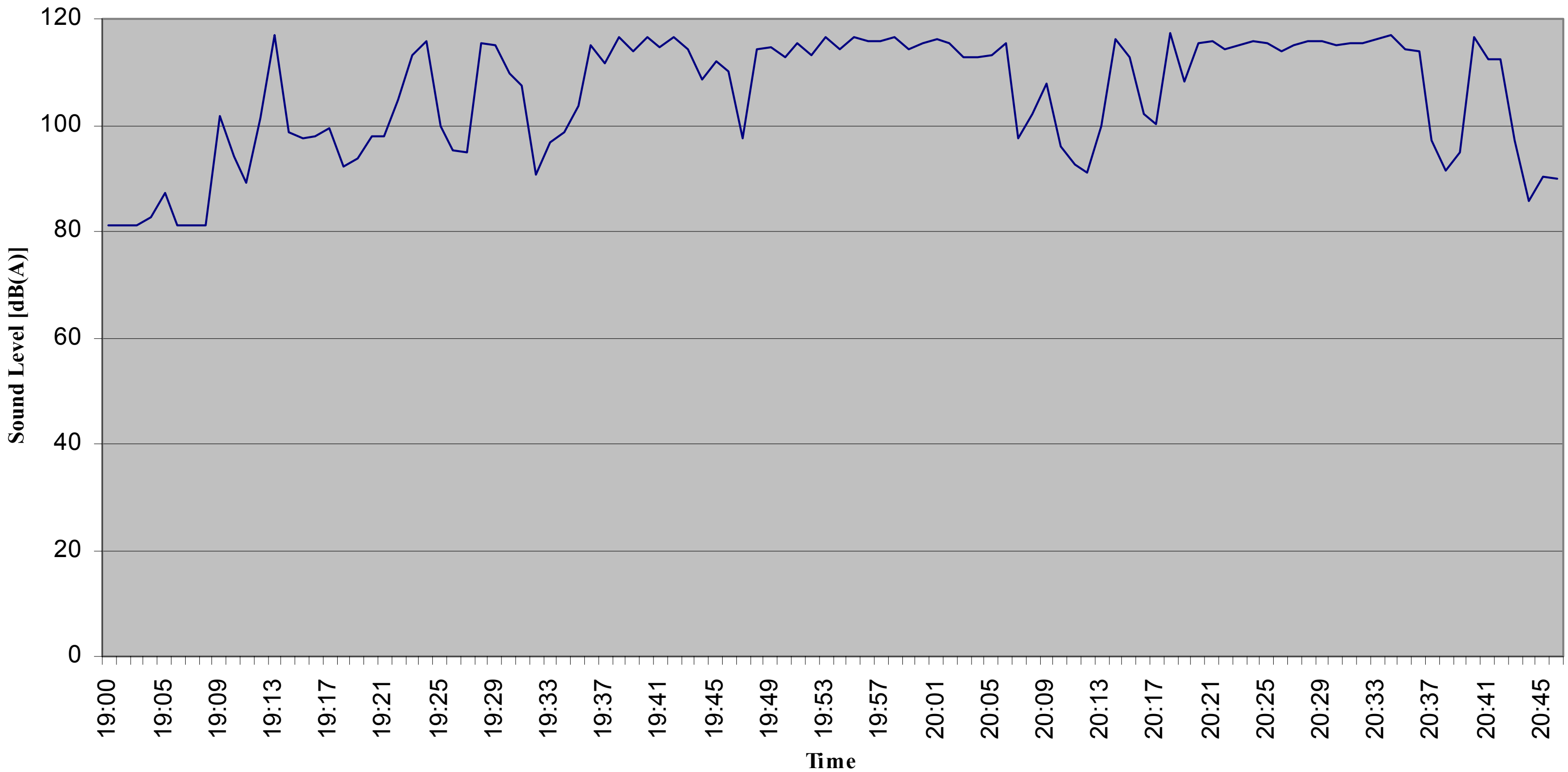


Figure 14

Personal Noise Levels - Race Track/Near Team's Race Car Hauler (Race)
August 25, 2000

L_{NIOSH} = 114.5 dB(A)



APPENDIX

Account Managers:
Function - Handle marketing coordination for various companies who contract their services.
Work environment - 90% office work. Offices are enclosed and utilize insulated doors to protect against noise.
Number of Employees at this position - 2

Public Relations Director:
Function - Responsible for maximizing the media exposure received by our sponsors.
Work environment - 90% office work during the week. Two days per race weekend spent at the track.
Number of Employees at this position - 1

Crew Chief:
Function - Organize and direct the work on the cars by all mechanical personnel.
Work environment - 30% office work during the week. Three days per race weekend spent at the track.
Number of Employees at this position - 1

Suspension assembly:
Function - Prepares the various suspension components for installation under the car. Also works as a general mechanic during the week.
Work Environment - 30% of time spent in suspension assembly room (separate from fabrication area), with remainder spent in set-up area. Three days per race weekend spent at the track.
Number of Employees at this position - 1

Mechanics:
Function - Installs the suspension, motors, and drive line in the race cars.
Work Environment - 80% of time spent working in the set-up area. Occasionally, some work is done in the fabrication area. Spends three days per race weekend at the track.
Number of Employees at this position - 3

Fabricators:
Function - Installs all metal on and around the race car.
Work Environment - 100% of time spent in fabrication area.
Number of Employees at this position - 5

Paint & Body:
Function - Final paint and body work on the race cars.
Work Environment - 100% of time spent in the paint and body shop area.
Number of Employees at this position - 1

Parts Manager/CFO:
Function - Order and inventory parts as needed; bookkeeping.
Work Environment - 90% of time spent in parts room.
Number of Employees at this position - 1

Transportor Driver:
Function - Transport race cars to and from the track. Stock truck with parts and feed employees at the track.
Work Environment - About 50% of time spent in the garage, with remainder spent on the road and at the track.
Number of Employees at this position - 1

Showcar Driver:
Function - Transport and execute store front promotions for sponsors.
Work Environment - 80% of time is spent on the road, traveling to different promotions.
Number of Employees at this position - 4

For Information on Other Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh

National Institute for Occupational Safety and Health
NIOSH

Delivering on the Nation's promise:
• Safety and health at work for all people through research and prevention