CDC Workplace Safety and Health

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2003-0364-3012
Mesaba Airlines, Inc.
Minneapolis, MN

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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

PREFACE

The Hazard Evaluation 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. 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 employers 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.

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.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Randy L. Tubbs of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Analytical support was provided by Ardith Grote of the Chemical Exposure Monitoring Branch, NIOSH. Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

Copies of this report have been sent to employee and management representatives at Mesaba Airlines, the Association of Flight Attendants (AFA) AFL-CIO, and the FAA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

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.

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a confidential union request for a health hazard evaluation (HHE) at Mesaba Airlines in Minneapolis, Minnesota. The union submitted the HHE request because of concerns by flight attendants about noise and air contaminants in the passenger cabins of the aircraft flown by Mesaba. NIOSH investigators conducted an investigation in November 2004.

What NIOSH Did

- We measured personal noise exposures for 20 flight attendants.
- We sampled the air in the aft passenger compartment for chemicals.
- We measured area noise in the back of the passenger cabin during take-off and landing and at cruise altitude.

What NIOSH Found

- Some chemicals were found in very low concentrations. These were presumed to be from cleaning products, jet fuel, deicing fluid, and engine operations.
- The personal noise measurements for a few flight attendants were above or near the recommended limits of NIOSH.
- The area noise measurements were slightly louder in aircraft that the flight attendants had identified as "noisy."

What Mesaba Airlines Managers Can Do

- Continue to measure personal noise exposures in the aircraft on a periodic basis.
- Begin a hearing testing program to insure that flight attendants are not showing changes in their hearing.
- Be active in a health and safety committee with employees to discuss workplace concerns and make sure that correct and up-to-date information is being passed on to all employees.

What the Mesaba Airlines Employees Can Do

- Report changes in the aircrafts' passenger compartments.
- Keep current on all information that the union and management provide about workplace conditions.
- Participate on the Mesaba Airline's health and safety committee.

CDC Workplace Safety and Health

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 #2003-0364-3012

NIOSH

Health Hazard Evaluation Report 2003-0364-3012
Mesaba Airlines, Inc.
Minneapolis, MN
August 2006

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SUMMARY

On September 8, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a confidential union request from Mesaba Airlines in Minneapolis, Minnesota about the work conditions inside the aircraft passenger cabin. Specifically, the request identified concerns about noise levels and air contaminants in the aft vestibule of the cabin during aircraft operations.

An onsite evaluation was conducted November 8-12, 2004, out of the Minneapolis/St. Paul International Airport. Twenty flight attendants volunteered to wear a noise dosimeter for most of their work shift. Additionally, area samples for noise and air contaminants were taken in 10 aircraft flown by Mesaba Airlines. The results of the noise and air sampling revealed that the flight attendants had exposures that were generally below applicable occupational exposure limits. The air contaminants were all below the criteria, and only 1 of 20 noise dosimeter measurements exceeded the NIOSH recommended exposure limit for occupational noise.

Exposures found in the passenger cabins during the NIOSH investigation were consistently below the relevant occupational limits. Air contaminants were identified, but in concentrations that are not considered to pose an increased risk for health effects. The noise levels were generally also below evaluation criteria, but a few of the personal samples approached or exceeded the limits. Based on these results, the NIOSH investigator recommended periodic monitoring of the occupational noise exposures and their effects on the flight attendants' hearing.

Keywords: NAICS 481111 (Air passenger carriers, scheduled), commercial airline, flight attendants, noise, carbon monoxide, aircraft cabin air pollution, noise dosimetry, volatile organic compounds

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INTRODUCTION

On September 8, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a confidential union request from Mesaba Airlines in Minneapolis, Minnesota. The requesters were concerned about the conditions inside the aircraft passenger cabin to which the flight attendants were exposed during their work shift. Specifically, the request identified concerns about noise levels and air contaminants in the aft vestibule of the cabin during aircraft operations. The auxiliary power unit (APU) was suspected as a source for some of the exposures.

An initial site visit was made by a NIOSH investigator to Mesaba Airlines headquarters on April 30, 2004, to meet with Mesaba Airline safety and inflight managers and a Mesaba Association of Flight Attendants (AFA) union representative. The purpose of this visit was to discuss the proposed protocol for the health hazard evaluation (HHE). A Principal Avionics Inspector with the Federal Aviation Administration's Minneapolis Flight Standards District Office was identified to review the equipment NIOSH planned to use on the aircraft during flight operations and certify that it did not interfere with any navigational equipment on the aircraft. The technical specifications of the air and noise measuring instruments planned for the survey were forwarded to this individual for approval. It was decided at the initial site visit to perform the survey in November after the busy summer vacation period, but before the holiday travel period. November 8-12, 2004, was chosen to conduct the evaluation of Mesaba Airlines.

BACKGROUND

Mesaba Airlines operates as a Northwest Airlink affiliate under code-sharing agreements with Northwest Airlines. Mesaba Airlines is the 12th largest regional airline in the United States and currently provides service to more than 100 cities and 31 states and Canada from Northwest Airline's three major hubs in Minneapolis/St. Paul, Minnesota; Detroit, Michigan; and Memphis, Tennessee. Mesaba Airlines operates a fleet of 77 regional jet and jet-prop aircraft, consisting of the 69-passenger Avro RJ-85, the 50-passenger CRJ-200, and the 30-34 passenger Saab 340. In 2005, Mesaba Airlines carried more than 5.7 million passengers.[1]

NIOSH had previously investigated noise levels at a regional airline that flew turboprop aircraft and found that the exposures in the passenger cabin were not sufficient to increase the risk of occupational hearing loss for the flight attendants.[2] NIOSH has also investigated the low levels of air contamination found in transcontinental flights.[3] This investigation was planned to add to the body of knowledge concerning working conditions for flight attendants.

METHODS

A flight schedule arranged by Mesaba Airlines allowed the NIOSH investigator to be on two outbound/inbound flights originating at the Minneapolis St. Paul (MSP) airport each day of the five survey days so that 10 different Avro RJ-85 aircraft were sampled in this manner. On each aircraft tested, the NIOSH investigator was seated in a back location in the cabin near the aft vestibule during the entire flight collecting spectral noise measurements during takeoff and landing, and at cruising altitude. Also, on the flights on which the NIOSH investigator flew, air monitors were attached on the back wall of the aft vestibule with duct tape. The air monitors were turned on at the beginning of the flight out and turned off when the aircraft returned to MSP. Finally, two groups of flight attendants, two per aircraft, were identified by the airline to ask if they would volunteer to wear a noise dosimeter throughout the work day. The flight attendants either started their day at MSP or flew into the airport early in their shift when a dosimeter was placed on them. They either ended their day in or flew into MSP near the end of their assigned daily itinerary so that the dosimeters could be collected from them. Mesaba's inflight department provided NIOSH with the scheduled itinerary for the flight attendants along with the Avro RJ-85 tail numbers for identification. The 10 aircraft tested with dosimeters on the flight attendants were different than the 10 airplanes that the NIOSH investigator sampled.

Noise

Quest® Electronics Model Q-300 Noise Dosimeters were used to collect the daily noise exposure measurements from the flight attendants who volunteered to be in the NIOSH evaluation. The dosimeters were secured on the employees' belts and the dosimeter microphones attached to their shirts, halfway between the collar and the point of the shoulder. A windscreen provided by the dosimeter manufacturer was placed over the microphone during recordings. The dosimeters were worn for the entire time that the flight attendants were on their assigned aircraft. The noise information was downloaded to a personal computer for interpretation with QuestSuite® Professional computer software and the dosimeters reset for the next day. The dosimeters were calibrated before and after the work shift according to the manufacturer's instructions.

The spectral noise measurements were made with a Larson-Davis Laboratory Model 2800 Real-Time Analyzer and a Larson-Davis Laboratory Model 2559 ½" random incidence response microphone. The microphone was connected to the analyzer with a 6-ft. cable. The analyzer allows for the analysis of noise into its spectral components in a real-time mode. The ½"-diameter microphone has a frequency response range (± 2 decibels [dB]) from 4 Hertz (Hz) to 21 kilohertz (kHz) that allows for the analysis of sounds in the region of concern. One-third octave bands consisting of center frequencies from 25 Hz to 20 kHz were integrated for 15 seconds and stored in the analyzer. The analyzer was set in the auto-store mode so that a 15-second sample was automatically stored at the end of the period and the analyzer reset to instantly begin the next 15-second sample period. The series of sample periods was continued for a total of 5 minutes, thus yielding 20 samples for each of the aircraft activities. Take-off sampling was started when the aircraft first began to move on the runway and ended 5 minutes later. Samples taken at cruise altitude were collected for a period of 5 minutes once the aircraft had leveled off in the sky. Finally, landing samples began when the pilot lowered the landing gear or the wing flaps and continued for 5 minutes or, in some cases, until the aircraft came to a stop at the gate.

Air Contaminants

Carbon Monoxide (CO)

Carbon monoxide exposures were evaluated with the Biosystems Toxi Ultra, a real-time, data-logging, passive CO monitor that logs, in parts per million (ppm), average exposures, 8-hour time-weighted averages (TWA), maximum 15-minute short-term exposures, and maximum peak exposures. These instruments were operated in a passive diffusion mode with a 1-minute sampling interval. One area sample was collected on each airplane ridden by the NIOSH investigator by attaching the instrument to the aft cabin wall with duct tape, making sure the sensor was open to the environment. The CO monitor was turned on at the beginning of the outbound flight and left on until the aircraft returned to MSP.

Volatile Organic Compounds (VOCs)

Area air samples that screen for VOCs were collected on each aircraft ridden by the NIOSH investigator. The samples were collected on thermal desorption tubes attached by Tygon® tubing to SKC® Pocket Pumps® calibrated at a flow rate of 0.05 liters per minute (Lpm). The thermal desorption tubes used for qualitative identification of VOCs contain three beds of sorbent material: a front layer of Carbopack Y™, a middle layer of Carbopack B™, and a back section of Carboxen 1003™. The tubes were analyzed by the NIOSH laboratory in a Perkins-Elmer ATD 400 automatic thermal desorption system. The thermal unit was interfaced directly to an HP5890A gas chromatograph with an HP5970 mass selective detector according to the NIOSH Manual of Analytical Methods (NMAM) Method 2549.[4]

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 become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[5] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[6] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[7] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs®, or whichever are the more protective criteria.

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.

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.

Noise

Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[8] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[9]

The A-weighted decibel (dBA) is the preferred unit for measuring sound levels to assess worker noise exposures. The dBA 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 dBA scale is logarithmic, increases of 3 dBA, 10 dBA, and 20 dBA represent a doubling, tenfold increase, and hundredfold 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)[10] specifies a maximum PEL of 90 dBA 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 dBA for no more than 4 hours, to 100 dBA for 2 hours, etc. Conversely, up to 16 hours exposure to 85 dBA is allowed by this exchange rate. The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

$$\text{Dose} = 100 \text{ X } (C_1/T_1 + C_2/T_2 + ... + C_n/T_n),$$

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

The OSHA regulation has an additional action level (AL) of 85 dBA; 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 dBA, feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels.

NIOSH, in its Criteria for a Recommended Standard,[11] and the ACGIH[6] propose exposure criteria of 85 dBA as a TWA for 8 hours, 5 dB less than the OSHA standard. The criteria also use a more conservative 3 dB time/intensity trading relationship in calculating exposure limits. Thus, a worker can be exposed to 85 dBA for 8 hours, but to no more than 88 dBA for 4 hours or 91 dBA for 2 hours. Twelve-hour exposures have to be 83 dBA or less according to the NIOSH REL.

Air Contaminants

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas which can be a product of the incomplete combustion of organic compounds. CO combines with hemoglobin and interferes with the oxygen carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death.[12] The NIOSH REL for carbon monoxide is 35 ppm for an 8-hour TWA, with an additional recommendation for a ceiling limit of 200 ppm which should not be exceeded at any time during the workday.[5] The OSHA PEL for carbon monoxide is 50 ppm for an 8-hour TWA.[7] The ACGIH TLV for carbon monoxide is 25 ppm as an 8-hour TWA.[6]

Volatile Organic Compounds

Volatile organic compounds describe a large class of chemicals which are organic (i.e., containing carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. These compounds are emitted in varying concentrations from numerous indoor sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. Two major compounds were identified in this evaluation that have published occupational exposure limits: toluene and 2-butoxyenthanol (Butyl Cellosolve®).

Toluene

Toluene is a colorless, aromatic organic liquid containing a six carbon ring (a benzene ring) with a methyl group (CH3) substitution. It is a typical solvent found in paints and other coatings, and 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 exposure. Toluene can cause 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.[12]

The NIOSH REL for toluene is 375 milligrams per cubic meter (mg/m^3) for up to a 10-hour TWA.[5] NIOSH has also set a recommended STEL of 560 mg/m^3 for a 15-minute sampling period. The OSHA PEL for toluene is 754 mg/m^3 for an 8-hour TWA.[7] The ACGIH TLV is 188 mg/m^3 for an 8-hour TWA, but a notice of intended change has been published to reduce this level down to 75 mg/m^3.[6] This ACGIH TLV carries a skin notation, indicating that cutaneous exposure contributes to the overall absorbed inhalation dose and potential systemic effects.

2-Butoxyethanol

2-Butoxyethanol, also known as ethylene glycol monobutyl ether, or Butyl Cellosolve®, is a colorless liquid solvent with a mild ether odor.[12] 2-Butoxyethanol is a widely used solvent and cleaning agent. The low vapor pressure of 2-butoxyethanol is such that high air concentrations are unlikely; however, the material can be absorbed through the skin. The NIOSH REL for 2-butoxyethanol is 24 mg/m^3 for up to a 10-hour TWA.[5] While intended to prevent hematotoxicity, the REL should also prevent eye and mucous membrane irritation.[13] The OSHA PEL is 240 mg/m^3 as an 8-hour TWA.[7]

RESULTS

Noise

The Quest dosimeters collect data so that one can directly compare the information with the three different noise criteria used in this survey, the OSHA PEL and AL, and the NIOSH REL. The OSHA criteria use a 90 dBA criterion and 5-dB exchange rate for the PEL and AL. The difference between the two is the threshold level employed, with a 90 dBA threshold for the PEL and an 80 dBA threshold for the AL. The threshold level is the lower limit of noise values included in the calculation of the criteria; values less than the threshold are ignored by the dosimeter. The NIOSH criterion differs from OSHA in that the criterion is 85 dBA, the threshold is 80 dBA, and it uses a 3-dB exchange rate.

Twenty flight attendants flying in 10 Avro RJ-85 airplanes wore noise dosimeters for a majority of their scheduled daily itinerary, usually four flight legs, over the five survey days. One pair of attendants was sampled over only two flight legs because of scheduling difficulties. The individual flight attendants' noise dosimeter data are presented in Figures 1-20. Each figure shows the minute-by-minute dBA levels over the sampled work shift. Included in each figure are the scheduled departure times (D) and the scheduled arrival times (A) for each flight leg as well as the equivalent noise levels (TWA) for the total sampled period calculated according the OSHA AL and NIOSH REL criteria. These data are also summarized in Table 1, which shows the total sampling time and the percent dose accumulations calculated according to the three evaluation criteria for each flight attendant.

Only one flight attendant was found to have a daily noise dose in excess of the NIOSH REL (attendant 1 - #507 Figure 17). All others were below the criterion for the time that they were wearing the dosimeter. No flight attendant exceeded the OSHA criteria. As noted earlier, the flight attendants generally had one additional flight the day on which they wore the noise dosimeter that was not included in the measured daily noise dose. To see the effect of this additional flight leg, the average noise levels calculated according to the NIOSH REL and OSHA AL criteria were determined for each of the scheduled times between departure and arrival given on the flight attendant's itinerary furnished by Mesaba Airlines to find an average noise level for the time the aircraft was flying. The reference duration for the average level was calculated and the remaining flight time for each attendant was put into the C_n/T_n formula to estimate the added noise dose from the unmeasured portion of the flight attendant's day. These estimated noise dose values are presented in Table 2. Only the OSHA AL criterion was calculated because the PEL dose measurements were so far below the 100% allowable dose. None of the extrapolated noise doses exceeded the OSHA AL criterion. However, two more flight attendants were found to have extrapolated daily noise doses above the NIOSH REL.

In addition to the noise dosimeter data collected on flight attendants, spectral noise data were collected on 10 different aircraft during an outbound flight from MSP and the subsequent return flight to MSP on the same airplane. For each flight, the NIOSH investigator sat near the back of the aircraft in a passenger seat collecting noise data with the real-time analyzer during take-off and landing, and while the aircraft was at cruise altitude. The data were stored as one-third octave bands over the frequency range of 20 – 20,000 Hz. These data are presented graphically in an appendix to this report.

The flight attendants' local union identified five of Mesaba's Avro RJ-85 aircraft as being particularly noisy. The list included aircraft #508, #511, #513, #521, and #527. Scheduling difficulties did not allow for each of the identified aircraft to be investigated during this evaluation. However, aircraft #511 and #513 were included in the spectral noise evaluation. The median dBA levels measured during take-off, cruise, and landing were calculated for the 10 aircraft included in the survey. For aircraft #511, the median levels were 82.7 dBA for take-off, 84.0 dBA for cruise, and 82.7 dBA for landing. For aircraft #513, the median levels were 82.1 dBA, 84.0 dBA, and 80.8 dBA for the three flight conditions. The median noise levels for the remaining eight aircraft tested during the evaluation were 82.2 dBA for take-off, 81.7 dBA for cruise, and 78.7 dBA for landing. Thus, for aircraft operations during cruise altitude and landing, the two "noisy" aircraft were louder than the rest of the measured fleet, by 2 – 4 dBA. There was little difference in noise levels emitted during take-off for the 10 aircraft.

Air Contaminants

Carbon Monoxide

The monitors continuously measured the levels of CO in the rear portion of the passenger compartment from the time the NIOSH investigator boarded the aircraft at MSP until it returned. The results for the 10 individual Avro RJ-85 aircraft are shown in Table 3. The flight durations were generally 3-4 hours in length. All of the measured CO levels were minimal, with most TWAs found to be 0 ppm and STELs much less than the ceiling limit. Aircraft #516 was found to have the highest concentrations of CO, showing a peak level of 13 ppm and a STEL of 6 ppm. A review of the time when peak CO levels occurred revealed that they usually happened during the first time the airplane took-off from MSP. This is seen in Figure 21 for aircraft #516 where take-off began at 5:32 pm. The second recorded take-off began at 7:32 pm. A second aircraft with one of the higher measured peak CO levels was #511, exhibiting a 6 ppm concentration. For this aircraft, the highest peak occurred during the first take-off operation as seen for aircraft #516, but a second smaller peak happened during the second take-off. This is shown graphically in Figure 22.

Volatile Organic Compounds

Total ion chromatograms were generated for the thermal desorption tube samples collected on 10 Avro RJ-85 aircraft. The major components identified on many of the samples were limonene, toluene, propylene glycol, and 2-butoxyethanol (Butyl Cellosolve®). The samples were quantified for these major components. However, since the sampling and analytical techniques used in these analyses have not been validated, all of these results should be considered as estimates. With the exception of aircraft #532, at least one of the major compounds was detected on each of the aircraft during the two scheduled flight legs that were sampled. Concentrations for all of the estimated contaminants were 2.0 $\mu g/m^3$ or less.

DISCUSSION

The results of the noise and air sampling in Mesaba's aircraft revealed that the flight attendants had exposures that are generally below all relevant evaluation criteria. The VOC and CO air contaminants were all below the criteria, and only 1 of 20 flight attendants' noise dosimeter measurements exceeded the NIOSH REL for occupational noise.

The CO meter readouts showed that the levels were generally 0 ppm in the aft vestibule of the aircraft. The only time that detectable levels of this air contaminant were noted was during take-off on a majority of the sampled fleet. The highest recorded peak of 13 ppm in aircraft #516 is much lower than the NIOSH ceiling level of 200 ppm. The major VOCs identified on the 10 aircraft were also at very low concentrations. The four major components identified on the thermal desorption tubes, limonene, toluene, propylene glycol, and 2-butoxyethanol, are readily explainable as to their origin. Both limonene and 2-butoxyethanol are found in common cleaning agents. Toluene is a component of jet A fuel and propylene glycol is listed as one of the ingredients in the deicing fluid used by Mesaba Airlines. The CO could be a combustion byproduct from the aircraft's engines.

These chemical contaminants were a concern of the Mesaba flight attendants and their union representatives. A Department of Transportation, Federal Aviation Administration (FAA) Final Rule was published in 2004 where a new airworthiness directive, applicable to certain BAE Systems (Operations) Limited Model BAe 146 and Avro 146-RJ series airplanes, required replacing the existing bellows inlet duct of the APU system with a new, improved rectangular metallic bellows inlet duct.[14] The directive stated that this action is necessary to prevent air from the APU bay being ingested into the flight deck and passenger cabin, resulting in poor air quality and, if the air is contaminated, possible incapacitation of the flightcrew and passengers. Because the airworthiness directive does not address the Avro RJ-85, the NIOSH investigator contacted the technical support section of BAE Systems to clarify the aircraft covered by the directive. A BAE Systems Technical Support Engineer responded that the original design of the AVRO RJ-85 incorporated the modifications specified in the directive and therefore there is no reason to apply the airworthiness directive to these aircraft.[15]

Measured noise levels were almost always below the most conservative evaluation criterion. Only one dosimeter measured noise in excess of the NIOSH REL for the portion of the flight attendant's shift that was sampled. The extrapolated exposures that attempt to account for the flight legs that were not actually measured only put two additional flight attendants in a category where their noise levels exceed the criterion. However, three more attendants were found to have daily noise doses greater than 90% of the allowable amount according to the NIOSH REL after the extrapolation. Also, the median noise levels during cruising in the two aircraft identified as being noisier than the rest of the fleet were calculated to be 84 dBA, a value near the limit of 85 dBA for an 8-hour work shift. Because of the closeness of the noise exposures to the NIOSH criterion, Mesaba airlines should monitor flightcrews' occupational noise exposures and their hearing ability more closely.

For most industries in the U.S., OSHA is the agency that oversees worker health and safety. However, the FAA published a Federal Register notice in 1975 asserting its complete and exclusive responsibility for the regulation of occupational safety and health standards of employees engaged in civil aircraft operations.[16] Because OSHA has statutory authority governing the occupational safety and health of most employees, the FAA and OSHA entered into a Memorandum of Understanding in August 2000 to establish a procedure for coordinating and supporting enforcement of the Occupational Safety and Health Act with respect to the working conditions of employees on aircraft in operation (other than flight deck crew) and for resolving jurisdictional questions. A FAA/OSHA Aviation Safety and Health Team was formed, and a report was issued in December 2000. Included in this report was a section on occupational exposure to noise where the team looked at the application of OSHA's general industry standards on occupational noise to employees on aircraft in operation. Although the team reports that they have no data as to the levels of noise encountered by employees during operation, they felt that many of the OSHA provisions, such as training and testing, could be applied without any effect on aviation safety. However, the team felt that engineering and administrative controls and the use of hearing protection devices (HPDs) would affect aviation safety and would therefore require FAA approval. On June 18, 2002, the Aviation Safety and Health Team released an Action Plan proposing an Aviation Safety and Health Partnership Program which would expand the FAA's role in worker safety and health issues. OSHA's role in this program would be advisory only. On May 15, 2003, the FAA issued a Departmental Order (1110.134) describing a voluntary Aviation Safety and Health Partnership Program (ASHPP) with a rulemaking committee consisting of members from the FAA, air carriers, and air carrier employee unions. This action led to a suit filed in District Court on September 19, 2005, by the Association of Flight Attendants against OSHA and the FAA for their failure to ensure the health and safety of flight attendants and other employees working in the airline industry.[17]

Because the oversight of occupational noise exposure in flight attendants is not detailed in such a manner as the OSHA Occupational Noise Standard, it should be possible to institute many of the components of an effective hearing loss prevention program and be in compliance with FAA regulations and approvals. Because the noise exposures measured in the NIOSH evaluation approached or exceeded the REL in a number of instances, additional periodic assessments of flight attendants' noise levels should be put into Mesaba Airline's operating procedures. This will verify that the noise has not begun to routinely exceed levels where there is a risk of occupational hearing loss. Along with noise exposure measurements, an audiometric testing program should be implemented to check to see that the employees are not exhibiting gradual losses of hearing which would affect their ability to perform their work activities, which could be classified as "hearing critical." Early identification of hearing loss will allow Mesaba management to intervene with additional actions, such as maintenance or engineering controls on the aircraft, reduced time in the aircraft, or hearing protection devices for the flightcrew that meet FAA approval.

CONCLUSIONS

Conditions found in the passenger cabins during the NIOSH investigation were consistently below the relevant occupational exposure standards. Air contaminants were identified, but in concentrations that are not considered to pose an increased risk for health effects. The likely sources of the major components are cleaning products, deicing fluids, jet fuel, and combustion products emitted by the engines.

The noise exposures experienced by the flight attendants were usually below the most conservative evaluation criterion. However, the measured levels did approach the NIOSH REL and should be checked periodically to assure management officials and employees that the noise conditions are not increasing to levels that may put the flight attendants at risk for occupational hearing loss. Also, in striving to keep the noise levels low in the passenger cabins, the auditory experience of Mesaba employees and their customers will be better. Communications between and among employees and the passengers will improve as the background noise levels from engines and other aircraft components are reduced.

Finally, incorporating a periodic audiometric examination as part of the flight attendants' medical or wellness program will insure that their hearing levels are not deteriorating over time. If there should be a change in the schedules of the flight attendants that increases their daily time on aircraft or should the type of aircraft flown by Mesaba change to one that has higher noise exposures, then there will be historical data on the hearing levels of the employees that may be necessary to meet the regulatory requirements of a hearing conservation program.

RECOMMENDATIONS

Based on the findings and observations of this evaluation, the following recommendations are offered to Mesaba Airlines and its flight attendants to improve the work environment on the AVRO RJ-85 aircraft.

1. Mesaba Airlines should institute a noise monitoring program which includes both personal noise dosimetry to document the flight attendants' exposures and general area noise samples of the passenger cabins. The noise monitoring should be conducted on a periodic basis, e.g., annually or biennially, or whenever flight attendants notice that the noise levels of a particular aircraft seem to be getting louder.

2. An audiometric testing program should be instituted by Mesaba Airlines for their flight attendants. The program should minimally use pure-tone threshold testing. The Council for Accreditation in Occupational Hearing Conservation (CAOHC) has guidelines for such a program.[18]

3. If the flight attendants feel that the use of HPDs would help them in performing communication tasks during flights, FAA approval would first have to be secured by the airline. If allowed, there are HPDs on the market that are characterized as flat spectrum, moderate attenuation devices, sometimes referred to as "musician earplugs."[19] They offer levels of attenuation from 9 – 25 dB and tend to lower sound equally over the entire spectrum. Thus, they do not have the characteristic shape of increasingly higher attenuation of sound in the high frequencies, which tends to be detrimental to detecting speech signals in a background of noise.

4. A health and safety committee with representatives from management and the union should be active at Mesaba Airlines. The concern over the FAA airworthiness directive about the replacement of the bellows inlet appears to be based on faulty information. This committee could work on obtaining the most up-to-date information about employees' concerns and communicating this information to all workers.

REFERENCES

1. Mesaba Airlines [2006]. Mesaba Info. World Wide Web [URL=http://www.mesaba.com/mescom/home.nsf/main?openframeset&Frame=main&Src=/mescom/home.nsf/splash/information?opendocument]. Date accessed: June 2006.

2. Tubbs RL [2004]. Health hazard evaluation: Horizon Air, Seattle, Washington, 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, HETA Report No. 2003-0094-2931.

3. Waters MA, Bloom TF, Grajewski B, Deddens J [2002]. Measurements of Indoor Air Quality on Commercial Transport Aircraft. In Indoor Air 2002: Proceedings of the 9th International Conference on Indoor Air Quality and Climate, Vol. 4, H Levin, ed., Santa Cruz, California, pp. 782-787

4. NIOSH [2006]. NIOSH manual of analytical methods (NMAM®). 4th ed. Schlecht PC, O'Connor PF, eds. 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 94–113 (August, 1994); 1st Supplement Publication 96–135, 2nd Supplement Publication 98–119; 3rd Supplement 2003–154. [http://www.cdc.gov/niosh/nmam/]

5. 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.

6. ACGIH® [2006]. 2006 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

7. CFR [2003]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

8. Ward WD, Royster LH, Royster JD [2000]. Anatomy & physiology of the ear: normal and damaged hearing. Chapter 4. In: Berger EH, Royster LH, Royster JD, Driscoll DP, & Layne M, eds. The noise manual. 5th ed. Fairfax, VA: American Industrial Hygiene Association, pp 101-122.

9. Suter AH [1978]. The ability of mildly-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.

10. CFR [2003]. 29 CFR 1910.95. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

11. 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.

12. Proctor NH, Hughes JP, Fischman ML [1988]. Chemical hazards of the workplace, 2nd ed. Philadelphia, PA: J.B. Lippincott Company.

13. NIOSH [1990]. Criteria for a recommended standard: occupational exposure to ethylene glycol monobutyl ether and ethylene glycol monobutyl ether acetate. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90–118.

14. 69 Fed. Reg. 44594 [2004]. Federal Aviation Administration: Airworthiness Directives; BAE Systems (Operations) Limited Model BAe 146 and Avro 146-RJ Series Airplanes; final rule.

15. King M (martyn.king@baesystems.com) [2005]. Clarification of Airworthiness Directive. Private e-mail message to Randy L. Tubbs (rlt2@cdc.gov), December 1.

16. 40 Fed. Reg. 29114 [1975]. Federal Aviation Administration: Occupational Safety or Health Standards for Aircraft Crewmembers.

17. Association of Flight Attendants - CWA [2006]. AFA Files Suit Against OSHA, FAA. World Wide Web [URL=http://ashsd.afacwa.org/index.cfm?zone=/unionactive/view_article.cfm&HoneID=25835]. Date accessed: March 2006.

18. Suter AH [2002]. Hearing conservation manual. 4th ed. Milwaukee, WI: Council for

Accreditation in Occupational Hearing Conservation.

19. Hager LD [2003]. Hearing conservation - Encouraging compliance. Advance for Audiologists, Merion Publications, Inc.: King of Prussia, PA, November/December, 32-34.

Table 1
Noise Dosimeter Results
Percent Dose for Actual Time Sampled
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364-3012
November 8-12, 2004

Flight Attendant – Aircraft Tail #	Time Sampled [hh:mm]	Percent Dose OSHA PEL	Percent Dose OSHA AL	Percent Dose NIOSH REL
Attendant 1 - #522	08:39	1%	14%	35%
Attendant 2 - #522	08:37	1%	18%	43%
Attendant 1 - #514 & #504	09:46	3%	20%	52%
Attendant 2 - #514 & #504	09:47	3%	23%	66%
Attendant 1 - #527 & #524	11:04	1%	31%	80%
Attendant 2 - #527 & #524	11:04	3%	28%	70%
Attendant 1 - #522	08:54	4%	24%	63%
Attendant 2 - #522	08:59	6%	27%	75%
Attendant 1 - #510 & #515	10:36	4%	26%	62%
Attendant 2 - #510 & #515	10:39	1%	19%	52%
Attendant 1 - #522 & #520	09:22	3%	24%	61%
Attendant 2 - #522 & #520	09:29	5%	28%	81%
Attendant 1 - #520 & #532	08:59	4%	23%	58%
Attendant 2 - #520 & #532	09:01	3%	19%	54%
Attendant 1 - #521 & #522	07:21	6%	21%	75%
Attendant 2 - #521 & #522	07:20	2%	15%	41%
Attendant 1 - #507	10:33	9%	49%	128%
Attendant 2 - #507	10:36	7%	34%	94%
Attendant 1 - #520	03:41	1%	9%	25%
Attendant 2 - #520	03:43	0%	6%	15%

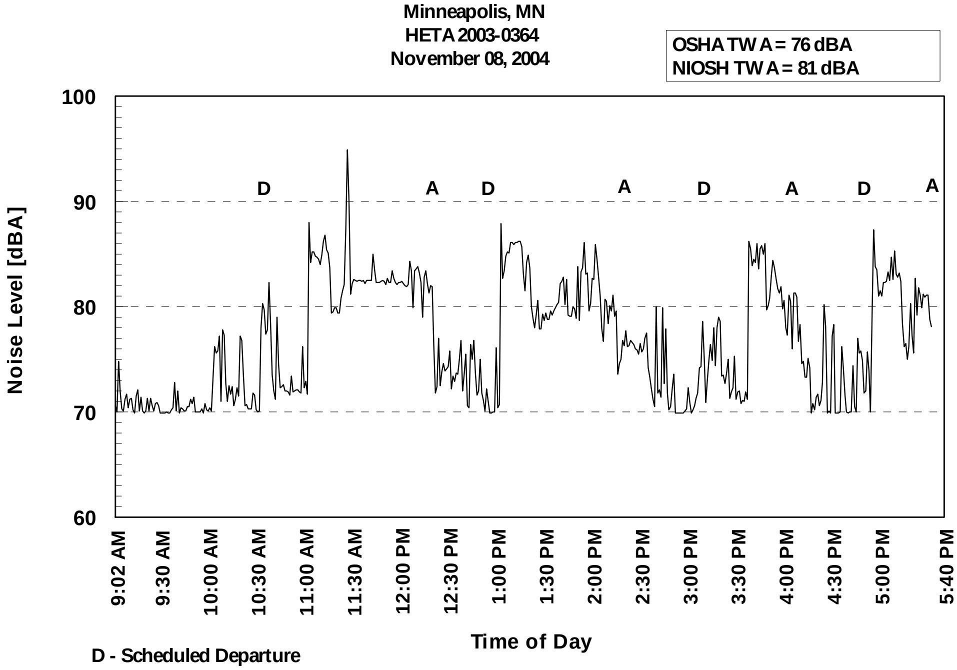
Table 2
Extrapolated Percent Dose for Additional Scheduled Flight Time
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364-3012
November 8-12, 2004

Flight Attendant – Aircraft Tail #	**Remaining Flight Time [hh:mm]**	**Extrapolated Percent Dose OSHA AL**	**Extrapolated Percent Dose NIOSH REL**
Attendant 1 - #522	02:09	20%	47%
Attendant 2 - #522	02:09	25%	58%
Attendant 1 - #514 & #504	01:52	26%	67%
Attendant 2 - #514 & #504	01:52	29%	81%
Attendant 1 - #527 & #524	01:08	36%	93%
Attendant 2 - #527 & #524	01:08	32%	80%
Attendant 1 - #522	02:09	31%	84%
Attendant 2 - #522	02:09	35%	97%
Attendant 1 - #510 & #515	01:28	32%	76%
Attendant 2 - #510 & #515	01:28	23%	60%
Attendant 1 - #522 & #520	01:57	29%	75%
Attendant 2 - #522 & #520	01:57	35%	103%
Attendant 1 - #520 & #532	01:09	28%	71%
Attendant 2 - #520 & #532	01:09	22%	62%
Attendant 1 - #521 & #522	03:31	34%	111%
Attendant 2 - #521 & #522	03:31	25%	67%
Attendant 1 - #507	00:00	49%	128%
Attendant 2 - #507	00:00	34%	94%
Attendant 1 - #520	02:51	18%	44%
Attendant 2 - #520	02:51	13%	30%

Table 3
Aircraft Carbon Monoxide Levels
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364-3012
November 8-12, 2004

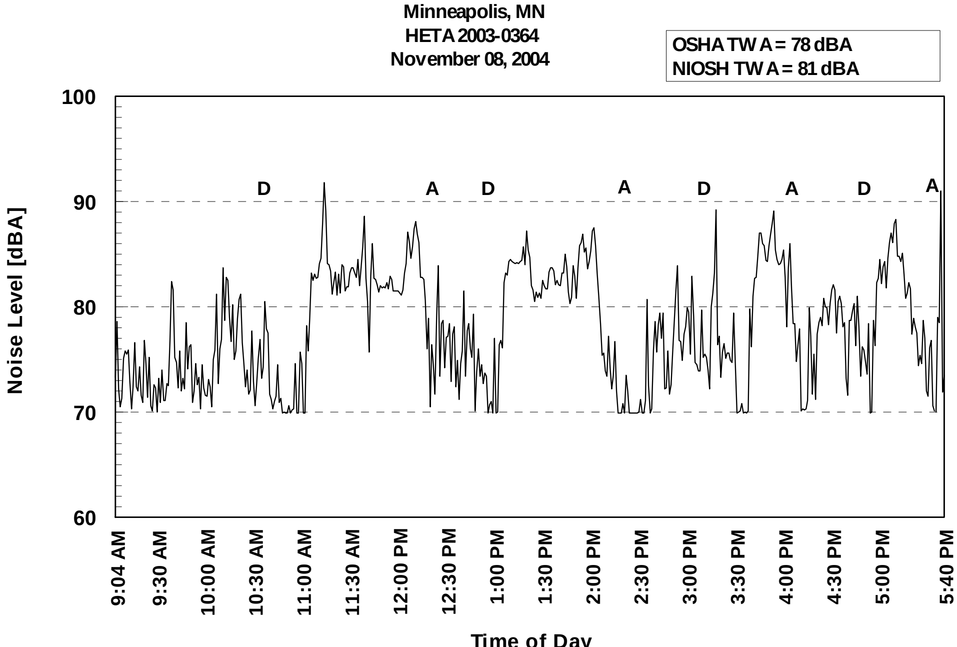
Aircraft Tail #	Sample Duration [Min]	8-hr. TWA [ppm]	TWA For Sample Duration	Max. STEL [ppm]	Max. Peak [ppm]
506	184	0	0	1	1
532	199	0	1	2	4
513	223	0	1	3	7
511	209	0	1	3	6
514	204	0	0	2	3
522	227	1	1	3	3
509	179	0	1	2	2
516	199	1	1	6	13
533	198	0	1	3	3
529	193	1	2	4	4

Figure 1
Avro RJ-85 (#522) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 08, 2004



D - Scheduled Departure
A - Scheduled Arrival

Figure 2
Avro RJ-85 (#522) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 08, 2004



D - Scheduled Departure
A - Scheduled Arrival

Figure 3
Avro RJ-85 (#514 & #504) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 08, 2004

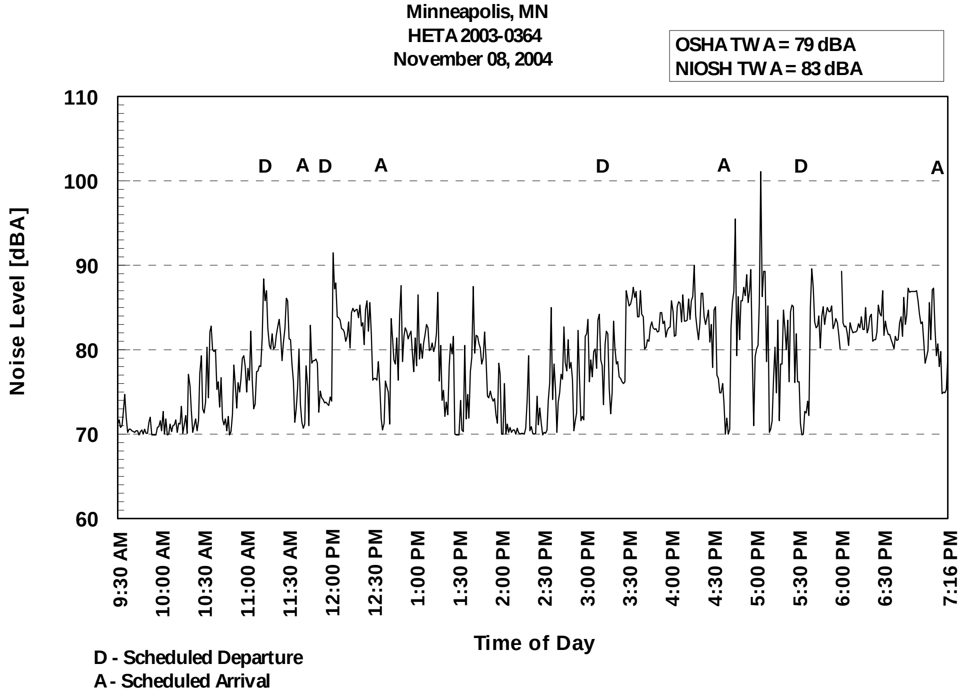


Figure 4
Avro RJ-85 (#514 & #504) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 08, 2004

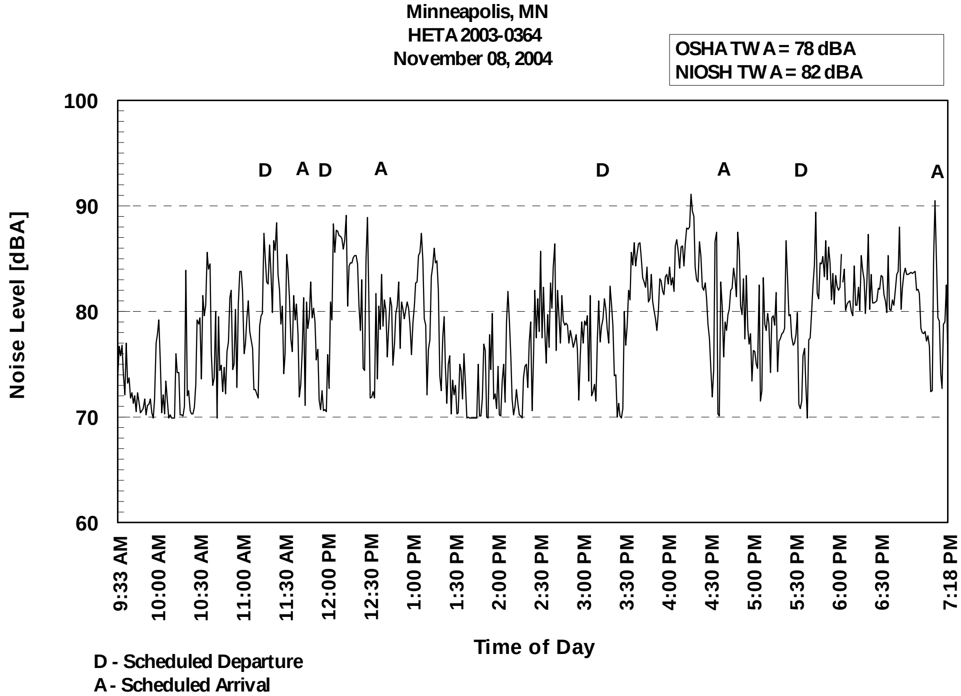


Figure 5
Avro RJ-85 (#527 & #524) Aft Cabin Flight Attendant
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 09, 2004

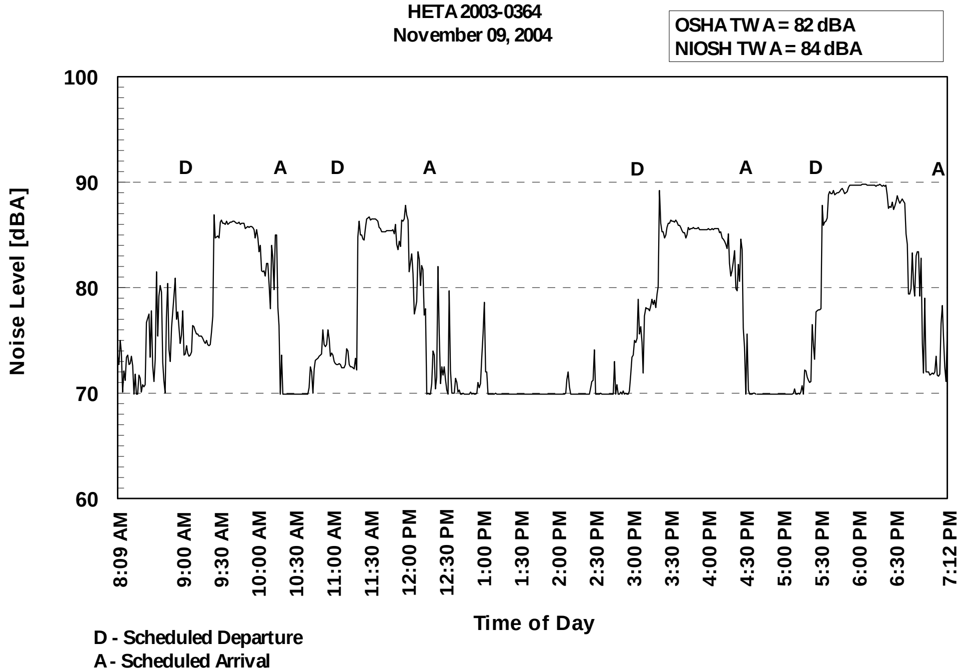


Figure 6
Avro RJ-85 (#527 & #524) Forward Cabin Flight Attendant
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 09, 2004

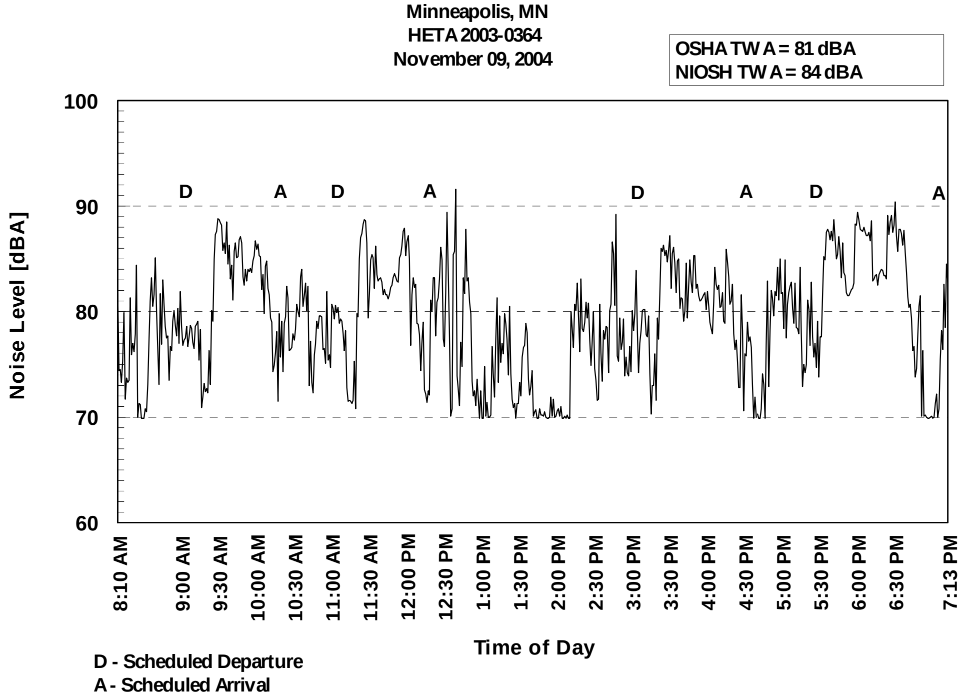
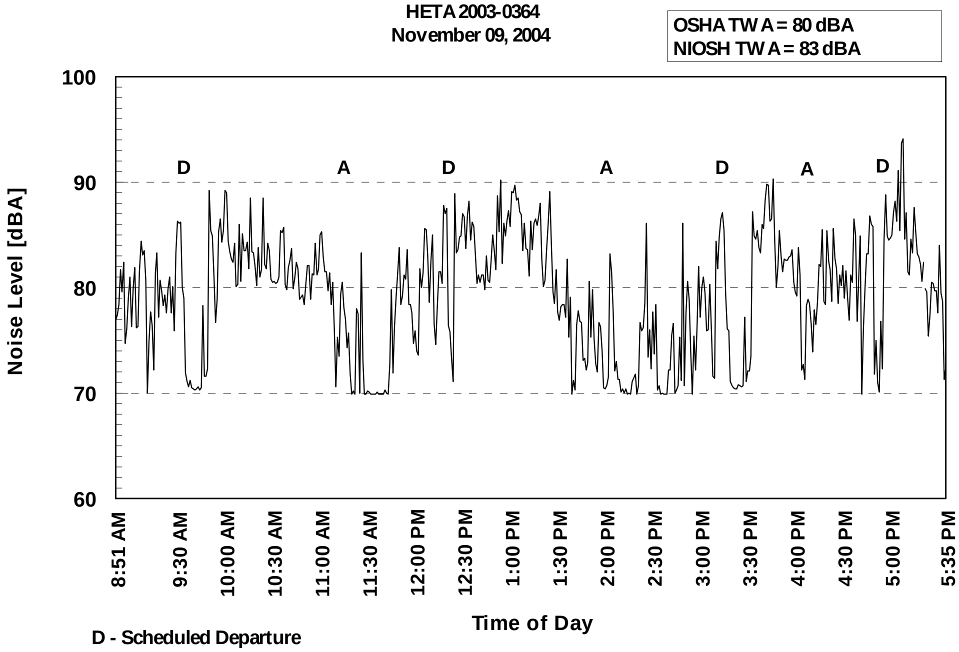
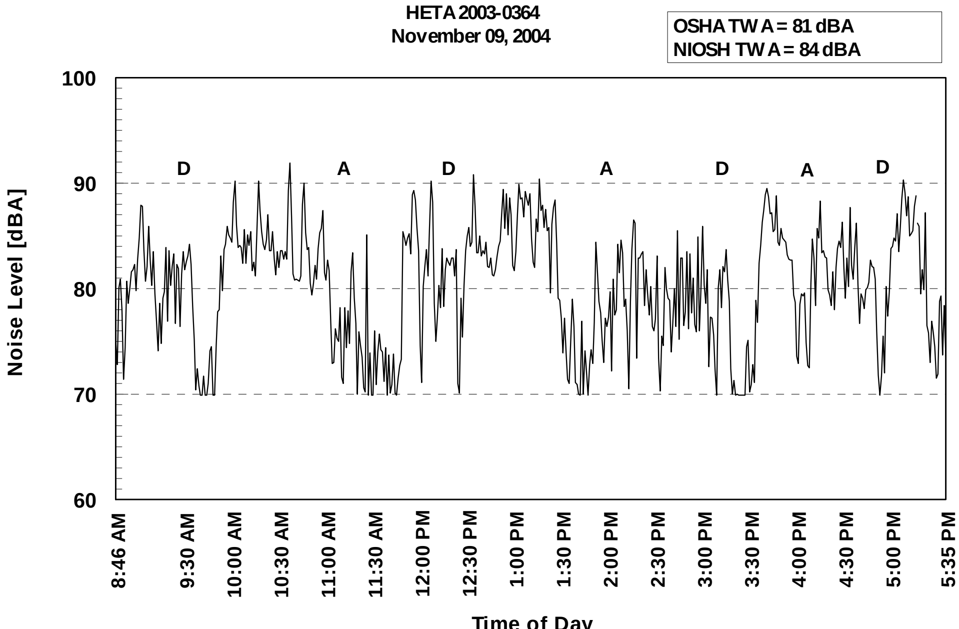


Figure 7
Avro RJ-85 (#522) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 09, 2004



D - Scheduled Departure
A - Scheduled Arrival

Figure 8
Avro RJ-85 (#522) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 09, 2004



D - Scheduled Departure
A - Scheduled Arrival

Figure 9
Avro RJ-85 (#510 & #515) Aft Cabin Flight Attendant
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 10, 2004

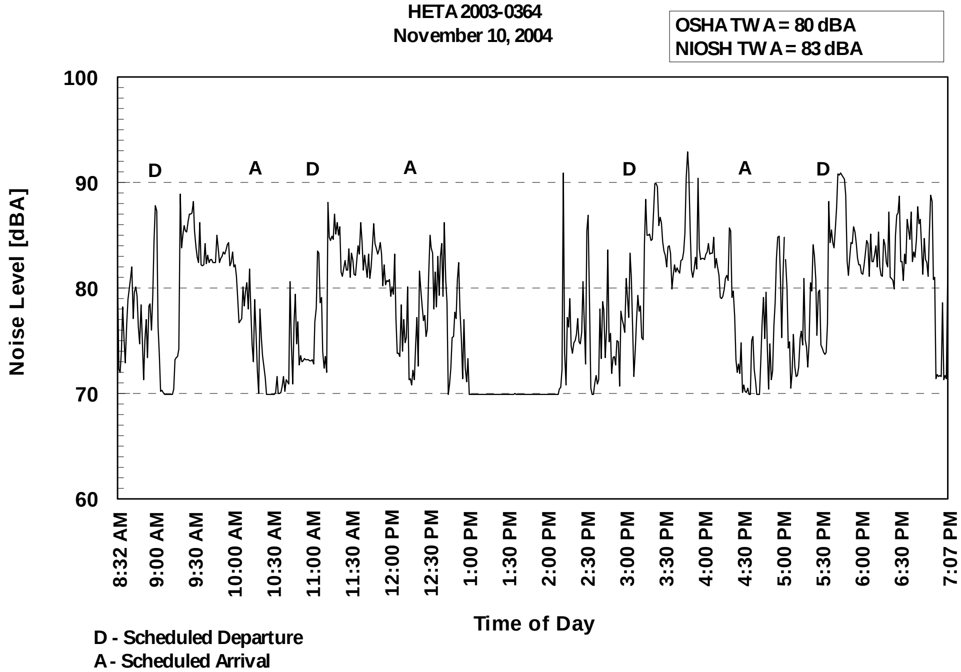


Figure 10
Avro RJ-85 (#510 & #515) Forward Cabin Flight Attendant
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 10, 2004

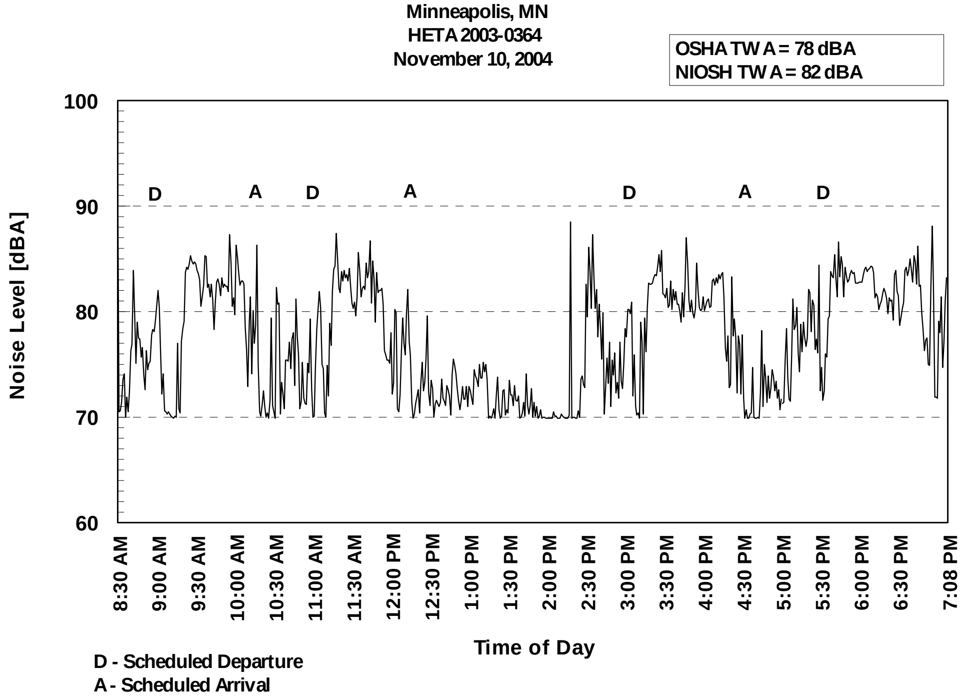
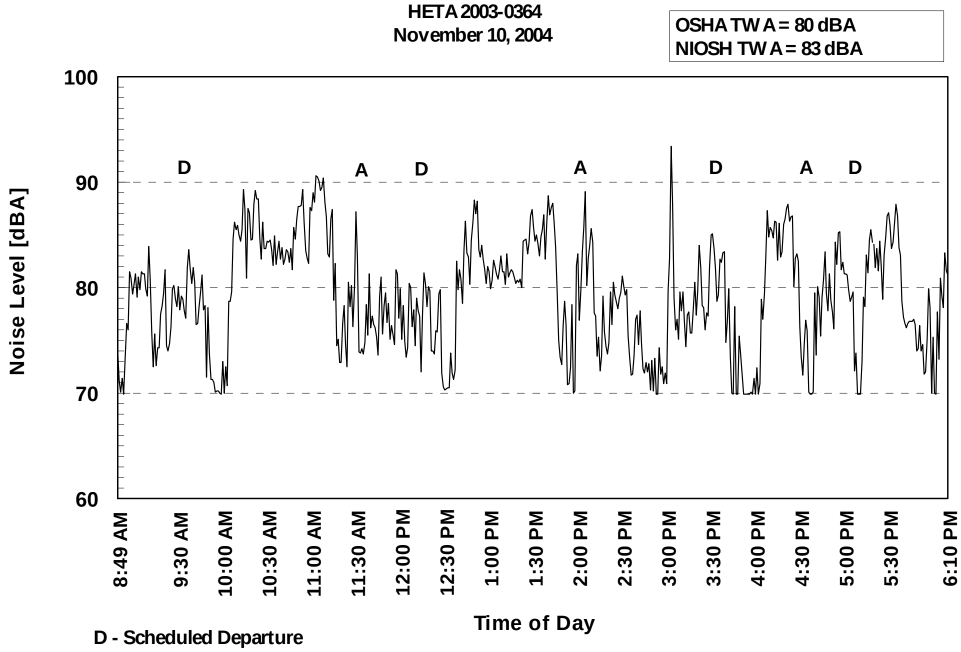
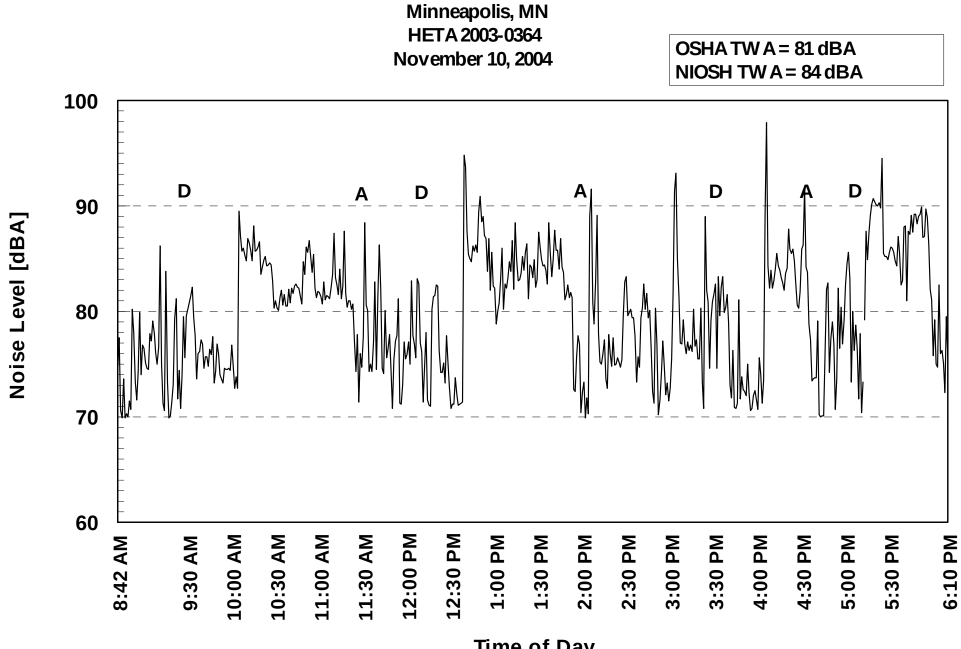


Figure 11
Avro RJ-85 (#522 & #520) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 10, 2004



D - Scheduled Departure
A - Scheduled Arrival

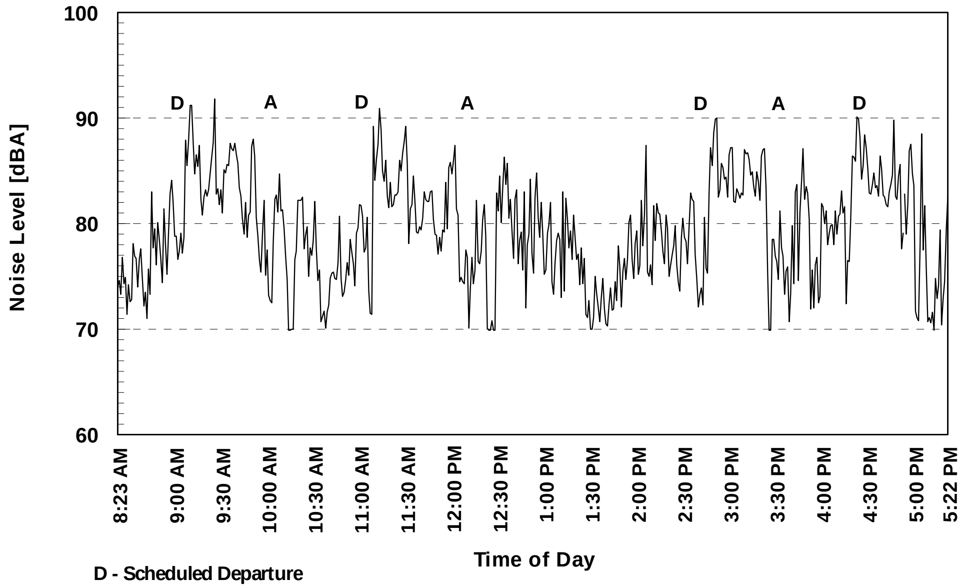
Figure 12
Avro RJ-85 (#522 & #520) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 10, 2004



D - Scheduled Departure
A - Scheduled Arrival

Figure 13
Avro RJ-85 (#520 & #532) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 11, 2004

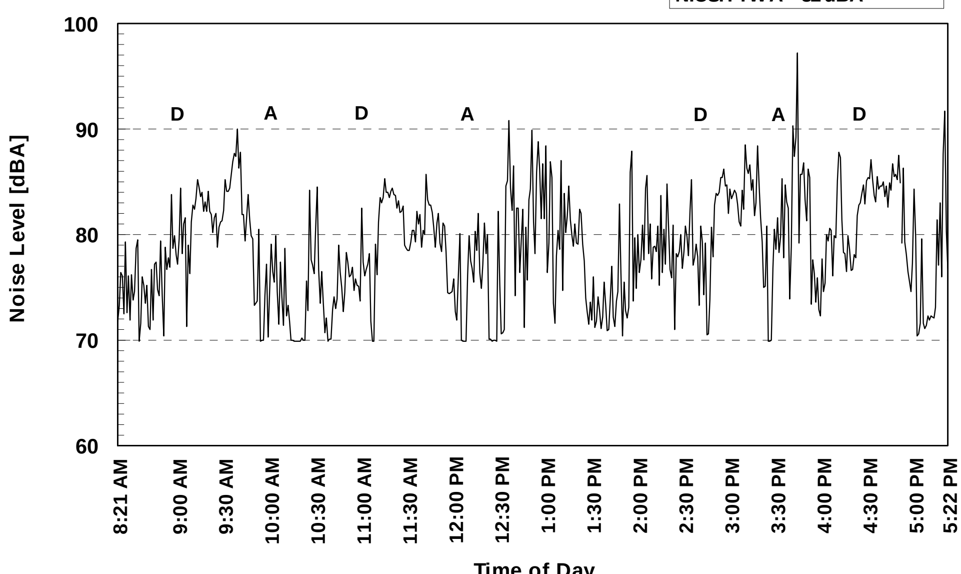
OSHA TWA = 79 dBA
NIOSH TWA = 83 dBA



D - Scheduled Departure
A - Scheduled Arrival

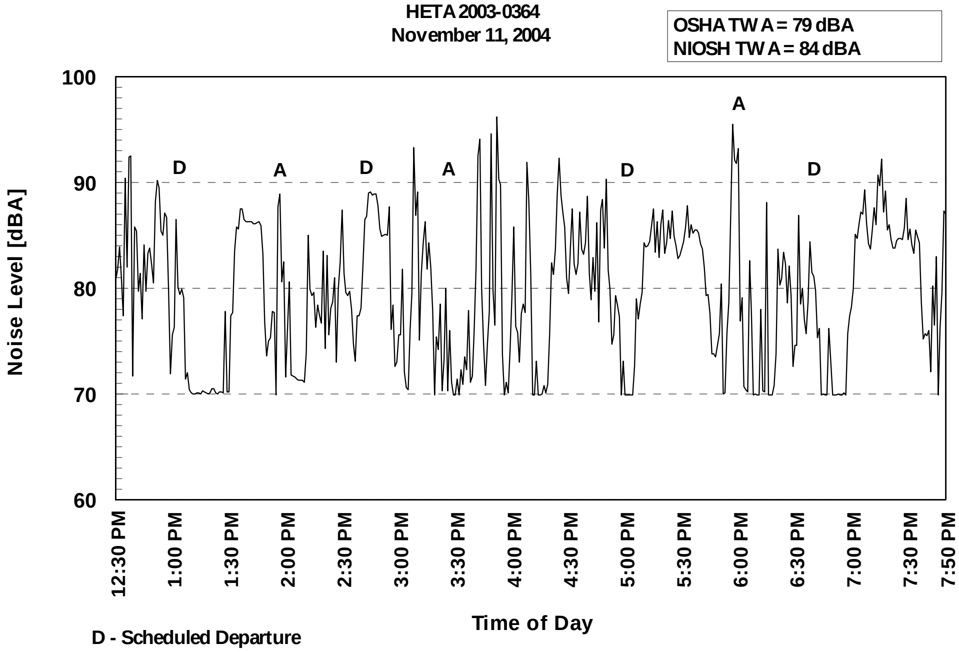
Figure 14
Avro RJ-85 (#520 & #532) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 11, 2004

OSHA TWA = 78 dBA
NIOSH TWA = 82 dBA



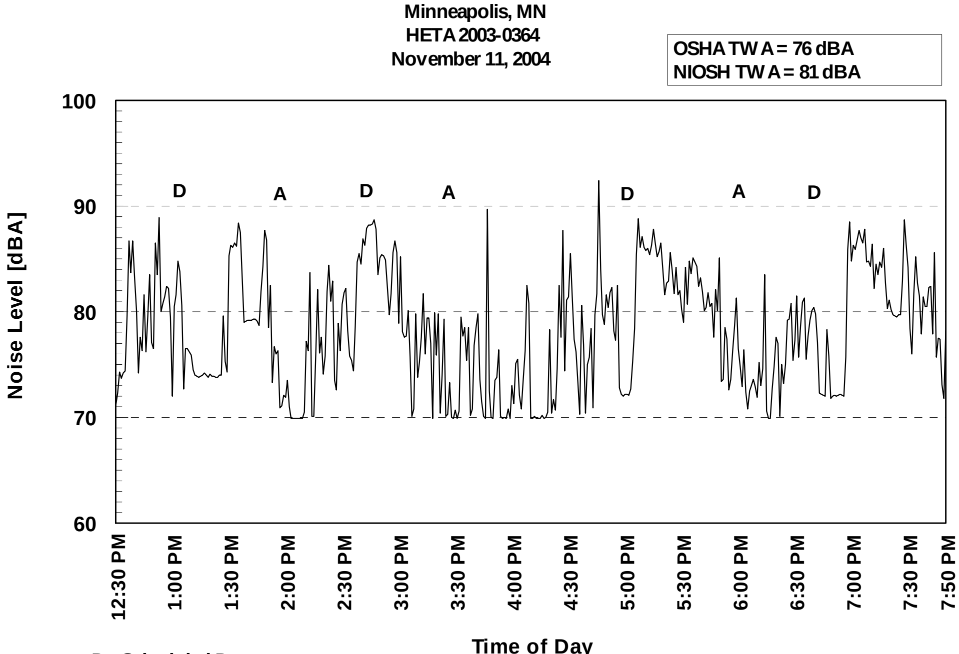
D - Scheduled Departure
A - Scheduled Arrival

Figure 15
Avro RJ-85 (#521 & #522) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 11, 2004



D - Scheduled Departure
A - Scheduled Arrival

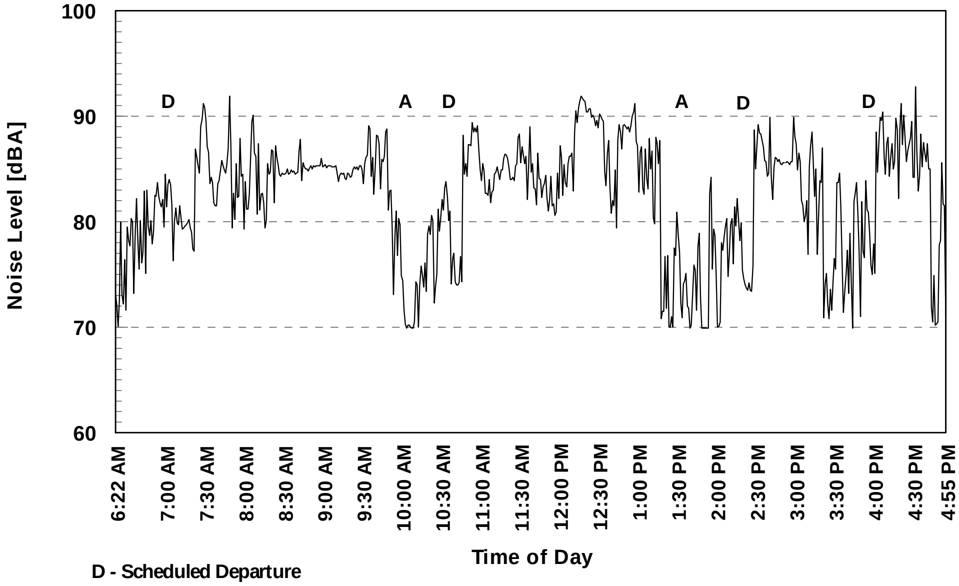
Figure 16
Avro RJ-85 (#521 & #522) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 11, 2004



D - Scheduled Departure
A - Scheduled Arrival

Figure 17
Avro RJ-85 (#507) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 12, 2004

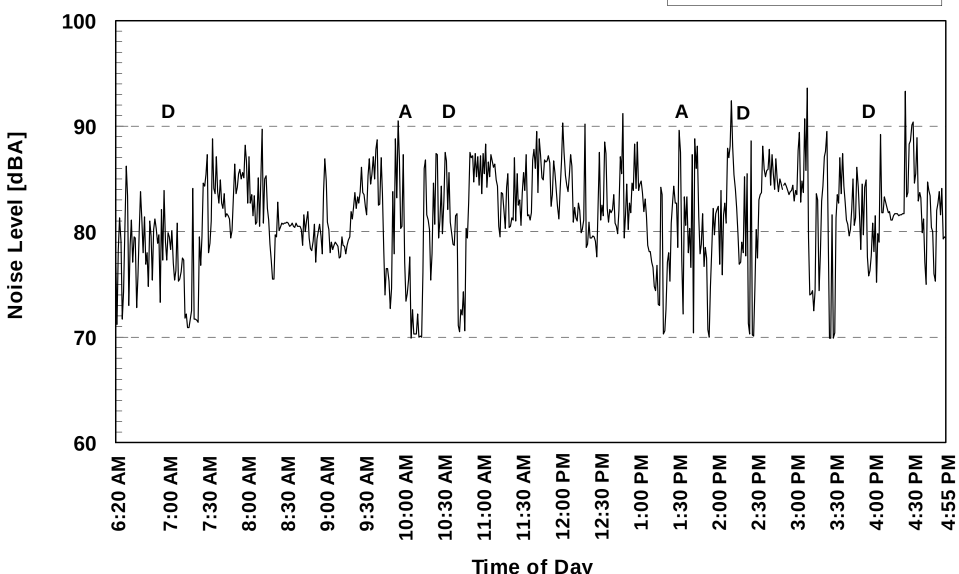
OSHA TWA = 85 dBA
NIOSH TWA = 86 dBA



D - Scheduled Departure
A - Scheduled Arrival

Figure 18
Avro RJ-85 (#507) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 12, 2004

OSHA TWA = 82 dBA
NIOSH TWA = 85 dBA



D - Scheduled Departure
A - Scheduled Arrival

Figure 19
Avro RJ-85 (#520) Flight Attendant 1
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 12, 2004

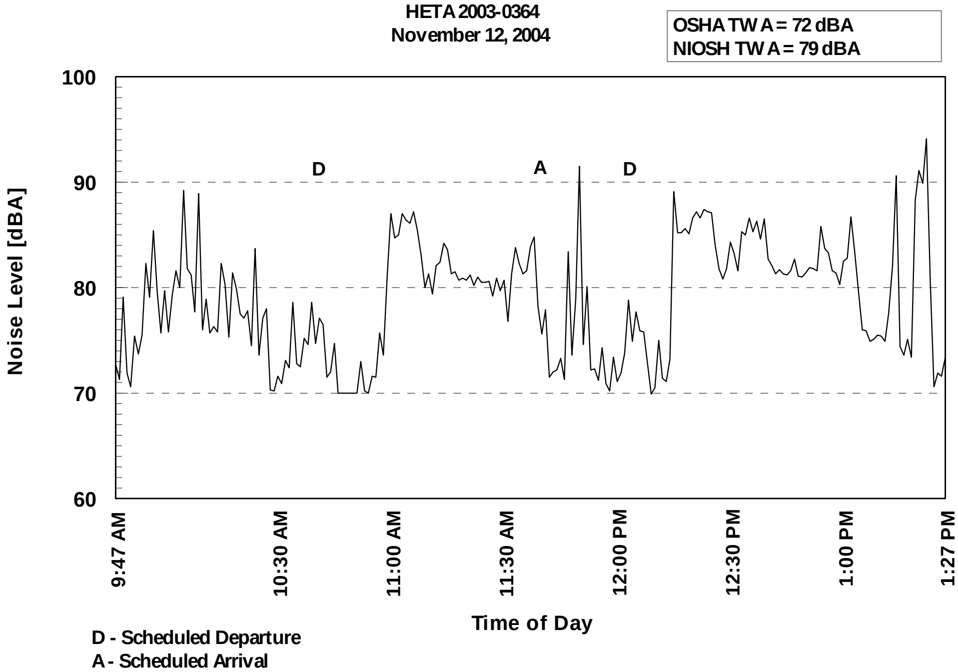


Figure 20
Avro RJ-85 (#520) Flight Attendant 2
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 12, 2004

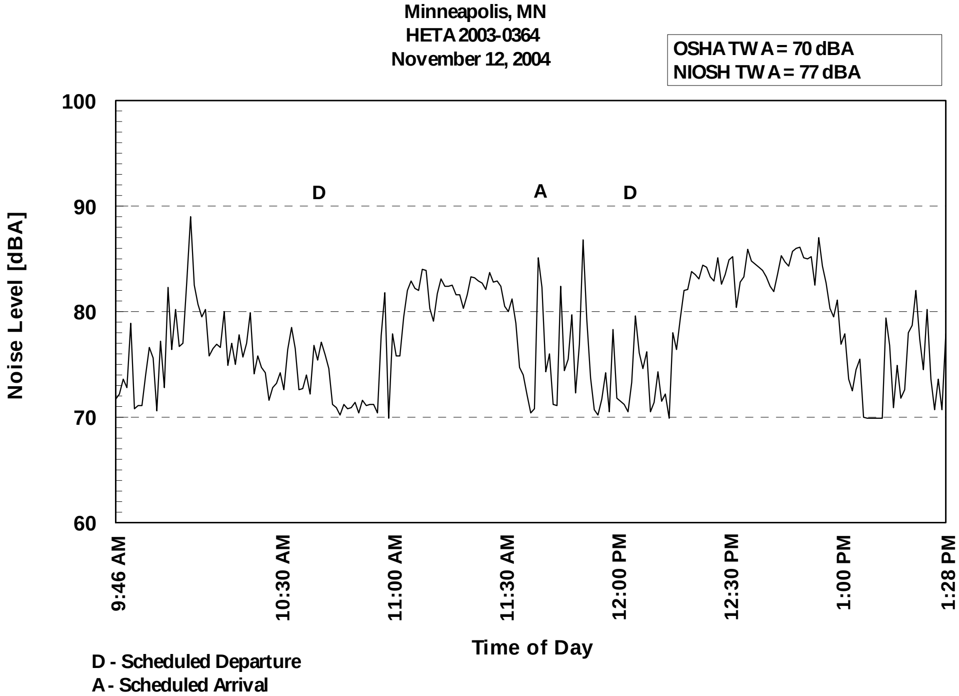


Figure 21
Peak CO Levels for Avro RJ-85 #516
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 11, 2004

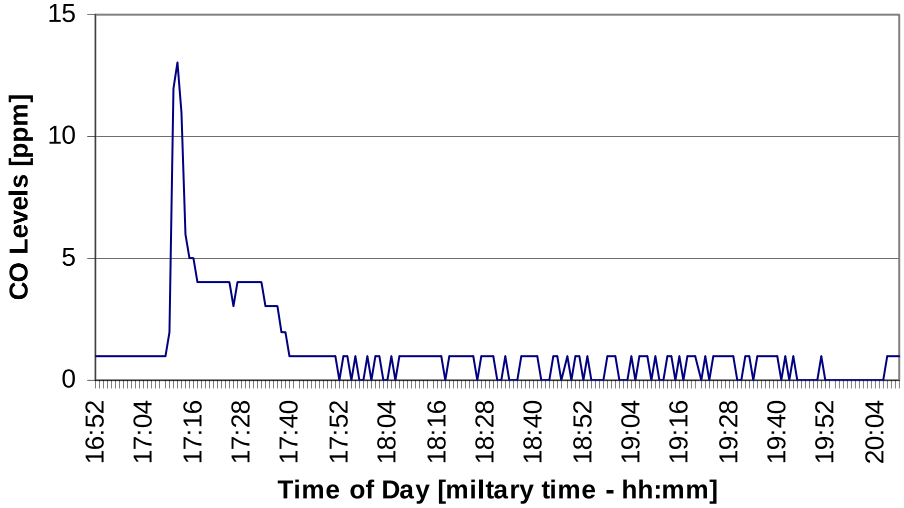
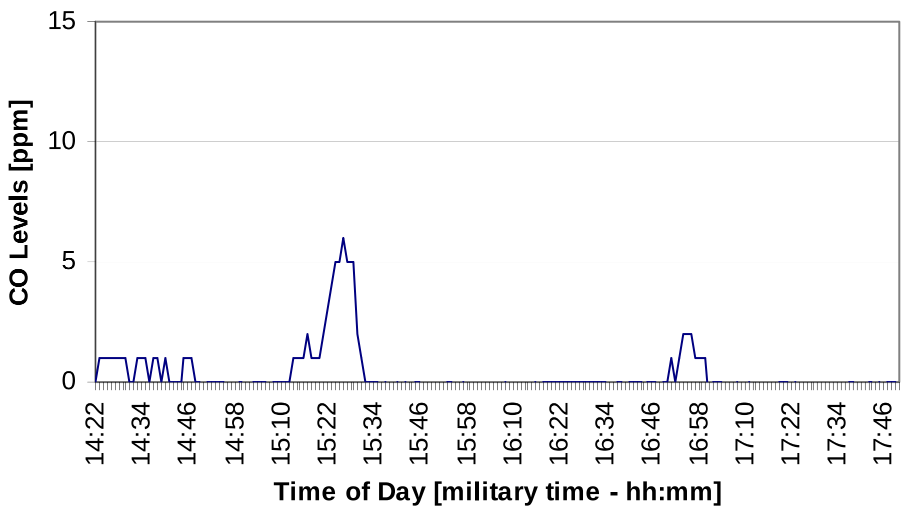


Figure 22
Peak CO Levels for Avro RJ-85 #511
Mesaba Airlines
Minneapolis, MN
HETA 2003-0364
November 9, 2004

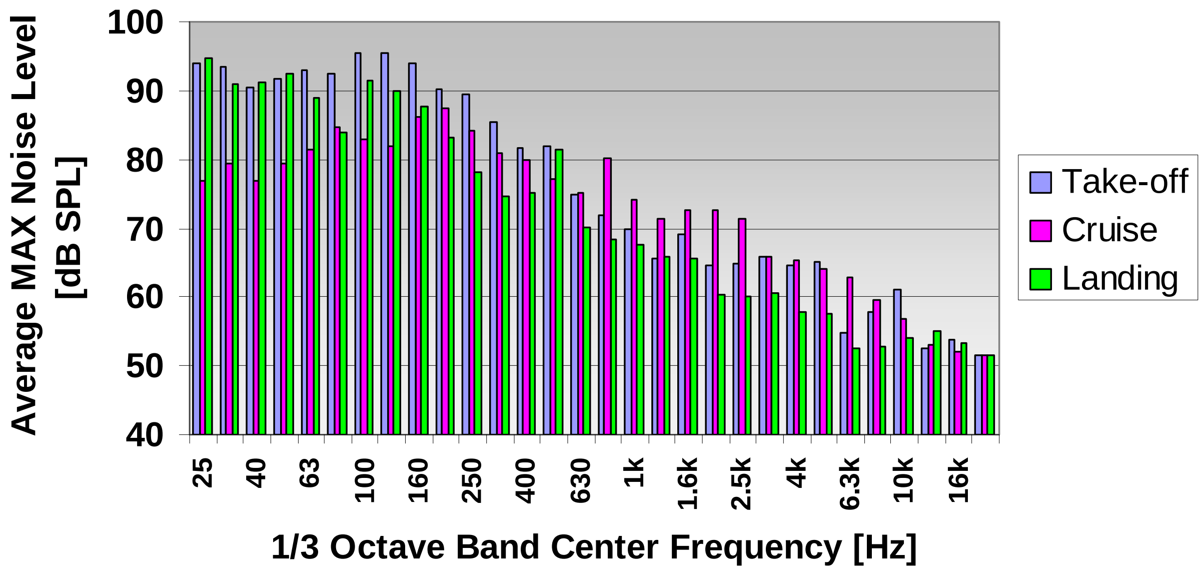


APPENDIX

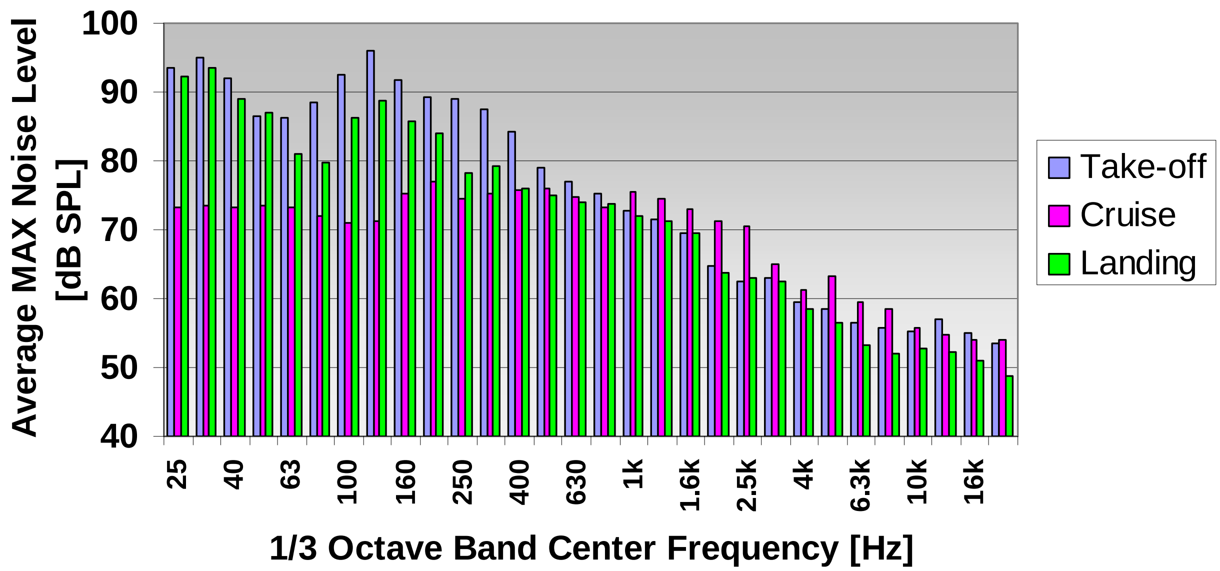
Noise Spectra for the 10 AVRO RJ-85 Aircraft Tested During the NIOSH Investigation

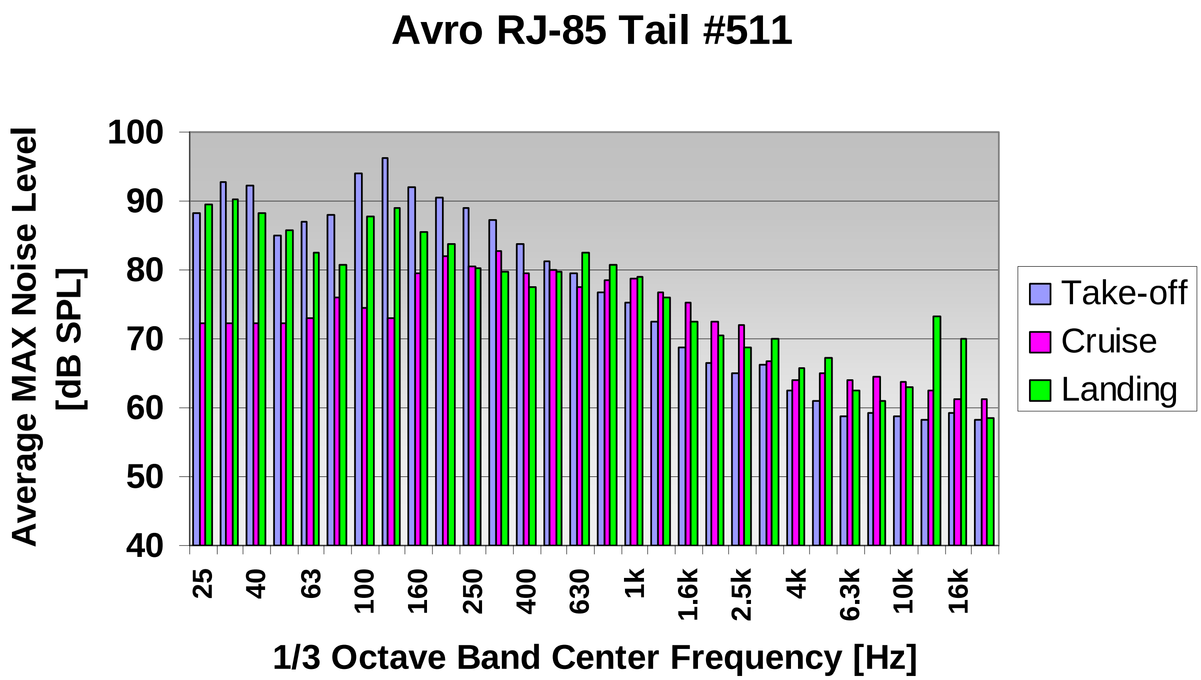
The noise levels presented in the graphs are the average of two maximum noise levels measured on two different flights during take-off and landing and at cruise altitude. The bars on the graphs represent these three flight conditions for each of the measured one-third octave center frequencies sampled.

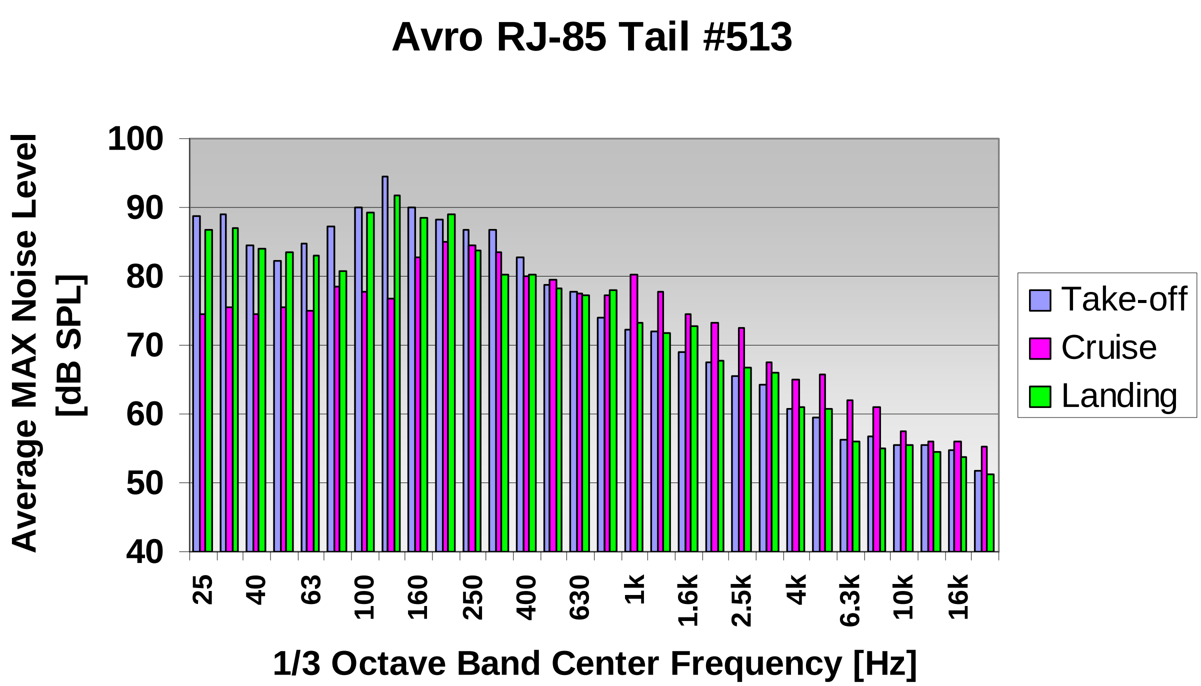
Avro RJ-85 Tail #506

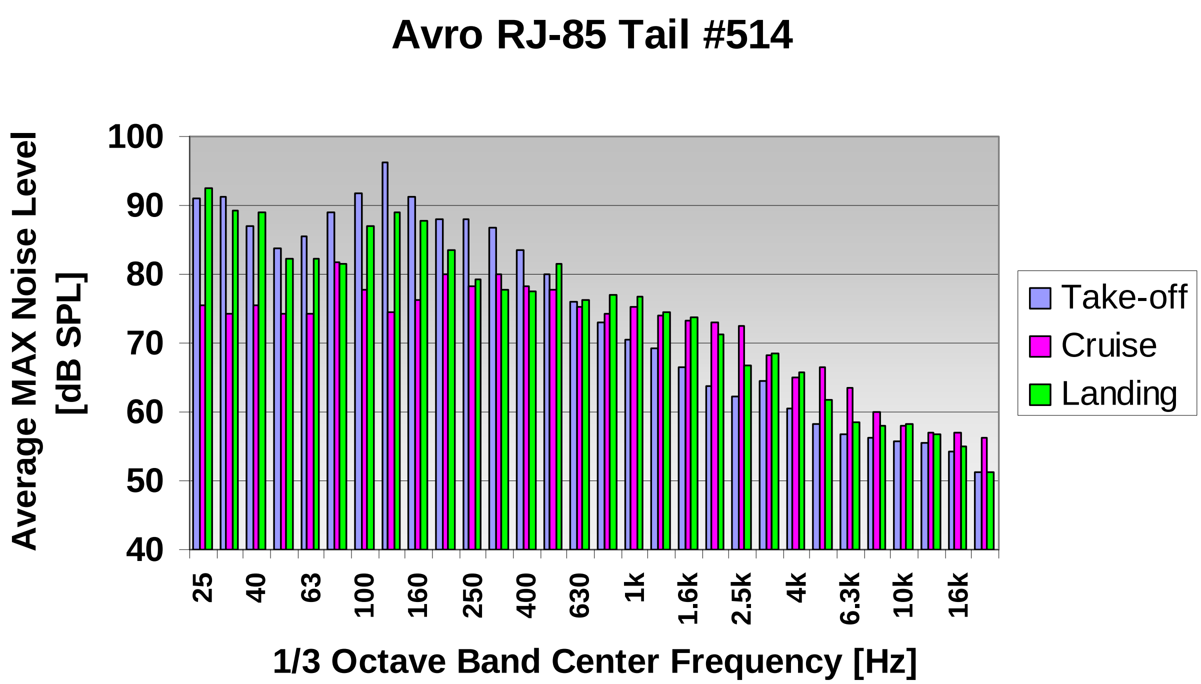


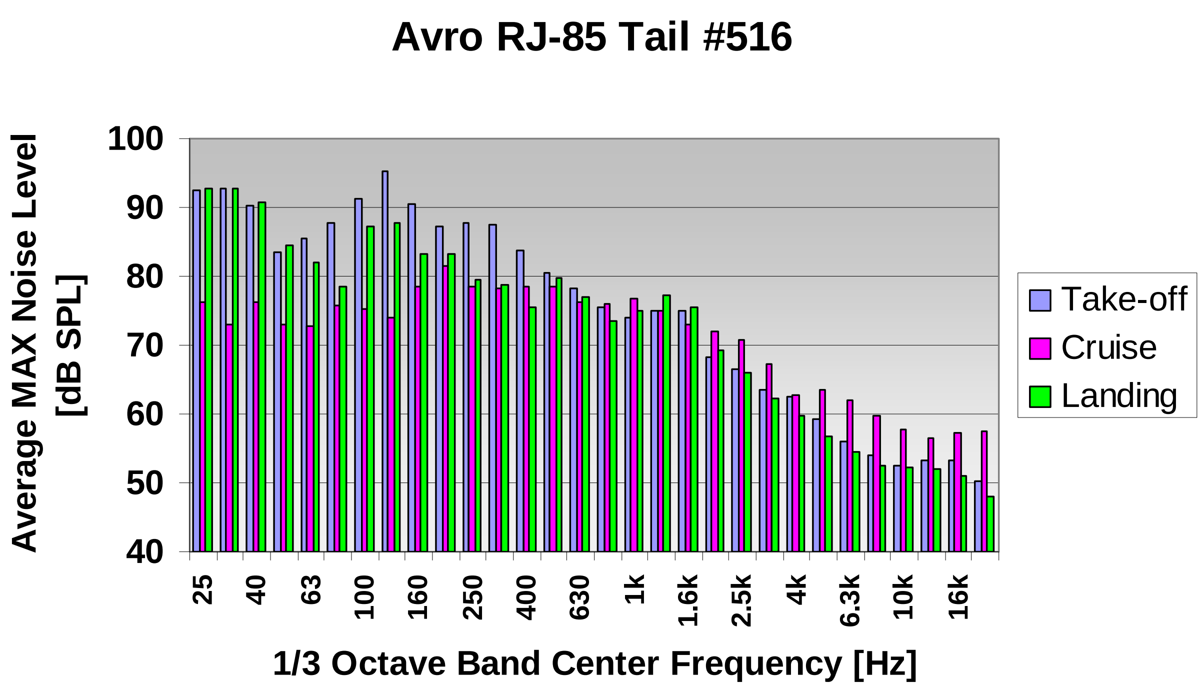
Avro RJ-85 Tail #509

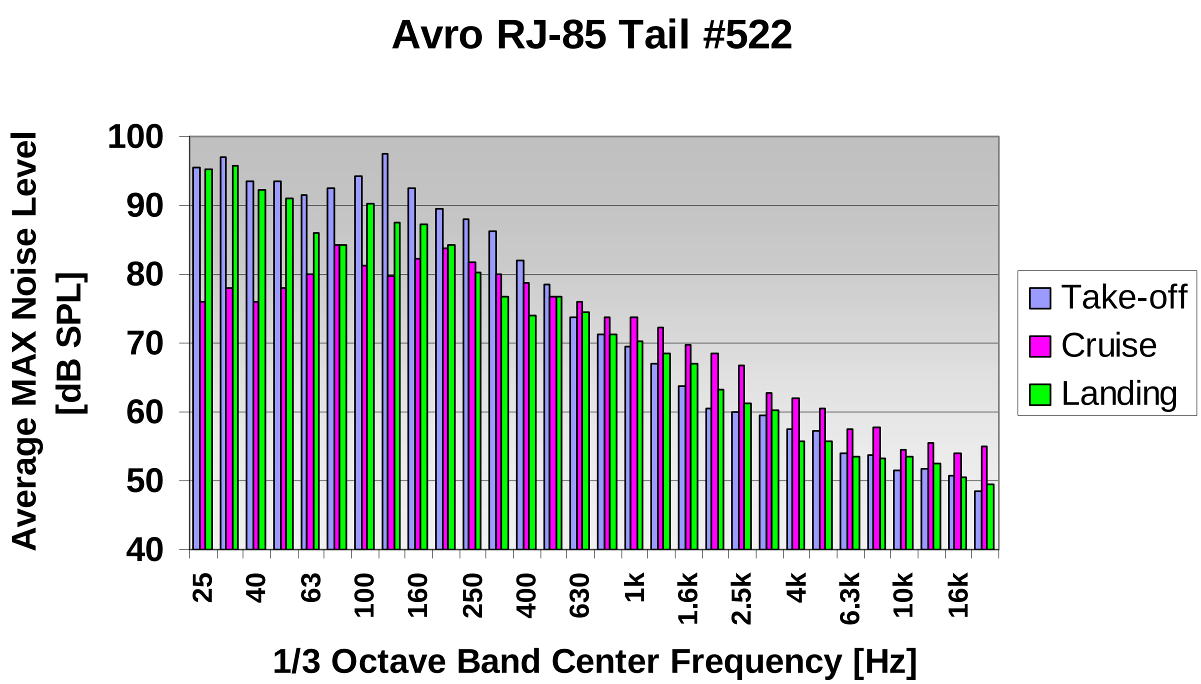


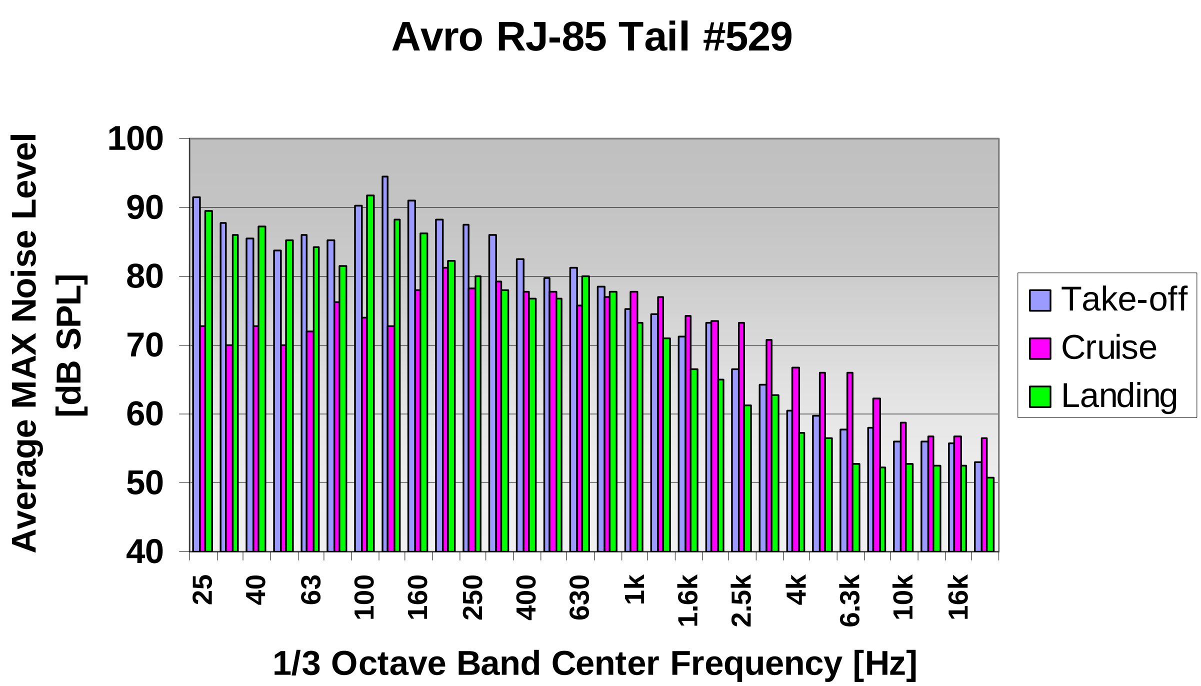

Avro RJ-85 Tail #511
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing

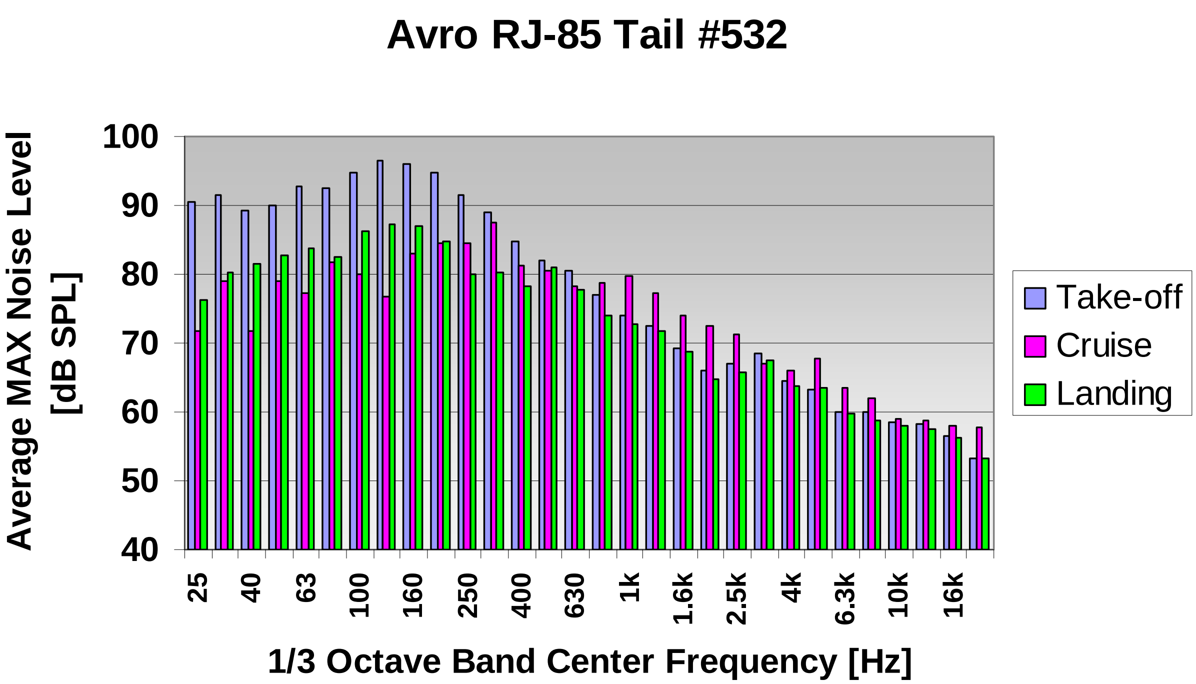

Avro RJ-85 Tail #513
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing

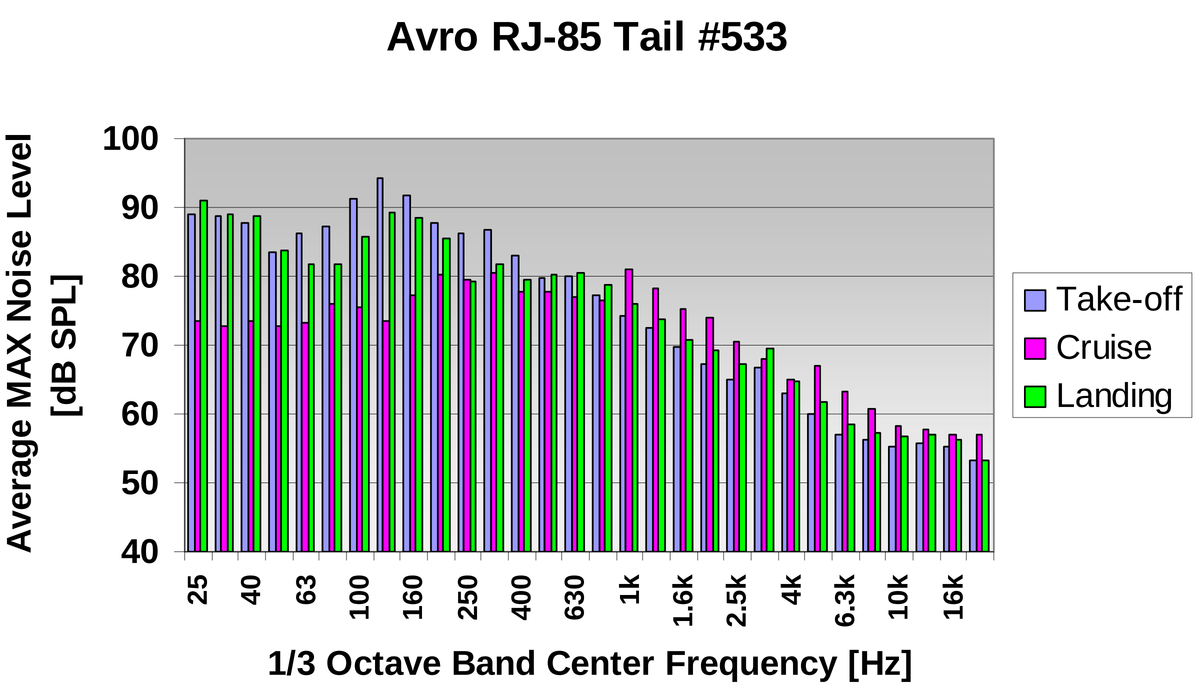

Avro RJ-85 Tail #514
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing


Avro RJ-85 Tail #516
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing


Avro RJ-85 Tail #522
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing


Avro RJ-85 Tail #529
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing


Avro RJ-85 Tail #532
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing


Avro RJ-85 Tail #533
Average MAX Noise Level [dB SPL]
100
90
80
70
60
50
40
25
40
63
100
160
250
400
630
1k
1.6k
2.5k
4k
6.3k
10k
16k
1/3 Octave Band Center Frequency [Hz]
Take-off
Cruise
Landing

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