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SOUTHWEST AIRLINES
HOUSTON HOBBY AIRPORT
HOUSTON, TEXAS

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SUMMARY

In response to a confidential request from Southwest Airlines employees at the Houston Hobby Airport, representatives of the National Institute for Occupational Safety and health (NIOSH) conducted an industrial hygiene evaluation of aircraft ground crew exposures to diesel and gasoline engine exhaust. Employees were concerned about exposure to potentially "excessive fumes and soot" during aircraft loading and unloading operations. Some employees reported transient eye and throat irritation, presumably from exposures to engine exhaust. Full-shift personal breathing zone (PBZ) and area sampling for elemental carbon (C_e) and carbon monoxide (CO) was conducted. Area sampling for nitrogen dioxide (NO_2) was also conducted.

The highest concentration of C_e was collected from a ramp agent (14.8 micrograms per cubic meter ($\mu g/m^3$), while an area sample (jetway area) had the lowest concentration (1.8 $\mu g/m^3$). The three C_e PBZ samples (geometric mean = 9.5 $\mu g/m^3$) were similar to those found by NIOSH in a previous evaluation of diesel exhaust exposures among truck drivers. Although exposure criteria have not been established, sampling was conducted for C_e to determine the relative diesel emission levels in different areas, and to provide baseline information that could be useful for assessing the effectiveness of future control measures.

The full-shift, personal sample results for CO (six samples) ranged from 3 to 7 parts per million (ppm). These results were below the NIOSH Recommended Exposure Limit (REL) of 35 ppm. The highest instantaneous peak concentrations were 91 and 111 ppm, also under the NIOSH REL Ceiling limit of 200 ppm. NO_2 was not detected on any samples (minimum detectable concentration: 0.5 ppm).

Informal interviews conducted with ramp agents and load agents found workers were periodically experiencing eye or throat irritation they attributed to engine exhaust.

A health hazard from exposures to CO or NO_2 was not found on the day of the NIOSH Survey. Because of transient irritation reported by some employees and the "potential occupational carcinogen" designation for diesel exhaust, efforts to reduce exhaust exposures should be implemented. Suggestions for controlling exposures are offered in the Recommendation section of this report.

KEYWORDS: SIC 4512 (Air Transportation, Scheduled). Diesel exhaust exposures, nitrogen dioxide, carbon monoxide, elemental carbon, eye and throat irritation.

INTRODUCTION

In response to a confidential employee request, NIOSH conducted an industrial hygiene evaluation of aircraft ground crew exposures to diesel and gasoline engine exhaust. The evaluation was conducted during the first shift on Friday (a busy day for Southwest Airlines), August 20, 1993. Some employees had reported transient eye and throat irritation, which they associated with potentially excessive exposures to diesel and gasoline engine exhaust. An interim report was distributed on November 1, 1993.

BACKGROUND

The Southwest Airlines terminal at Houston Hobby Airport typically handles about 140 flights per day. Workers involved in the ground operations (about 150) include ramp agents (load and unload baggage, mail, and freight), provisioning agents (service the inside of the aircraft - food, trash, etc.), fuelers (fuel the aircraft), and aircraft maintenance (repair aircraft at gate). The loading, unloading, and re-fueling processes typically take 15-20 minutes. Typically, four or five employees service the aircraft at the gate.

Motorized equipment include the pushback tug (truck to push aircraft from the gate area), belt loader (conveyer to remove and load baggage, mail, and freight), Lav cart (truck used to service aircraft restrooms), power unit (generator to provide aircraft power while on the ground - not always used), provisioning truck (services aircraft needs - food, etc.), and fuel truck. The baggage tugs, belt loaders, and Lav carts have gasoline engines, while most of the other equipment utilize diesel engines. All diesel equipment uses jet propellant-4 (JP4) fuel because it is readily available, instead of diesel fuel. No emissions control equipment are utilized on any gasoline or diesel equipment.

Employee complaints have centered around emissions from fuel trucks and belt loaders. During re-fueling, the fuel truck's diesel engine runs at higher speeds to pump fuel into the aircraft. The exhaust outlet is almost at ground level at the front of the truck, resulting in exposures to nearby employees. Houston Hobby Airport does not have below-ground fueling capability.

The belt loader's exhaust is under the conveyor, about half way up the belt. The exhaust pipe is usually on the opposite side from the workers, but emissions are reportedly still a problem under some climatic conditions. According to management, emissions from the Lav carts were a problem in the past, but Southwest Airlines re-routed the exhaust port away from the employees' work area. At the time of the NIOSH visit, Southwest Airlines discussed the possibility of converting some belt loaders to use propane fuel.

EVALUATION PROCEDURES

The NIOSH evaluation consisted of the following elements:

(1) A visual inspection to review employee work areas, loading/unloading locations, and engineering controls. Company information regarding work-shifts and administrative procedures were obtained.

(2) A literature search to review the health effects associated with exposure to diesel emissions, to determine appropriate sampling methodologies, and to review the results of other industrial hygiene investigations involving the assessment of exposure to diesel exhaust emissions.

(3) Environmental monitoring to assess airborne levels of the following constituents of diesel exhaust: elemental carbon (C_e), carbon monoxide (CO), and nitrogen dioxide (NO_2). Area and PBZ sampling was conducted during the first shift on August 20, 1993.

Specific sampling and analytical methods used during the evaluation were as follows:

Elemental Carbon

Integrated air samples for C_e were collected using calibrated Gilian HFS 513A sampling pumps. Nominal flow rates of 2 liters per minute (Lpm) were used to collect the samples. Pre-fired 37 millimeter quartz fiber filters were used as the collection media. Cellulose ester backup pads in 3-piece polystyrene cassettes were used to hold the filters. The cassettes were connected to the pumps with Tygon® tubing. As only a portion of the filter is analyzed, samples were collected in the open-face mode to help ensure a more even distribution across the filter. Personal sampling was conducted by attaching the pumps to selected workers and placing the sampling media in the employees' breathing zone. Employees were cautioned not to touch the sampling media. Sampling was conducted throughout the work shift. After sampling, the pumps were post-calibrated and the filters shipped to the laboratory (Sunset Laboratory, Forest Grove, OR) for analysis. Field blanks were submitted with the samples.

The filters were analyzed by a method known as thermal-optical analysis. With this technique, using various temperatures and furnace atmospheres, organic and elemental carbon is differentiated and driven off of the filter in stages. The released carbon is first oxidized to carbon dioxide (CO_2), reduced to methane (CH_4), and subsequently quantified with a flame-ionization detector.[1]

Carbon Monoxide and Nitrogen Dioxide

Biosystems Toxilog Model 1801DL CO dosimeters were used to measure instantaneous and integrated personal (waist level) CO concentrations. The integrated measurements were collected from a fueler. The instrument was calibrated with 50 ppm CO calibration gas prior to use. It records in 1 ppm increments and has a 1 ppm limit of detection.

Additional integrated personal concentrations of CO of a ramp agent were measured with a Metrosonics PM-7700 Toxic gas monitor (sensor was placed in the breathing zone). The instrument was calibrated with 50 ppm CO. The instrument has a sensor repeatability of ± 2% of the reading at an operating temperature of -5 to 40 ^{o}C.

Additional breathing-zone samples for CO were collected using direct-reading long-term colorimetric detector tubes manufactured by Dräger (67 28741). These tubes contain a chemically impregnated media which will change color in proportion to the concentration of CO. The samples were collected using constant-volume SKC model 223 low-flow sampling pumps. Flow rates of 15-20 cubic-centimeters per minute (cc/min) were used to collect the samples. Sampling times for each colorimetric tube ranged from 3 to 4 hours (two tubes were used for the full shift). The pumps are equipped with a pump stroke counter and the number of strokes necessary to pull a known volume of air was determined. This information was used to calculate an air volume per pump stroke "K" factor. The pump stroke count was recorded before and after sampling and the difference used to calculate the total volume of air sampled. According to Dräger, the relative standard deviation for this particular sampling method is 10-15%.[2]

Area sampling for nitrogen dioxide (NO_2) was conducted using direct-reading colorimetric indicator tubes (Dräger NO_2 tube 0.5/c CH30001) and a hand-operated bellows pump. The manufacturer lists the relative standard deviation for this method as 10-15%.[2]

CRITERIA USED TO INTERPRET RESULTS

As a guide to the evaluation of the hazards posed by work place exposures, NIOSH field staff use established environmental criteria for the assessment of a number of chemical and physical agents. These criteria 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 should be noted, however, that not all workers will be protected from adverse health effects if their exposures are below the applicable limit. A small percentage may experience adverse health effects due to individual susceptibility, pre-existing medical conditions, and/or hypersensitivity (allergy).

Some hazardous substances or physical agents may act in combination with other work place exposures or the general environment to produce health effects even if occupational exposures are controlled at the applicable limit. Due to recognition of these factors, and as new information on toxic effects of an agent becomes available, evaluation criteria may change.

The primary sources of environmental evaluation criteria for the work place are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standards.[3-5] Often, NIOSH recommendations and ACGIH TLVs may be different than the corresponding OSHA standard. Both NIOSH recommendations and ACGIH TLVs are usually based on more recent information than OSHA standards due to the lengthy process involved with promulgating federal regulations. OSHA standards also may be required to consider the feasibility of controlling exposures in various industries where the hazardous agents are found; the NIOSH recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease.

Whole Diesel Exhaust

Based on findings of carcinogenic responses in exposed rats and mice, NIOSH recommends that whole diesel exhaust be considered a potential occupational carcinogen and that exposures be reduced to the lowest feasible concentration.[6] In addition to the carcinogenic effects, eye irritation and reversible pulmonary function changes have been experienced by workers exposed to diesel exhaust.[6-9]

Diesel exhaust is a complex mixture that consists of both a gaseous and particulate fraction. The composition will vary greatly with fuel and engine type, maintenance, tuning, and exhaust gas treatment.[6,10] The gaseous constituents include carbon dioxide, carbon monoxide, nitrogen dioxide, oxides of sulfur and hydrocarbons. The particulate fraction (soot) of diesel exhaust is comprised of solid carbon cores produced during the combustion process. More than 95% of these particles are less than 1 micron diameter (µmd) size. It has been estimated that up to 18,000 different substances from the combustion process can be adsorbed onto diesel exhaust particulate.[6] Up to 65% of the total particulate mass may be these adsorbed substances and includes compounds such as polynuclear aromatic hydrocarbons (PAHs), some of which are carcinogenic.[6] Particles in this size range are considered respirable because when inhaled they reach the deeper, non-ciliated portions of the lungs where they may be retained. In general, particles greater than 7-10 µmd are all removed in the nasal passages and have little probability of penetrating to the lung. Particles smaller than this can reach the air-exchange regions (alveoli, respiratory bronchiole) of the lung, and are considered more hazardous.

As noted, based on the results of laboratory animal and human epidemiology studies, NIOSH considers whole diesel exhaust to be a potential occupational carcinogen.[6] The studies of rats and mice exposed to diesel emissions, especially the particulate portion, confirmed an association with lung tumors.[6] Human epidemiology studies also suggest an association between occupational exposure to whole diesel exhaust and lung cancer.[6,11]

In addition to the carcinogenic potential, many other components of diesel exhaust have known toxic effects. These effects include pulmonary irritation from nitrogen oxides, eye and mucous membrane irritation from sulfur dioxide and aldehyde compounds, and chemical asphyxiation effects from CO. Exposure criteria has been established for some of these compounds; however, there are no exposure limits directly applicable to evaluation of whole diesel exhaust emissions.

Assessing worker exposure to diesel exhaust is difficult because of the complex makeup of emissions, uncertainty about which specific agent(s) may be responsible for the carcinogenic properties, and the effect of other potential sources of similar compounds (e.g., tobacco smoke particles are also primarily < 1 µmd). Measurements of some commonly found components of diesel exhaust have generally shown concentrations to be well below established exposure criteria. Efforts have focused on evaluating the particulate portion because most studies have associated the carcinogenic potential of diesel exhaust with the particulate fraction. NIOSH is currently investigating the use of elemental carbon (C_e) as a surrogate index of exposure. The use of C_e holds promise because the sampling and analytical method is very sensitive, and a high percentage of diesel particulate (80-90%) is elemental carbon, whereas tobacco smoke particulate is composed primarily of organic carbon.[12] Although exposure criteria has not been established, sampling was conducted for C_e to determine the relative diesel emission levels in different areas, and to provide baseline information that could be useful for assessing the effectiveness of future control measures.

Carbon Monoxide

CO is also associated with gasoline and diesel exhaust and is of concern because of its insidious nature. CO is a colorless, odorless gas that is a product of incomplete combustion. Engine exhaust, tobacco smoking, and inadequately ventilated combustion products from heaters that use hydrocarbon fuel are sources of CO. CO interferes with the oxygen carrying capacity of blood. Overexposure to CO may cause initial symptoms such as headache, dizziness, drowsiness, and nausea. These symptoms may progress to vomiting, loss of consciousness, or collapse if high exposures are encountered.[13] The NIOSH REL for CO is 35 ppm as a time-weighted average for up to 8 hours per day. NIOSH also recommends a ceiling level of 200 ppm for CO.[3]

Nitrogen Dioxide

Sampling was conducted for NO_2 because it is commonly associated with gasoline and diesel emissions, and because of its acute irritant effects. NO_2 is a reddish/dark-brown gas with a pungent, acrid odor. NO_2 is a respiratory irritant and can cause pulmonary edema.[14] The NIOSH REL for NO_2 is 1 ppm as a 15 minute short-term exposure limit (STEL).[3] Most reported cases of severe illness due to NO_2 have been from accidental exposures to explosion or combustion of nitroexplosives, nitric acid, arc or gas welding (particularly in confined spaces), or entry into unvented agricultural silos.[15]

RESULTS

Elemental (C_e) and Organic Carbon

The results of C_e sampling are depicted in Table 1. The organic carbon fraction (not specific to diesel emissions) is determined during analysis and is also shown in the table. The highest concentration of C_e (14.8 $\mu g/m^3$) and organic carbon (291.6 $\mu g/m^3$) was collected from a ramp agent on Gate 5. The area samples (break room and jetway on Gate 3) had the lowest concentrations of C_e (2.1 and 1.8 $\mu g/m^3$, respectively) and organic carbon (37.0 and 20.8 $\mu g/m^3$, respectively). As previously noted, there is no exposure criteria for elemental or organic carbons. However, the data do provide information for comparison purposes, as well as providing a baseline for assessing the effectiveness of controls.[12]

The personal C_e sample results were similar to exposures among truck drivers in a different health hazard evaluation.[18] The truck drivers' personal C_e exposures were 5.5, 8.1, and 17.0 $\mu g/m^3$ (geometric mean = 9.1 $\mu g/m^3$), while the personal C_e sample results in this evaluation were 7.3, 7.9, and 14.8 $\mu g/m^3$ (geometric mean = 9.5 $\mu g/m^3$). The concentrations were less than those found in a NIOSH study of fire department personnel who were exposed to diesel exhaust inside engine houses (18 samples, geometric mean = 35.3 $\mu g/m^3$).[19]

Carbon Monoxide/Nitrogen Dioxide

The results of the CO air sampling are depicted in Table 2, Figure 1, and Figure 2. All carbon monoxide concentrations were below the NIOSH REL on the day of sampling. The time-weighted average (TWA) concentrations ranged from 3 to 7 ppm, which were less than the REL TWA concentration of 35 ppm. The highest instantaneous peak concentrations recorded with dosimeters were 111 and 91 ppm (a fueler and ramp agent, respectively). The specific workpractice that resulted in these instantaneous peak concentrations could not be identified. However, these concentrations were less than the NIOSH REL Ceiling concentration of 200 ppm.

All area NO_2 samples were non-detected (Limit of Detection: 0.5 ppm; NIOSH REL: 1 ppm - 15 minute short-term exposure limit).

Employee Interviews

Five employees from the "ground crew" were informally interviewed. The interviewed employees were chosen at random by the NIOSH investigator. Three of the five employees reported transient eye and throat irritation, which they attributed to engine exhaust exposures. One employee reported transient dizziness, and one employee reported no symptoms.

RECOMMENDATIONS

The following recommendations are offered to reduce employee exposures to potentially harmful or objectionable exhaust constituents.

1. To reduce emissions, Southwest Airlines should ensure equipment maintenance and tune-up schedules adhere to manufacturers' recommendations. Methods for decreasing engine exhaust include using appropriate fuel-air mixtures, careful adjustment of ignition timing, and placing a limit on the power developed by the engine.

2. Southwest Airlines should consider using exhaust stacks on fuel trucks to better remove diesel exhaust from the work areas during fueling operations. Currently, exhaust is released at ground level. The fuel truck manufacturer should be consulted regarding the feasibility of this modification.

3. Certain wind conditions may increase engine exhaust exposures for workers near the belt loaders. Under these conditions, Southwest Airlines may consider using exhaust tubing to discharge exhaust away from work areas. The exhaust tube should not be placed near the aircraft baggage compartment entrance.

4. Because of high work rates and high temperatures in summer, heat-stress training should be incorporated into the Southwest Airlines safety training program for ground crew personnel. Information on working in hot environments can be found in the NIOSH publication "Criteria for a Recommended Standard: Occupational Exposure to Hot Environment, Revised Criteria 1986."[20]

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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.

Table 1

Elemental Carbon Sampling Results
Southwest Airlines
Houston Hobby Airport
Houston, Texas
HETA 93-0816

JOB	LOCATION	SAMPLE PERIOD[1]	Elemental Carbon[2] (µg/m³)	Organic Carbon[3] (µg/m³)
Ramp Agent	Gate 7	6:45 a.m. - 12:55 p.m. (370 minutes)	7.3	46.1
Ramp Agent	Gate 5	6:32 a.m. - 1:07 p.m. (395 minutes)	14.8	291.6
Fueler	All gates	7:20 a.m. - 1:36 p.m. (376 minutes)	7.9	63.6
(Area Sample)	Gate 3, near jetway	7:52 a.m. - 1:51 p.m. (359 minutes)	1.8	20.8
(Area Sample)	Break Area	7:43 a.m. - 1:49 p.m. (366 minutes)	2.1	37.0
Limit of Detection[4]			1.1	1.1

[1] Flow rate for all samples was approximately 2 liters per minute
[2] Time-weighted average concentration of elemental carbon in terms of micrograms per cubic meter air sampled.
[3] Time-weighted average concentration of organic carbon in terms of micrograms per cubic meter air sampled.
[4] Approximate Limit of Detection based on a sample volume of 800 liters. LOD was 0.855 micrograms per filter.

Table 2

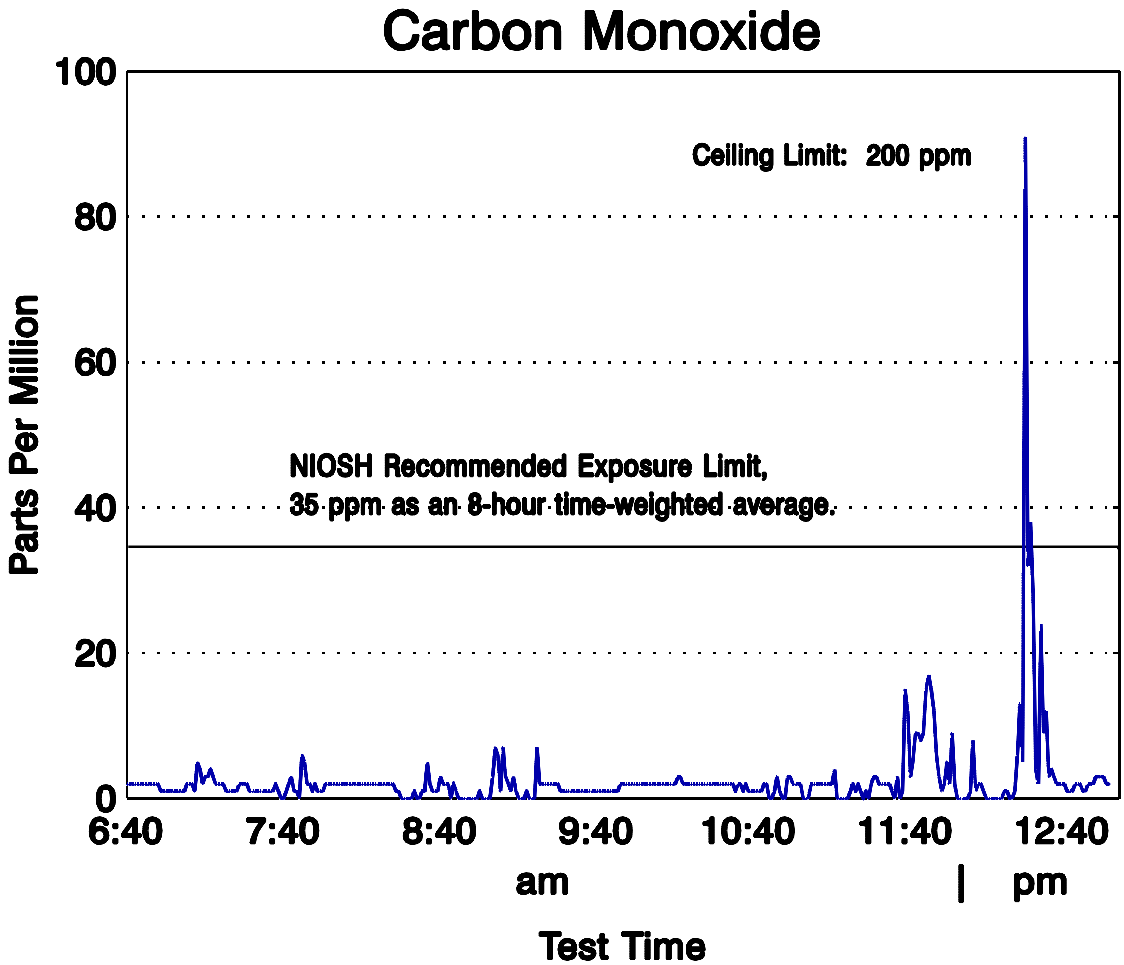
Personal Carbon Monoxide Samples
Southwest Airlines
Houston Hobby Airport
Houston, Texas
HETA 93-0816

JOB	LOCATION	SAMPLE PERIOD	CONC (ppm)[1]	TWA (ppm)[2]
Load Agent	Gate 3	6:55 a.m. - 10:39 a.m. 10:39 a.m. - 1:08 p.m. (372 minutes total)[3]	5 5	5
Ramp Agent	Gate 7	6:30 a.m. - 10:49 a.m. 10:49 a.m. - 12:52 p.m. (382 minutes total)[4]	3 5	4
Load Runner	All Gates	7:39 a.m. - 10:34 a.m. 10:34 a.m. - 12:55 p.m. (316 minutes total)[5]	6 8	7
Transfer Driver	Gates 3,5,7	7:40 a.m. - 10:28 a.m. 10:28 a.m. - 1:10 p.m. (330 minutes total)[6]	3 3	3
NIOSH Recommended Exposure Limit (up to 8 hours per day)				35

[1] Concentration of Carbon Monoxide in parts per million
[2] Time-weighted average concentration in parts per million. Sampling was discontinued around 1:00 pm because no additional aircraft were scheduled to arrive through the end of the shift.
[3] Average sample air flow rate: 15.3 milliliters per minute (mL/min)
[4] Average sample air flow rate: 18.3 mL/min
[5] Average sample air flow rate: 16.2 mL/min
[6] Average sample air flow rate: 16.6 mL/min

Figure 1

Personal Carbon Monoxide Dosimetry, Ramp Agent
Southwest Airlines
Houston Hobby Airport
Houston, Texas
HETA 93-0816

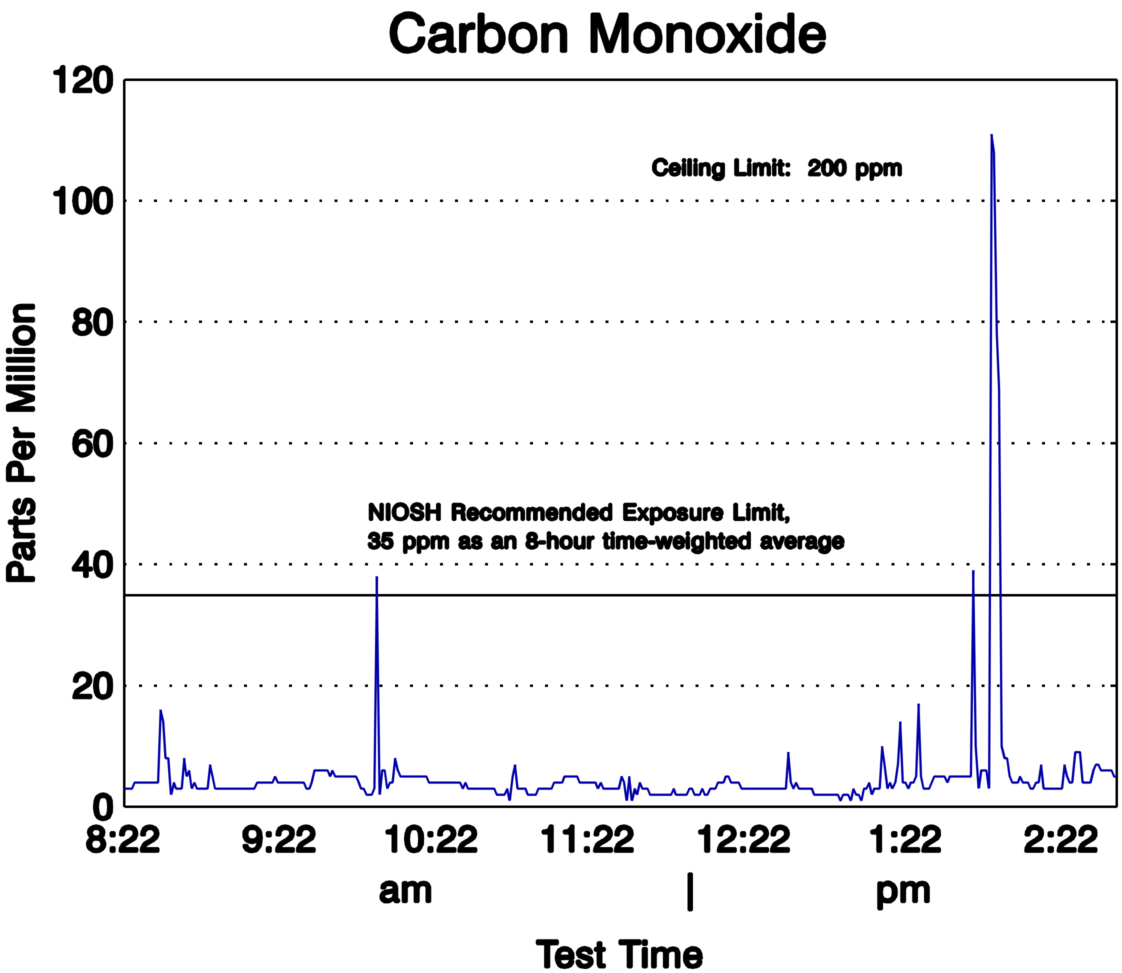


Data collected with a Metrosonics PM-7700 Toxic Gas Monitor, equipped with a carbon monoxide probe. The instrument was calibrated prior to use with 50 ppm carbon monoxide calibration gas. The values plotted on this graph constitute one minute averages collected throughout the sampling period.

The time-weighted average concentration over the sampled period was 3 ppm CO, and the highest instantaneous peak was 91 ppm.

Figure 2

Personal Carbon Monoxide Dosimetry, Fueler
Southwest Airlines
Houston Hobby Airport
HETA 93-0816



Data collected with a Biosystems Inc. Toxilog Carbon Monoxide Dosimeter, Model 1801DL. The instrument was calibrated prior to use with 50 ppm carbon monoxide calibration gas.

The time-weighted average concentration over the sampled period was 4 ppm, and the highest instantaneous peak was 111 ppm.