November 21, 2000
HETA 2000-0400

Mr. Joe Alston, Park Superintendent
US National Park Service
Glen Canyon National Recreational Area
P.O. Box1507
Page, Arizona 86040

Dear Mr. Alston:

On October 10 - 13, 2000, the National Institute for Occupational Safety and Health (NIOSH) conducted a carbon monoxide (CO) investigation on houseboats at Lake Powell, which is in the U.S. National Park Service (USNPS) Glen Canyon National Recreational Area (GLCA). This letter describes our evaluation methods, findings, and conclusions.

Background

An initial investigation was conducted in September, 2000 involving representatives from NIOSH, U.S. Coast Guard, U.S. National Park Service, Department of Interior, and Utah Parks and Recreation in response to CO related poisonings and deaths on houseboats at Lake Powell. The September, 2000 investigation characterized CO poisonings through epidemiologic data gathering, and severely hazardous CO concentrations measured on houseboats at Lake Powell.[1] Incident reports provided by the National Park Service revealed 9 known boat-related CO poisoning deaths on the lake since 1994. Some of these incidents involved numerous poisonings in addition to the deaths reported (total of 25 people poisoned in the 8 incidents involving fatalities). Information regarding the fatalities were provided in the previous report.[1]

Some of the severely hazardous situations identified during the September evaluation included:

- The open space under the swim platform could be lethal under certain circumstances (i.e., generator/motor exhaust discharging into this area) on some houseboats.
- Some CO concentrations above and around the swim platform were at or above the immediately dangerous to life and health (IDLH) level [greater than1,200 parts of CO per million parts of air (ppm)].
- Measurements of personal CO exposure during boat maintenance activities indicated that employees may be exposed to hazardous concentrations of CO.

This second investigation was conducted to gather additional CO concentration data on various houseboats at Lake Powell. Please refer to Attachments 1 and 2 for discussions of health effects of CO exposure and relevant evaluation criteria.

Methods and Materials

The environment in the space below the swim deck (see Figure 1) was characterized using a KAL Equip Model 5000 Four Gas Emissions Analyzer. This analyzer measures CO, carbon dioxide (CO_2), hydrocarbons, and oxygen. All measurements are expressed as percentages. [One percent of contaminant is equivalent to 10,000 ppm.] Air contaminants in the space were determined with only the generator operating and with the generator and boat engines operating simultaneously.

CO concentrations were measured on the back of the houseboats using ToxiUltra Atmospheric Monitors (Biometrics, Inc.) with CO sensors. All ToxiUltra CO monitors were calibrated before and after each use according to the manufacturer's recommendations. These monitors are direct-reading instruments with data logging capabilities. The instruments were operated in the passive diffusion mode, with a 15 - 30 second sampling interval. The instruments have a nominal range from 0 ppm to 500 ppm with the highest instantaneous reading of 1000 ppm. Figure 2 shows the ToxiUltra CO monitor sampling locations on most of the houseboats.

CO concentration data was also collected with detector tubes [Drager CO, CH 29901– range 0.3 % (3,000 ppm) to 7 % (7,000 ppm)] in the areas below and around the swim deck. The detector tubes are used by drawing air through the tube with a bellows–type pump. The resulting length of the stain in the tube (produced by a chemical reaction with the sorbent) is proportional to the concentration of the air contaminant.

Grab samples were collected using Mine Safety and Health Administration (MSHA) 50–mL glass evacuated containers. These samples were collected by snapping open the top of the glass container and allowing the air to enter. The containers were sealed with wax–impregnated MSHA caps. The samples were then sent by overnight delivery to the MSHA laboratory in Pittsburgh, Pennsylvania where they were analyzed for CO using a HP6890 gas chromatograph equipped with dual columns (molecular sieve and porapak) and thermal conductivity detectors.

Houseboat Area Sampling Results

Stardust Houseboat

During the early afternoon on October 10, 2000, area CO samples were collected on a Stardust houseboat with the specifications listed below. The generator ran approximately 60 minutes and the motors ran approximately 23 minutes during this evaluation.

Engines: 2 Mercruiser 5.0 liter V-8 Bravo engines, hub exhaust
Generator: 15 Kw Westerbeke, 4 cylinder, 4 stroke
Approximate dimensions of space below deck: 4' X 16' X 1.5'
Exhaust Configuration: Engines and generator exhaust into the below-deck space
Air speed above deck: 10 air speed readings were obtained with an average of 170 feet per minute
Air speed below deck: 10 air speed readings were obtained with an average of 20 feet per minute

Area Below Swim Deck

Measurements taken in the space below the swim deck (see Figure 1) with the gas emissions analyzer indicated CO concentrations in the range of 0.08 % (800 ppm) to 0.24 % (2,400 ppm) with the generator running. When the generator and motors were in operation the gas emissions analyzer indicated CO concentrations in the range of 0.8 % (8,000 ppm) to 1.5 % (15,000 ppm) in the space below the swim deck. Detector tubes taken in this space indicated CO concentrations of 1 % (10,000 ppm) and 1.5 % (15,000 ppm) when the generator and motors were in operation. The gas emissions analyzer also indicated that the area under the swim deck was oxygen deficient (16.9 % O_2) during the time period when the generator and motors were running.

Evacuated container grab samples where also taken in the area under the swim deck when the generator was operating, and when the generator and motors were operating together. Two evacuated container samples obtained in the opening to the area below the swim deck (when only the generator was running) indicated CO concentrations of 6,903 ppm and 2,490 ppm. An evacuated container sample obtained when the generator and motors were in operation indicated a CO concentration of 3,516 ppm in the opening to the area under the swim deck. When the samples were collected, they may not have been sealed properly with the wax-impregnated caps due to jagged edges on the sample vials when they were broken. Therefore, CO concentrations may have been higher than what the evacuated containers indicated.

The Toxi Ultra CO monitors were not placed in the area below the swim deck because of the high CO concentrations. Concentrations above 1000 ppm for an extended period of time may damage the sensor on these instruments.

Area Above Swim Deck on Back of Boat

During the evaluation on the back of the Stardust houseboat there was noticeable air movement (average air speed measured with a velometer during the evaluation was 170 fpm). Toxi Ultra CO monitors were placed at various locations on the back of houseboats (see Figure 2). On the Stardust houseboat, CO monitors were placed in the following locations to record CO concentrations while the generator and motors were operating: 1) on the back of the slide at breathing zone height; 2) on the left side (when on the boat and facing the water) of the swim

platform; 3) on the right side of the swim platform; and 3) on the top deck of boat.

The CO monitor placed on the back of the slide indicated an average CO concentration of 3 ppm with a peak CO concentration of 41ppm. The CO monitor placed on the left side of the swim platform indicated and average CO concentration of 31 ppm and a peak concentration of 197 ppm. The CO monitor placed on the right side of the swim platform indicated an average CO concentration of 31 ppm and a peak concentration of 197 ppm. The CO monitor placed on the top deck indicated that CO concentrations ranged from 1 to 2 ppm.

Two Sumerset Boats Tied Together

During the afternoon on October 10, 2000, area CO samples were collected on two Sumerset houseboats while they were tied together. The boats were tied together to evaluate the impact of side-exhausting generators in this configuration. Only the generator and motors on the right boat were running during this evaluation. The generator exhausted to the side into the area between the two boats (see Figure 3). The generator ran for approximately 85 minutes and the motors ran for approximately 20 minutes. The Sumerset boats had the following specifications.

Boat Manufacturer: Sumerset
Engines: 2 115 HP Mercury outboards with above deck exhaust enclosure
Generator: 15 Kw Westerbeke, 4 cylinder, 4 stroke
Exhaust Configuration: Generator exhausts to the side of the boat cabin
Air speed above deck: not measured (it was noted that there was a strong breeze)
Air speed below deck: not measured
Approximate dimensions of space below deck: 16' X 4' X 2'

Area Between Boats near Generator Exhaust

The gas emissions analyzer was placed near the generator exhaust in the space between the two boats. The exhaust for the outboard motors was exhausted above the swim deck and was not located near the generator exhaust. The emissions analyzer indicated CO concentrations in the range of 0.02 % (200 ppm) to 0.32 % (3,200 ppm) with the generator running. When the generator and motors were in operation the gas emissions analyzer indicated CO concentrations in the range of 0.02 % (200 ppm) to 0.23 % (2,300 ppm) in the space between boats near generator exhaust.

Area Samples Obtained on Swim Decks of Boats

The CO monitors were placed at the following locations on the back of the two houseboats (see Figure 3 for monitor locations): 1) on the top deck of the right boat near the area between boats (A1); 2) on the lower deck in the sleeping quarters of the left boat (A2) (windows in this boat where shut during this evaluation); 3) on the swim platform of the right boat (A3); 4) on the swim platform of the left boat (A4); 5) attached to the back of the slide on the left boat at breathing

zone height (A5); 6) on the stairs of the right boat (A6)(the stairs were located between the two boats near the front); and 7) in the area at the front of the boats near water level (A7) (located where swimming activities could occur at the front of the boats).

Refer to Figure 3 for CO monitor locations on the two boats. The CO monitor placed on the top deck of the right boat indicated low CO concentrations in this area (0-4 ppm). The CO monitor placed in the lower deck sleeping quarters of the left boat indicated CO concentrations ranging from 0 to 12 ppm (windows on the boats were shut during this evaluation). The CO monitor placed on the swim platform of the right boat indicated an average CO concentration of 68 ppm and a peak concentration of 683 ppm with only the generator running. When motors and generator on the right boat were in operation, the CO monitor placed on the swim platform of the right boat indicated an average CO concentration of 90 ppm and a peak concentration of 173 ppm (see Figure 4). The CO monitor placed on the swim platform of the left boat indicated an average CO concentration of 136 ppm and a peak of 1033 ppm. When the motors and generator were in operation on the right boat, the CO monitor placed on the swim platform of the left boat indicated an average CO concentration of 142 ppm and a peak concentration of 464 ppm (see Figure 5). The CO monitor attached to the back of the slide (at breathing zone height) on the left boat indicated an average CO concentration of 9 ppm and a peak of 70 ppm. When the motors and generator on the right boat were in operation, the CO monitor attached to the back of the slide indicated an average CO concentration of 20 ppm and a peak concentration of 86 ppm.

A CO monitor was also placed near the front of the boats in the area of the stairs (see Figure 3 for A6 sample location). This monitor indicated an average CO concentration of 53 ppm and a peak concentration of 411 ppm when the generator and motors on the boat were in operation. The area at the front of the boats near water level (A7 on Figure 3) indicated an average CO concentration of 13 ppm with a peak of 190 ppm.

Lakeview Houseboat

During the morning on October 11, 2000, area CO samples were collected on a 70 foot Lakeview houseboat with the specifications summarized below. The generator ran for approximately 64 minutes and was not placed under a load. The motors were not operated during this evaluation.

Engines: 2 Mercruiser 4.3 liter engines
Generator: 12.5 Kw Kohler, 4 cylinder, 4 stroke
Exhaust Configuration: Engines and generator exhaust into cavity below the rear deck
Air speed on swim platform: 26 -164 feet per minute
Air speed on back deck: 9 - 55 feet per minute
Approximate dimensions of space below deck: 4' X 16' X 1.5' - no side vents in the space

Area Below Swim Deck and off the Back of Boat

Measurements taken in the space below the swim deck with the gas emissions analyzer indicated CO concentrations in the range of 0.2 % (2000 ppm) to 0.85 % (8,500 ppm) with the generator running. A detector tube taken in the space below the swim deck indicated a CO concentration of 0.3 % (3,000 ppm). The gas emissions analyzer also indicated that the area under the swim deck was oxygen deficient (ranging from 17.9 to 19.5 % O_2) during the time period when the generator and motors were running.

Evacuated container grab samples where also taken near the opening of a small hole where the air conditioner utility wires and pipes ran into the space below the back deck. This was the only access area to the space below the deck from on the boat. Three evacuated samples were taken near the opening of this access hole and indicated CO concentrations of 16, 1172, and 57 ppm.

Two additional evacuated container grab samples were collected off the back of the swim deck approximately 8 inches above the water. This is an area where individuals could swim and access the swim deck. These two samples indicated CO concentrations of 7,208 ppm (E1 location on Figure 6) and 1,502 ppm (E2 location on Figure 6). Smoke tube tests indicated that the air was stagnant in the area off the back of the boat (see Figure 2 and Figure 6).

Area Above Swim Deck on Back of Boat

The Toxi Ultra CO monitors were placed at various locations on the back of houseboats (see Figure 2) during the Lake Powell evaluation. On the Lakeview houseboat, Toxi Ultra CO monitors were placed in the following locations: 1) on the back deck stairs at breathing zone height; 2) on the left side of the back deck at breathing zone height; 3) on the right side of the swim platform; 4) on the left side of the swim platform; and 5) on the top deck of the boat.

The monitor placed on the back deck stairs indicated an average CO concentration of 5 ppm with a peak CO concentration of 26 ppm. The monitor placed on the left side of the back deck at breathing zone height indicated an average CO concentration of 2 ppm and a peak concentration of 6 ppm. The monitor placed on the left side of the swim platform indicated an average CO concentration of 43 ppm and a peak concentration of 275 ppm. The monitor on the right side of the swim platform indicated an average CO concentration of 140 ppm and a peak of 918 ppm. The monitor on the top deck of the boat indicated that CO concentrations ranged from 0 to 5 ppm in this area.

Skipper Liner Houseboat

During the morning of October 12, 2000, area CO samples were collected for approximately 25 minutes on a Skipper Liner houseboat with the following specifications. Only the generator ran during this evaluation.

Engines: 2 Mercruiser 470, 4 cylinder engines
Generator: 9.0 Kw , Westerbeke

Exhaust Configuration: Engines and generator exhaust into cavity below the rear deck
Air speed on swim platform: 7 - 85 feet per minute
Air speed on under swim back deck: 42 - 216 feet per minute
Approximate dimensions of space below deck: 4' X 16' X 1.5'

Area Below Swim Deck and off the Back of Boat

Measurements taken in the space below the swim deck with the gas emissions analyzer indicated CO concentrations in the range of 0.01 % (100 ppm) to 0.5 % (5,000 ppm). Two evacuated container grab samples were obtained in the opening of the view port that opens into the space below the back deck. These samples indicated CO concentrations of 297 and 470 ppm.

Area Above Swim Deck on Back of Boat

The Toxi Ultra CO monitors were placed at various locations on the back of houseboats (see Figure 2). On the Skip Liner houseboat CO monitors were placed in the following locations: 1) on the left side of back deck at breathing zone height; 2) on the right side of back deck at breathing zone height; 3) on the right side of the swim platform; 4) on the left side of the swim platform; 5) on the back of the slide at breathing zone height; and 6) on the top deck of the boat.

The monitor placed on the left side of the back deck indicated an average CO concentration of 14 ppm with a peak CO concentration of 31 ppm. The monitor placed on the right side of the back deck indicated an average CO concentration of 14 ppm and a peak concentration of 40 ppm. The monitor placed on the right side of the swim platform indicated an average CO concentration of 370 ppm and a peak concentration of 750 ppm. The monitor on the left side of the swim platform indicated an average CO concentration of 170 ppm and a peak of 477 ppm. The monitor on the back of the slide at breathing zone height indicated an average CO concentration of 114 ppm and a peak of 359 ppm. The monitor on the top deck of the boat indicated an average CO concentration 12 ppm and a peak of 109 ppm.

Personal Sampling Results

Search Boat

Personal samples were collected on Park Service employees during a search mission for a drowning victim. The employees were working on a boat built by Metal Craft Marine that was approximately 45 feet in length. The boat was equipped with a diesel generator that ran continuously during the search operations and was only shut off during lunch periods. Personal CO monitors were placed on the following workers: 1) two workers who ran the line for the rover; 2) the worker who operated the sonar; and 3) the worker operating the rover in the cabin of the boat. An additional CO monitor was placed on the NIOSH employee on the search boat during the sampling period. An evacuated container sample was taken near the generator on the search boat which indicated a CO concentration of 24 ppm. Table 1 list the results of personal

sampling during search operations. Two area monitors placed on the search boat are listed in Table 1.

Table 1. Personal CO monitoring results on search boat.

Worker	Average CO Concentration During Sampling Period (ppm)	Peak CO Concentration During Sampling Period (ppm)
Worker Running Line for Rover	0.56	16
Worker Running Line for Rover	0.06	15
Worker operating Sonar	0.45	49
Worker operating Rover	1.2	197
NIOSH Employee on transport boat to Search area	3.2	51
NIOSH Employee on Search Boat	0.5	36
Area inside cabin on captains table	0.3	21
Area outside cabin on boat	2.4	82

On October 11, 2000, personal samples were collected on Park Service employees during the search mission, Park Service maintenance employees, and a toll booth worker. Personal samples were also collected on Aramark employees at the Wahweap marina. The results of these personal samples are listed in Table 2.

Table 2. Personal CO monitoring results on 10/11/00.

Worker	**Average CO Concentration During Sampling Period (ppm)**	**Peak CO Concentration During Sampling Period (ppm)**
Search Boat Workers		
Worker Running Line for Rover	2	130
Worker operating Sonar	2	132
Worker on Picket Boat	2	79
Park Service Employees		
Worker #1 (maintenance supervisor)	7	780*
Worker #2	1	87
Toll Booth Worker	1	17
Aramark Employees at Wahweap Marina		
Maintenance worker on Houseboats	4	320*
Maintenance worker on small boats	3	350*
Instructor on houseboats	0.14	19
Gas Pump Operator	2	140
Rainbow Bridge Tour Deck Hand-Canyon Odyssey Boat with Diesel Motors (Twin 8v92TI Detroit Diesel) - No generator	6	40
* **Figures 7-9.** Worker exposures to CO that exceed the NIOSH ceiling limit of 200 ppm.		

On October 12, 2000, personal samples were collected on Park Service and Wahweap marina employees during maintenance and marina activities. The results of these personal samples are listed in Table 3.

Table 3. Personal CO monitoring results on 10/12/00.

Worker	**Average CO Concentration During Sampling Period (ppm)**	**Peak CO Concentration During Sampling Period (ppm)**
Park Service Employees		
Maintenance Supervisor on Search Boat	0.06	21
Boat Maintenance Employee	3	86
Wahweap Marina Employees		
Fuel Dock Worker	2	325*
Maintenance Worker on Houseboats	3	207
Boat Pilot (drove houseboats in and out of the marina)	6	87
* **Figure 10.** Worker exposures to CO that exceed the NIOSH ceiling limit of 200 ppm.		

Personal samples were collected on Aramark employees at the Wahweap marina during maintenance and marina activities on October 13, 2000. The results of these personal samples are listed in Table 4.

Table 4. Personal CO monitoring results on 10/13/00.

Worker	**Average CO Concentration During Sampling Period (ppm)**	**Peak CO Concentration During Sampling Period (ppm)**
Aramark Employees		
Small boat maintenance worker	7	370*
Houseboat Instructor	5	471*
Maintenance worker	12	255*
Fuel Supervisor	1	18
Small boat Instructor	3	340*
* **Figure 11-14.** Worker exposures to CO that exceed the NIOSH ceiling limit of 200 ppm.		

Discussion and Recommendations

This investigation confirmed the issues of concern regarding CO exposure potentials on houseboats. The houseboats evaluated are designed with generators that supply the boat with electrical power to run the on-board appliances (e.g, air-conditioner, refrigerator, stove, lights, and charging batteries). When these generators are in operation, the area under the swim deck and around the back of the swim platform (near water level), on houseboats that exhaust the combustion gases in the space below the back deck, are extremely hazardous. These hazardous conditions also exist when the engines are in operation on the boats. CO concentrations measured with three separate methods (i.e., real time instruments, evacuated containers, and detector tubes) in these areas indicated concentrations well above the NIOSH IDLH value of 1,200 ppm.[2] Individuals swimming or working in the area under the swim platform, or around the area directly behind the swim platform (near the water level), with the generator or motors in operation could experience CO poisoning or death within a short period of time.

The area on the swim deck of the houseboats is also a concern. When the generator or motors are in operation, the area around the back deck of the houseboats can be hazardous under certain conditions (i.e., lack of air movement). This is substantiated by the CO poisonings and deaths that have been reported in this area of the boat.[1] During this evaluation, CO measurements obtained in this area indicated that CO concentrations could reach up to 1000 ppm (upper limit for the Toxilog CO monitors). CO measurements obtained on the top deck of the boats did not indicate a CO hazard during this evaluation.

The diesel-operated search boat did not appear to present a major CO exposure problem for the workers during this evaluation. However, one individual had a short-term CO peak of 197 ppm which is near the NIOSH ceiling limit of 200 ppm. Other environmental assessments are currently being conducted on different lakes in other parts of the nation to further validate CO problems on both diesel and gas generators/motors associated with houseboats.

Personal sampling results indicate that some workers were exposed to CO concentrations that exceed the NIOSH ceiling limit of 200 ppm.[3] One Park Service maintenance worker received a peak CO exposure of 780 ppm. The following recommendations are provided to reduce CO concentrations around and under the swim platform on houseboats, and to help reduce worker exposures.

1) The cavity below and the area directly around the swim platform must be immediately addressed through design changes to help reduce CO hazards when the generator or motors are in operation. Public education efforts must also be utilized to immediately inform and warn all individuals (including boat owners, renters, and workers) potentially exposed to CO hazards. Public education programs should continue until control solutions that eliminate the problem are in place.

2) Improved maintenance and/or design of boat engines and platforms should be accomplished to ensure safety when engines and/or generators are operated.

3) An effort is being made to inform manufacturers of houseboats concerning the environmental data that has been collected, and the related design concerns. On September 1, 2000, the National Park Service (NPS) sent each of these manufacturers a letter informing them of the numerous deaths that may be attributed to CO poisoning from generator and/or engine exhaust. In these letters, the Park Service specifically pointed out that most of the deaths occurred when the victim was either on the back deck or in the water near or under the swim platform. In addition to this effort, the initial NIOSH letter describing the first evaluation of CO on houseboats at Lake Powell was also sent to all houseboat manufacturers.[1] This effort should be continued until all manufacturers are aware of the problem and solutions are formulated to redesign and correct the exhaust configuration. This should also include the redesigning of side-exhausting boats to help eliminate CO problems when boats are tied together, or when someone is in the area where the exhaust gases are expelled from the boat.

4) The feasibility and effectiveness of engineering controls must be investigated to reduce CO exposures of boat maintenance mechanics. If repairs are conducted outside and at the boat dock (where electric power is easily available), the use of a high volume fan or other air-moving device may be effective in preventing short-term high-level exposures to CO.

5) Training about the severity of CO hazards in boating should be developed for Park Service personnel (including EMS providers), so that symptoms experienced by either employees or other boat operators might be more easily associated with exposures. This training should include both environmental data, as well as information about the number and circumstances of CO poisonings on the lake.

6) The U.S. NPS has launched an awareness campaign to inform boaters on their lake about boat-related CO hazards. This Alert included press releases, flyers distributed to boat and dock-space renters, and verbal information included in the boat check-out training provided for users of concessionaire rental boats. Training about the specific boat-related CO hazards provided for houseboat renters should be enhanced to include specific information about the circumstances and number of poisonings and deaths. The training (including videotaped training such as that viewed during this evaluation) should include anecdotal information about deaths and near misses, and should specifically target warnings against entering air spaces under the boat (such as the cavity below the swim platform), or immediately behind the swim platform, that may contain a lethal atmosphere.

7) When houseboats are in the water, the area under the swim deck meets NIOSH and OSHA criteria for a permit-required confined space; therefore, permit-required confined space requirements should be followed before any workers enter this area. This recommendation is based on the following discussion.

Record reviews indicate three CO poisonings occurred within the span of 12 days in August, 1998, as a result of entering the airspace beneath the swim deck for engine maintenance or clearing ropes from propellers. In the first instance, a 56-year-old man died when he swam under the swim platform several times while the boat generator was operating. Ten days later, a 24-year-old employee was working under a houseboat changing the engine propeller while the boat generator was operating. He was found unconscious in the water and transported to a nearby medical clinic, where he was treated for carbon monoxide inhalation. Two days later, a 38-year-old man entered the airspace beneath the swim deck after deactivating the boat engines. Approximately 3 hours later, his body was located in approximately 8 feet of water.

One of these incidents involved an employee that worked at the marina. OSHA regulation 29 CFR 1910.146 defines a ***confined space*** as a space that meets three criteria: (1) is large enough and configured so that an employee can bodily enter and perform any assigned work; (2) is a space that has limited or restricted means for entry or exit (for example, tanks, vessels, storage bins, vaults, and pits that have limited means of entry); and (3) a space that is not designed for continuous employee occupancy. The standard then defines a ***permit–required confined space*** as a space that meets one or more of the following criteria: (1) a space that contains or has a potential to contain a hazardous atmosphere; (2) a space that contains a material that has the potential for engulfing (surrounding and capturing of a person by a liquid or finely divided solid substance that can be aspirated and cause death or that can exert enough pressure to cause death by strangulation, constriction, or crushing) the person entering the space; (3) the internal configuration of the space is designed in a way that the person entering the space could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross section; or (4) a space that contains any other recognized serious safety or health hazard.[4] NIOSH defines a confined space as "an area which by design has limited openings for entry and exit, unfavorable natural ventilation which could contain (or produce) dangerous air contaminates, and which is not intended for continuous employee occupancy.[5] The NIOSH criteria for working in confined spaces further classifies confined spaces based upon the atmospheric characteristics such as oxygen level, flammability, and toxicity. As shown in Table 5, if any of the hazards present a situation which is immediately dangerous to life or health (IDLH), the confined space is designated Class A. A Class B confined space has the potential for causing injury and/or illness, but is not an IDLH atmosphere. A Class C confined space is one in which the hazard potential would not require any special modification of the work procedure. Table 6 lists the confined space program elements which are recommended (or must be considered by a qualified person, as defined by the criteria) before entering and during work within confined spaces based on the established hazard classification.

Table 5

CONFINED SPACE CLASSIFICATION TABLE

Parameters	Class A	Class B	Class C
Characteristics	Immediately dangerous to life – rescue procedures require the entry of more than one individual fully equipped with life support equipment – maintenance of communication requires an additional standby person stationed within the confined space	Dangerous, but not immediately life threatening – rescue procedures require the entry of no more than one individual fully equipped with life support equipment – indirect visual or auditory communication with workers	Potential hazard – requires no modification of work procedures – standard rescue procedures – direct communication with workers, from outside the confined space
Oxygen	16% or less *(122 mm Hg) or greater than 25% *(190 mm HG)	16.1% to 19.4% *(122 – 147 mm Hg) or 21.5% to 25% (163 – 190 mm Hg)	19.5 % – 21.4% *(148 – 163 mm Hg)
Flammability Characteristics	20% or greater of LFL	10% – 19% LFL	10% LFL or less
Toxicity	**IDLH	greater than contamination level, referenced in 29 CFR Part 1910 Sub Part Z – less than **IDLH	less than contamination level referenced in 29 CFR Part 1910 Sub Part Z

* Based upon a total atmospheric pressure of 760 mm Hg (sea level)

** Immediately Dangerous to Life or Health – as referenced in NIOSH Registry of Toxic and Chemical Substances, Manufacturing Chemists data sheets, industrial hygiene guides or other recognized authorities.

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 80–106.

Table 6

CHECK LIST OF CONSIDERATIONS FOR ENTRY, WORKING IN AND EXITING CONFINED SPACES

ITEM	CLASS A	CLASS B	CLASS C
1. Permit	X	X	X
2. Atmospheric Testing	X	X	X
3. Monitoring	X	0	0
4. Medical Surveillance	X	X	0
5. Training of Personnel	X	X	X
6. Labeling and Posting	X	X	X
7. Preparation			
Isolate/lockout/tag	X	X	0
Purge and ventilate	X	X	0
Cleaning Processes	0	0	0
Requirements for special equipment/tools	X	X	0
8. Procedures			
Initial plan	X	X	X
Standby	X	X	0
Communications/observation	X	X	X
Rescue	X	X	X
Work	X	X	X
9. Safety Equipment and Clothing			
Head protection	0	0	0
Hearing protection	0	0	0
Hand protection	0	0	0
Foot protection	0	0	0
Body protection	0	0	0
Respiratory protection	0	0	
Safety belts	X	X	X
Life lines, harness	X	0	
10. Rescue Equipment	X	X	X
11. Recordkeeping/Exposure	X	X	

X = indicates requirement
0 = indicates determination by the qualified person

NIOSH [1979]. Criteria for a recommended standard: working in confined spaces. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 80–106.

Thank you for your cooperation with this investigation, and for providing extensive important data related to this serious issue. Please contact either of us if you have any questions about this

letter or any aspect of the evaluation.

Sincerely,

Ronald M. Hall, M.S.
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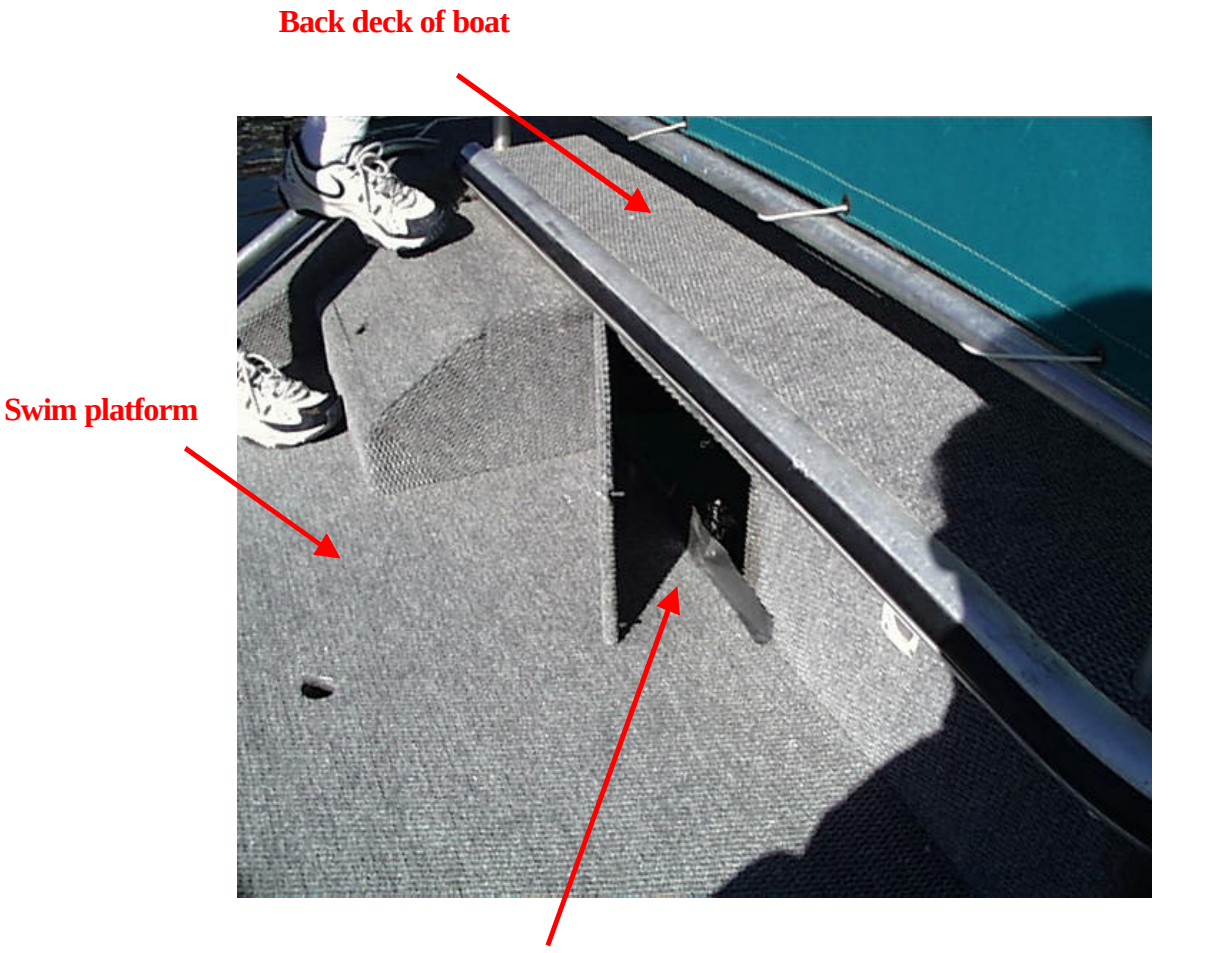

Figure 1. View port into space below swim deck on some boats.

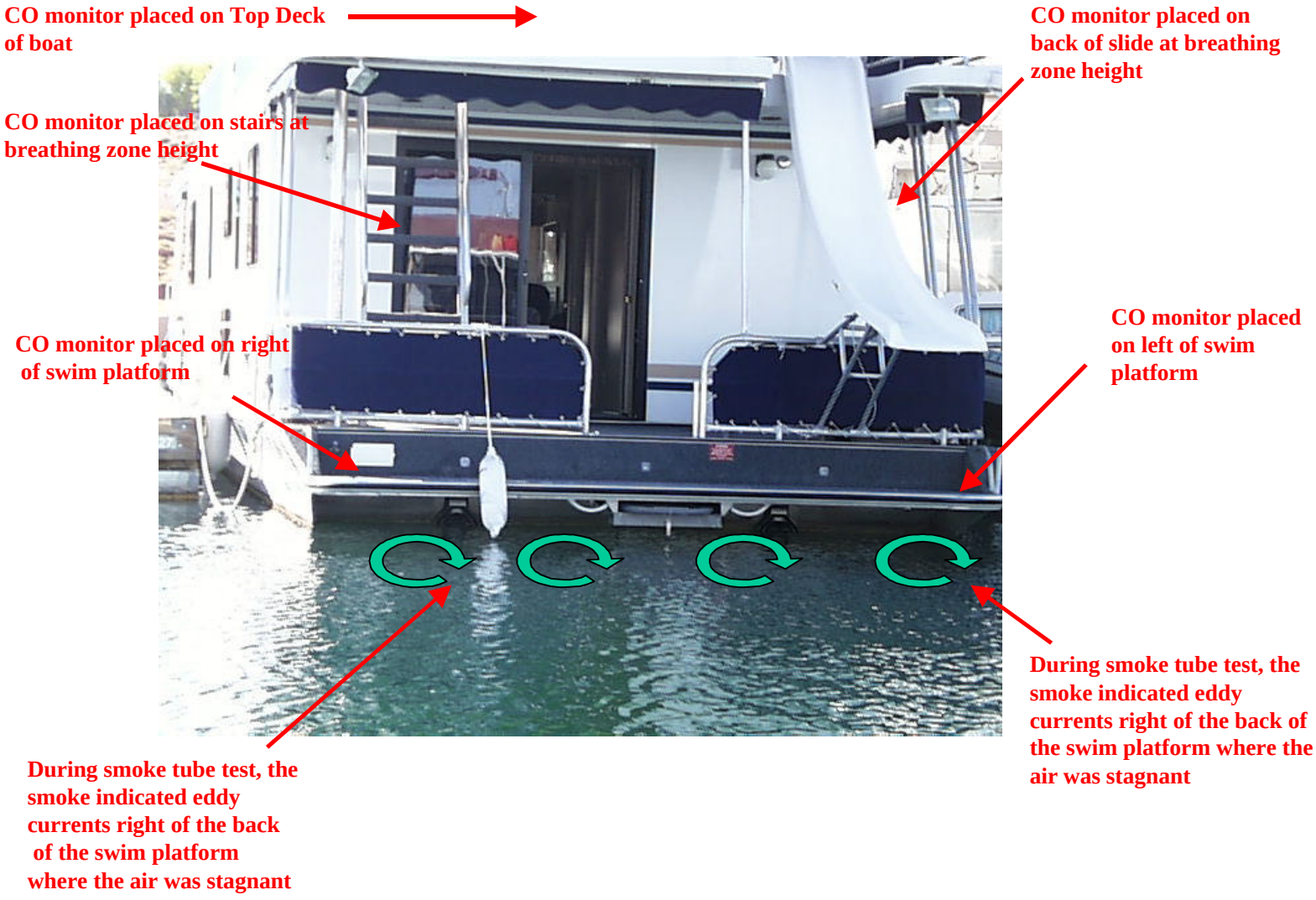

Figure 2.

Swim platform and back deck of houseboat with CO sample locations and smoke tube test results identified.

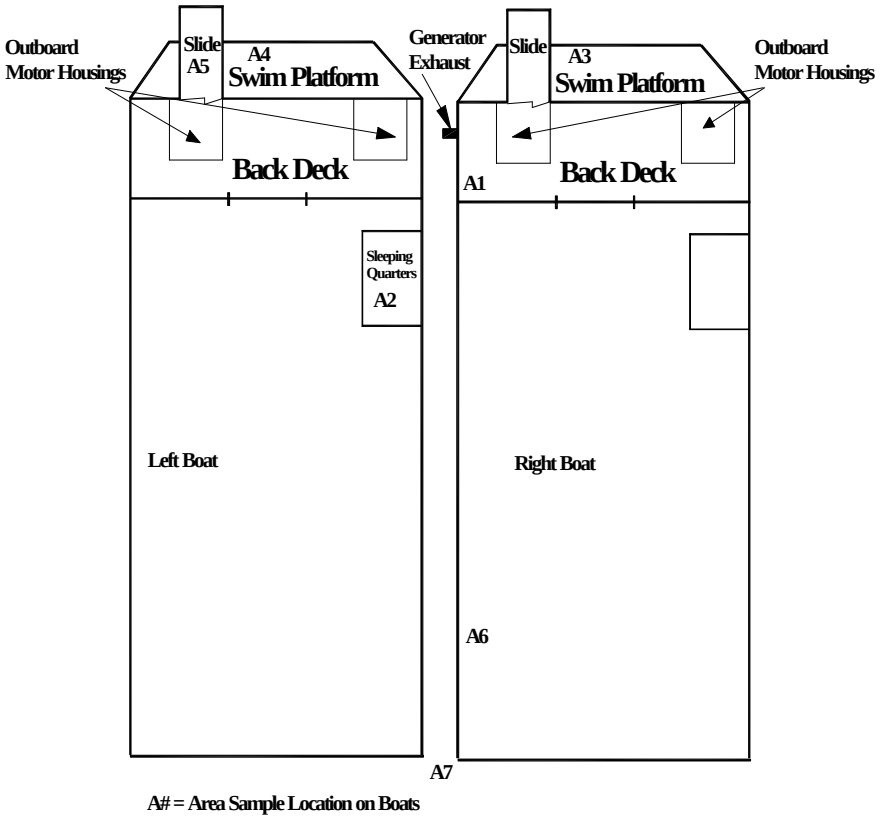

Figure 3. Area Sample location on Boats

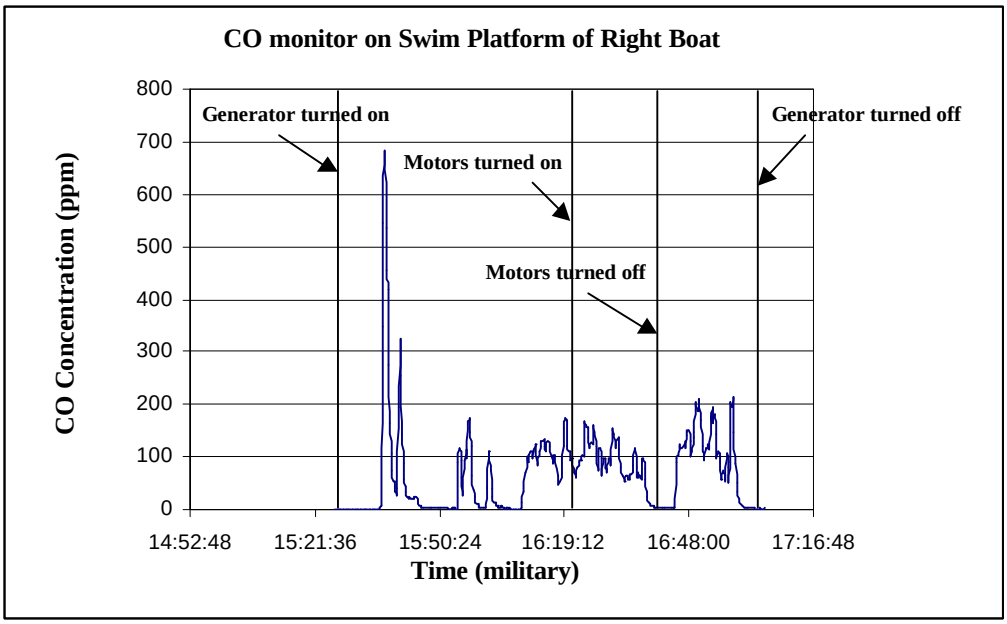

Figure 4. CO monitor on swim platform of right boat

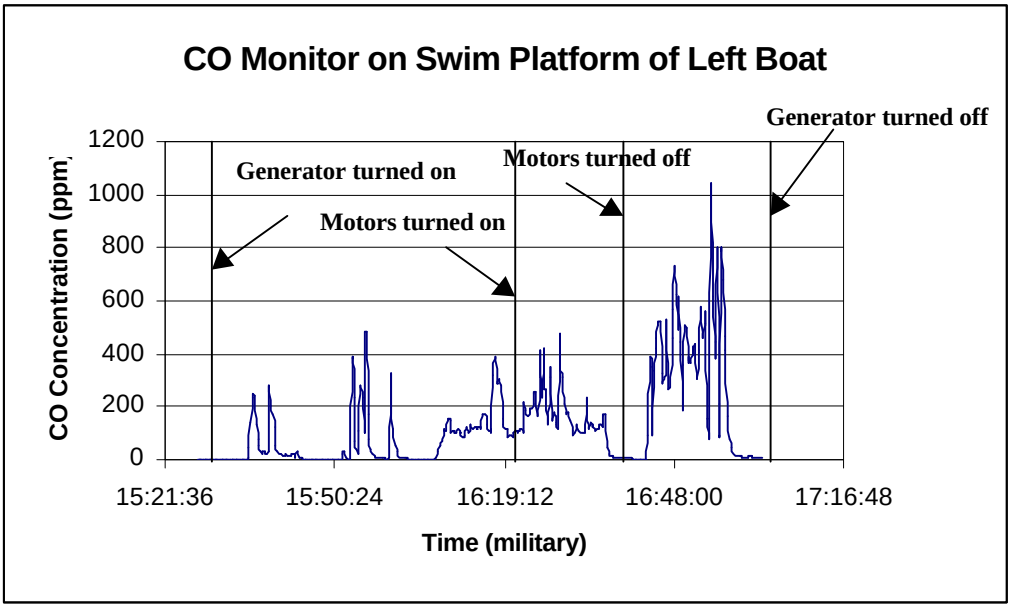

Figure 5. CO monitor on swim platform of left boat

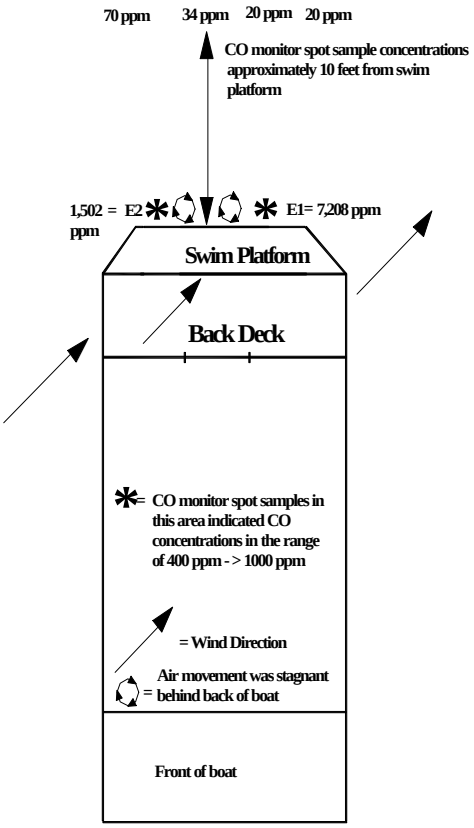

Figure 6. Lakeview Boat displaying sample locations and concentrations off the back of swim platform.

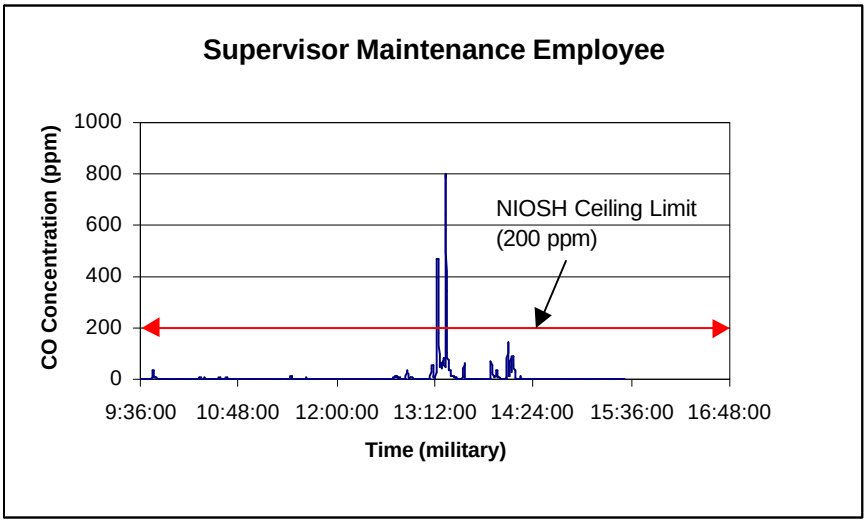

Figure 7. Park Service Maintenance Employee CO exposures on 10/11/00.

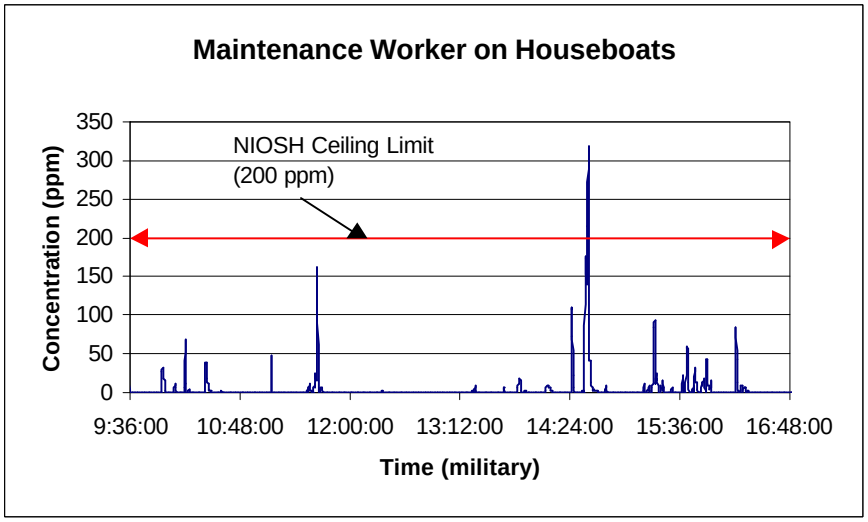

Figure 8. Aramark Houseboats Maintenance Employee CO exposures on 10/11/00.

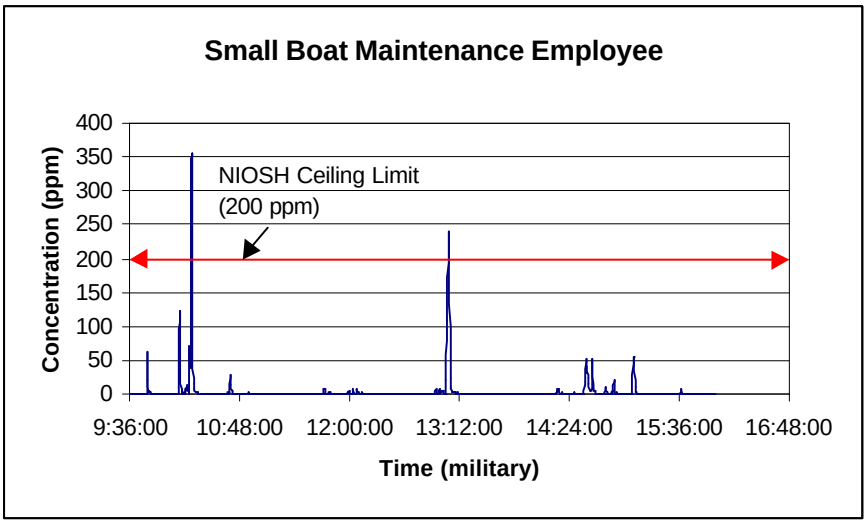

Figure 9. Aramark Houseboats Maintenance Employee CO exposures on 10/11/00.

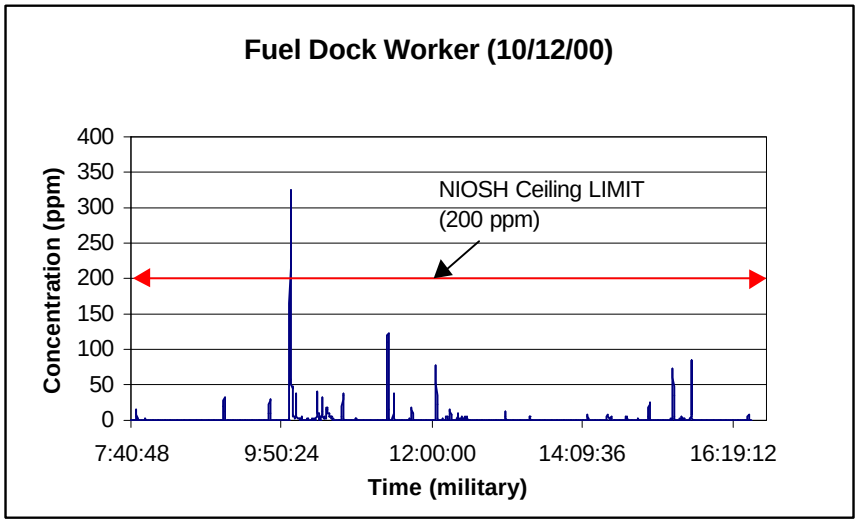

Figure 10. Wahweap Fuel Dock Employee CO exposures on 10/12/00.

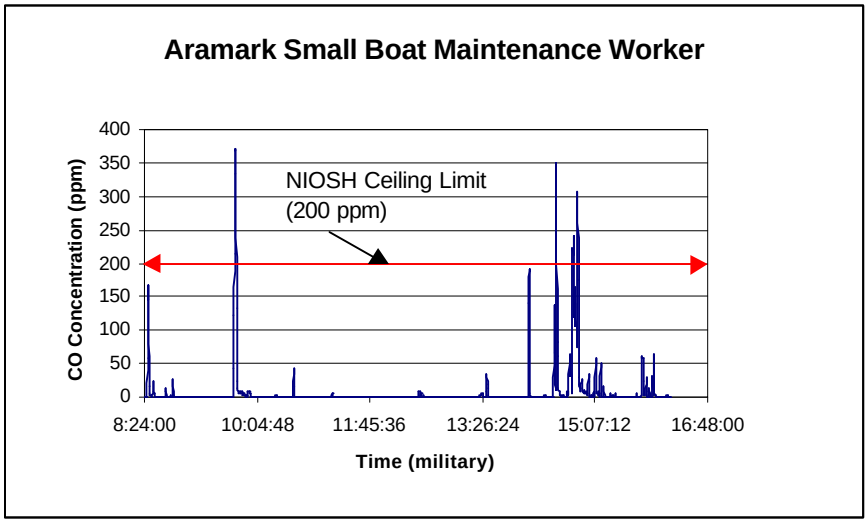

Figure 11. Aramark small boat maintenance employee.

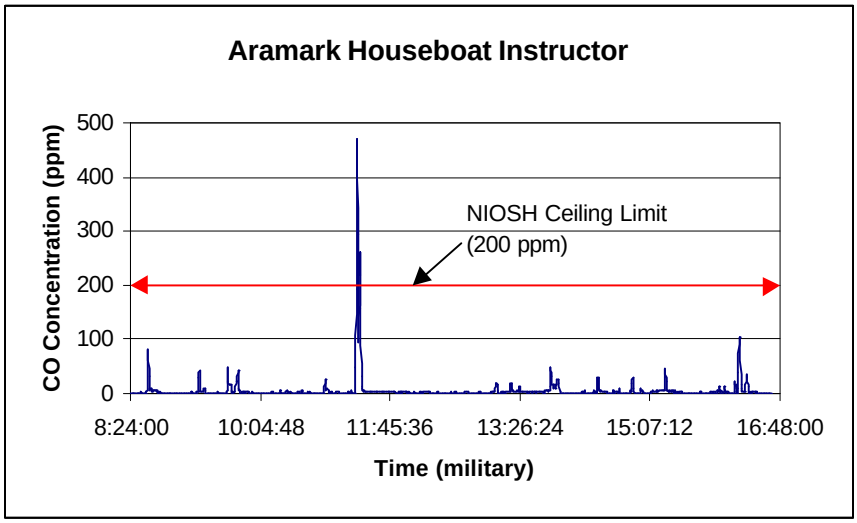

Figure 12. Aramark Houseboat Instructor.

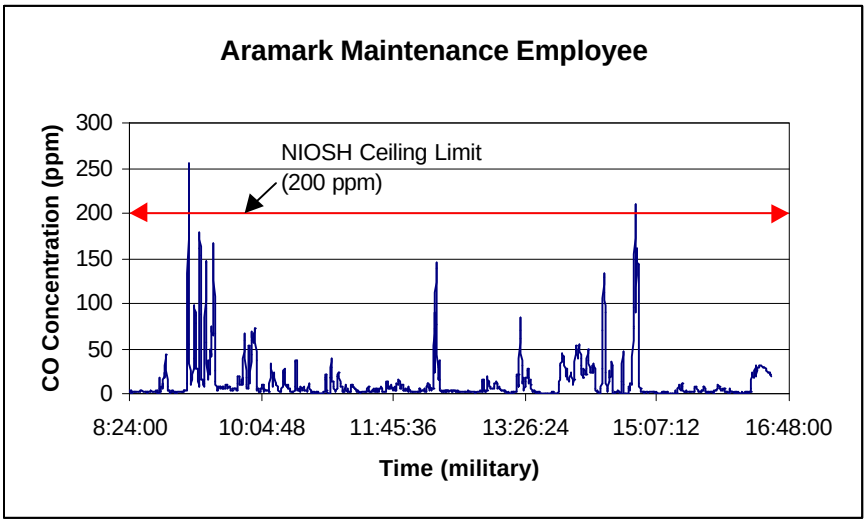

Figure 13. Aramark Maintenance Employee.

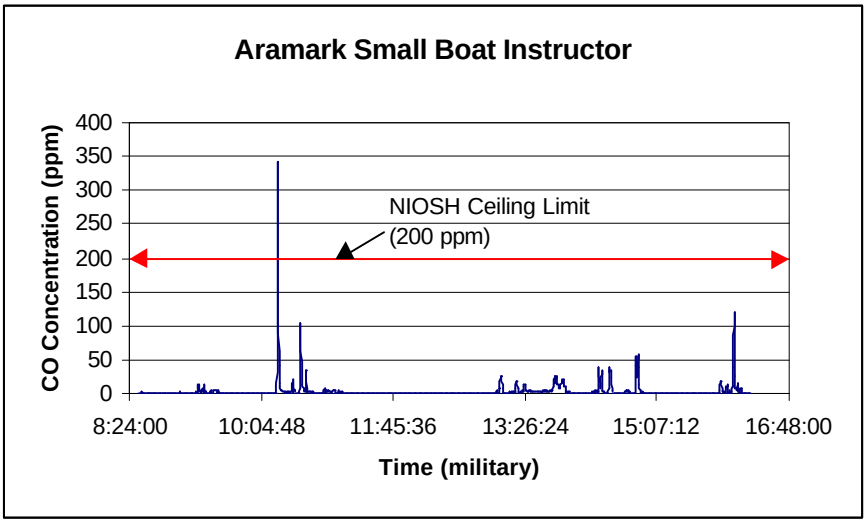

Figure 14. Aramark Small Boat Instructor.

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Attachment 1
Health Effects of Exposure to Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline or propane fuel. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, or nausea. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. If the exposure level is high, loss of consciousness may occur without other symptoms. Coma or death may occur if high exposures continue.[1-6] The display of symptoms varies widely from individual to individual, and may occur sooner in susceptible individuals such as young or aged people, people with preexisting lung or heart disease, or those living at high altitudes.

Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with the hemoglobin to form carboxyhemoglobin (COHb). Blood has an estimated 210-250 times greater affinity for CO than oxygen, thus the presence of CO in the blood can interfere with oxygen uptake and delivery to the body. Once absorbed into the bloodstream, the half-life of bloodborne CO at sea level and standard pressure is approximately five hours. This means that an initial COHb level of 10% could be expected to drop to 5% in five hours, and then 2.5% in another five hours. If oxygen is administered to the exposed person, as happens in emergency treatment, the COHb concentration drops more quickly. Once exposed, the body compensates for the reduced bloodborne oxygen by increasing cardiac output, thereby increasing blood flow to specific oxygen-demanding organs such as the brain and heart. This ability may be limited by preexisting heart or lung diseases that inhibit increased cardiac output.

The altitude of this lake is 3,500 feet. Altitude effects the toxicity of CO. With 50 ppm CO in the air, the COHb level in the blood is approximately 1% higher at an altitude of 4,000 feet than at sea level. This occurs because the partial pressure of oxygen (the gas pressure causing the oxygen to pass into the blood) at higher altitudes is less than the partial pressure of CO. Furthermore, the effects of CO poisoning at higher altitudes are more pronounced. For example, at an altitude of 14,000 feet, a 3% COHb level in the blood has the same effect as a 20% COHb at sea level.[7]

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Attachment 2
Evaluation Criteria

Although NIOSH typically focuses on occupational safety and health issues, the Institute is a public health agency, and cannot ignore the overlapping exposure concerns in this type of setting. Park Service and Aramark employees should be in a state of health typical of any industrial worker. Thus, occupational criteria for CO exposure are applicable to that group.
The general boating public, however, may range from infant to aged, be in various states of health and susceptibility, and be functioning at a higher rate of metabolism because of increased physical activity. The effects of CO are more pronounced in a shorter time if the person is physically active, very young, very old, or has preexisting health conditions such as lung or heart disease. Persons at extremes of age and persons with underlying health conditions may have marked symptoms and may suffer serious complications at lower levels of carboxyhemoglobin.[(1)] The occupational exposure limits noted below should not be used for interpreting general population exposures because they would not provide the same degree of protection they do for the healthy worker population.

Occupational Exposure 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, or a pre-existing medical condition. 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. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[(2)] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®), [(3)] (3) the legal requirements of the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs),[(4)] and (4) the American Society of Heating, Refrigerating, and Air-ConditioningEngineers (ASHRAE) Standard for ventilation for acceptable indoor air quality.[(5)] Employers are encouraged to follow the more protective criterion listed.

A TWA exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure

limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

The NIOSH REL for CO is 35 ppm for full shift TWA exposure, with a ceiling limit of 200 ppm which should never be exceeded.[6,7] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5%.[1] NIOSH has established the immediately dangerous to life and health (IDLH) value for CO as 1,200 ppm.[8] An IDLH value is defined as a concentration at which an immediate or delayed threat to life exists or that would interfere with an individual's ability to escape unaided from a space.

The ACGIH recommends an eight-hour TWA TLV of 25 ppm based upon limiting shifts in COHb levels to less than 3.5%, thus minimizing adverse neurobehavioral changes such as headache, dizziness, etc, and to maintain cardiovascular exercise capacity.[9]

The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.[10]

Health Criteria Relevant to the General Public.
The US EPA has promulgated a National Ambient Air Quality Standard (NAAQS) for CO. This standard requires that ambient air contain no more than 9 ppm CO for an 8-hour TWA, and 35 ppm for a one-hour average.[11] The NAAQs for CO was established to protect "the most sensitive members of the general population" by maintaining increases in carboxyhemoglobin to less than 2.1%.

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