CARBON MONOXIDE EMISSIONS AND EXPOSURES ON RECREATIONAL BOATS UNDER VARIOUS OPERATING CONDITIONS
(Lake Norman, NC)

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Highlights of the NIOSH In-Depth Survey

Carbon Monoxide Emissions and Exposures on Recreational Boats Under Various Operating Conditions (Lake Norman, NC)

At the request of the United States Coast Guard (USCG), National Institute for Occupational Safety and Health (NIOSH) researchers evaluated carbon monoxide (CO) exposures on 16 recreational boats on Lake Norman, North Carolina. The boats were propelled by gasoline-powered engines; the cabin cruisers also used gasoline-powered generators to provide electricity. This study was performed for the USCG to better understand how CO poisoning can occur on recreational boats and to identify the most hazardous conditions. Exposures to high CO concentrations on recreational boats are the result of many factors; including an individual's location; type and make of boat; relative wind speed and direction; engine size and design; and the influence U.S. Environmental Protection Agency regulations have had on engine design.

What NIOSH Did

- NIOSH researchers conducted air sampling for CO and made wind and boat speed measurements on 16 different recreational boats.

- Data were collected to evaluate CO exposures on and near the boats, under various operating conditions.

- Wind velocity measurements were collected using ultrasonic anemometers or hand-held wind meters.

- CO concentrations were measured at various locations on the boats (and on a pole held over the water behind the boats) using ToxiUltra atmospheric monitors with CO sensors.

- CO concentrations were also measured with detector tubes, emissions analyzers, and evacuated containers in the vicinity of the drive engine and/or generator exhaust outlet.

What NIOSH Found

- CO concentrations, as measured by three separate methods (i.e., real-time instruments, evacuated containers, and detector tubes), indicated concentrations approaching or exceeding the NIOSH IDLH value of 1,200 ppm for many boats.

- CO concentrations were highest during cold starts and during operation of gasoline-powered engines when the boat is stationary.

- CO exposures tend to decrease as wind speeds increase.

- For any given engine under stationary conditions, measured CO concentrations were directly related to the CO sensor's proximity to the engine's exhaust. CO concentrations near the boat's stern were typically the highest, while the CO concentrations measured inside the boat and on the pole behind the boat were substantially lower.

- CO data for boats underway show that hazardous exposures may occur under certain conditions. As the speed of a boat increases, the CO exposure typically decreases.

Conclusion

This study showed that stationary operations and operating at speeds less that 5 mph near the stern of the boat appear to be most hazardous. The data collected show that nearly 90% of the evaluated boat engines produced hazardous CO concentrations, and CO poisoning could occur. Manufacturers, owners, and users of recreational boats should be aware of the potential for CO poisoning from gasoline-powered engines.

EXECUTIVE SUMMARY

Under an interagency agreement with the United States Coast Guard, National Institute for Occupational Safety and Health (NIOSH) researchers evaluated carbon monoxide (CO) exposures on 16 recreational boats on Lake Norman, NC, including ski boats, cabin cruisers, bow riders, deck boats, and personal watercraft. Most of the evaluated boats were speed boats or cabin cruisers, ranging in age from new to 13 years old. These boats were propelled by gasoline-powered engines; the cabin cruisers also used gasoline-powered generators to provide electricity.

This investigation followed a series of recent studies to reduce CO exposures and poisonings on houseboats. Epidemiologic investigations found that from 1990 to 2000, 111 CO poisonings occurred on Lake Powell, located in the Glen Canyon National Recreation Area in Utah and Arizona. Seventy-four of the poisonings occurred on houseboats and 37 poisonings occurred on other types of recreational boats. NIOSH researchers are aware of 106 CO poisonings associated with recreational boats (non-houseboats) nationwide.

This study was performed for the U.S. Coast Guard to better understand how CO poisonings can occur on recreational boats and to identify the most hazardous conditions. Boats were evaluated while stationary and at multiple speeds. CO concentrations were measured by multiple real-time instruments, which were placed at different locations on the boats and at various distances behind the boat while moving.

Study results indicated that stationary conditions were generally the most hazardous; however, many boats had elevated CO concentrations near the rear deck while moving. Most of the evaluated boats generated hazardous CO concentrations: peak CO concentrations often exceeded 1,000 parts per million (ppm), while average CO concentrations were well over 100 ppm at the stern (rear).

Elimination of gasoline-powered marine engines without emissions controls could dramatically reduce the likelihood of CO poisonings related to recreational boats. Development and use of emission control technologies such as catalytic converters and emission control devices (ECDs), and greater use of cleaner-burning drive engines and generators could minimize the future number of CO poisonings in the marine environment.

BACKGROUND

On May 13 through 16, 2002, researchers from the National Institute for Occupational Safety and Health (NIOSH) evaluated carbon monoxide (CO) emissions and exposures on a variety of recreational boats on Lake Norman, North Carolina. This evaluation was conducted under an interagency agreement between the U.S. Coast Guard Office of Boating Safety and NIOSH to gather information about the extent of CO emissions and exposures that may occur on recreational boats in use in the United States. A cross-section of recreational boats were evaluated including bow riders, cabin cruisers, and personal watercraft. Each of the evaluated boats were propelled by gasoline-powered engines. The cabin cruisers evaluated also had gasoline-powered generators to provide electrical power for onboard appliances. This report provides background information and describes the NIOSH study methods, results, conclusions, and recommendations. A similar NIOSH study was conducted on Lake Mead and Lake Powell. The results of that study were presented in a separate report [Earnest et al. 2003].

This investigation of CO exposures on recreational boats followed a series of studies related to carbon monoxide exposures and poisonings on houseboats. Initial investigations of CO exposure and poisonings on houseboats began at Lake Powell in September and October 2000. During these investigations, hazardous CO concentrations were measured on numerous houseboats [Hall and McCammon 2000; McCammon and Radtke 2000]. Epidemiologic investigations revealed that from 1990 to 2000, 111 CO poisoning cases occurred on Lake Powell. Seventy-four of the poisonings occurred on houseboats, and 37 poisonings occurred on other types of recreational boats [McCammon et al. 2001]. A substantial amount of work has been done to evaluate engineering controls for CO on houseboats, but less effort has been expended to understand the extent of the CO hazard on other types of recreational boats.

The question remained, how and why did 37 CO poisonings occur on non-houseboats and how typical is this of other U.S. bodies of water? Overall, 106 CO poisonings are known to have occurred on or near recreational boats (non-houseboats). Forty-two of these poisonings occurred at Lake Powell and 64 occurred on other waters.

The severity and extent of these poisonings (described below) led to a number of questions, such as:

- Where is it safe on the boat?
- Is it safe to pull my children (or grandchildren) behind the boat on a tube?
- How long should the rope be?
- Under what conditions is it safe to sit in the rear seat?

The current study was intended to provide a better understanding of the CO exposures that occur on recreational boats and to identify the most hazardous conditions. Collection of environmental data was vital to this effort, by testing the variability between different kinds of boats, engines, and design features. These data will be used to develop mathematical models to more fully answer some of the above questions.

CO Poisonings Outside the Cabin Area of Recreational Boats (Non-houseboats)

At Lake Powell, since 1990, 3 deaths and 22 non-fatal poisonings have occurred outside of any enclosure on (non-houseboat) recreational boats, such as ski boats and cabin cruisers. The first person died while sitting in the driver's side transom seat, near the exhaust ports, while the boat pulled a personal watercraft at about 10 miles per hour (mph), for approximately 45 minutes. The second fatal poisoning was an 18-year-old ski-boat passenger who died while "teak surfing"— a common water activity where a passenger, grasping boat handles and resting their upper torso on the boat's teakwood platform, is pulled behind the speeding boat [McCammon et al. 2001]. In this case, after only one to two minutes, one of three teak surfers lost consciousness, sank beneath the surface, and died. An autopsy revealed a carboxyhemoglobin (COHb) level of 57%, and NIOSH calculated that his exposure ranged from 9,000 to 27,000 parts per million (ppm). The third fatal poisoning was a 9-year-old girl playing in shallow water, at the rear of a cabin cruiser, near the terminus of the exhaust of a gasoline-powered 5 kW generator [McCammon et al. 2002].

Another fatal poisoning occurred in a recreational boat, which had a cockpit enclosed by a canvas roof and side walls, but was open at the back. The victim was driving this boat and towing a second. After an estimated 10-30 minutes, all four occupants lost consciousness. The boat eventually beached itself and the engine stopped upon running out of gas, and twelve hours later, the three passengers awoke to find the driver dead. Autopsy results indicated that the COHb concentration for the victim was 53%.

Of the 21 non-fatal CO poisonings occurring outside the cabin area of recreational boats, 11 resulted in loss of consciousness. All but 1 of the 22 outdoor recreational boat poisonings were associated with exposures to emissions from gasoline-powered propulsion engines: 10 passengers were riding in the back of a moving boat; 4 were in a boat being towed by another boat; 3 were teak surfing (2 of these involved the teak surfing fatality described above); 1 lost consciousness as he occupied the swim platform; 1 was on the swim platform playing with a shower device that drew water from the operating propulsion engine; and 2 were in the water. Exposure duration was documented for 14 of these cases: 3 were exposed to engine exhaust for less than 10 minutes; 5 were exposed for 10 to 60 minutes; and 6 were exposed for greater than 60 minutes.

On other bodies of water, 38 boat-related CO poisonings (18 fatal and 20 non-fatal) have been reported outside the cabin area of recreational boats (non-houseboat). Investigative and/or medical records were obtained for 37 of these cases. Four of the outdoor poisonings occurred on or near cabin-cruisers and 32 occurred on or near ski boats. Twenty-three of the 38 poisonings occurred while the boat was underway (again, outside any enclosure), and 12 occurred while the boat was stationary. Twenty-seven of these 38 poisonings were related to occupancy of the swim platform or swim step at the rear of the boat. Five of these people were swimming behind stationary recreational boats when poisoned, and six were seated on the transoms or in the rear seats of the boats.

CO Poisonings Inside the Cabin Area of Recreational Boats (Non-houseboats)

Indoor CO poisonings have long been recognized as a problem on boats and in automobiles and buildings. Since 1990, a total of 84 CO poisonings have been reported as occurring inside the enclosed cabin area of recreational boats. Seventeen of these poisonings resulted in death (1 at Lake Powell and 16 on other bodies of water). Nineteen non-fatal poisonings inside recreational boats at Lake Powell and 48 on other bodies of water have been reported. The U.S. Coast Guard has records of additional watercraft indoor poisonings in their database.

Carbon Monoxide Symptoms and Exposure Limits

CO is a lethal poison, produced when fuels such as gasoline or propane are burned. It is one of many chemicals found in the exhaust from internal combustion engines, which results from incomplete combustion. Because CO is a colorless, odorless, and tasteless gas, it may overcome the exposed person without warning. 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 can occur without other symptoms. Coma or death may occur if high exposures continue [NIOSH 1972; NIOSH 1977a; NIOSH 1977b]. 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 [Hathaway et al 1996; ACGIH 2001; NIOSH 2002].

Exposure to CO limits the ability of blood to carry oxygen to tissues because it binds with hemoglobin to form 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 [Forbes et al. 1945].

Although NIOSH typically focuses on occupational safety and health issues, the Institute is a public health agency, and cannot ignore the overlapping exposure concerns between marine workers and boat passengers in this type of setting. NIOSH researchers have done a considerable amount of work related to controlling CO exposures in the past [NIOSH 1996; Earnest et al. 1997; Kovein et al. 1998].

Exposure Criteria

Occupational criteria for CO exposure are applicable to U.S. National Park Service (USNPS) and concessionaire employees who have been shown to be at risk of boat-related CO poisoning. The occupational exposure limits noted below should not be used for interpreting general population exposures (such as visitors engaged in boating activities) because occupational standards do not provide the same degree of protection to the general public as they do for the healthy worker population. The effects of CO are more pronounced in a shorter time if the exposed individual is physically active, very young, very old, or has preexisting health conditions such as lung or heart disease. Persons at extremes of age and those with underlying health conditions may have marked symptoms and may suffer serious complications at lower levels of carboxyhemoglobin.

Standards relevant to the general population take these factors into consideration, and are listed following the occupational exposure limits.

The NIOSH Recommended Exposure Limit (REL) for occupational exposures to CO gas in air is 35 parts per million (ppm) for full shift time-weighted average (TWA) exposure, and a ceiling limit of 200 ppm, which should never be exceeded [CDC 1988]. The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5% [Kales 1993]. NIOSH has established the immediately dangerous to life and health (IDLH) value for CO as 1,200 ppm [NIOSH 2002]. The American Conference of Governmental Industrial Hygienists (ACGIH®) recommends an 8-hour TWA threshold limit value (TLV®) for occupational exposures of 25 ppm [ACGIH 2001] and discourages exposures above 125 ppm for more than 30 minutes during a workday. The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for CO is 50 ppm for an 8-hour TWA exposure [29 CFR 1910.1000 (1997)].

Health Criteria Relevant to the General Public

The U.S. Environmental Protection Agency (EPA) has promulgated a National Ambient Air Quality Standard (NAAQS) for CO. This standard requires that ambient air contain no more than 9 ppm CO for an 8-hour TWA, and 35 ppm for a 1-hour average [EPA 2003]. The NAAQS for CO was established to protect "the most sensitive members of the general population" by maintaining increases in carboyhemoglobin to less than 2.1%.

The World Health Organization (WHO) have recommended guideline values and periods of time-weighted average exposures related to CO exposure in the general population [WHO 2000]. WHO guidelines are intended to ensure that COHb levels do not exceed 2.5% when a normal subject engages in light or moderate exercise. Those guidelines are:

- 100 mg/m^3 (87 ppm) for 15 minutes
- 60 mg/m^3 (52 ppm) for 30 minutes
- 30 mg/m^3 (26 ppm) for 1 hour
- 10 mg/m^3 (9 ppm) for 8 hours

METHODS

NIOSH investigators conducted air sampling for CO and made wind velocity measurements on 16 different recreational boats on May 13-16, 2002. The boats evaluated were built by several manufacturers, including Malibu Boats, Crownline Boats, Thunderbird Products, Silverton Marine, Bombardier Recreational Products, Carver Boat, and Sea Ray Boats. The boats ranged in age from new to 13 years old. Drive engines and generators on the boats also had a wide range of ages. Drive engines used on the evaluated boats were manufactured by Chevrolet, Mercury Marine, Volvo, and others. The five evaluated cabin cruisers and one of the sport cruisers also had generator sets. The generators were manufactured by Kohler and Quicksilver. Data were collected to evaluate the CO emitted by the engines and to evaluate CO exposures on and near the boats, operating under various conditions.

Brief descriptions of the boats and their drive engines and generators are provided below.

Description of the Recreational Boats Evaluated

1. **Boat:** Malibu Escape, Malibu Boats, Merced, CA
   23 LSV (luxury sport vee)
   Engine: Chevrolet Monsoon 350 CID
   Approximate dimensions: 22'6" long, 7'6" wide

2. **Boat:** Crownline Model 225 BR, Crownline Boats, Inc. West Frankfort, IL
   22 ft bowrider
   Engine: Mercruiser Model MCM 5.7L (350 CID) EFI V-8
   Approximate dimensions: 22'5" long, 8'6" wide

3. **Boat:** Formula 41 PC, Thunderbird Products, Decatur, IN
   41 ft cabin cruiser
   Engine: Two Mercruiser 502 CID
   Approximate dimensions: 43'1" long, 13'6" wide
   Generator: 7.3 kW Kohler with ECD

4. **Boat:** Silverton 410 Sport, Silverton Marine, Millville, NJ
   Sport Bridge Cabin Cruiser
   Engine: Twin 8.1L MPI/425 HP Crusader
   Approximate dimensions:46'3" long, 14'3" wide
   Generator: 7.3 kW Kohler

5. **Boat:** Formula 370 SS, Thunderbird Products, Decatur, IN
   37 ft Sports Cruiser
   Engine: Twin 496 CID Mercruiser FI
   Approximate dimensions: 37'1" long, 10'9" wide
   Generator: 7.3 kW Kohler

6. **Boat:** Formula Fas^{3}tech 312, Thunderbird Products, Decatur, IN
   31 ft Sports Cruiser
   Engine: Twin 350 CID Mercruiser MPI
   Approximate dimensions: 31'2" long, 8'3" wide

7. **Boat:** Formula 260 SS, Thunderbird Products, Decatur, IN
   26 ft sport cruiser
   Engine: 6.2 L Mercruiser MPI
   Approximate dimensions: 26' long, 8'6" wide

8. **Boat:** Crownline 270, Crownline Boats, Inc.,West Frankfort, IL
   26 ft bowrider
   Engine: 8.1 L GI Volvo Penta
   Approximate dimensions: 26'1" long, 8'6" wide

9. **Boat:** Bombardier Seadoo, Bombardier Recreational Products
   Personal water craft
   Engine: unknown

10. **Boat:** Crownline 239 DB, Crownline Boats, Inc., West Frankfort, IL
    23 ft deckboat
    Engine: 5.0 L Mercruiser Fuel Injected
    Approximate dimensions: 23'9" long, 8'6" wide

11. **Boat:** Malibu Sunsetter, Malibu Boats, Merced, CA
    21 ft SV (sport vee)
    Engine: Malibu Vortec 310 hp carbureted
    Approximate dimensions: 21' long, 7'9" wide

12. **Boat:** Formula 280 BR, Thunderbird Products, Decatur, IN
    28 ft bowrider
    Engine: two 5.7 L Volvo Penta GSI
    Approximate dimensions: 28' long, 9'2" wide

13. **Boat:** Malibu Wakesetter, Malibu Boats, Merced, CA
    21 ft SV (sport vee)
    Engine: Chevy Vortec Monsoon 350 CID
    Approximate dimensions: 21' long, 7'9" wide

14. **Boat:** Carver 3395 Mariner, Carver Boat Corporation, LLC
    Cabin Cruiser
    Engine: twin 350 CID OMC engines
    Generator: Kohler

15. **Boat:** 1990 SeaRay Sundancer 310, Sea Ray Boats, Inc., Knoxville, TN
    33 ft Cabin Cruiser
    Engine: Twin Mercury 350 cu in
    Generator: Quicksilver 5 kW

16. **Boat:** Malibu Sunsetter, Malibu Boats, Merced, CA
    with transom shower (same as 11)

Two primary differences between automobile engines and marine engines used in recrea are related to the cooling and exhaust systems. The cooling system in an automobile en closed loop, with an air-to-water radiator. In contrast, marine engines are open-loop, dra lake water into the engine's water pump. The second major difference between automol marine engines is that marine engines use water-cooled exhaust manifolds to mix water gases for cooling. The objective is to keep all surface temperatures within the boat belo contrast, automobile engines do not add water to the engine exhaust.

For the boats that had generators, the hot exhaust gases from the generators were typically injected with water near the end of the exhaust manifold in a process commonly called "water-jacketing." Water-jacketing is used for exhaust cooling and noise reduction. Because the generator sits below the waterline, the water-jacketed exhaust passed through a lift muffler that further reduced noise and forced the exhaust gases and water up and out through a hole near the stern of the vessel.

Description of the Evaluation Equipment

Emissions from the generator and drive engines were characterized using a Ferret Instruments (Cheboygan, MI) Gaslink LT Five Gas Emissions Analyzer and a KAL Equipment (Cleveland, Ohio) Model 5000 Four Gas Emissions Analyzer. Both analyzers measure CO, carbon dioxide (CO_2), hydrocarbons, and oxygen. The five gas analyzer also measures nitrogen oxides (NO_x). All measurements are expressed as percentages except hydrocarbons and NO_x which are presented in parts per million (ppm). [One percent of contaminant is equivalent to 10,000 ppm.]

CO concentrations were measured at various locations on the boats using ToxiUltra Atmospheric Monitors (Biosystems, Middletown, CT) with CO sensors. The ToxiUltra CO monitors were calibrated before and after 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 999 ppm.

CO concentrations were also measured with detector tubes (Draeger A.G.,Lubeck, Germany) in the vicinity of the drive engine and/or generator exhaust outlet. 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 a sorbent in the tube) is proportional to the concentration of the contaminant in the air sample.

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 then 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.

Wind velocity measurements were collected when the boats were stationary using ultrasonic anemometers: 3D Anemometer Model 1210R3 and 2D Anemometer Model 1390 (Gill Instruments Ltd., Hampshire, U.K.). Measurements of air velocity with respect to the boat were made when the boats were underway using the same instruments. These instruments use a basic time-of-flight operating principle that depends upon the dimensions and geometry of an array of transducers. Transducer pairs alternately transmit and receive pulses of high frequency ultrasound. The time-of-flight of the ultrasonic waves are measured and recorded, and this time is used to calculate wind velocities. Hand-held multi-directional impeller wind meters were also used during the survey. (Skywatch Meteos, JDC Electronic SA, Yverdon-les-Bains, Switzerland).

Description of Procedures

Evaluations were conducted on various boats and involved teams of two or three people. Each team also included a person from the collaborating organization to steer the boats, start the engines, and provide mechanical assistance when necessary. Evaluations were conducted over several days. Following each day of data collection, NIOSH researchers downloaded data and recalibrated instruments. Two to four boats were typically evaluated per day. For small ski boats, evaluations were fairly quick and required only one or two hours. For larger cabin cruisers equipped with a generator and drive engines, evaluations required more time. Most of the evaluations included both stationary and underway conditions. During the evaluations of the larger boats the generator alone was operated for approximately 30 minutes, followed by both drive engines and the generator in an operating mode for another 15 minutes. Cold start emissions were also evaluated during the stationary tests.

Boat emissions were evaluated while underway at three or four different speeds. These data are particularly important for ski boats and other boats that pull people in the water. Boat speeds typically included idle speed, one or two midrange speeds, and open throttle. Boat speed was measured using a global positioning system (GPS) receiver (Meridian Marine, model 980598-04, Magellan Consumer Products, Thales Navigation, Santa Clara, CA). When boats were underway, the North heading on the wind monitors were pointed to the front of the boat. With this orientation they measured wind speed over the bow when the boat moved forward and there was no cross-wind. The ToxiUltra CO monitors were placed at various locations on the boats (typically three across the stern or swim platform, placed starboard, port, and amidships; two in the cockpit, starboard and port, and one near the driver's seat). These positions were selected to collect representative samples at locations where people might be seated while a boat is underway, and because emissions typically originate in the stern. In addition, 3 or 4 monitors were attached to a telescoping rod at intervals of approximately 2 feet and held over the water by a NIOSH investigator seated in the stern of the boat, so that the outermost monitor was approximately 12 feet behind the boat. Monitors over the water were partially wrapped in plastic to protect them from the water. The emissions analyzer was used to measure high CO concentrations near the boats' sterns.

RESULTS

Results of Air Sampling with ToxiUltra CO Monitors

Summary statistics for the data collected with the Toxiultra CO monitors is shown in Tables 1 through 23 of the Appendix. These tables are organized so that the sample location is designated along the left-hand column and the operating conditions are listed across the top row. For each sample location and condition a CO mean, standard deviation, sample number and peak concentration is reported. The values in the tables are rounded to the nearest whole number. Carbon monoxide concentrations exceeding 1,000 ppm in Tables 1 through 23 of the Appendix indicate that the upper limit of the ToxiUltra monitor's range was reached and the exact CO concentration and duration of exposure at that level are uncertain.

ToxiUltra CO Samples while the Boats were Stationary

Carbon monoxide concentrations measured on stationary boats were generally high. Peak CO concentrations commonly reached and exceeded the upper limit of the ToxiUltra CO monitor's range of 1,000 ppm. The mean CO concentrations measured near the stern of many boats ranged from 500 to 1,000 ppm.

Carbon monoxide concentrations measured inside stationary boats were much lower than those measured near the stern. One of the most dramatic differences was found on the Formula 370 SS (Appendix, Table 2). Although mean CO concentrations measured on the lower rear deck of the Formula 370 SS ranged from approximately 90 to 140 ppm at 1800 rpm, the mean CO concentrations measured in the interior of the boat were 15 ppm or less. Several of the boats had mean CO concentrations measured at interior locations of less than 20 ppm. There were a few boats that had higher interior concentrations. For example, the Crownline 225 BR (Appendix, Table 7) had mean CO concentrations of 104-179 ppm at the driver's seat with the engine running.

ToxiUltra CO Samples while the Boat was Underway

Air sampling data were collected while the boats were underway, resulting in generally lower concentrations than those measured while the boats were stationary. CO concentrations measured on the boats tended to fall as the boats began to move and the speed increased. CO concentrations were measured in three areas:

- On or near the rear deck of the boat
- Inside the boat
- On a pole at various distances 8 to 12 feet behind the boat

CO concentrations measured on or near the sterns and rear decks of the boats were considerably higher than those measured either on the pole behind the boat or inside of the boat. For example, the Carver 3395 Mariner Cabin Cruiser with twin 350 CID OMC engines (Appendix, Table 13) had mean CO concentrations near the rear deck of at least 1,100 ppm at a speed of approximately 20 miles per hour. These values compare to CO concentrations ranging from 184 to 211 ppm 8 to 12 feet behind the boat and 2 to 27 ppm at the interior of the boat. Under most conditions, it appears that the concentrations measured eight to twelve feet behind the boat were slightly higher than the CO concentrations measured inside the boat.

As boat speeds increased, CO concentrations at all locations tended to fall. However, this observed trend did not occur all of the time, as can be seen by closely examining the Tables in the Appendix. A summary of average CO concentrations for four different boats is provided in Figures 1 through 4. These figures present average carbon monoxide concentrations at various loactions and speeds for the Formula 370 SS, Crownline 270, Formula 260 SS, and Malibu Escape, respectively. Review of these tables and figures reveal several trends.

- Mean CO concentrations are typically highest across a boat's stern.
- Mean CO concentrations measured behind the boat and inside the boat are much less than those at the stern.
- Mean CO concentrations measured at all locations fall as the velocity of the boat increases.

Gas Emissions Analyzer, Detector Tubes, and Evacuated Container Results

Gas emissions analyzers, detector tubes, and glass evacuated containers were primarily used to characterize CO concentrations in and near the exhaust. These instruments were used because they are capable of reading higher CO concentrations than the ToxiUltra CO monitors, which have an upper limit of approximately 1,000 ppm. Because of the exhaust configurations on the evaluated boats (below or near the waterline in constricted areas), measurements were not made directly in the engine exhaust. Instead, samples with these instruments were collected as close to the engine exhaust as practical. The inlet to the emissions analyzer was typically secured to the outboard edge at the center of the rear deck or swim platform. Detector tube and evacuated container samples were collected at the same point. Differences between detector tube results and evacuated container results in Table 1 may be due to spatial or temporal differences when the samples were collected, differences in the accuracy of the methods, or the fact that the evacuated container is an instantaneous sample, while the detector tubes require about one minute per pump stroke to collect a sample.

Summaries of the detector tube and evacuated container air sampling results are shown in Table 1. Table 1 shows that CO varied greatly depending upon location and operating condition. Several measurements made while the boats were stationary were in excess of the IDLH limit of 1,200 ppm. For example, a concentration of 2300 ppm was measured behind the Formula Fas^{3}tech 312, equipped with twin 350 CID Mercruiser MPI engines, while it moved at 12 mph.

Data collected with the emissions analyzers indicated that in general, CO concentrations were fairly high during cold starts, and began to fall after a few minutes of engine operation. Underway measurements varied widely.

Wind Velocity Measurements

Difficulties with the ultrasonic anemometers preclude reporting all of their results. Data were also gathered with the hand-held wind meters while the boats were stationary and underway. The boats were oriented in a variety of directions depending upon the day and time.

DISCUSSION

The current study has shown that hazardous CO concentrations occur on and near many U.S. recreational boat models and makes. This problem results from both old and new boats and engines. CO concentrations, as measured by three separate methods (i.e., real-time instruments, evacuated containers, and detector tubes), indicated concentrations approaching or exceeding the NIOSH IDLH value of 1,200 ppm for many boats. These high CO exposures are affecting the boating public, too, rather than being limited to just healthy adult marina workers. The general public, including young children and the elderly, may be more susceptible to CO health risks than the typical worker. In addition, many of these exposures occur to people who are in the water, where the combination of dangerously high CO concentrations with a potential for drowning compounds the risk. Exposures to high CO concentrations on recreational boats are the result of many factors, including an individual's location, type and make of boat, relative wind speeds, engine size and design, and the influence EPA regulations have had on engine designs. Many of these issues are discussed in more detail below.

Sample Location, Boat Speed, and Wind Conditions

CO concentrations are highest during cold starts and during operation of gasoline-powered engines when the boat is stationary. At these two times in particular, people swimming or located near an exhaust terminus of an operating drive engine or generator can potentially experience CO poisoning, possibly leading to death. In general, high CO emissions from gasoline-powered generators cause the most concern because they frequently are operated while boats are stationary. Drive engines are less problematic because they usually operate while boats are moving and, thus, individuals avoid getting near the operating drive engines for fear of a propellor strike. These reasons may explain why much of the initial surveillance and epidemiological CO poisoning data have involved houseboats. Many houseboats have fairly large gasoline-powered generators. Similarly, many cabin cruisers also have gasoline-powered generators.

For any given engine under stationary conditions, measured CO concentrations were directly related to the CO sensor's proximity to the engine's exhaust. CO concentrations near the boat's stern were typically the highest, and the CO concentrations measured inside the boat and on the pole behind the boat were substantially lower. On a calm day, proximity to the exhaust terminus is the critical factor influencing exposure levels. As the wind speed increases, CO exposures on or near the boat tend to fall. The one notable exception to this rule can occur if a slight, sustained tailwind blows engine exhaust directly toward individuals on or near the boat. Among other factors that may influence CO concentrations near the stern of the boat are the size and shape of the boat, location of exhaust terminus, and the presence of people or other objects in the area directly behind the boat, such "teak surfers," whose bodies affect air flow around the stern.

The CO data for boats underway show that hazardous exposures may occur under certain conditions. For example, if a boat is operated at 5 mph or less, fairly high CO exposures (near the NIOSH ceiling of 200 ppm) can occur within 10 ft of the boat's stern. These results are produced by circumstances similar to those found during an engine cold start or idling. Typically, as the speed of a boat increases, the CO exposures decrease.

Our research showed that as a boat's speed increased, the CO sensors (which represented the potential exposures for people on a boat or participating in water sports behind a boat) were exposed to the highest CO concentrations for a shorter period. At speeds of 20 mph or more, individuals at the bow (front) of the boat are not likely to be exposed to any CO while individuals near the stern or behind the boat may be exposed to high CO concentrations but for less time. Individuals near the stern of the boat can be exposed to hazardous CO concentrations during such activities as teak-surfing or wake boarding. Generally, the closer the individual's breathing zone is to the engine exhaust and the slower the boat's speed, the more potentially hazardous the situation becomes. This is due in part to the boat's slow operating speed creating exhaust eddies (circular movements of air) which may cause high CO concentrations to recirculate behind the moving boat..

Wind conditions are also important because CO exposures tend to decrease as wind speeds increase. For a boat underway, induced wind and ambient wind are additive. In the current study, the additive effect was accounted for by measuring the relative wind velocity on the boat. For example, when a boat moves at 10 mph under completely calm wind conditions, the relative wind is approximately 10 mph from the bow toward the stern. If a boat moves at 10 mph into a head wind of 5 mph because the effect is additive, the relative wind condition is 15 mph. Under this condition, the two wind effects, (ambient and induced) tend to reduce CO exposures. However, if a boat moved at 10 mph under a tail wind of 8 mph, the relative wind condition would be just 2 mph toward the stern of the boat. For this scenario, the ambient tail wind would tend to increase the CO exposure as compared to the same condition with no ambient wind. The data for this study show that for all of the underway tests, the average relative wind velocity was toward the rear of the boat. Similarly, in most of the test conditions, the average relative wind velocity was greater than the boat speed indicating that the wind tended to reduce CO exposures.

Engine design

When large gasoline-powered engines operate as designed and have no catalytic converter or other pollution control devices, dangerously high CO concentrations are commonly emitted into the atmosphere. Exhaust gases released from a gasoline engine may contain from 0.1% to 10% CO (1,000 to 100,000 ppm). Engines operating at full-rated hp produce exhaust gases having approximately 0.3% CO (3,000 ppm) [Heywood 1988].

The relative CO concentrations produced by gasoline-powered engines depend upon engine design, operating conditions, and most importantly the fuel/air equivalence ratio [Plog et al. 1988]. The fuel/air equivalence ratio is the actual fuel to air ratio, divided by the stoichiometric fuel to air ratio. Generally, an engine running rich will tend to produce higher concentrations of CO than the same engine running lean. Simeone predicted CO concentrations exhausted from marine engines as a function of air inlet and several other parameters [Simeone 1990]. Any restrictions that may exist on air inlets and exhaust ports for marine engines can potentially increase CO concentrations in the exhaust. As observed in this study, many factors influence the CO concentration exhausting from an engine.

Environmental Protection Agency Regulations

Environmental Protection Agency (EPA) regulations for recreational boat drive engines and generators were intended to control hydrocarbon and nitrous oxide emissions rather than CO. The EPA estimates that recreational marine engines contribute the second highest average quantity of hydrocarbon exhaust emission only behind lawn and garden equipment [EPA 1996]. Under the Clean Air Act, EPA regulations apply specifically to new engines, rather than to the millions of engines currently used on U.S. recreational boats.

EPA regulations for the recreational boating industry can be divided into three categories:

1. Regulations for outboard spark-ignition marine engines and personal watercraft
2. Regulations for inboard and stern drive engines
3. Regulations for large (>19 kW) and small (<19 kW) generators

EPA regulations that apply to outboard spark-ignition marine engines and personal watercraft were passed in 1996 under 40 CFR, Part 91. This regulation is currently being phased in between 1998 and 2006. It is intended to reduce hydrocarbon and nitrous oxide emissions by a factor of four. Although this regulation is not directed at CO, the current evaluation shows that there are CO benefits. The primary emission reduction technologies under this regulation are replacement of conventional two-stroke engines by four-stroke engines, or by electronic direct fuel-injected two-stroke engines.

The other class of recreational boat drive engines are the inboard and stern-drive spark-ignition engines. EPA has recently published a notice to regulate inboard and stern-drive marine engines. These engines are often larger than outboard engines and have much higher horsepowers. Many of these types of engines have automotive origins. Inboard and stern drive engines could potentially reduce emissions by using feedback electronic air-fuel control, electronically controlled exhaust gas recirculation, and three-way catalytic converters. The Southwest Research Institute is currently conducting work in this area for the EPA.

The final class of engines that are used on recreational boats are generators. Generators are not addressed under Marine engine rules. Rather they fall under small equipment and large spark-ignition rules, depending upon their size. Large generators are classified as those producing 25-hp or 19-kW or more. These regulations become effective by 2004 and require catalysts to control hydrocarbons and nitrous oxides, requiring a 95% reduction in CO by 2007. All of the generators evaluated during the NIOSH field surveys for recreational boats were smaller than 19-kW, thus falling under small equipment rules, which are directed at residential lawn and garden tools. Because these rules are primarily concerned with hydrocarbon emissions, CO has not been an issue. Today, it is common to see new, large gasoline-powered generators, which produce 5 grams of CO per kilowatt-hour (kWh) and small gasoline-powered generators, having a mass CO production rate that is 100 times greater (500 grams of CO per kWh). The CO cap, which shall not be exceeded, for small equipment under EPA regulations is 610 grams of CO per kWh. The differences in CO emission rates between large and small gasoline-powered generators is primarily related to economic issues and industry concerns rather than technological feasibility.

CONCLUSIONS AND RECOMMENDATIONS

This study showed that stationary operations and operating at speeds less that 5mph near the stern of the boat appear to be most hazardous. The data collected show that nearly 90% of the evaluated boat engines produced hazardous CO concentrations, and CO poisoning could occur. The following recommendations are provided to reduce CO concentrations on and around recreational boats, particularly in the stern area, and provide a safer and healthier environment to boaters:

1) All manufacturers/owners/users of recreational boats with gasoline-powered engines should be aware of and concerned about the potential for CO poisoning. There are approximately 17 million recreational boats used in the United States, and based upon the

results of current and previous NIOSH studies, it is very likely that many of these gasoline-powered engines produce hazardous CO concentrations. The data collected in the current evaluation show that nearly 90% of the evaluated boat engines produced hazardous CO concentrations, and CO poisonings could occur from use of these engines under certain conditions.

2) Additional work should be conducted using the data collected during this survey and computational fluid dynamics modeling to identify the most hazardous conditions. Stationary operations and operating at speeds less than 5 mph near the stern of the boat appear to be most hazardous. A model could potentially be developed to more clearly define how the various factors such as engine type and size, boat speed, distance behind boat, and relative wind conditions interrelate.

3) The role of engineering control technologies to prevent CO poisonings on marine vessels should continue to be investigated. Previous studies have shown that CO hazards from houseboat generators can be reduced by engineering control systems [Dunn et al. 2001a; Dunn et al. 2001b; Earnest et al. 2001]. For example, the vertical stack, emission control devices (ECD), or other types of ventilation options for generator exhaust could potentially be applied to cabin cruisers. Boat manufacturers should investigate whether engineering control systems used to control CO on houseboats could be effectively used for other types of recreational boats.

4) The role of cleaner burning engines and emission control technologies in reducing the CO hazard should be more fully investigated. It is clear from data gathered in the current study on modern outboard engines that cleaner burning engines, which comply with EPA regulations, will reduce CO concentrations and exposures. This ongoing NIOSH-Coast Guard partnership is evaluating the long-term performance of ECDs to reduce CO emissions. Engineers from the Southwest Research Institute are studying catalytic converter technologies to reduce CO emissions from inboard and stern-drive engines. Each of these technologies should be considered as a possible way to reduce the CO hazard on recreational boats.

5) Governmental and consensus standard setting bodies should carefully examine existing standards to determine if they adequately address the potential CO hazard from many types of recreational boats. For example, the EPA has an existing standard that is being phased in for outboard marine engines. The outboard marine engine standard will substantially reduce engine emissions. EPA personnel should evaluate how their existing and future standards for inboard marine engines and small marine generators can best address the CO poisoning problem. Similarly, the American Boat and Yacht Council (ABYC) has recently modified their standard for acceptable exhausting from marine engines to include a vertical exhaust stack. Attention should be given to whether or not ABYC standards could adequately apply to other types of recreational boats in reducing the potential CO hazard.

7) The educational campaign related to CO and houseboats should continue and expand to include other types of recreational boats and boat-related CO hazards. These materials may include warning signs, hand-out materials, newspaper articles, videos, and public service announcements, as described in previous NIOSH Health Hazard Evaluation Reports on CO

poisonings and recreational boats. Public education efforts should be continued to inform and warn all individuals (including boat owners, renters, and workers) of potential exposures to CO hazards. The U.S. National Park Service has launched an awareness campaign to inform boaters on their lakes 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 checkout training provided users of concessionaire rental boats. These and other educational materials are available at the following web site: http://safetynet.smis.doi.gov/COhouseboats.htm.

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Table 1. Evacuated Container and Detector Tube Results for Boats Evaluated on Lake Norman

Evaluated Boat	Location and Circumstances	Carbon Monoxide Concentration	
		Evacuated Container (ppm)	Detector Tube
Malibu Escape	Near exhaust, cold start	1100	0.6%
Malibu Escape	Near exhaust, after running 7 minutes	219	0.5%
Malibu Escape	Near exhaust, rev engine to ~2000 rpm	3000	0.5%
Crownline 225 BR	Cold start 600 rpm	427	0.3-0.5%
Malibu Sunsetter	Cold start drive engines	147	0.5%
Formula 280 BR	Cold start drive engines	762	0.3%
Crownline 270	Nine minutes after cold start of drive engines	9900	100-200 ppm
Formula 41 PC	Moving at 2.6 mph	64	500 ppm
Crownline 270	Cold start drive engines	3	2500 ppm
Crwonline 239 DB	Cold start drive engines	nd	0.5%
Crownline 225 BR	engine at ~2600 rpm	201	≤0.3%
Silverton 410 Sport	generator (under load) cold start	1000	trace, 0.1% after 20 minutes
Formula 370 SS	generator cold start (very windy), samples at generator exhaust	13	nd high range, 150 ppm on low range tube
Formula 41 PC	12" from generator exhaust after 5 running minutes	nd	0
Formula 41 PC	generator cold start 12" from exhaust	123	0.3%

Formula 41 PC	Engine cold start	6100	1.0% 0.3% after 3 minutes
Formula Fas3tech 312	Underway at 12 mph, sampled near exhaust	2300	1000 ppm
Formula 260 SS	Cold start drive engines	6600	1200 ppm 1 minute after start, ~2000 ppm at 2000 rpm, 500 ppm at 3000 rpm
Carver 3395 Mariner Cabin Cruiser	Cold start drive engines	1000	0.5%
Formula 280	Cold start drive engines 4mph	9200	0.5% 0.3%
Malibu Wakesetter	Cold start drive engines	889	0.3%
Malibu Sunsetter	10 mph	nd	0.2%
Malibu Sunsetter	Idling, sampled at forward edge of swim deck	2700	150 ppm
Crownline 239 DB	25 mph	9	10 ppm
Formula 260 SS	Cold start drive engines 5 mph	3300	0.5% 100 ppm
Malibu Escape	Cold start drive engines 20 mph	429	1000 ppm nd
Searay Sundancer 310	Cold start generator	3	2600
Formula 370 SS	Cold start drive engines, generator off, sampled at lower exhaust	nd	0.2%
Formula 370 SS	Switch to top exhaust, sample at top exhaust	487	~0.3%
Formula Fas^{3}tech 312	Cold start drive engines, sample at exhaust	13	0.1% ~ 0.1% after six minutes, 1.2% at ~2,000 rpm

Formula 370 SS	Top exhaust, engines at 1800 rpm	1100	nd high range 100 ppm on low range tube
Searay Sundancer 310	Port engine cold start	5	0.5%
Searay Sundancer 310	Starboard engine cold start	6	
Searay Sundancer 310	Engines off, generator on, sampled off starboard swim deck	1800	25 ppm
Formula 370 SS	Underway at 5 mph, sampled off back of transom	4600	0.3% 0.2 % at 10 mph 500 ppm at 15 mph switch to top exhaust, 160 ppm at 10 mph
Silverton 410 Sport	Underway at 10 mph, sampled off center of transom.	1000	100 ppm 200 ppm at 18 mph
Crownline 270	Underway at 10 mph, sampled over transom	16	100 ppm 200 ppm at 5 mph nd at 15 mph <10 ppm at 25 mph
Crownline 239 DB	Underway at 5 mph	16	300 ppm

Table 2 - Formula 260 SS, Carbon Monoxide (ppm)

	Drive Engines Idling		RPM = 2000		RPM = 3000	
L1	Mean	262	Mean	268	Mean	64
Back Deck Port	Std dev	164	Std dev	188	Std dev	80
	Samples	43	Samples	48	Samples	19
	Peak	823	Peak	780	Peak	261
L2	Mean	532	Mean	714	Mean	454
Back Deck Center	Std dev	257	Std dev	299	Std dev	198
	Samples	43	Samples	48	Samples	19
	Peak	1283	Peak	1361	Peak	877
L3	Mean	400	Mean	584	Mean	360
Back Deck	Std dev	285	Std dev	238	Std dev	122
Starboard	Samples	43	Samples	48	Samples	19
	Peak	973	Peak	1359	Peak	561
L4	Mean	28	Mean	13	Mean	3
Interior Seat Port	Std dev	22	Std dev	15	Std dev	1
	Samples	43	Samples	48	Samples	19
	Peak	70	Peak	73	Peak	4
L5	Mean	27	Mean	15	Mean	6
Interior Seat	Std dev	21	Std dev	11	Std dev	3
Starboard	Samples	43	Samples	48	Samples	19
	Peak	83	Peak	48	Peak	18
L6	Mean	16	Mean	17	Mean	6
Front	Std dev	12	Std dev	15	Std dev	1
	Samples	43	Samples	48	Samples	19
	Peak	42	Peak	62	Peak	8

Table 3 - Formula 370 SS, Carbon Monoxide (ppm)

	Generator Running		Generator Off		Start Drive Engines	
L1	Mean	29	Mean	2	Mean	69
Back Deck Port	Std dev	36	Std dev	1	Std dev	129
	Samples	54	Samples	24	Samples	24
	Peak	131	Peak	2	Peak	488
L2	Mean	58	Mean	3	Mean	158
Back Deck Center	Std dev	60	Std dev	1	Std dev	164
	Samples	54	Samples	24	Samples	24
	Peak	243	Peak	6	Peak	621
L3	Mean	119	Mean	6	Mean	302
Back Deck	Std dev	103	Std dev	2	Std dev	146
Starboard	Samples	54	Samples	24	Samples	24
	Peak	435	Peak	10	Peak	586
L4	Mean	4	Mean	2	Mean	3
Interior Seat Port	Std dev	3	Std dev	1	Std dev	4
	Samples	54	Samples	24	Samples	24
	Peak	14	Peak	3	Peak	22
L5	Mean	5	Mean	3	Mean	5
Interior Seat	Std dev	3	Std dev	1	Std dev	3
Starboard	Samples	54	Samples	24	Samples	24
	Peak	18	Peak	5	Peak	18
L6	Mean	8	Mean	6	Mean	6
Front	Std dev	2	Std dev	0	Std dev	0
	Samples	54	Samples	24	Samples	24
	Peak	15	Peak	7	Peak	6

Table 3 (cont.) - Formula 370 SS, Carbon Monoxide Concentrations (ppm)

	Drive Engine Top Exhaust 1800 rpm		Drive Engine Top Exhaust Idle Speed	
L1	Mean	115	Mean	261
Back Deck Port	Std dev	84	Std dev	285
	Samples	36	Samples	24
	Peak	412	Peak	1049
L2	Mean	144	Mean	200
Back Deck Center	Std dev	189	Std dev	122
	Samples	36	Samples	24
	Peak	677	Peak	491
L3	Mean	91	Mean	326
Back Deck	Std dev	124	Std dev	408
Starboard	Samples	36	Samples	24
	Peak	488	Peak	1356
L4	Mean	8	Mean	23
Interior Seat Port	Std dev	4	Std dev	21
	Samples	36	Samples	24
	Peak	20	Peak	70
L5	Mean	15	Mean	35
Interior Seat	Std dev	12	Std dev	31
Starboard	Samples	36	Samples	24
	Peak	53	Peak	126
L6	Mean	12	Mean	23
Front	Std dev	6	Std dev	14
	Samples	36	Samples	24
	Peak	32	Peak	60

Table 4 - Formula 370 SS, Carbon Monoxide (ppm)

	Generator Idling		Start Drive Engines		5 mph		10 mph	
L1	Mean	79	Mean	1050	Mean	1022	Mean	1203
Back Deck Port	Std dev	66	Std dev	389	Std dev	375	Std dev	2
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	288	Peak	1209	Peak	1209	Peak	1207
L2	Mean	139	Mean	382	Mean	1213	Mean	1277
Back Deck Center	Std dev	145	Std dev	294	Std dev	300	Std dev	167
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	650	Peak	863	Peak	1327	Peak	1331
L3	Mean	230	Mean	488	Mean	1390	Mean	1427
Back Deck	Std dev	206	Std dev	461	Std dev	212	Std dev	2
Starboard	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	821	Peak	1432	Peak	1432	Peak	1431
L4	Mean	28	Mean	31	Mean	230	Mean	133
Interior Seat Port	Std dev	34	Std dev	17	Std dev	327	Std dev	109
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	136	Peak	63	Peak	1120	Peak	381
L5	Mean	55	Mean	29	Mean	252	Mean	38
Interior Seat	Std dev	59	Std dev	15	Std dev	261	Std dev	58
Starboard	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	255	Peak	63	Peak	1122	Peak	224
L6	Mean	16	Mean	12	Mean	49	Mean	22
Front	Std dev	13	Std dev	4	Std dev	52	Std dev	15
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	58	Peak	20	Peak	234	Peak	57
L7	Mean	21	Mean	21	Mean	121	Mean	85
8' Pole	Std dev	24	Std dev	10	Std dev	124	Std dev	31
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	93	Peak	41	Peak	500	Peak	154
L8	Mean	30	Mean	17	Mean	120	Mean	83
10' Pole	Std dev	33	Std dev	11	Std dev	114	Std dev	34
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	149	Peak	41	Peak	495	Peak	154
L9	Mean	43	Mean	18	Mean	114	Mean	80
12' pole	Std dev	40	Std dev	17	Std dev	98	Std dev	31
	Samples	66	Samples	13	Samples	72	Samples	78
	Peak	155	Peak	52	Peak	456	Peak	132

Table 4 (cont.) - Formula 370 SS, Carbon Monoxide (ppm)

	15 mph		20 mph		45 mph		10 mph	
L1	Mean	1209	Mean	1213	Mean	528	Mean	659
Back Deck Port	Std dev	1	Std dev	1	Std dev	317	Std dev	367
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	1212	Peak	1214	Peak	1215	Peak	1215
L2	Mean	649	Mean	186	Mean	290	Mean	551
Back Deck Center	Std dev	232	Std dev	91	Std dev	285	Std dev	435
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	1272	Peak	358	Peak	1335	Peak	1331
L3	Mean	875	Mean	623	Mean	609	Mean	616
Back Deck	Std dev	484	Std dev	558	Std dev	345	Std dev	532
Starboard	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	1435	Peak	1435	Peak	1439	Peak	1441
L4	Mean	30	Mean	4	Mean	3	Mean	44
Interior Seat Port	Std dev	19	Std dev	2	Std dev	2	Std dev	54
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	92	Peak	9	Peak	13	Peak	262
L5	Mean	24	Mean	4	Mean	26	Mean	74
Interior Seat	Std dev	62	Std dev	4	Std dev	37	Std dev	121
Starboard	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	287	Peak	21	Peak	139	Peak	471
L6	Mean	14	Mean	6	Mean	7	Mean	34
Front	Std dev	6	Std dev	1	Std dev	4	Std dev	52
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	37	Peak	8	Peak	19	Peak	220
L7	Mean	41	Mean	6	Mean	6	Mean	75
8' Pole	Std dev	19	Std dev	7	Std dev	4	Std dev	55
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	91	Peak	29	Peak	17	Peak	210
L8	Mean	40	Mean	2	Mean	8	Mean	83
10' Pole	Std dev	26	Std dev	3	Std dev	10	Std dev	67
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	121	Peak	10	Peak	47	Peak	230
L9	Mean	13	Mean	2	Mean	2	Mean	2
12' pole	Std dev	12	Std dev	1	Std dev	1	Std dev	0
	Samples	43	Samples	23	Samples	48	Samples	72
	Peak	43	Peak	3	Peak	3	Peak	3

Table 5 - Silverton 410 Sport, Carbon Monoxide (ppm)

	Generator Idling		Start Main Engines		Underway 1 - 2 mph		4 mph	
L1	Mean	6	Mean	208	Mean	127	Mean	148
Back Deck Port	Std dev	10	Std dev	377	Std dev	34	Std dev	59
	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	47	Peak	1223	Peak	218	Peak	281
L2	Mean	12	Mean	122	Mean	153	Mean	153
Back Deck Center	Std dev	16	Std dev	215	Std dev	58	Std dev	55
	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	61	Peak	677	Peak	286	Peak	302
L3	Mean	80	Mean	119	Mean	150	Mean	122
Back Deck	Std dev	102	Std dev	114	Std dev	46	Std dev	44
Starboard	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	405	Peak	386	Peak	252	Peak	226
L4	Mean	13	Mean	21	Mean	37	Mean	32
Interior Seat Port	Std dev	9	Std dev	19	Std dev	11	Std dev	11
	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	37	Peak	52	Peak	64	Peak	54
L5	Mean	32	Mean	40	Mean	8	Mean	15
Interior Seat	Std dev	18	Std dev	21	Std dev	6	Std dev	9
Starboard	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	83	Peak	74	Peak	28	Peak	40
L6	Mean	4	Mean	9	Mean	12	Mean	4
Front	Std dev	1	Std dev	6	Std dev	9	Std dev	2
	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	7	Peak	26	Peak	33	Peak	7
L7								
8' Pole								
L8	Mean	1	Mean	18	Mean	39	Mean	87
10' Pole	Std dev	2	Std dev	18	Std dev	16	Std dev	54
	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	11	Peak	66	Peak	68	Peak	246
L9	Mean	3	Mean	20	Mean	47	Mean	107
12' pole	Std dev	1	Std dev	14	Std dev	19	Std dev	54
	Samples	54	Samples	18	Samples	30	Samples	36
	Peak	7	Peak	45	Peak	88	Peak	219

Table 5 (cont.) - Silverton 410 Sport, Carbon Monoxide (ppm)

	10 mph		18 mph		25 mph	
L1	Mean	532	Mean	462	Mean	339
Back Deck Port	Std dev	225	Std dev	211	Std dev	143
	Samples	78	Samples	96	Samples	48
	Peak	865	Peak	1121	Peak	777
L2	Mean	621	Mean	392	Mean	343
Back Deck Center	Std dev	260	Std dev	280	Std dev	123
	Samples	78	Samples	96	Samples	48
	Peak	1141	Peak	1340	Peak	887
L3	Mean	551	Mean	409	Mean	529
Back Deck	Std dev	215	Std dev	359	Std dev	111
Starboard	Samples	78	Samples	96	Samples	48
	Peak	962	Peak	1449	Peak	933
L4	Mean	73	Mean	126	Mean	79
Interior Seat Port	Std dev	39	Std dev	46	Std dev	18
	Samples	78	Samples	96	Samples	48
	Peak	186	Peak	218	Peak	144
L5	Mean	15	Mean	37	Mean	23
Interior Seat	Std dev	7	Std dev	42	Std dev	16
Starboard	Samples	78	Samples	96	Samples	48
	Peak	47	Peak	172	Peak	80
L6	Mean	3	Mean	3	Mean	4
Front	Std dev	0	Std dev	1	Std dev	1
	Samples	78	Samples	96	Samples	48
	Peak	4	Peak	4	Peak	6
L7	Mean	118	Mean	271	Mean	177
8' Pole	Std dev	54	Std dev	98	Std dev	50
	Samples	78	Samples	96	Samples	48
	Peak	302	Peak	494	Peak	264
L8	Mean	134	Mean	324	Mean	194
10' Pole	Std dev	75	Std dev	147	Std dev	59
	Samples	78	Samples	96	Samples	48
	Peak	407	Peak	682	Peak	324
L9	Mean	134	Mean	388	Mean	170
12' pole	Std dev	84	Std dev	196	Std dev	58
	Samples	78	Samples	96	Samples	48
	Peak	419	Peak	847	Peak	292

Table 5 (cont.) - Silverton 410 Sport, Carbon Monoxide (ppm)

	12 mph		10 mph		1 -2 mph	
L1	Mean	845	Mean	243	Mean	218
Back Deck Port	Std dev	276	Std dev	152	Std dev	148
	Samples	24	Samples	24	Samples	24
	Peak	1206	Peak	499	Peak	480
L2	Mean	815	Mean	209	Mean	439
Back Deck Center	Std dev	299	Std dev	137	Std dev	129
	Samples	24	Samples	24	Samples	24
	Peak	1314	Peak	550	Peak	621
L3	Mean	821	Mean	187	Mean	267
Back Deck	Std dev	360	Std dev	95	Std dev	78
Starboard	Samples	24	Samples	24	Samples	24
	Peak	1425	Peak	379	Peak	395
L4	Mean	256	Mean	53	Mean	151
Interior Seat Port	Std dev	162	Std dev	27	Std dev	43
	Samples	24	Samples	24	Samples	24
	Peak	506	Peak	113	Peak	201
L5	Mean	22	Mean	25	Mean	71
Interior Seat	Std dev	14	Std dev	16	Std dev	54
Starboard	Samples	24	Samples	24	Samples	24
	Peak	51	Peak	56	Peak	175
L6	Mean	5	Mean	4	Mean	8
Front	Std dev	1	Std dev	2	Std dev	6
	Samples	24	Samples	24	Samples	24
	Peak	6	Peak	8	Peak	20
L7	Mean	144	Mean	52	Mean	87
8' Pole	Std dev	38	Std dev	48	Std dev	62
	Samples	24	Samples	24	Samples	24
	Peak	196	Peak	178	Peak	186
L8	Mean	153	Mean	57	Mean	95
10' Pole	Std dev	43	Std dev	59	Std dev	81
	Samples	24	Samples	24	Samples	24
	Peak	225	Peak	251	Peak	239
L9	Mean	82	Mean	19	Mean	40
12' pole	Std dev	13	Std dev	19	Std dev	33
	Samples	24	Samples	24	Samples	24
	Peak	98	Peak	75	Peak	92

Table 6 - Malibu Sunsetter (Stationary), Carbon Monoxide (ppm)

	Engines Idling	
L1	Mean	1115
Back Deck Port	Std dev	313
	Samples	81
	Peak	1209
L2	Mean	1311
Back Deck Center	Std dev	146
	Samples	81
	Peak	1333
L3	Mean	1278
Back Deck	Std dev	390
Starboard	Samples	81
	Peak	1439
L4	Mean	112
Interior Seat Port	Std dev	124
	Samples	81
	Peak	532
L5	Mean	51
Interior Seat	Std dev	55
Starboard	Samples	81
	Peak	252
L6	Mean	17
Front	Std dev	16
	Samples	81
	Peak	75
L7	Mean	29
8' Pole	Std dev	44
	Samples	81
	Peak	210
L8	Mean	36
10' Pole	Std dev	76
	Samples	81
	Peak	415
L9	Mean	25
12' pole	Std dev	49
	Samples	81
	Peak	278

Table 7 - Crownline 270, Carbon Monoxide (ppm)

	Start Engines		1 -2 mph		5 mph		10 mph	
L1	Mean	558	Mean	930	Mean	898	Mean	187
Back Deck Port	Std dev	362	Std dev	312	Std dev	325	Std dev	55
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	1207	Peak	1207	Peak	1206	Peak	358
L2	Mean	373	Mean	494	Mean	536	Mean	68
Back Deck Center	Std dev	180	Std dev	163	Std dev	237	Std dev	47
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	831	Peak	760	Peak	1130	Peak	217
L3	Mean	457	Mean	484	Mean	91	Mean	61
Back Deck	Std dev	235	Std dev	240	Std dev	80	Std dev	61
Starboard	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	1038	Peak	1148	Peak	282	Peak	226
L4	Mean	87	Mean	50	Mean	23	Mean	2
Interior Seat Port	Std dev	46	Std dev	61	Std dev	19	Std dev	1
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	161	Peak	241	Peak	80	Peak	4
L5	Mean	81	Mean	16	Mean	5	Mean	3
Interior Seat	Std dev	51	Std dev	19	Std dev	3	Std dev	0
Starboard	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	185	Peak	85	Peak	13	Peak	4
L6	Mean	47	Mean	11	Mean	5	Mean	1
Front	Std dev	24	Std dev	13	Std dev	2	Std dev	1
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	106	Peak	49	Peak	8	Peak	4
L7	Mean	76	Mean	41	Mean	21	Mean	13
8' Pole	Std dev	41	Std dev	45	Std dev	21	Std dev	5
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	199	Peak	169	Peak	84	Peak	23
L8	Mean	101	Mean	29	Mean	17	Mean	12
10' Pole	Std dev	78	Std dev	31	Std dev	20	Std dev	5
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	341	Peak	105	Peak	72	Peak	24
L9	Mean	146	Mean	19	Mean	15	Mean	11
12' pole	Std dev	94	Std dev	20	Std dev	18	Std dev	4
	Samples	24	Samples	30	Samples	60	Samples	60
	Peak	433	Peak	84	Peak	72	Peak	18

Table 7 (cont.) - Crownline 270, Carbon Monoxide (ppm)

	15 mph		25 mph		Idling		50 mph	
L1	Mean	49	Mean	20	Mean	577	Mean	323
Back Deck Port	Std dev	12	Std dev	6	Std dev	331	Std dev	326
	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	69	Peak	39	Peak	970	Peak	916
L2	Mean	10	Mean	32	Mean	304	Mean	185
Back Deck Center	Std dev	4	Std dev	102	Std dev	269	Std dev	167
	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	18	Peak	581	Peak	799	Peak	471
L3	Mean	9	Mean	4	Mean	460	Mean	177
Back Deck	Std dev	5	Std dev	3	Std dev	369	Std dev	194
Starboard	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	23	Peak	15	Peak	911	Peak	571
L4	Mean	3	Mean	3	Mean	3	Mean	3
Interior Seat Port	Std dev	1	Std dev	0	Std dev	1	Std dev	1
	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	4	Peak	3	Peak	4	Peak	4
L5	Mean	4	Mean	4	Mean	4	Mean	4
Interior Seat	Std dev	0	Std dev	1	Std dev	1	Std dev	2
Starboard	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	4	Peak	5	Peak	7	Peak	10
L6	Mean	2	Mean	2	Mean	1	Mean	1
Front	Std dev	1	Std dev	1	Std dev	1	Std dev	1
	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	3	Peak	4	Peak	2	Peak	2
L7	Mean	3	Mean	2	Mean	36	Mean	16
8' Pole	Std dev	1	Std dev	1	Std dev	31	Std dev	16
	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	4	Peak	3	Peak	98	Peak	47
L8	Mean	2	Mean	2	Mean	37	Mean	16
10' Pole	Std dev	1	Std dev	1	Std dev	35	Std dev	18
	Samples	60	Samples	60	Samples	12	Samples	12
	Peak	4	Peak	9	Peak	97	Peak	54
L9	Mean	3	Mean	4	Mean	26	Mean	16
12' pole	Std dev	1	Std dev	7	Std dev	36	Std dev	19
	Samples	60	Samples	7	Samples	12	Samples	12
	Peak	4	Peak	7	Peak	115	Peak	59

Table 7 (cont.) - Crownline 270, Carbon Monoxide (ppm)

	14 mph		52 mph		33 mph		2 - 3 mph	
L1	Mean	182	Mean	61	Mean	48	Mean	378
Back Deck Port	Std dev	183	Std dev	48	Std dev	93	Std dev	268
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	543	Peak	163	Peak	472	Peak	929
L2	Mean	27	Mean	10	Mean	84	Mean	271
Back Deck Center	Std dev	12	Std dev	4	Std dev	104	Std dev	73
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	48	Peak	20	Peak	333	Peak	438
L3	Mean	26	Mean	6	Mean	176	Mean	742
Back Deck	Std dev	15	Std dev	2	Std dev	231	Std dev	426
Starboard	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	52	Peak	11	Peak	740	Peak	1447
L4	Mean	3	Mean	3	Mean	3	Mean	28
Interior Seat Port	Std dev	1	Std dev	1	Std dev	1	Std dev	18
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	5	Peak	4	Peak	4	Peak	52
L5	Mean	6	Mean	4	Mean	5	Mean	89
Interior Seat	Std dev	1	Std dev	1	Std dev	2	Std dev	69
Starboard	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	6	Peak	5	Peak	17	Peak	247
L6	Mean	3	Mean	2	Mean	2	Mean	31
Front	Std dev	1	Std dev	1	Std dev	1	Std dev	20
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	4	Peak	3	Peak	4	Peak	71
L7	Mean	6	Mean	6	Mean	12	Mean	36
8' Pole	Std dev	3	Std dev	5	Std dev	14	Std dev	31
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	12	Peak	19	Peak	52	Peak	105
L8	Mean	3	Mean	5	Mean	13	Mean	53
10' Pole	Std dev	3	Std dev	6	Std dev	15	Std dev	48
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	9	Peak	20	Peak	54	Peak	168
L9	Mean	8	Mean	3	Mean	14	Mean	50
12' pole	Std dev	5	Std dev	1	Std dev	14	Std dev	37
	Samples	6	Samples	12	Samples	60	Samples	18
	Peak	17	Peak	4	Peak	52	Peak	131

Table 7 (cont.) - Crownline 270, Carbon Monoxide (ppm)

	Docked	
L1	Mean	863
Back Deck Port	Std dev	459
	Samples	18
	Peak	1213
L2	Mean	144
Back Deck Center	Std dev	117
	Samples	18
	Peak	339
L3	Mean	165
Back Deck	Std dev	106
Starboard	Samples	18
	Peak	331
L4	Mean	35
Interior Seat Port	Std dev	26
	Samples	18
	Peak	90
L5	Mean	42
Interior Seat	Std dev	36
Starboard	Samples	18
	Peak	137
L6	Mean	17
Front	Std dev	9
	Samples	18
	Peak	32
L7	Mean	33
8' Pole	Std dev	19
	Samples	18
	Peak	65
L8	Mean	28
10' Pole	Std dev	28
	Samples	18
	Peak	96
L9	Mean	71
12' pole	Std dev	73
	Samples	18
	Peak	280

Table 8 - Crownline 225, Carbon Monoxide (ppm)

	Start Boat Engine		2600 rpm		Stopped Engines	
L1	Mean	469	Mean	960	Mean	590
Back Deck Port	Std dev	579	Std dev	285	Std dev	540
	Samples	42	Samples	18	Samples	57
	Peak	1226	Peak	1226	Peak	1226
L2	Mean	724	Mean	1298	Mean	795
Back Deck Center	Std dev	559	Std dev	0	Std dev	577
	Samples	42	Samples	18	Samples	57
	Peak	1298	Peak	1298	Peak	1298
L3	Mean	912	Mean	1315	Mean	330
Back Deck	Std dev	372	Std dev	1	Std dev	496
Starboard	Samples	42	Samples	18	Samples	57
	Peak	1317	Peak	1316	Peak	1316
L4	Mean	337	Mean	434	Mean	11
Port Canopy	Std dev	160	Std dev	182	Std dev	11
	Samples	42	Samples	18	Samples	57
	Peak	777	Peak	767	Peak	62
L5	Mean	264	Mean	546	Mean	9
Starboard Canopy	Std dev	145	Std dev	247	Std dev	15
	Samples	42	Samples	18	Samples	57
	Peak	661	Peak	1034	Peak	95
L6	Mean	94	Mean	223	Mean	14
Front	Std dev	67	Std dev	94	Std dev	22
	Samples	42	Samples	18	Samples	57
	Peak	244	Peak	373	Peak	126
L7	Mean	104	Mean	179	Mean	6
Drivers Seat	Std dev	49	Std dev	68	Std dev	6
	Samples	42	Samples	18	Samples	57
	Peak	291	Peak	254	Peak	30

Table 9 - Malibu Escape, Carbon Monoxide (ppm)

	Start Boat Engine		2000 rpm		Shut Engines Off	
L1	Mean	387	Mean	752	Mean	404
Back Deck Port	Std dev	519	Std dev	476	Std dev	519
	Samples	60	Samples	36	Samples	90
	Peak	1227	Peak	1228	Peak	1227
L2	Mean	713	Mean	1296	Mean	1253
Back Deck Center	Std dev	648	Std dev	2	Std dev	191
	Samples	60	Samples	36	Samples	90
	Peak	1298	Peak	1298	Peak	1299
L3	Mean	675	Mean	972	Mean	113
Back Deck	Std dev	499	Std dev	360	Std dev	297
Starboard	Samples	60	Samples	36	Samples	90
	Peak	1318	Peak	1317	Peak	1317
L4	Mean	45	Mean	169	Mean	5
Port Canopy	Std dev	48	Std dev	54	Std dev	11
	Samples	60	Samples	36	Samples	90
	Peak	259	Peak	299	Peak	90
L5	Mean	52	Mean	176	Mean	5
Starboard Canopy	Std dev	52	Std dev	108	Std dev	15
	Samples	60	Samples	36	Samples	90
	Peak	262	Peak	576	Peak	93
L6	Mean	13	Mean	56	Mean	6
Front	Std dev	12	Std dev	22	Std dev	12
	Samples	60	Samples	36	Samples	90
	Peak	51	Peak	106	Peak	76
L7	Mean	26	Mean	73	Mean	4
Drivers Seat	Std dev	25	Std dev	46	Std dev	10
	Samples	60	Samples	36	Samples	90
	Peak	101	Peak	235	Peak	99

Table 10 - Formula 260 SS, Carbon Monoxide (ppm)

	Boat in front of ours started		Cold Start		3.4mph		5mph	
L1	Mean	19	Mean	632	Mean	541	Mean	124
Back Deck Port	Std dev	33	Std dev	380	Std dev	441	Std dev	186
	Samples	54	Samples	12	Samples	72	Samples	11146
	Peak	234	Peak	1355	Peak	1355	Peak	876
L2	Mean	18	Mean	413	Mean	214	Mean	56
Back Deck Center	Std dev	31	Std dev	175	Std dev	217	Std dev	50
	Samples	54	Samples	12	Samples	72	Samples	5071
	Peak	215	Peak	758	Peak	953	Peak	292
L3	Mean	12	Mean	157	Mean	241	Mean	266
Back Deck	Std dev	15	Std dev	250	Std dev	262	Std dev	140
Starboard	Samples	54	Samples	12	Samples	72	Samples	23902
	Peak	56	Peak	941	Peak	931	Peak	694
L4	Mean	14	Mean	35	Mean	17	Mean	7
Interior	Std dev	15	Std dev	31	Std dev	17	Std dev	3
	Samples	54	Samples	12	Samples	72	Samples	654
	Peak	58	Peak	89	Peak	73	Peak	15
L5	Mean	13	Mean	28	Mean	18	Mean	8
Front	Std dev	14	Std dev	23	Std dev	13	Std dev	1
	Samples	54	Samples	12	Samples	72	Samples	750
	Peak	54	Peak	77	Peak	75	Peak	11
L6	Mean	13	Mean	43	Mean	15	Mean	11
8' Pole	Std dev	15	Std dev	34	Std dev	11	Std dev	5
	Samples	54	Samples	12	Samples	72	Samples	991
	Peak	71	Peak	107	Peak	64	Peak	29
L7	Mean	17	Mean	50	Mean	17	Mean	11
10' Pole	Std dev	22	Std dev	36	Std dev	16	Std dev	7
	Samples	54	Samples	12	Samples	72	Samples	988
	Peak	105	Peak	126	Peak	70	Peak	34
L8	Mean	31	Mean	98	Mean	22	Mean	14
12' Pole	Std dev	54	Std dev	86	Std dev	38	Std dev	8
	Samples	54	Samples	12	Samples	72	Samples	1238
	Peak	253	Peak	269	Peak	231	Peak	42

Table 10 (cont.) - Formula 260 SS, Carbon Monoxide (ppm)

	10mph		15mph		20mph		45mph	
L1	Mean	38	Mean	10	Mean	12	Mean	83
Back Deck Port	Std dev	20	Std dev	2	Std dev	21	Std dev	142
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	105	Peak	16	Peak	136	Peak	603
L2	Mean	91	Mean	18	Mean	9	Mean	55
Back Deck Center	Std dev	33	Std dev	7	Std dev	3	Std dev	109
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	178	Peak	32	Peak	19	Peak	361
L3	Mean	76	Mean	154	Mean	31	Mean	16
Back Deck	Std dev	49	Std dev	70	Std dev	13	Std dev	24
Starboard	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	250	Peak	297	Peak	57	Peak	77
L4	Mean	8	Mean	6	Mean	4	Mean	4
Interior	Std dev	2	Std dev	2	Std dev	1	Std dev	2
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	15	Peak	10	Peak	5	Peak	9
L5	Mean	6	Mean	3	Mean	2	Mean	6
Front	Std dev	2	Std dev	1	Std dev	0	Std dev	11
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	13	Peak	5	Peak	3	Peak	48
L6	Mean	4	Mean	13	Mean	8	Mean	3
8' Pole	Std dev	3	Std dev	3	Std dev	3	Std dev	1
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	18	Peak	19	Peak	14	Peak	4
L7	Mean	5	Mean	14	Mean	9	Mean	1
10' Pole	Std dev	6	Std dev	4	Std dev	4	Std dev	1
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	20	Peak	22	Peak	14	Peak	3
L8	Mean	7	Mean	17	Mean	12	Mean	2
12' Pole	Std dev	6	Std dev	4	Std dev	5	Std dev	0
	Samples	42	Samples	30	Samples	36	Samples	36
	Peak	22	Peak	25	Peak	21	Peak	4

Table 10 (cont.) - Formula 260 SS, Carbon Monoxide (ppm)

	5mph		Idle		Docked	
L1	Mean	20	Mean	81	Mean	43
Back Deck Port	Std dev	19	Std dev	87	Std dev	80
	Samples	54	Samples	12	Samples	60
	Peak	86	Peak	287	Peak	355
L2	Mean	44	Mean	121	Mean	40
Back Deck Center	Std dev	42	Std dev	45	Std dev	102
	Samples	54	Samples	12	Samples	60
	Peak	140	Peak	198	Peak	552
L3	Mean	123	Mean	200	Mean	33
Back Deck	Std dev	249	Std dev	170	Std dev	74
Starboard	Samples	54	Samples	12	Samples	60
	Peak	909	Peak	561	Peak	421
L4	Mean	6	Mean	12	Mean	9
Interior	Std dev	3	Std dev	8	Std dev	14
	Samples	54	Samples	12	Samples	60
	Peak	14	Peak	23	Peak	84
L5	Mean	4	Mean	10	Mean	7
Front	Std dev	3	Std dev	9	Std dev	7
	Samples	54	Samples	12	Samples	60
	Peak	12	Peak	26	Peak	45
L6	Mean	5	Mean	5	Mean	7
8' Pole	Std dev	6	Std dev	2	Std dev	19
	Samples	54	Samples	12	Samples	60
	Peak	30	Peak	7	Peak	114
L7	Mean	5	Mean	22	Mean	6
10' Pole	Std dev	9	Std dev	47	Std dev	16
	Samples	54	Samples	12	Samples	60
	Peak	45	Peak	146	Peak	113
L8	Mean	6	Mean	7	Mean	3
12' Pole	Std dev	7	Std dev	7	Std dev	4
	Samples	54	Samples	12	Samples	60
	Peak	39	Peak	29	Peak	31

Table 11 - Malibu Escape, Carbon Monoxide (ppm)

	Cold Start		Under Way		5mph		10mph	
L1	Mean	1330	Mean	1328	Mean	1327	Mean	1329
Back Deck Port	Std dev	1	Std dev	1	Std dev	0	Std dev	1
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	1331	Peak	1328	Peak	1328	Peak	1331
L2	Mean	1196	Mean	1197	Mean	1198	Mean	1203
Back Deck Center	Std dev	1	Std dev	1	Std dev	1	Std dev	2
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	1197	Peak	1198	Peak	1199	Peak	1205
L3	Mean	860	Mean	1442	Mean	1101	Mean	491
Back Deck	Std dev	364	Std dev	1	Std dev	342	Std dev	59
Starboard	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	1443	Peak	1443	Peak	1443	Peak	782
L4	Mean	9	Mean	12	Mean	3	Mean	2
Interior	Std dev	5	Std dev	12	Std dev	1	Std dev	1
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	20	Peak	46	Peak	4	Peak	4
L5	Mean	4	Mean	6	Mean	6	Mean	4
Front	Std dev	2	Std dev	6	Std dev	3	Std dev	1
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	10	Peak	30	Peak	9	Peak	7
L6	Mean	11	Mean	7	Mean	7	Mean	9
8' Pole	Std dev	5	Std dev	6	Std dev	3	Std dev	6
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	20	Peak	34	Peak	14	Peak	26
L7	Mean	14	Mean	4	Mean	10	Mean	13
10' Pole	Std dev	9	Std dev	4	Std dev	4	Std dev	8
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	34	Peak	25	Peak	19	Peak	34
L8	Mean	16	Mean	2	Mean	10	Mean	15
12' Pole	Std dev	13	Std dev	2	Std dev	6	Std dev	9
	Samples	12	Samples	42	Samples	36	Samples	30
	Peak	36	Peak	9	Peak	23	Peak	36

Table 11 (cont.) - Malibu Escape, Carbon Monoxide (ppm)

	15mph		20mph		25mph		30mph	
L1	Mean	1157	Mean	181	Mean	204	Mean	151
Back Deck Port	Std dev	364	Std dev	64	Std dev	41	Std dev	16
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	1343	Peak	441	Peak	306	Peak	171
L2	Mean	1210	Mean	506	Mean	118	Mean	98
Back Deck Center	Std dev	2	Std dev	213	Std dev	18	Std dev	12
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	1213	Peak	1213	Peak	188	Peak	118
L3	Mean	322	Mean	292	Mean	333	Mean	310
Back Deck	Std dev	102	Std dev	76	Std dev	6	Std dev	7
Starboard	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	458	Peak	456	Peak	342	Peak	320
L4	Mean	2	Mean	3	Mean	3	Mean	3
Interior	Std dev	1	Std dev	1	Std dev	1	Std dev	0
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	4	Peak	4	Peak	4	Peak	3
L5	Mean	2	Mean	2	Mean	1	Mean	2
Front	Std dev	1	Std dev	1	Std dev	1	Std dev	1
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	3	Peak	2	Peak	2	Peak	3
L6	Mean	6	Mean	5	Mean	4	Mean	4
8' Pole	Std dev	2	Std dev	1	Std dev	0	Std dev	0
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	9	Peak	6	Peak	5	Peak	5
L7	Mean	6	Mean	4	Mean	2	Mean	1
10' Pole	Std dev	3	Std dev	2	Std dev	1	Std dev	0
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	15	Peak	8	Peak	3	Peak	2
L8	Mean	9	Mean	5	Mean	2	Mean	2
12' Pole	Std dev	5	Std dev	2	Std dev	0	Std dev	0
	Samples	48	Samples	48	Samples	30	Samples	30
	Peak	19	Peak	10	Peak	3	Peak	2

Table 11 (cont.) - Malibu Escape, Carbon Monoxide (ppm)

	44mph		25mph		Idle		15-20mph parallel	
L1	Mean	144	Mean	105	Mean	1058	Mean	893
Back Deck Port	Std dev	43	Std dev	22	Std dev	270	Std dev	565
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	259	Peak	166	Peak	1348	Peak	1347
L2	Mean	110	Mean	207	Mean	1212	Mean	1210
Back Deck Center	Std dev	40	Std dev	282	Std dev	1	Std dev	2
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	221	Peak	1214	Peak	1214	Peak	1213
L3	Mean	267	Mean	227	Mean	213	Mean	256
Back Deck	Std dev	18	Std dev	7	Std dev	1	Std dev	23
Starboard	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	295	Peak	236	Peak	215	Peak	280
L4	Mean	3	Mean	2	Mean	5	Mean	4
Interior	Std dev	1	Std dev	0	Std dev	2	Std dev	2
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	3	Peak	3	Peak	8	Peak	14
L5	Mean	1	Mean	2	Mean	3	Mean	2
Front	Std dev	1	Std dev	0	Std dev	2	Std dev	2
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	3	Peak	2	Peak	7	Peak	10
L6	Mean	3	Mean	3	Mean	3	Mean	3
8' Pole	Std dev	1	Std dev	0	Std dev	0	Std dev	0
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	5	Peak	3	Peak	3	Peak	4
L7	Mean	2	Mean	4	Mean	3	Mean	5
10' Pole	Std dev	1	Std dev	2	Std dev	2	Std dev	4
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	4	Peak	8	Peak	9	Peak	17
L8	Mean	2	Mean	2	Mean	2	Mean	2
12' Pole	Std dev	0	Std dev	0	Std dev	0	Std dev	0
	Samples	36	Samples	18	Samples	12	Samples	60
	Peak	3	Peak	2	Peak	2	Peak	2

Table 11 (cont.) - Malibu Escape, Carbon Monoxide (ppm)

	44mph	
L1	Mean	104
Back Deck Port	Std dev	12
	Samples	30
	Peak	123
L2	Mean	758
Back Deck Center	Std dev	333
	Samples	30
	Peak	1214
L3	Mean	270
Back Deck	Std dev	3
Starboard	Samples	30
	Peak	278
L4	Mean	5
Interior	Std dev	7
	Samples	30
	Peak	28
L5	Mean	2
Front	Std dev	2
	Samples	30
	Peak	6
L6	Mean	3
8' Pole	Std dev	1
	Samples	30
	Peak	3
L7	Mean	3
10' Pole	Std dev	2
	Samples	30
	Peak	8
L8	Mean	2
12' Pole	Std dev	0
	Samples	30
	Peak	2

Table 12 - Searay Sundancer, Carbon Monoxide (ppm)

	Generator On		Generator Off		Under Way		5 mph	
L1	Mean	795	Mean	422	Mean	566	Mean	144
Back Deck Port	Std dev	476	Std dev	511	Std dev	444	Std dev	64
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	1351	Peak	1351	Peak	1350	Peak	341
L2	Mean	693	Mean	306	Mean	746	Mean	243
Back Deck Center	Std dev	351	Std dev	463	Std dev	443	Std dev	104
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	1217	Peak	1217	Peak	1217	Peak	495
L3	Mean	365	Mean	192	Mean	875	Mean	510
Back Deck	Std dev	221	Std dev	363	Std dev	341	Std dev	127
Starboard	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	872	Peak	1455	Peak	1455	Peak	800
L4	Mean	57	Mean	43	Mean	121	Mean	55
Interior	Std dev	71	Std dev	54	Std dev	101	Std dev	15
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	278	Peak	247	Peak	419	Peak	90
L5	Mean	31	Mean	31	Mean	63	Mean	21
Front	Std dev	31	Std dev	45	Std dev	44	Std dev	6
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	98	Peak	211	Peak	188	Peak	33
L6	Mean	8	Mean	34	Mean	74	Mean	29
8' Pole	Std dev	3	Std dev	57	Std dev	47	Std dev	21
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	12	Peak	254	Peak	254	Peak	74
L7	Mean	56	Mean	76	Mean	49	Mean	20
10' Pole	Std dev	34	Std dev	134	Std dev	25	Std dev	14
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	125	Peak	643	Peak	116	Peak	50
L8	Mean	2	Mean	2	Mean	2	Mean	2
12' Pole	Std dev	1	Std dev	0	Std dev	0	Std dev	0
	Samples	30	Samples	102	Samples	36	Samples	30
	Peak	2	Peak	2	Peak	3	Peak	3

Table 12 (cont.) - Searay Sundancer, Carbon Monoxide (ppm)

	10 mph		15 mph		20 mph		25 mph	
L1	Mean	55	Mean	58	Mean	115	Mean	276
Back Deck Port	Std dev	15	Std dev	16	Std dev	54	Std dev	195
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	94	Peak	101	Peak	311	Peak	715
L2	Mean	95	Mean	120	Mean	40	Mean	81
Back Deck Center	Std dev	52	Std dev	59	Std dev	17	Std dev	66
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	294	Peak	242	Peak	78	Peak	215
L3	Mean	202	Mean	350	Mean	126	Mean	167
Back Deck	Std dev	105	Std dev	67	Std dev	33	Std dev	86
Starboard	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	556	Peak	510	Peak	203	Peak	314
L4	Mean	25	Mean	33	Mean	26	Mean	15
Interior	Std dev	12	Std dev	17	Std dev	13	Std dev	13
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	55	Peak	76	Peak	52	Peak	46
L5	Mean	12	Mean	25	Mean	13	Mean	8
Front	Std dev	3	Std dev	11	Std dev	5	Std dev	4
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	17	Peak	45	Peak	25	Peak	17
L6	Mean	12	Mean	41	Mean	4	Mean	61
8' Pole	Std dev	8	Std dev	18	Std dev	2	Std dev	52
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	34	Peak	100	Peak	9	Peak	166
L7	Mean	15	Mean	36	Mean	3	Mean	87
10' Pole	Std dev	25	Std dev	17	Std dev	3	Std dev	52
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	102	Peak	57	Peak	15	Peak	176
L8	Mean	3	Mean	3	Mean	2	Mean	3
12' Pole	Std dev	1	Std dev	0	Std dev	0	Std dev	0
	Samples	30	Samples	30	Samples	30	Samples	36
	Peak	3	Peak	3	Peak	3	Peak	3

Table 12 (cont.) - Searay Sundancer, Carbon Monoxide (ppm)

	32 mph		Slowing Down		Engines Off Generator On		Started Engine	
L1	Mean	160	Mean	351	Mean	253	Mean	303
Back Deck Port	Std dev	73	Std dev	235	Std dev	226	Std dev	143
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	288	Peak	792	Peak	731	Peak	746
L2	Mean	14	Mean	154	Mean	89	Mean	73
Back Deck Center	Std dev	9	Std dev	113	Std dev	62	Std dev	34
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	39	Peak	365	Peak	217	Peak	126
L3	Mean	23	Mean	67	Mean	92	Mean	235
Back Deck	Std dev	14	Std dev	31	Std dev	61	Std dev	136
Starboard	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	63	Peak	117	Peak	201	Peak	428
L4	Mean	3	Mean	14	Mean	10	Mean	12
Interior	Std dev	1	Std dev	10	Std dev	5	Std dev	11
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	5	Peak	30	Peak	18	Peak	39
L5	Mean	2	Mean	35	Mean	11	Mean	11
Front	Std dev	1	Std dev	36	Std dev	6	Std dev	4
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	3	Peak	95	Peak	21	Peak	18
L6	Mean	63	Mean	41	Mean	31	Mean	48
8' Pole	Std dev	46	Std dev	33	Std dev	12	Std dev	18
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	172	Peak	120	Peak	56	Peak	76
L7	Mean	63	Mean	34	Mean	31	Mean	38
10' Pole	Std dev	45	Std dev	39	Std dev	23	Std dev	14
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	169	Peak	118	Peak	63	Peak	64
L8	Mean	5	Mean	4	Mean	3	Mean	3
12' Pole	Std dev	12	Std dev	5	Std dev	0	Std dev	0
	Samples	30	Samples	18	Samples	12	Samples	18
	Peak	59	Peak	22	Peak	3	Peak	3

Table 12 (cont.) - Searay Sundancer, Carbon Monoxide (ppm)

	Engine Off		Generator Off Engines On		8.4 mph		Idle	
L1	Mean	99	Mean	332	Mean	711	Mean	54
Back Deck Port	Std dev	111	Std dev	305	Std dev	140	Std dev	148
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	464	Peak	753	Peak	981	Peak	1348
L2	Mean	48	Mean	258	Mean	531	Mean	20
Back Deck Center	Std dev	75	Std dev	254	Std dev	112	Std dev	85
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	457	Peak	641	Peak	717	Peak	783
L3	Mean	49	Mean	96	Mean	217	Mean	22
Back Deck	Std dev	51	Std dev	55	Std dev	74	Std dev	60
Starboard	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	337	Peak	166	Peak	404	Peak	565
L4	Mean	6	Mean	12	Mean	24	Mean	7
Interior	Std dev	3	Std dev	11	Std dev	9	Std dev	15
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	24	Peak	33	Peak	51	Peak	116
L5	Mean	7	Mean	16	Mean	26	Mean	5
Front	Std dev	4	Std dev	11	Std dev	14	Std dev	9
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	19	Peak	41	Peak	73	Peak	89
L6	Mean	7	Mean	3	Mean	2	Mean	5
8' Pole	Std dev	5	Std dev	1	Std dev	1	Std dev	16
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	43	Peak	4	Peak	5	Peak	168
L7	Mean	2	Mean	1	Mean	1	Mean	5
10' Pole	Std dev	2	Std dev	0	Std dev	1	Std dev	18
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	14	Peak	2	Peak	3	Peak	152
L8	Mean	3	Mean	3	Mean	2	Mean	3
12' Pole	Std dev	0	Std dev	1	Std dev	0	Std dev	5
	Samples	108	Samples	12	Samples	108	Samples	378
	Peak	4	Peak	3	Peak	3	Peak	47

Table 13 - Malibu With Shower Device and Wedge, Carbon Monoxide (ppm)

	Shower Device (Stationary Test Under Covered Slip)		Underway with Wedge Device 1 - 2 mph		15 mph with Wedge Down	
L1	Mean	455	Mean	187	Mean	132
Back Deck Port	Std dev	329	Std dev	42	Std dev	70
	Samples	86	Samples	11	Samples	18
	Peak	1180	Peak	285	Peak	229
L2	Mean	805	Mean	295	Mean	154
Back Deck Center	Std dev	358	Std dev	127	Std dev	70
	Samples	86	Samples	11	Samples	18
	Peak	1092	Peak	599	Peak	294
L3	Mean	395	Mean	267	Mean	156
Back Deck	Std dev	230	Std dev	57	Std dev	89
Starboard	Samples	86	Samples	11	Samples	18
	Peak	1063	Peak	342	Peak	364
L4	Mean	44	Mean	14	Mean	7
Interior	Std dev	21	Std dev	3	Std dev	2
	Samples	86	Samples	11	Samples	18
	Peak	93	Peak	18	Peak	12
L5	Mean	29	Mean	2	Mean	3
Front	Std dev	20	Std dev	1	Std dev	1
	Samples	86	Samples	11	Samples	18
	Peak	73	Peak	4	Peak	4

Table 13 (cont.) - Malibu With Shower Device and Wedge,Carbon Monoxide (ppm)

	Stationary, Adjusting Wedge		15 mph with Wedge Up	
L1	Mean	172	Mean	74
Back Deck Port	Std dev	89	Std dev	113
	Samples	11	Samples	139
	Peak	356	Peak	776
L2	Mean	190	Mean	127
Back Deck Center	Std dev	124	Std dev	186
	Samples	11	Samples	139
	Peak	433	Peak	1085
L3	Mean	220	Mean	110
Back Deck	Std dev	160	Std dev	141
Starboard	Samples	11	Samples	139
	Peak	585	Peak	736
L4	Mean	11	Mean	6
Interior	Std dev	4	Std dev	10
	Samples	11	Samples	139
	Peak	19	Peak	49
L5	Mean	3	Mean	3
Front	Std dev	1	Std dev	6
	Samples	11	Samples	139
	Peak	5	Peak	43

Table 14 - Carver Cabin Cruiser, Carbon Monoxide (ppm)

	Stationary (Covered Slip)		1 -2 mph		5 mph		10 mph	
L1	Mean	1116	Mean	1179	Mean	1028	Mean	1150
Back Deck Port	Std dev	249	Std dev	0	Std dev	256	Std dev	64
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	1181	Peak	1180	Peak	1179	Peak	1178
L2	Mean	1034	Mean	1138	Mean	1139	Mean	1147
Back Deck Center	Std dev	302	Std dev	2	Std dev	2	Std dev	2
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	1145	Peak	1141	Peak	1143	Peak	1149
L3	Mean	1087	Mean	1133	Mean	1133	Mean	1132
Back Deck	Std dev	185	Std dev	0	Std dev	0	Std dev	0
Starboard	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	1136	Peak	1134	Peak	1133	Peak	1133
L4	Mean	10	Mean	34	Mean	18	Mean	47
Interior	Std dev	5	Std dev	6	Std dev	12	Std dev	26
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	23	Peak	49	Peak	50	Peak	94
L5	Mean	6	Mean	5	Mean	2	Mean	3
Front	Std dev	5	Std dev	4	Std dev	1	Std dev	1
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	15	Peak	17	Peak	4	Peak	5
L6	Mean	188	Mean	77	Mean	14	Mean	41
8' Pole	Std dev	85	Std dev	39	Std dev	15	Std dev	50
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	321	Peak	171	Peak	81	Peak	192
L7	Mean	164	Mean	84	Mean	9	Mean	35
10' Pole	Std dev	70	Std dev	46	Std dev	9	Std dev	47
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	280	Peak	158	Peak	52	Peak	167
L8	Mean	252	Mean	182	Mean	10	Mean	39
12' Pole	Std dev	131	Std dev	151	Std dev	8	Std dev	56
	Samples	15	Samples	30	Samples	54	Samples	61
	Peak	468	Peak	566	Peak	45	Peak	210

Table 14 (cont.) - Carver Cabin Cruiser, Carbon Monoxide (ppm)

	15 mph		20 mph		15 mph		5 mph	
L1	Mean	1171	Mean	1171	Mean	1171	Mean	1172
Back Deck Port	Std dev	1	Std dev	0	Std dev	0	Std dev	1
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	1174	Peak	1172	Peak	1171	Peak	1174
L2	Mean	1142	Mean	1142	Mean	1137	Mean	1129
Back Deck Center	Std dev	2	Std dev	0	Std dev	3	Std dev	2
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	1147	Peak	1142	Peak	1141	Peak	1132
L3	Mean	1130	Mean	1131	Mean	1132	Mean	1134
Back Deck	Std dev	1	Std dev	0	Std dev	1	Std dev	1
Starboard	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	1131	Peak	1131	Peak	1133	Peak	1135
L4	Mean	48	Mean	27	Mean	47	Mean	38
Interior	Std dev	27	Std dev	12	Std dev	12	Std dev	14
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	117	Peak	43	Peak	69	Peak	70
L5	Mean	2	Mean	2	Mean	2	Mean	5
Front	Std dev	1	Std dev	0	Std dev	0	Std dev	6
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	5	Peak	3	Peak	3	Peak	21
L6	Mean	162	Mean	184	Mean	189	Mean	39
8' Pole	Std dev	64	Std dev	71	Std dev	68	Std dev	31
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	277	Peak	295	Peak	271	Peak	96
L7	Mean	152	Mean	185	Mean	174	Mean	33
10' Pole	Std dev	63	Std dev	66	Std dev	79	Std dev	28
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	261	Peak	282	Peak	323	Peak	87
L8	Mean	168	Mean	211	Mean	176	Mean	31
12' Pole	Std dev	73	Std dev	82	Std dev	87	Std dev	26
	Samples	47	Samples	18	Samples	48	Samples	30
	Peak	297	Peak	332	Peak	316	Peak	91

Table 15 - Malibu Wakesetter With Transom Shower, Carbon Monoxide (ppm)

	Start Malibu Wakesetter engines (with shower device)		1 - 2 mph		20 mph		1 - 2 mph	
L1	Mean	287	Mean	310	Mean	50	Mean	153
Back Deck Port	Std dev	55	Std dev	106	Std dev	59	Std dev	163
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	316	Peak	535	Peak	393	Peak	1078
L2	Mean	522	Mean	193	Mean	23	Mean	141
Back Deck Center	Std dev	240	Std dev	86	Std dev	58	Std dev	151
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	794	Peak	384	Peak	389	Peak	1126
L3	Mean	197	Mean	158	Mean	18	Mean	138
Back Deck	Std dev	39	Std dev	78	Std dev	25	Std dev	120
Starboard	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	240	Peak	314	Peak	145	Peak	540
L4	Mean	11	Mean	9	Mean	2	Mean	11
Interior	Std dev	4	Std dev	5	Std dev	1	Std dev	19
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	15	Peak	17	Peak	4	Peak	112
L5	Mean	7	Mean	7	Mean	3	Mean	5
Front	Std dev	2	Std dev	3	Std dev	1	Std dev	4
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	9	Peak	11	Peak	4	Peak	22
L6	Mean	11	Mean	9	Mean	2	Mean	5
8' Pole	Std dev	4	Std dev	5	Std dev	1	Std dev	8
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	15	Peak	16	Peak	8	Peak	54
L7	Mean	17	Mean	8	Mean	3	Mean	4
10' Pole	Std dev	10	Std dev	5	Std dev	2	Std dev	5
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	29	Peak	16	Peak	14	Peak	35
L8	Mean	27	Mean	14	Mean	8	Mean	5
12' Pole	Std dev	13	Std dev	9	Std dev	6	Std dev	9
	Samples	4	Samples	9	Samples	78	Samples	108
	Peak	37	Peak	28	Peak	36	Peak	65

Table 15 (cont.) - Malibu Wakesetter With Transom Shower, Carbon Monoxide (ppm)

	10 mph		15 mph		Idle in Lake		5 mph with Wedge	
L1	Mean	93	Mean	114	Mean	12	Mean	29
Back Deck Port	Std dev	58	Std dev	99	Std dev	19	Std dev	45
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	210	Peak	356	Peak	78	Peak	156
L2	Mean	266	Mean	49	Mean	34	Mean	48
Back Deck Center	Std dev	129	Std dev	66	Std dev	46	Std dev	33
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	459	Peak	234	Peak	153	Peak	127
L3	Mean	383	Mean	93	Mean	106	Mean	125
Back Deck	Std dev	189	Std dev	130	Std dev	119	Std dev	115
Starboard	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	782	Peak	459	Peak	497	Peak	574
L4	Mean	7	Mean	4	Mean	2	Mean	3
Interior	Std dev	4	Std dev	1	Std dev	1	Std dev	1
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	20	Peak	7	Peak	4	Peak	4
L5	Mean	4	Mean	4	Mean	3	Mean	2
Front	Std dev	1	Std dev	1	Std dev	1	Std dev	1
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	8	Peak	6	Peak	6	Peak	3
L6	Mean	10	Mean	4	Mean	2	Mean	4
8' Pole	Std dev	9	Std dev	1	Std dev	1	Std dev	4
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	50	Peak	7	Peak	3	Peak	17
L7	Mean	11	Mean	3	Mean	1	Mean	3
10' Pole	Std dev	11	Std dev	2	Std dev	0	Std dev	5
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	40	Peak	8	Peak	1	Peak	20
L8	Mean	20	Mean	7	Mean	2	Mean	4
12' Pole	Std dev	20	Std dev	4	Std dev	1	Std dev	6
	Samples	61	Samples	23	Samples	36	Samples	30
	Peak	81	Peak	17	Peak	2	Peak	32

Table 15 (cont.) - Malibu Wakesetter With Transom Shower, Carbon Monoxide (ppm)

	10 mph with Wedge		20 mph with Wedge		1 -2 mph	
L1	Mean	104	Mean	25	Mean	203
Back Deck Port	Std dev	105	Std dev	34	Std dev	121
	Samples	30	Samples	12	Samples	26
	Peak	348	Peak	127	Peak	403
L2	Mean	152	Mean	10	Mean	236
Back Deck Center	Std dev	135	Std dev	14	Std dev	168
	Samples	30	Samples	12	Samples	26
	Peak	499	Peak	55	Peak	651
L3	Mean	300	Mean	16	Mean	297
Back Deck	Std dev	212	Std dev	6	Std dev	220
Starboard	Samples	30	Samples	12	Samples	26
	Peak	713	Peak	24	Peak	691
L4	Mean	3	Mean	3	Mean	4
Interior	Std dev	1	Std dev	0	Std dev	3
	Samples	30	Samples	12	Samples	26
	Peak	4	Peak	3	Peak	10
L5	Mean	4	Mean	2	Mean	4
Front	Std dev	2	Std dev	0	Std dev	2
	Samples	30	Samples	12	Samples	26
	Peak	9	Peak	3	Peak	8
L6	Mean	6	Mean	3	Mean	3
8' Pole	Std dev	4	Std dev	1	Std dev	1
	Samples	30	Samples	12	Samples	26
	Peak	18	Peak	6	Peak	6
L7	Mean	8	Mean	2	Mean	1
10' Pole	Std dev	7	Std dev	1	Std dev	1
	Samples	30	Samples	12	Samples	26
	Peak	23	Peak	5	Peak	4
L8	Mean	19	Mean	5	Mean	2
12' Pole	Std dev	17	Std dev	2	Std dev	2
	Samples	30	Samples	12	Samples	26
	Peak	79	Peak	8	Peak	8

Table 16 - Formula 280 BR, Carbon Monoxide (ppm)

	20 mph		29 mph		35 mph		9 mph	
L1	Mean	41	Mean	6	Mean	6	Mean	36
Back Deck Port	Std dev	30	Std dev	4	Std dev	4	Std dev	48
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	129	Peak	23	Peak	15	Peak	231
L2	Mean	38	Mean	6	Mean	5	Mean	45
Back Deck Center	Std dev	31	Std dev	5	Std dev	5	Std dev	83
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	154	Peak	19	Peak	17	Peak	449
L3	Mean	57	Mean	10	Mean	13	Mean	120
Back Deck	Std dev	48	Std dev	8	Std dev	18	Std dev	216
Starboard	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	192	Peak	28	Peak	54	Peak	1028
L4	Mean	10	Mean	4	Mean	3	Mean	4
Interior	Std dev	5	Std dev	1	Std dev	0	Std dev	5
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	20	Peak	6	Peak	3	Peak	19
L5	Mean	7	Mean	2	Mean	2	Mean	4
Front	Std dev	4	Std dev	0	Std dev	0	Std dev	2
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	14	Peak	3	Peak	3	Peak	10
L6	Mean	4	Mean	4	Mean	3	Mean	6
8' Pole	Std dev	1	Std dev	1	Std dev	1	Std dev	6
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	5	Peak	5	Peak	4	Peak	31
L7	Mean	2	Mean	2	Mean	1	Mean	4
10' Pole	Std dev	0	Std dev	1	Std dev	1	Std dev	5
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	2	Peak	4	Peak	3	Peak	29
L8	Mean	3	Mean	3	Mean	2	Mean	6
12' Pole	Std dev	1	Std dev	1	Std dev	1	Std dev	7
	Samples	30	Samples	108	Samples	18	Samples	72
	Peak	4	Peak	6	Peak	4	Peak	40

Table 17 - Formula 41 PC with ECD, Carbon Monoxide (ppm)

	Generator Running		Drive Engines On	
L1	Mean	24	Mean	664
Back Deck Port	Std dev	37	Std dev	337
	Samples	73	Samples	148
	Peak	124	Peak	1099
L2	Mean	55	Mean	668
Back Deck Center	Std dev	78	Std dev	337
	Samples	73	Samples	148
	Peak	283	Peak	1098
L3	Mean	56	Mean	559
Back Deck	Std dev	76	Std dev	299
Starboard	Samples	73	Samples	148
	Peak	220	Peak	1128
L4	Mean	6	Mean	168
Interior Seat Port	Std dev	5	Std dev	92
	Samples	73	Samples	148
	Peak	21	Peak	425
L5	Mean	7	Mean	181
Interior Seat	Std dev	5	Std dev	133
Starboard	Samples	73	Samples	148
	Peak	19	Peak	527
L6	Mean	1	Mean	20
Front	Std dev	0	Std dev	20
	Samples	73	Samples	148
	Peak	2	Peak	49

Table 18 - Fastec 312, Carbon Monoxide (ppm)

	Drive Engines Running (Stationary) Idle Speed		Drive Engines Running (Stationary) 2000 rpm		Drive Engines Running (Stationary) idle speed		Engines Off	
L1	Mean	339	Mean	940	Mean	157	Mean	5
Back Deck Port	Std dev	360	Std dev	236	Std dev	160	Std dev	5
	Samples	120	Samples	42	Samples	30	Samples	129
	Peak	1107	Peak	1106	Peak	630	Peak	62
L2	Mean	459	Mean	1096	Mean	702	Mean	19
Back Deck Center	Std dev	493	Std dev	1	Std dev	491	Std dev	11
	Samples	120	Samples	42	Samples	30	Samples	129
	Peak	1100	Peak	1099	Peak	1099	Peak	58
L3	Mean	344	Mean	984	Mean	1118	Mean	91
Back Deck	Std dev	480	Std dev	334	Std dev	1	Std dev	166
Starboard	Samples	120	Samples	42	Samples	30	Samples	129
	Peak	1123	Peak	1121	Peak	1121	Peak	1121
L4	Mean	8	Mean	18	Mean	11	Mean	2
Interior Seat Port	Std dev	10	Std dev	13	Std dev	9	Std dev	0
	Samples	120	Samples	42	Samples	30	Samples	129
	Peak	56	Peak	49	Peak	30	Peak	3
L5	Mean	15	Mean	21	Mean	12	Mean	3
Interior Seat	Std dev	18	Std dev	19	Std dev	14	Std dev	1
Starboard	Samples	120	Samples	42	Samples	30	Samples	129
	Peak	89	Peak	86	Peak	58	Peak	6
L6	Mean	11	Mean	21	Mean	19	Mean	5
Front	Std dev	14	Std dev	14	Std dev	20	Std dev	8
	Samples	120	Samples	42	Samples	30	Samples	129
	Peak	62	Peak	48	Peak	83	Peak	53
L7							Mean	2
8' Pole							Std dev	1
							Samples	129
							Peak	3
L8							Mean	1
10' Pole							Std dev	1
							Samples	129
							Peak	2
L9							Mean	2
12' pole							Std dev	2
							Samples	129
							Peak	10

Table 18 (cont.) - Fastec 312, Carbon Monoxide (ppm)

	Drive Engines Running (Stationary)		Idle Speed		5 mph		10 mph	
L1	Mean	181	Mean	280	Mean	291	Mean	969
Back Deck Port	Std dev	55	Std dev	269	Std dev	337	Std dev	257
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	300	Peak	1108	Peak	1108	Peak	1109
L2	Mean	279	Mean	217	Mean	124	Mean	498
Back Deck Center	Std dev	94	Std dev	75	Std dev	123	Std dev	234
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	494	Peak	346	Peak	592	Peak	1085
L3	Mean	408	Mean	571	Mean	1004	Mean	1121
Back Deck	Std dev	160	Std dev	225	Std dev	272	Std dev	1
Starboard	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	679	Peak	1101	Peak	1122	Peak	1122
L4	Mean	9	Mean	6	Mean	4	Mean	10
Interior Seat Port	Std dev	4	Std dev	3	Std dev	1	Std dev	10
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	15	Peak	13	Peak	6	Peak	45
L5	Mean	7	Mean	6	Mean	3	Mean	9
Interior Seat	Std dev	3	Std dev	3	Std dev	1	Std dev	10
Starboard	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	11	Peak	12	Peak	5	Peak	40
L6	Mean	2	Mean	3	Mean	5	Mean	5
Front	Std dev	1	Std dev	1	Std dev	2	Std dev	1
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	4	Peak	7	Peak	11	Peak	7
L7	Mean	6	Mean	5	Mean	17	Mean	17
8' Pole	Std dev	4	Std dev	3	Std dev	18	Std dev	17
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	15	Peak	13	Peak	78	Peak	59
L8	Mean	12	Mean	5	Mean	21	Mean	23
10' Pole	Std dev	12	Std dev	4	Std dev	23	Std dev	23
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	41	Peak	16	Peak	95	Peak	88
L9	Mean	24	Mean	5	Mean	26	Mean	26
12' pole	Std dev	15	Std dev	4	Std dev	25	Std dev	25
	Samples	17	Samples	22	Samples	48	Samples	30
	Peak	51	Peak	14	Peak	79	Peak	97

Table 18 (cont.) - Fastec 312, Carbon Monoxide (ppm)

	15 mph		25 mph		12 mph		20 mph	
L1	Mean	170	Mean	186	Mean	461	Mean	98
Back Deck Port	Std dev	197	Std dev	185	Std dev	380	Std dev	118
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	1109	Peak	584	Peak	1109	Peak	563
L2	Mean	121	Mean	22	Mean	397	Mean	96
Back Deck Center	Std dev	100	Std dev	15	Std dev	295	Std dev	180
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	382	Peak	62	Peak	1104	Peak	802
L3	Mean	594	Mean	65	Mean	475	Mean	284
Back Deck	Std dev	442	Std dev	24	Std dev	277	Std dev	222
Starboard	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	1123	Peak	141	Peak	1040	Peak	1126
L4	Mean	33	Mean	5	Mean	6	Mean	6
Interior Seat Port	Std dev	35	Std dev	2	Std dev	4	Std dev	4
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	115	Peak	9	Peak	26	Peak	23
L5	Mean	33	Mean	3	Mean	6	Mean	4
Interior Seat	Std dev	39	Std dev	1	Std dev	5	Std dev	2
Starboard	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	163	Peak	4	Peak	33	Peak	10
L6	Mean	14	Mean	30	Mean	10	Mean	8
Front	Std dev	10	Std dev	37	Std dev	15	Std dev	1
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	43	Peak	145	Peak	80	Peak	10
L7	Mean	40	Mean	9	Mean	4	Mean	3
8' Pole	Std dev	41	Std dev	4	Std dev	6	Std dev	1
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	159	Peak	19	Peak	31	Peak	5
L8	Mean	49	Mean	22	Mean	6	Mean	3
10' Pole	Std dev	54	Std dev	32	Std dev	10	Std dev	1
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	257	Peak	146	Peak	47	Peak	6
L9	Mean	54	Mean	42	Mean	3	Mean	2
12' pole	Std dev	64	Std dev	54	Std dev	1	Std dev	1
	Samples	36	Samples	24	Samples	102	Samples	43
	Peak	305	Peak	225	Peak	6	Peak	3

Table 19 - Crownline 270, Carbon Monoxide (ppm)

	Engines Idling		Increase RPM to 2000	
L1	Mean	1053	Mean	1150
	Std dev	239	Std dev	3
	Samples	89	Samples	42
	Peak	1157	Peak	1154
L2	Mean	980	Mean	1110
	Std dev	209	Std dev	1
	Samples	89	Samples	42
	Peak	1114	Peak	1112
L3	Mean	1084	Mean	1107
	Std dev	141	Std dev	2
	Samples	89	Samples	42
	Peak	1120	Peak	1112
L4	Mean	188	Mean	598
	Std dev	120	Std dev	425
	Samples	89	Samples	42
	Peak	649	Peak	1132
L5	Mean	46	Mean	147
	Std dev	28	Std dev	140
	Samples	89	Samples	42
	Peak	117	Peak	497
L6	Mean	70	Mean	250
	Std dev	47	Std dev	204
	Samples	89	Samples	42
	Peak	224	Peak	696
L7	Mean	2	Mean	2
	Std dev	0	Std dev	0
	Samples	89	Samples	42
	Peak	3	Peak	3
L8	Mean	2	Mean	2
	Std dev	1	Std dev	1
	Samples	89	Samples	42
	Peak	3	Peak	4

Table 20 - Formula 41 PC, Carbon Monoxide (ppm)

	Start Generator		Start Drive Engines		Idle Speed		2.6 mph		10 mph	
L1	Mean	28	Mean	828	Mean	140	Mean	329	Mean	668
	Std dev	57	Std dev	202	Std dev	136	Std dev	200	Std dev	185
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	257	Peak	1027	Peak	652	Peak	742	Peak	1045
L2	Mean	56	Mean	521	Mean	112	Mean	294	Mean	636
	Std dev	92	Std dev	162	Std dev	117	Std dev	165	Std dev	160
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	397	Peak	681	Peak	542	Peak	640	Peak	1027
L3	Mean	73	Mean	372	Mean	155	Mean	306	Mean	848
	Std dev	109	Std dev	209	Std dev	191	Std dev	146	Std dev	242
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	342	Peak	675	Peak	741	Peak	564	Peak	1125
L4	Mean	3	Mean	94	Mean	91	Mean	39	Mean	298
	Std dev	3	Std dev	109	Std dev	64	Std dev	42	Std dev	131
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	19	Peak	272	Peak	284	Peak	213	Peak	530
L5	Mean	1	Mean	65	Mean	39	Mean	101	Mean	145
	Std dev	1	Std dev	88	Std dev	63	Std dev	81	Std dev	90
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	4	Peak	217	Peak	218	Peak	277	Peak	333
L6	Mean	2	Mean	8	Mean	8	Mean	97	Mean	93
	Std dev	1	Std dev	5	Std dev	12	Std dev	62	Std dev	79
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	3	Peak	16	Peak	50	Peak	199	Peak	312
L7	Mean	2	Mean	1	Mean	53	Mean	42	Mean	67
	Std dev	1	Std dev	0	Std dev	37	Std dev	21	Std dev	33
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	3	Peak	2	Peak	140	Peak	88	Peak	141
L8	Mean	3	Mean	3	Mean	53	Mean	56	Mean	75
	Std dev	1	Std dev	1	Std dev	37	Std dev	29	Std dev	35
	Samples	72	Samples	6	Samples	30	Samples	42	Samples	78
	Peak	4	Peak	4	Peak	130	Peak	109	Peak	158

Table 20 (cont.) - Formula 41 PC, Carbon Monoxide (ppm)

	Pole Broke		15 mph		6.5 mph		4 mph		Backing on to dock	
L1	Mean	233	Mean	221	Mean	259	Mean	418	Mean	745
	Std dev	147	Std dev	148	Std dev	63	Std dev	122	Std dev	394
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	536	Peak	602	Peak	362	Peak	579	Peak	1168
L2	Mean	203	Mean	233	Mean	270	Mean	461	Mean	740
	Std dev	111	Std dev	164	Std dev	78	Std dev	109	Std dev	372
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	417	Peak	700	Peak	375	Peak	616	Peak	1123
L3	Mean	288	Mean	391	Mean	370	Mean	489	Mean	655
	Std dev	145	Std dev	193	Std dev	97	Std dev	105	Std dev	299
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	631	Peak	928	Peak	609	Peak	619	Peak	1125
L4	Mean	99	Mean	55	Mean	151	Mean	208	Mean	275
	Std dev	73	Std dev	58	Std dev	25	Std dev	76	Std dev	72
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	267	Peak	200	Peak	192	Peak	306	Peak	407
L5	Mean	81	Mean	67	Mean	62	Mean	98	Mean	187
	Std dev	72	Std dev	56	Std dev	38	Std dev	21	Std dev	74
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	302	Peak	265	Peak	123	Peak	113	Peak	298
L6	Mean	55	Mean	76	Mean	52	Mean	116	Mean	74
	Std dev	63	Std dev	52	Std dev	28	Std dev	27	Std dev	34
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	274	Peak	232	Peak	98	Peak	157	Peak	152
L7	Mean	86	Mean	38	Mean	117	Mean	138	Mean	246
	Std dev	72	Std dev	19	Std dev	38	Std dev	18	Std dev	54
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	293	Peak	99	Peak	167	Peak	157	Peak	374
L8	Mean	81	Mean	50	Mean	141	Mean	142	Mean	226
	Std dev	60	Std dev	32	Std dev	42	Std dev	24	Std dev	60
	Samples	42	Samples	78	Samples	12	Samples	6	Samples	12
	Peak	231	Peak	146	Peak	200	Peak	175	Peak	335

Table 21 - Bombardier Seadoo, Cabon Monoxide (ppm)

	Turn on	
L7	Mean	2
	Std dev	4
	Samples	102
	Peak	15
L8	Mean	3
	Std dev	4
	Samples	102
	Peak	17

Table 22 - Crownline 239 DB, Carbon Monoxide (ppm)

	Run Engine Idle Speed		Increase Engine to 2000 RPM	
L1	Mean	101	Mean	248
Back Deck Port	Std dev	150	Std dev	417
	Samples	37	Samples	24
	Peak	596	Peak	1176
L2	Mean	107	Mean	175
Back Deck Center	Std dev	123	Std dev	266
	Samples	37	Samples	24
	Peak	431	Peak	918
L3	Mean	154	Mean	177
Back Deck	Std dev	137	Std dev	227
Starboard	Samples	37	Samples	24
	Peak	517	Peak	715
L4	Mean	66	Mean	72
Interior Seat Port	Std dev	69	Std dev	102
	Samples	37	Samples	24
	Peak	301	Peak	399
L5	Mean	30	Mean	48
Interior Seat	Std dev	30	Std dev	60
Starboard	Samples	37	Samples	24
	Peak	108	Peak	214
L6	Mean	24	Mean	44
Front	Std dev	17	Std dev	55
	Samples	37	Samples	24
	Peak	75	Peak	174
L7	Mean	5	Mean	7
8' Pole	Std dev	5	Std dev	5
	Samples	37	Samples	24
	Peak	16	Peak	18
L8	Mean	5	Mean	6
10' Pole	Std dev	6	Std dev	6
	Samples	37	Samples	24
	Peak	19	Peak	22

Table 23 - Crownline 239 DB, Carbon Monoxide (ppm)

	Start Engine		1 -2 mph		5 mph		10 mph	
L1	Mean	20	Mean	335	Mean	420	Mean	164
Back Deck Port	Std dev	0	Std dev	319	Std dev	287	Std dev	65
	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	20	Peak	974	Peak	945	Peak	262
L2	Mean	9	Mean	119	Mean	345	Mean	102
Back Deck Center	Std dev	0	Std dev	191	Std dev	194	Std dev	66
	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	9	Peak	647	Peak	737	Peak	238
L3	Mean	8	Mean	19	Mean	185	Mean	19
Back Deck	Std dev	0	Std dev	24	Std dev	207	Std dev	4
Starboard	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	8	Peak	106	Peak	662	Peak	27
L4	Mean	3	Mean	5	Mean	6	Mean	3
Interior Seat Port	Std dev	0	Std dev	5	Std dev	4	Std dev	2
	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	4	Peak	19	Peak	21	Peak	9
L5	Mean	4	Mean	9	Mean	21	Mean	4
Interior Seat	Std dev	1	Std dev	11	Std dev	41	Std dev	1
Starboard	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	5	Peak	71	Peak	168	Peak	6
L6	Mean	6	Mean	7	Mean	6	Mean	3
Front	Std dev	1	Std dev	4	Std dev	2	Std dev	1
	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	6	Peak	27	Peak	14	Peak	5
L7	Mean	1	Mean	3	Mean	5	Mean	1
8' Pole	Std dev	0	Std dev	2	Std dev	6	Std dev	0
	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	1	Peak	12	Peak	28	Peak	2
L8	Mean	1	Mean	3	Mean	6	Mean	1
10' Pole	Std dev	0	Std dev	3	Std dev	7	Std dev	0
	Samples	7	Samples	52	Samples	42	Samples	48
	Peak	1	Peak	14	Peak	34	Peak	2

Table 23 (cont.) - Crownline 239 DB, Carbon Monoxide (ppm)

	15 mph		25 mph		Full Throttle	
L1	Mean	99	Mean	47	Mean	383
Back Deck Port	Std dev	66	Std dev	43	Std dev	305
	Samples	60	Samples	66	Samples	42
	Peak	312	Peak	171	Peak	1159
L2	Mean	68	Mean	42	Mean	195
Back Deck Center	Std dev	55	Std dev	29	Std dev	178
	Samples	60	Samples	66	Samples	42
	Peak	229	Peak	104	Peak	663
L3	Mean	9	Mean	8	Mean	19
Back Deck	Std dev	4	Std dev	4	Std dev	27
Starboard	Samples	60	Samples	66	Samples	42
	Peak	21	Peak	19	Peak	127
L4	Mean	2	Mean	3	Mean	4
Interior Seat Port	Std dev	1	Std dev	1	Std dev	4
	Samples	60	Samples	66	Samples	42
	Peak	5	Peak	4	Peak	21
L5	Mean	3	Mean	2	Mean	6
Interior Seat	Std dev	1	Std dev	0	Std dev	14
Starboard	Samples	60	Samples	66	Samples	42
	Peak	4	Peak	3	Peak	74
L6	Mean	3	Mean	3	Mean	3
Front	Std dev	1	Std dev	1	Std dev	2
	Samples	60	Samples	66	Samples	42
	Peak	5	Peak	5	Peak	9
L7	Mean	1	Mean	1	Mean	1
8' Pole	Std dev	0	Std dev	0	Std dev	0
	Samples	60	Samples	66	Samples	42
	Peak	2	Peak	2	Peak	2
L8	Mean	1	Mean	1	Mean	1
10' Pole	Std dev	0	Std dev	0	Std dev	0
	Samples	60	Samples	66	Samples	42
	Peak	1	Peak	2	Peak	2

Table 24 - Formula 280, Carbon Monoxide (ppm)

	Idle Drive Engines		2000 RPM	
L1	Mean	499	Mean	839
Back Deck Port	Std dev	489	Std dev	494
	Samples	36	Samples	30
	Peak	1174	Peak	1175
L2	Mean	182	Mean	792
Back Deck Center	Std dev	274	Std dev	476
	Samples	36	Samples	30
	Peak	1145	Peak	1145
L3	Mean	244	Mean	545
Back Deck	Std dev	353	Std dev	462
Starboard	Samples	36	Samples	30
	Peak	1178	Peak	1178
L4	Mean	17	Mean	361
Interior Seat Port	Std dev	17	Std dev	457
	Samples	36	Samples	30
	Peak	53	Peak	1137
L5	Mean	18	Mean	67
Interior Seat	Std dev	20	Std dev	58
Starboard	Samples	36	Samples	30
	Peak	74	Peak	194
L6	Mean	17	Mean	104
Front	Std dev	15	Std dev	154
	Samples	36	Samples	30
	Peak	49	Peak	564
L7	Mean	5	Mean	125
8' Pole	Std dev	5	Std dev	138
	Samples	36	Samples	30
	Peak	15	Peak	376
L8	Mean	4	Mean	87
10' Pole	Std dev	5	Std dev	108
	Samples	36	Samples	30
	Peak	15	Peak	341

Figure 1. Average CO Concentrations, Formula 370 ss

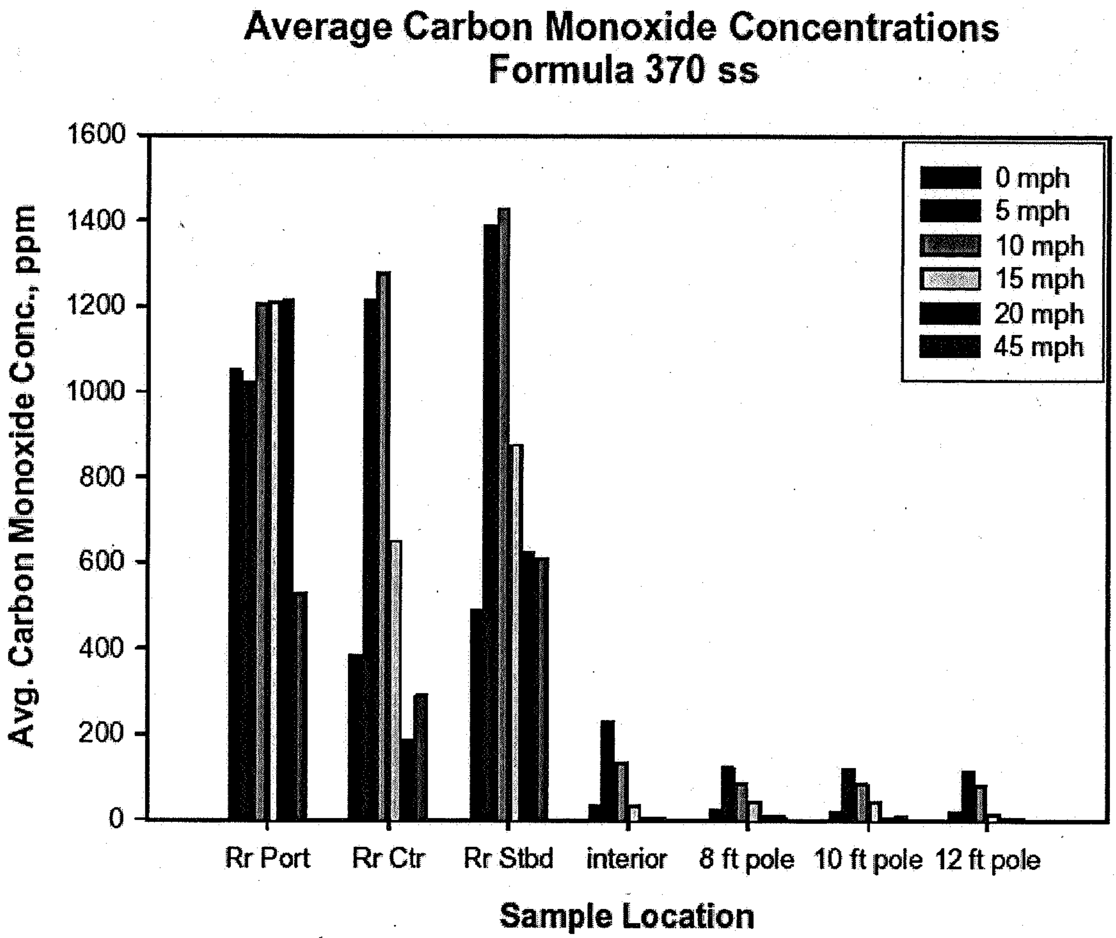

Figure 2. Average CO Concentrations, Crownline 270

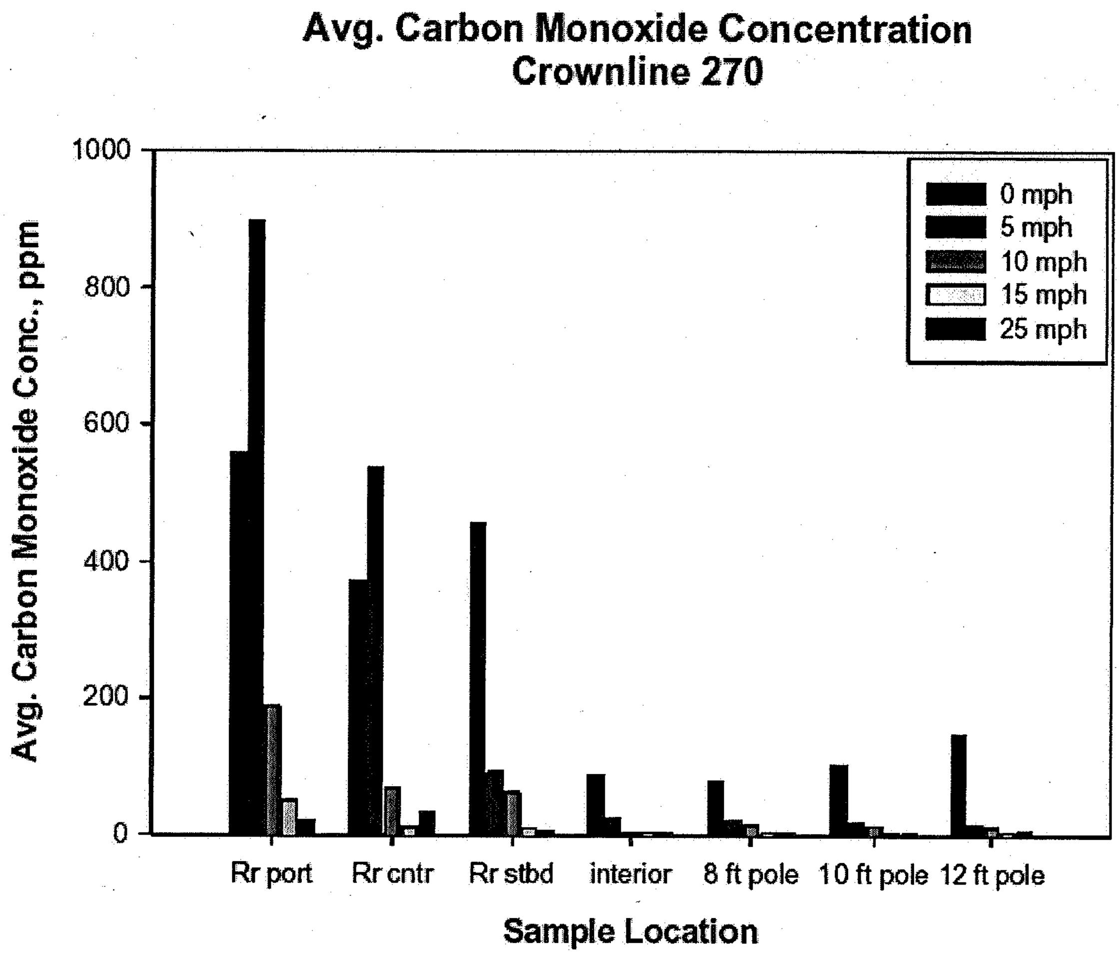

Figure 3. Average CO Concentrations, Formula 260 ss

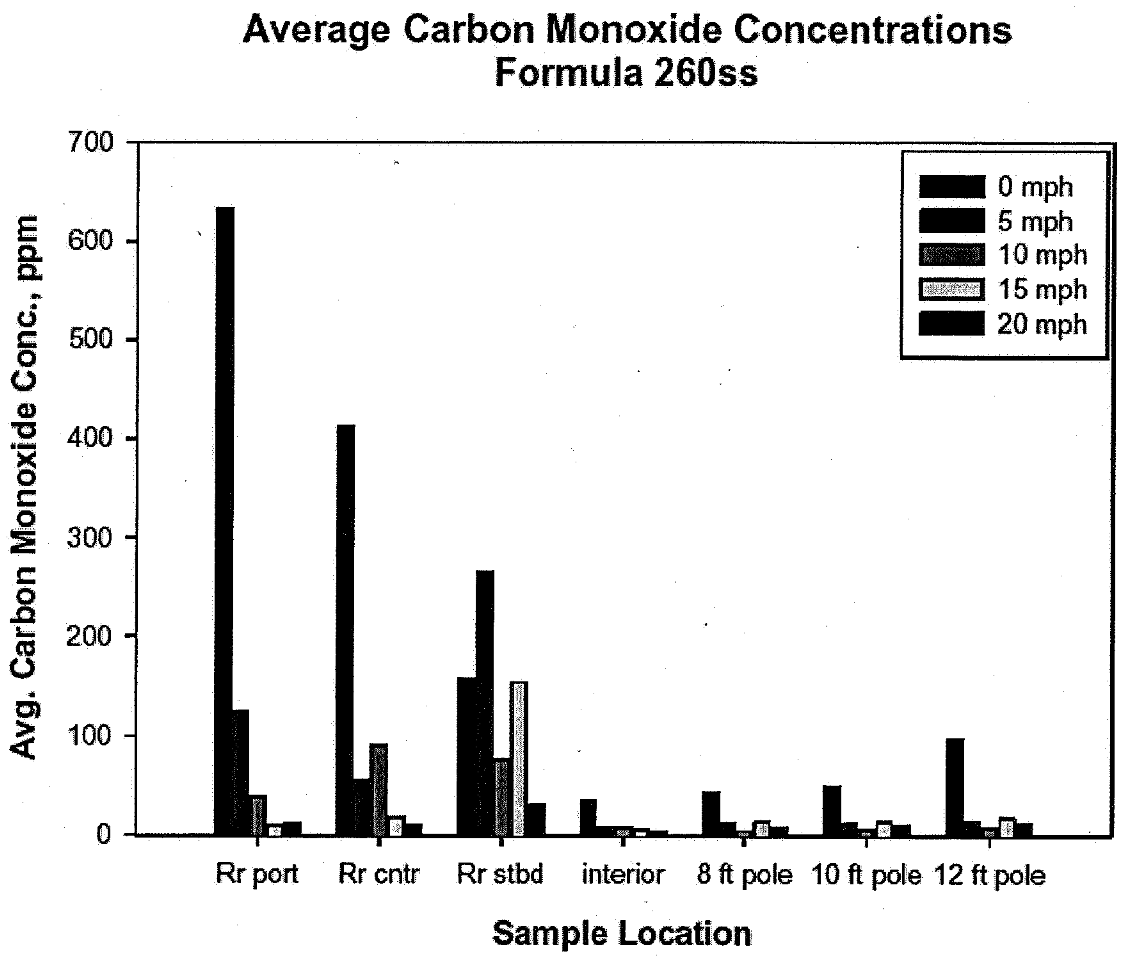

Figure 4. Average CO Concentrations, Malibu Escape