

CARBON MONOXIDE EMISSIONS AND EXPOSURES ON EXPRESS CRUISERS

Progress Summary

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BOAT DETAILS

Boat	Length	Engines	Exhaust	Generator
1	31'	Twin Volvo Penta 8.1 L	Through Hub	Gas 120 v 7.3KW Kohler
2	30'	Twin Mercruiser 5.0 L	Through Hub	Gas 120 v 5.0KW Kohler
3	40'	Twin Mercruiser 8.1 L	Sides and Underwater	Gas 120 v 7.3KW Kohler
4*	37'	Twin Mercruiser 8.1 L	Through Transom	Gas 120 v 7.3KW Kohler
5	33'	Twin Volvo Penta 5.7 L	Through Hub	Gas 120 v 5.0KW Kohler
6	36'	Twin Mercruiser 8.1 L	Sides and Underwater	Gas 120 v 7.3KW Kohler

* Boat 4 equipped with both through transom and through hub (underwater) exhaust, selectable by the operator

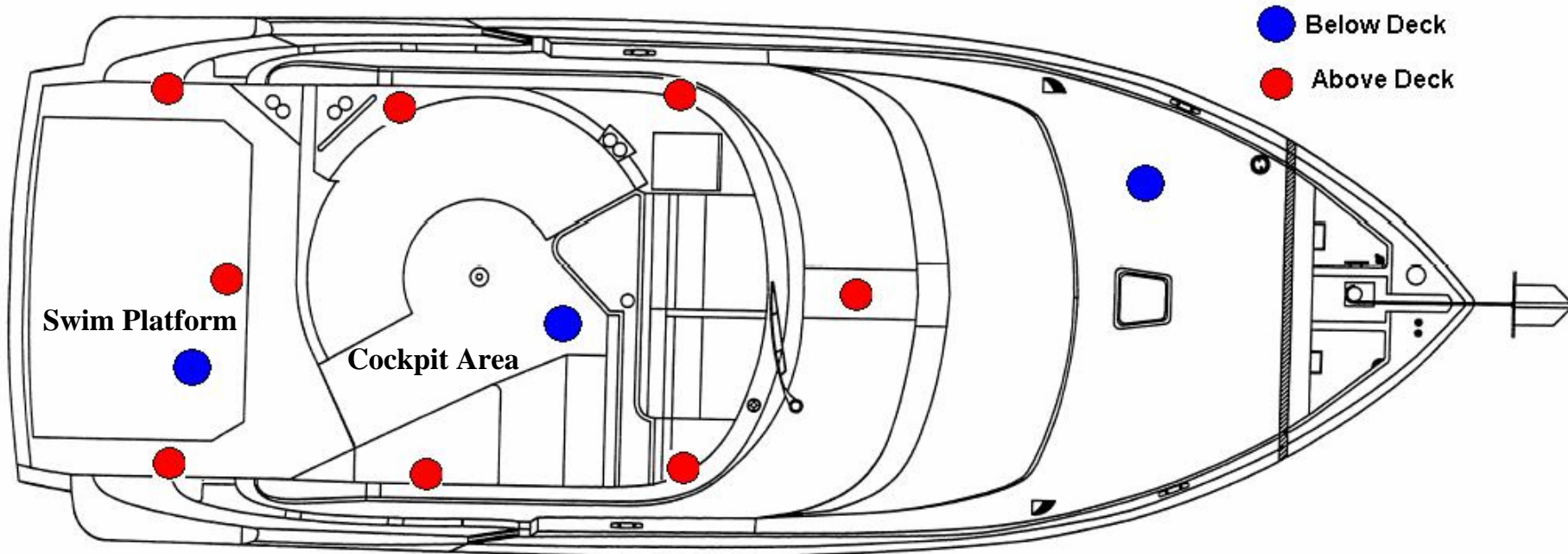
METHODS

- Evaluations typically took several hours for each boat.
- CO monitors and stop watches were synchronized with computer's clock to accurately correlate each test with downloaded data.
- CO monitors were placed at various locations on the boat.
- Air sampling occurred while boat was stationary and moving.
- While moving, boat speed and relative wind speed was measured and recorded.
- Smoke tests were performed while stationary and moving.
- Temperature and relative humidity were measured every time a new run was initiated.
- All warning labels were inspected.

TEST MATRIX

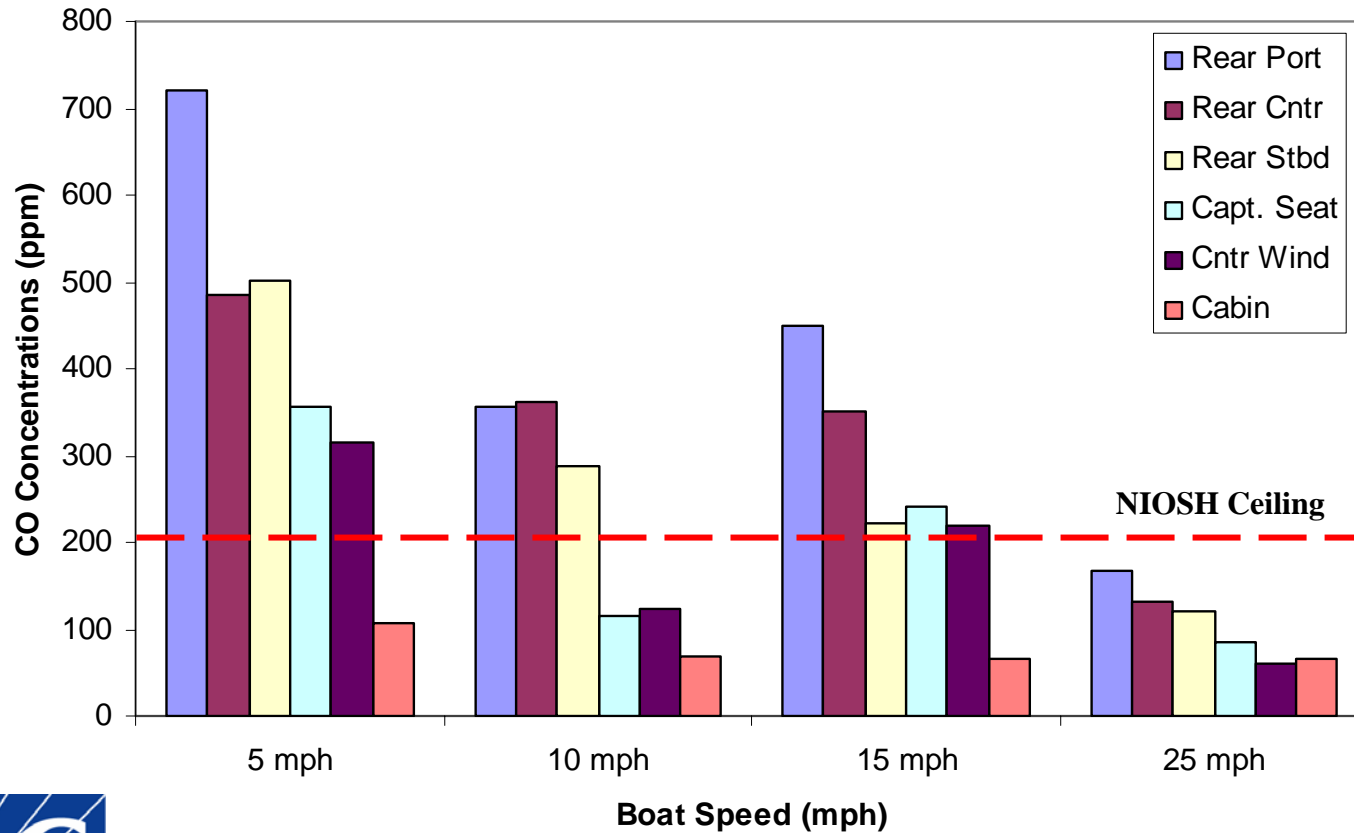
Stationary or Underway	Condition	Condition
Stationary (at slip)	Generator on	Generator and propulsion engines on
Stationary (on water)	Generator on	Generator and propulsion engines on
Idle speed	With canvas under 2-3 configurations such as - all up, side curtains off, only bimini top up, etc.	
2 mid-range speeds	With canvas under 2-3 configurations such as - all up, side curtains off, only bimini top up, etc.	
Open throttle	With canvas under 2-3 configurations such as - all up, side curtains off, only bimini top up, etc.	

TYPICAL SAMPLE LOCATIONS

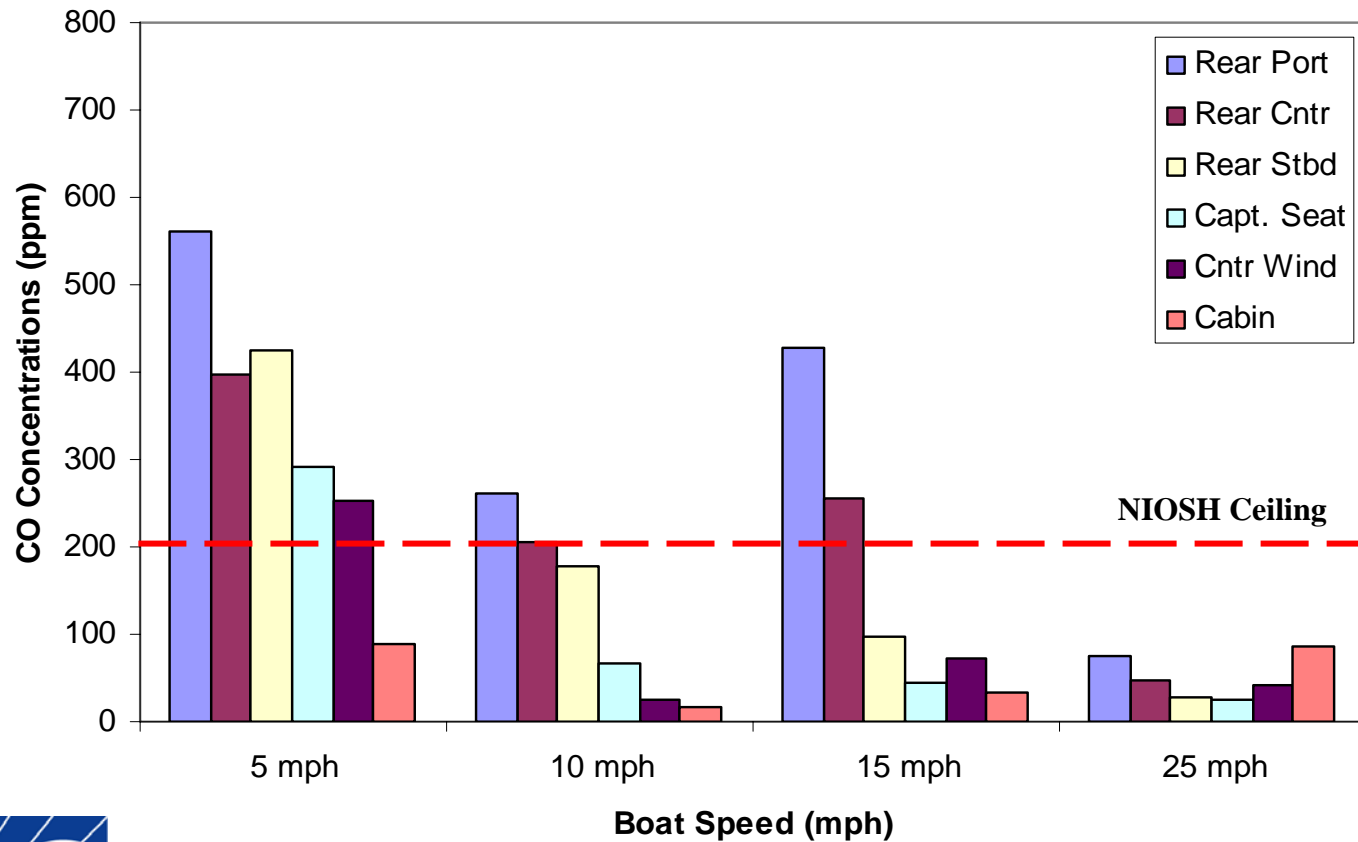


Not to Scale

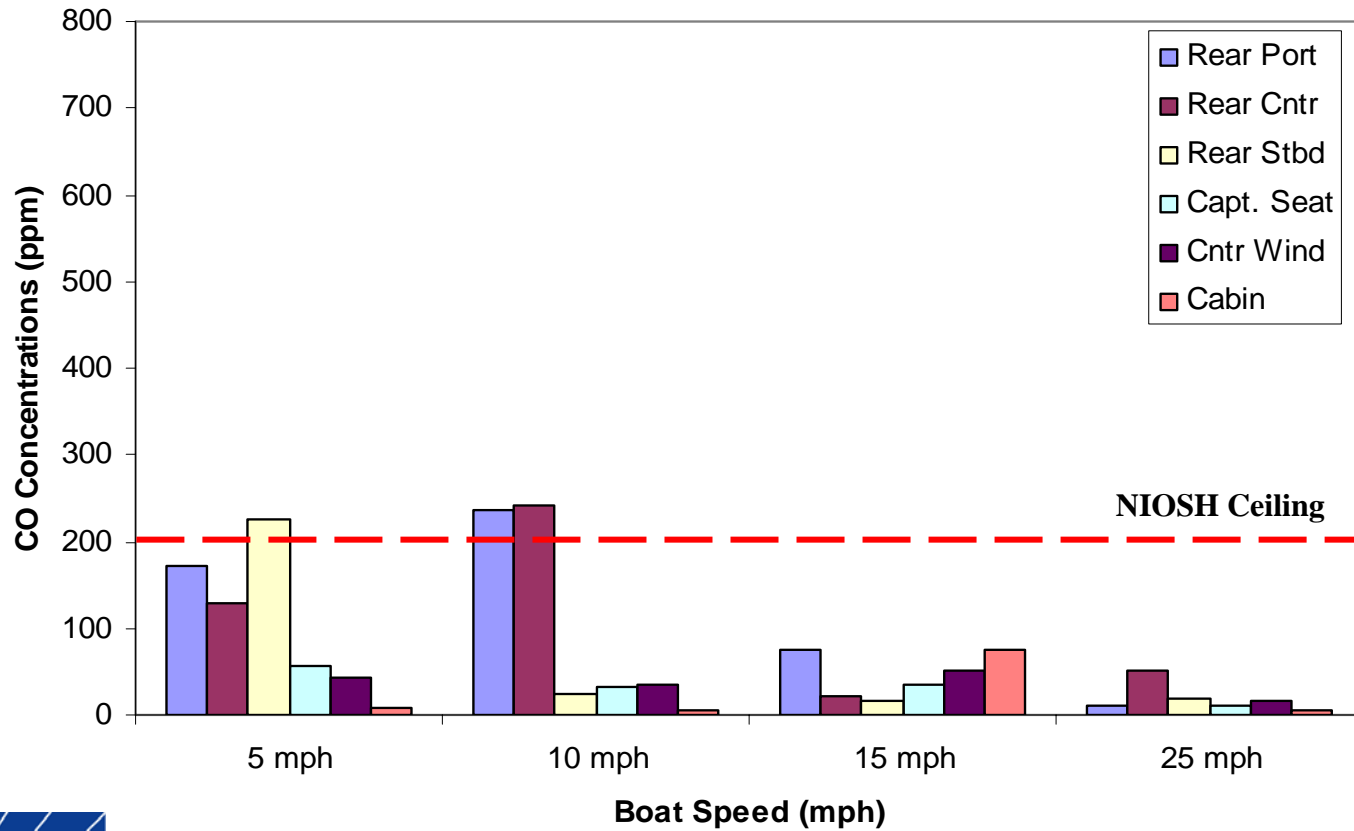
RESULTS BOAT 4 (Canvas Fully Deployed)



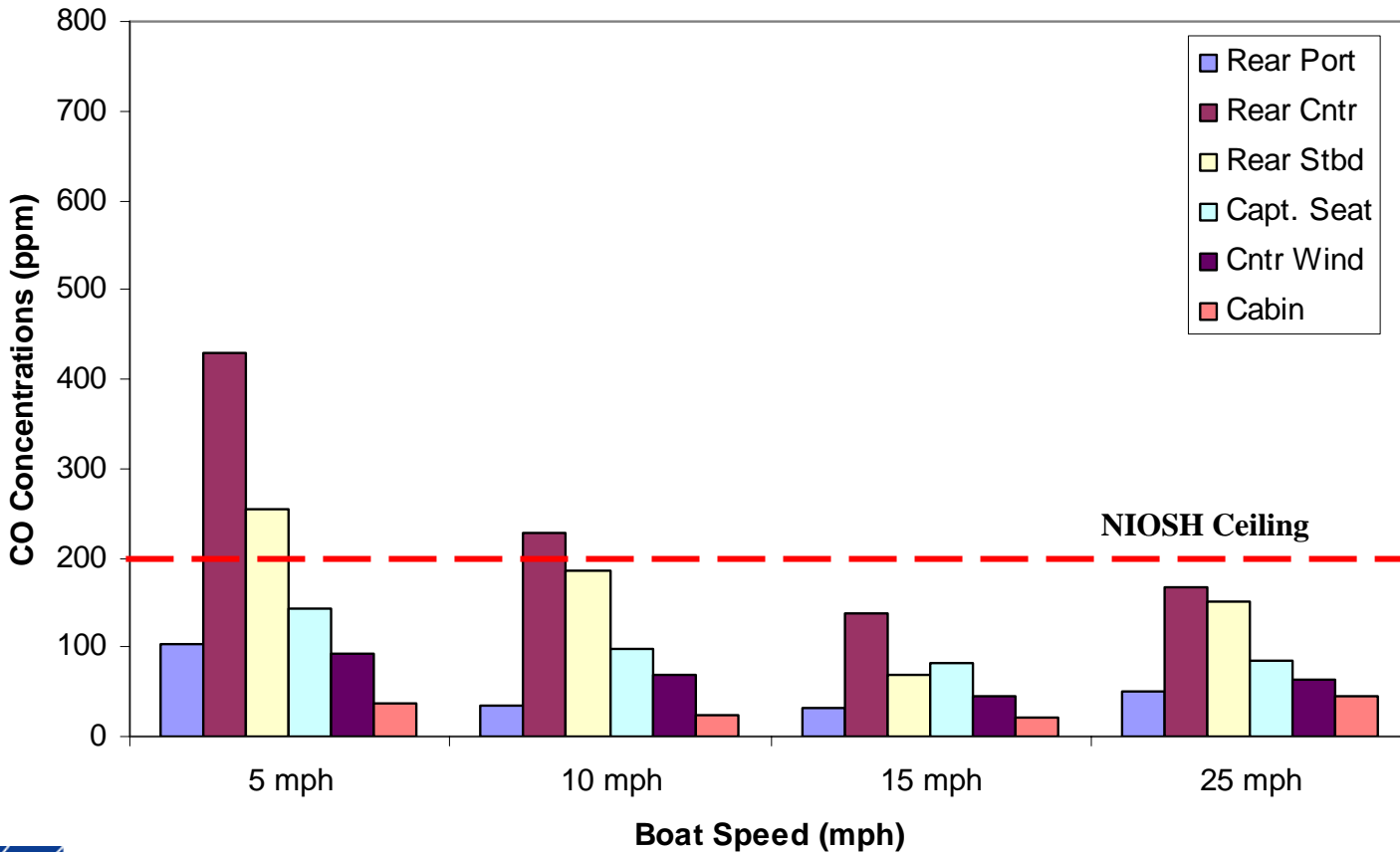
RESULTS BOAT 4 (Partial Canvas)



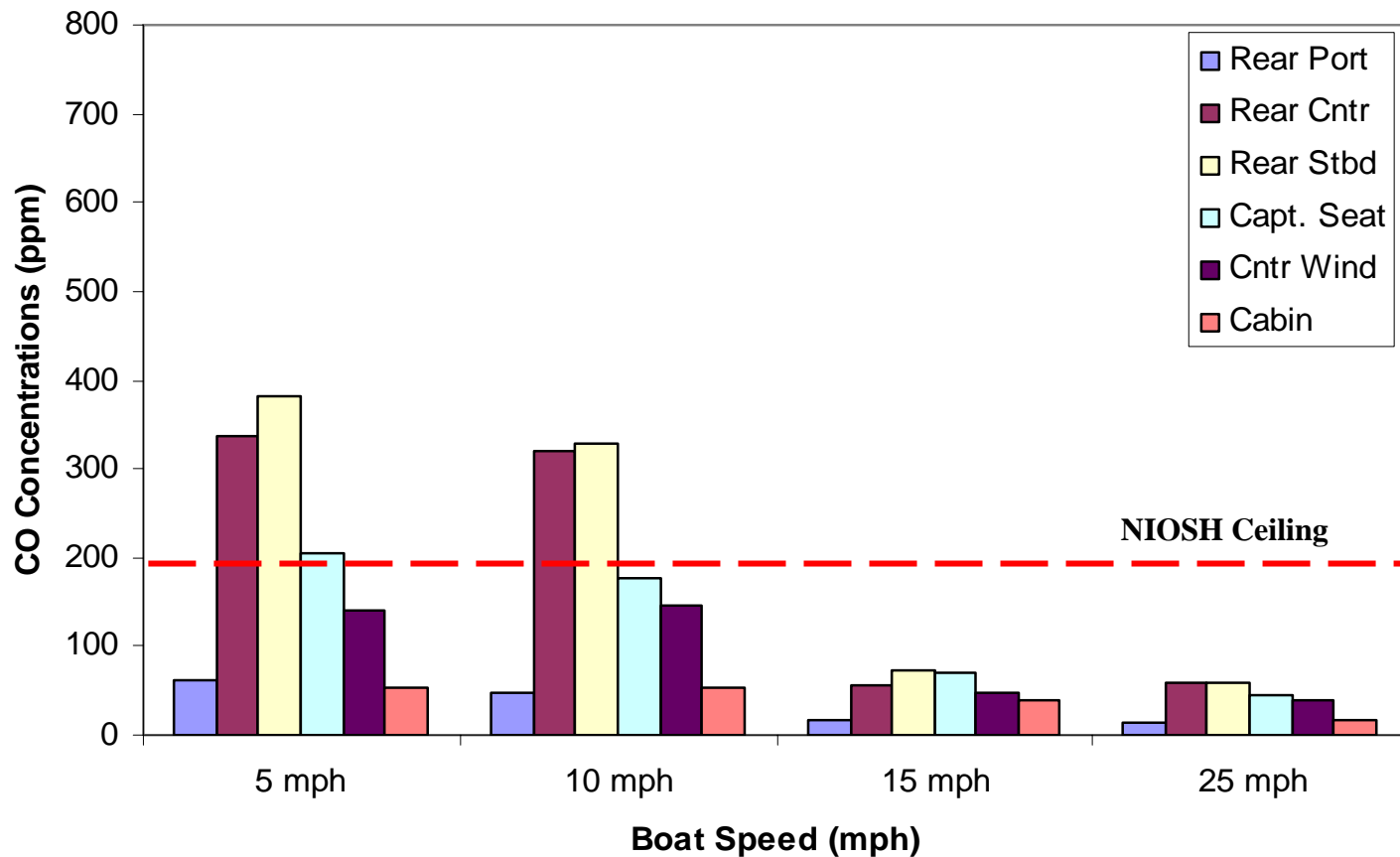
RESULTS BOAT 4 (Bimini Top)



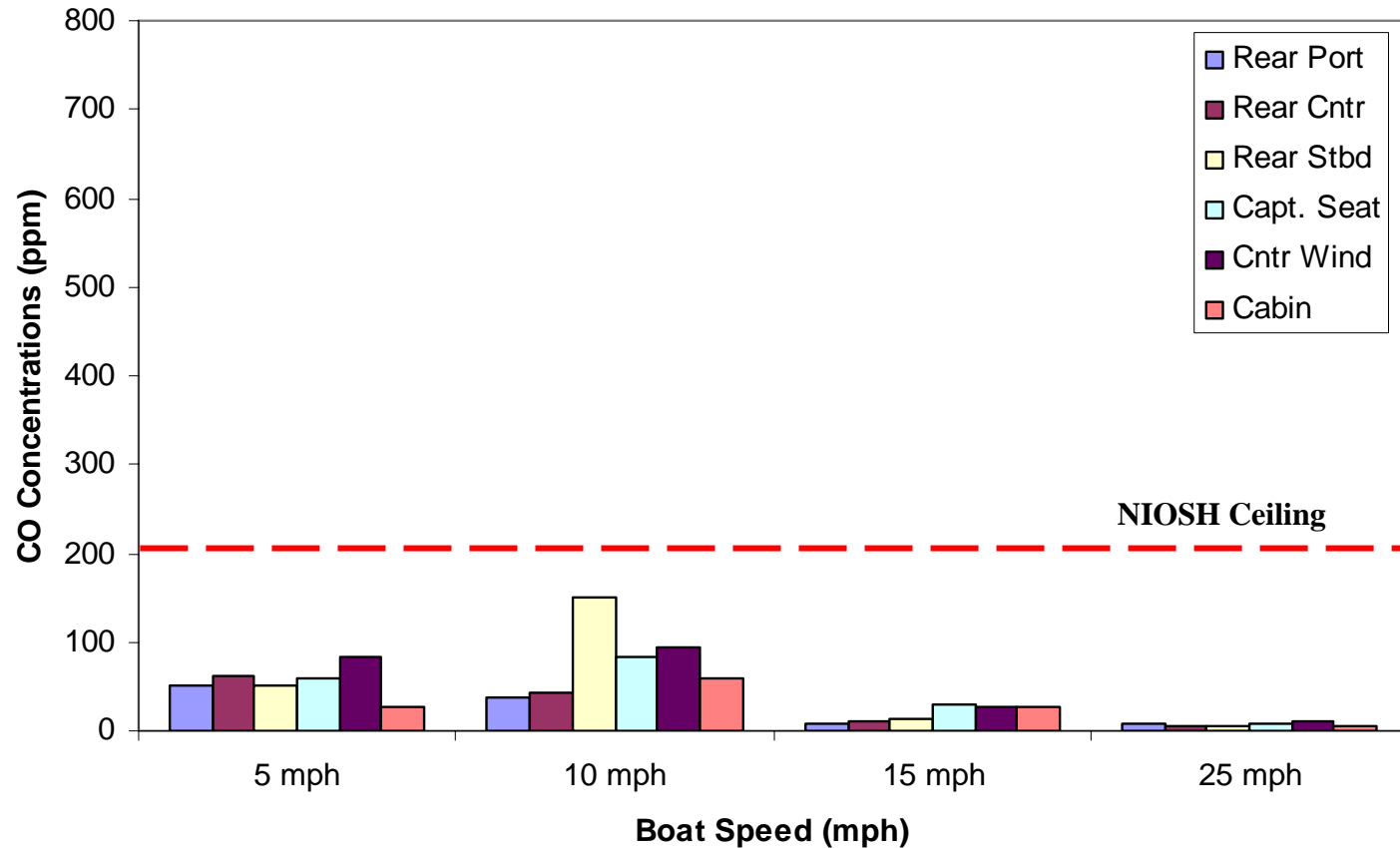
RESULTS BOAT 1 (Canvas Fully Deployed)



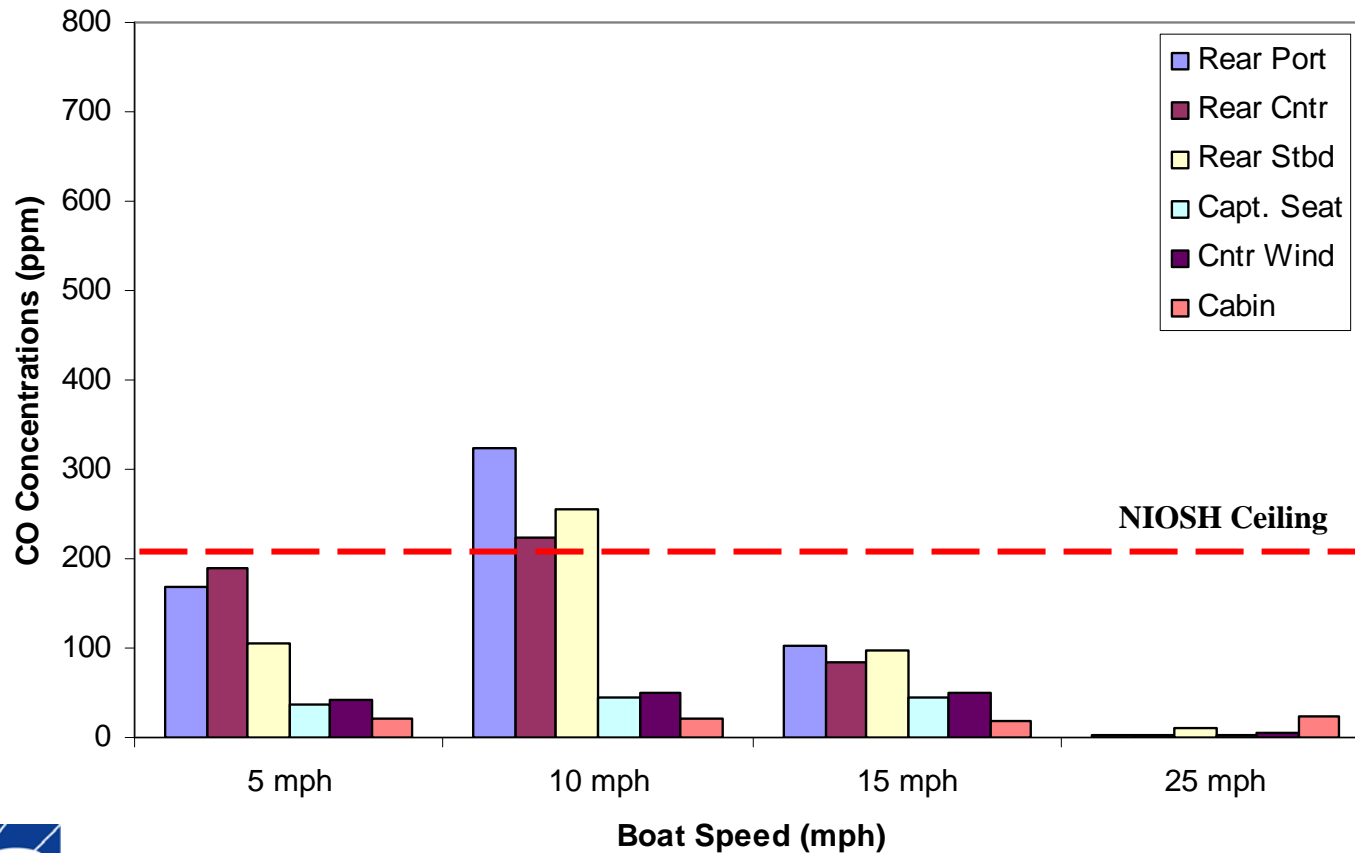
RESULTS BOAT 1 (Partial Canvas)



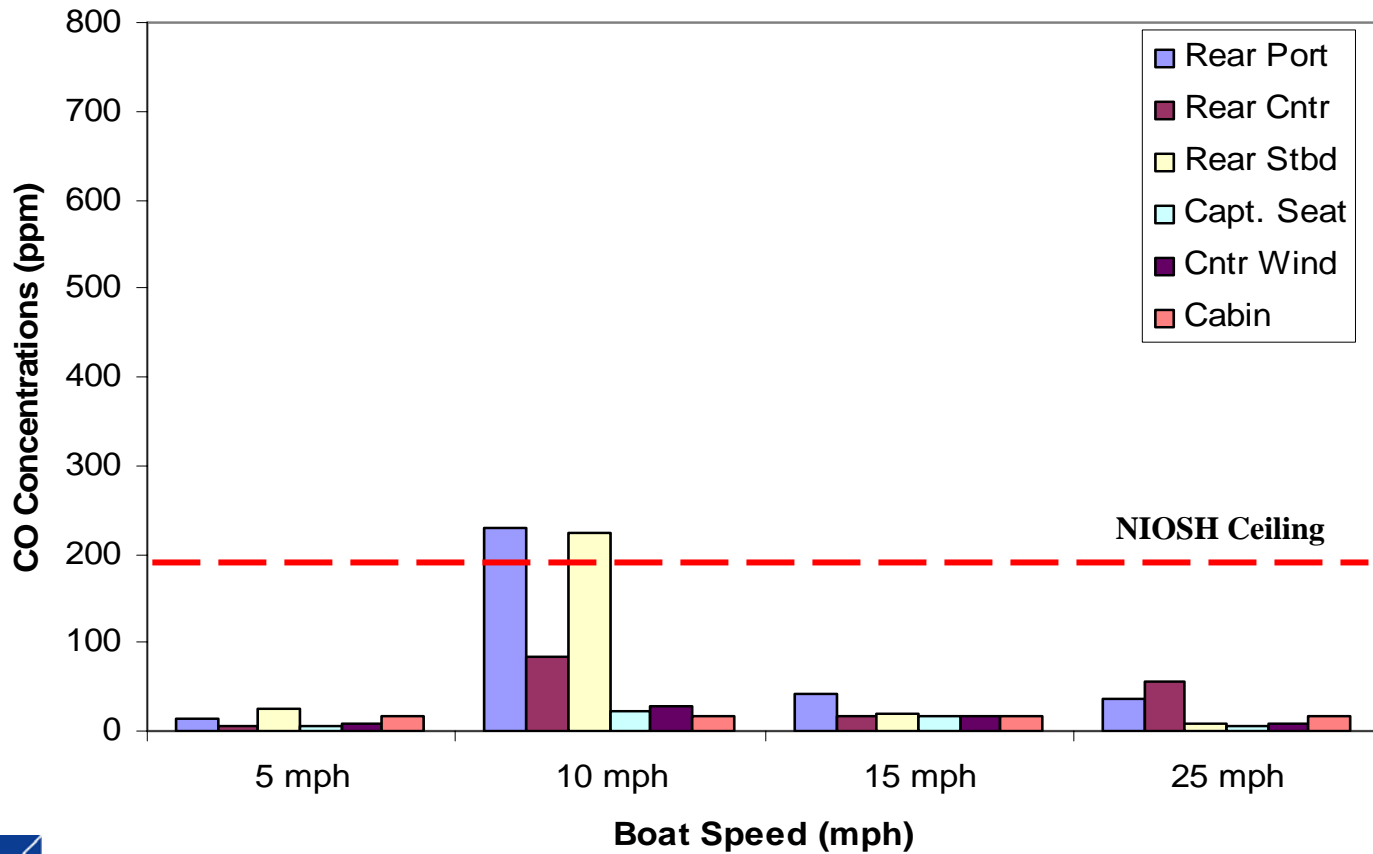
RESULTS BOAT 1 (Bimini Top)



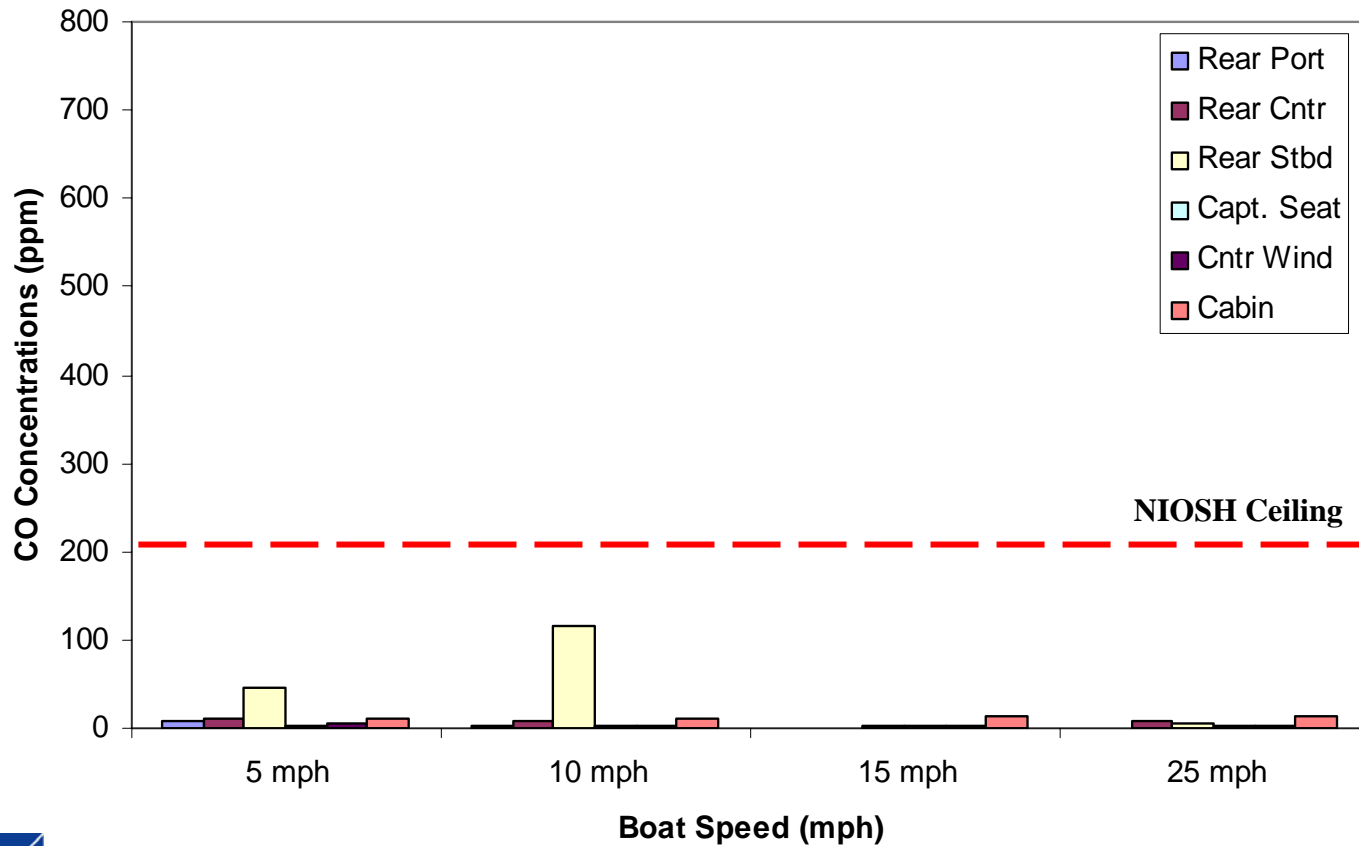
RESULTS BOAT 3 (Canvas Fully Deployed)



RESULTS BOAT 3 (Partial Canvas)



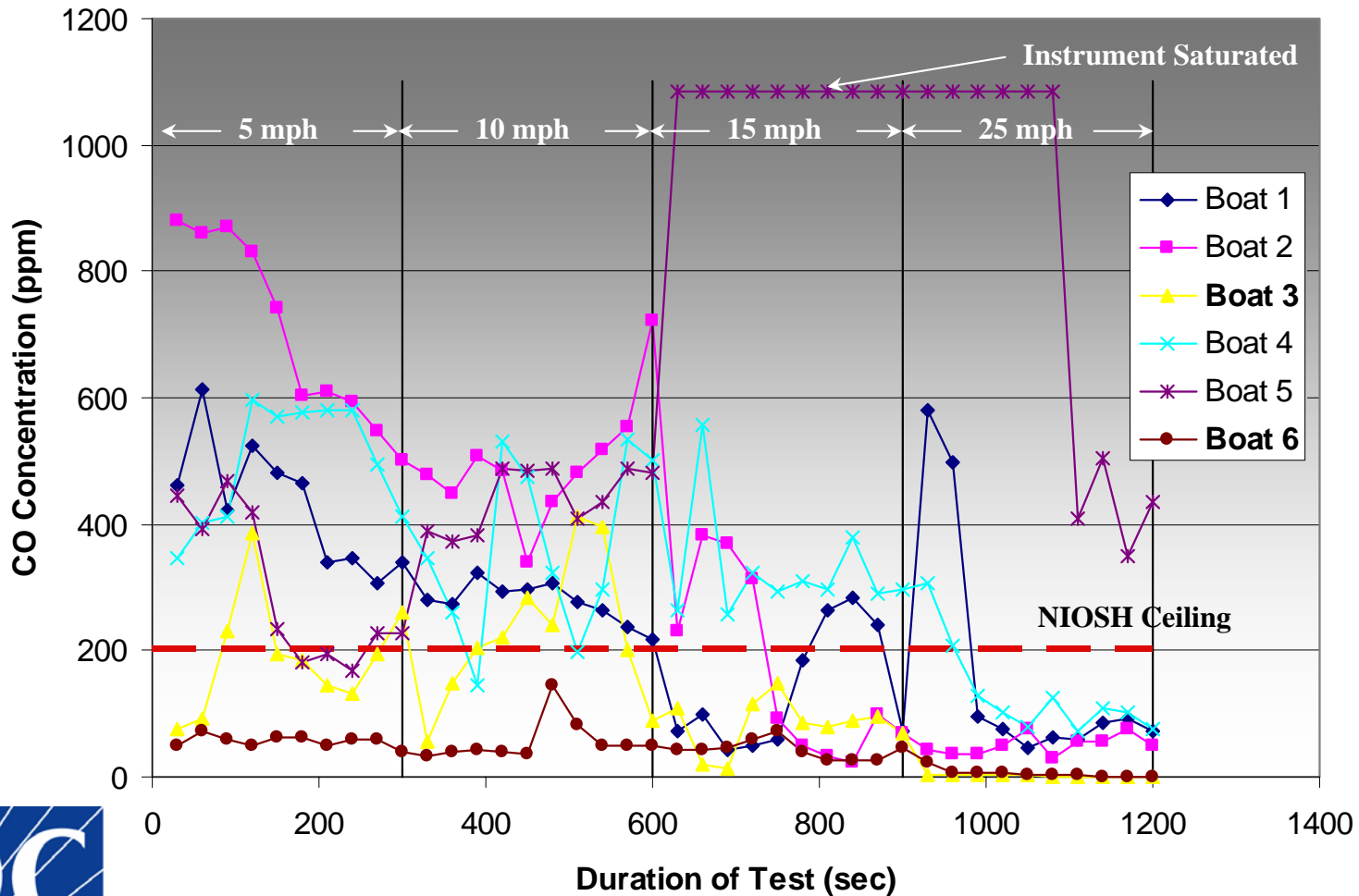
RESULTS BOAT 3 (Bimini Top)



RESULTS

BOAT COMPARISON

(CANVAS FULLY DEPLOYED)

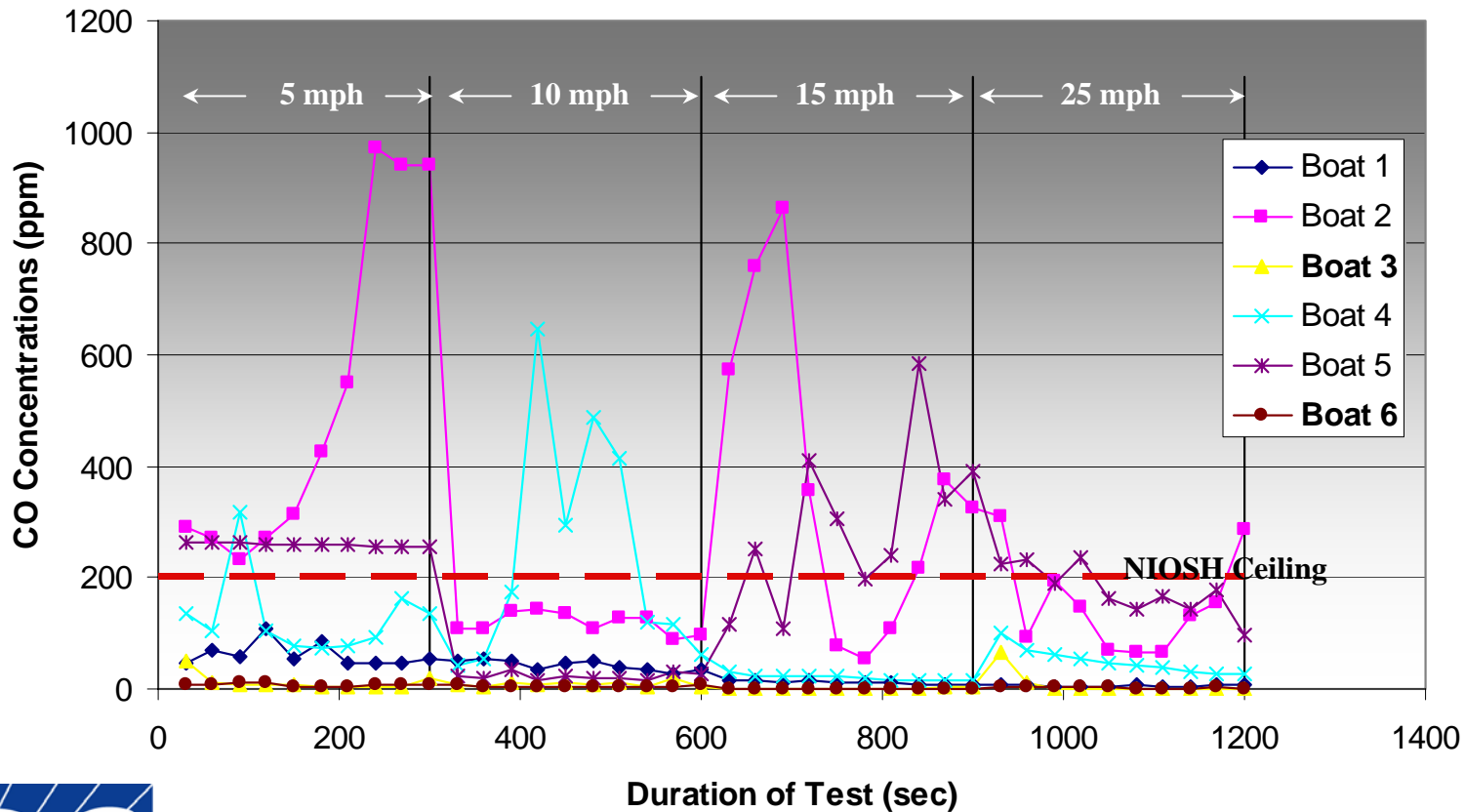


Samples taken on Center of Swimming Platform



RESULTS

BOAT COMPARISON (BIMINI TOP ONLY)



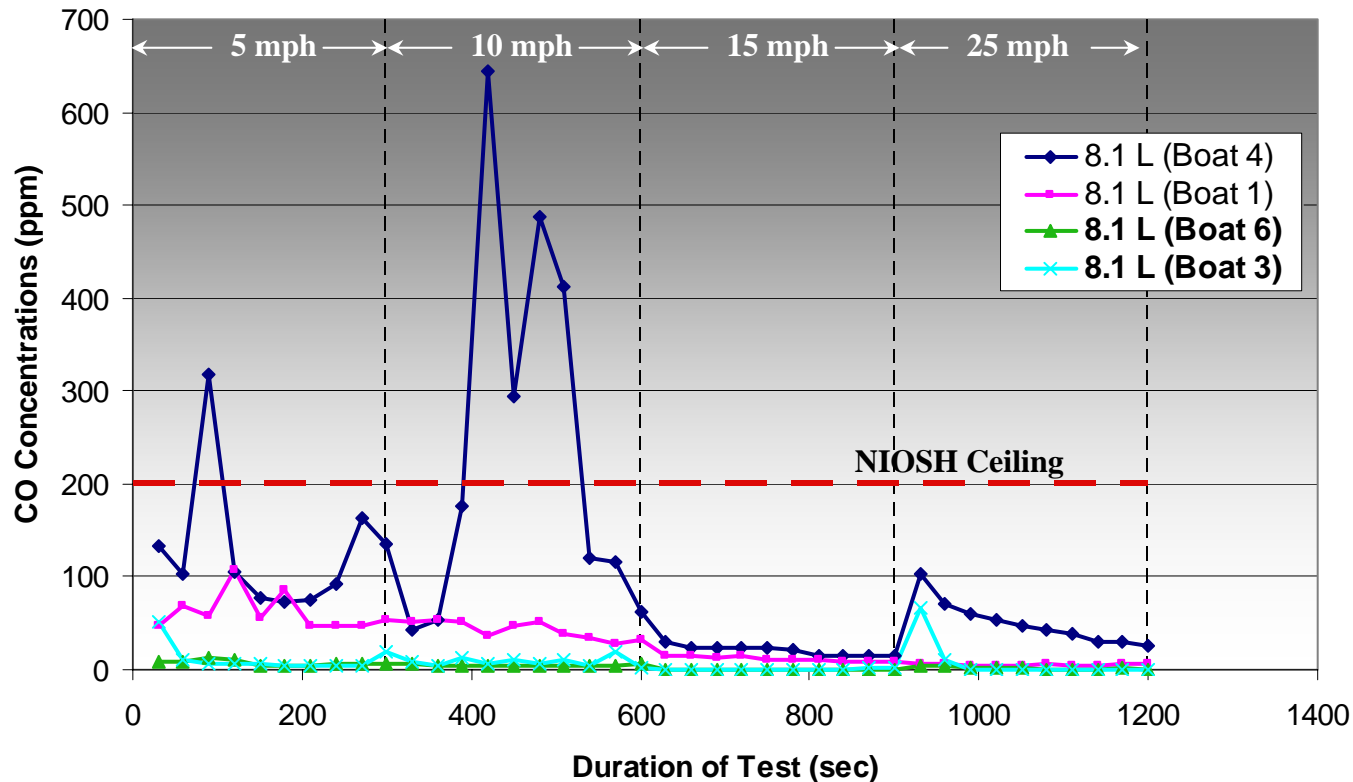
Samples taken on Center of Swimming Platform



RESULTS

EXHAUST COMPARISON 4 BOATS

CENTER OF STERN (BIMINI TOP ONLY)



- Boat 1: 31' Exhaust Hub
- Boat 3: 40' Exhaust S&U
- Boat 4: 37' Exhaust Transom
- Boat 6: 36' Exhaust S&U



RESULTS SUMMARY

- When canvas is deployed, CO concentrations reached instantaneous levels above the IDLH near the swimming platform for some of the evaluated boats.
- Canvas configuration significantly affects CO concentrations in the cockpit area.
- At low speeds and going into the wind with canvas fully deployed, with no forward hatches, windows nor front panels opened, the station wagon effect is maximized pulling significant amounts of CO into the cockpit.
- Different exhaust configurations have a major impact on how CO concentrations are entrained into the cockpit and occupied areas.

RESULTS SUMMARY

- CO concentrations are typically higher at the stern of the boat and gradually lower as you move forward.
- Stationary smoke tests into the engine compartment showed satisfactory sealing of the bulkhead between the engine and adjacent compartments on all boats.
- Warning labels were missing important information to properly warn users of potential hazards and preventive/corrective measures to prevent CO poisonings.
- With the cabin door closed, the cabin is typically under negative pressure when the A/C is running. This condition can lead to CO intrusions if a leak should occur.

DISCUSSION

- Evaluation of 6 express cruisers showed that most propulsion and generator engines produced hazardous CO concentrations near the stern.
- These concentrations are particularly hazardous for boats operating at idle or at slow speeds with canvas fully deployed or for a boater *near exhaust outlets*.
- Exhaust configuration and fresh air ventilation of cockpit area plays an important role on the CO concentrations into the cockpit and occupied areas.
- It seems to be apparent, by observing the charts, that high CO concentrations are also a problem outside the enclosure on the swim platform and a bigger problem with canvas deployed than when it is not deployed

CONCLUSIONS & RECOMMENDATIONS

- Underwater exhaust will significantly reduce CO concentrations inside the cockpit compared to surface exhaust.
- Some canvas configurations should not be used while boat is moving or propulsion and/or generator engines are running.
- Study the possibility of adding force draft blowers into the cabin to create a positive pressure minimizing the potential for CO intrusions. Auxiliary blowers can be fitted and routed to ventilate cockpit and swim platform to minimize/break the negative pressure areas throughout the vessel.

CONCLUSIONS & RECOMMENDATIONS

- Encourage the cabin sliding door suppliers to develop better sealing of these doors.
- Encourage windshield manufacturers to study the possible ventilation through the center and side wings of the windshield.
- Due care should be exercised when designing the powered ventilation system on the engine compartment to locate the air intake on the opposite side of the generator exhaust, potentially moving the intake much forward on the vessel.
- Continue development of cleaner burning engines with catalytic converters since they have the potential to greatly reduce CO concentrations to safer levels.

CONCLUSIONS & RECOMMENDATIONS

- Recommend that ABYC examine their standards and emphasize ventilation problems that can lead to CO intrusions and take a strong position against through transom exhaust. Since NMMA uses ABYC standards in their certification, the result will be a large number of boats built to this standard.
- Computational fluid dynamics (CFD) and other types of modeling are currently being conducted to better assess exhaust plume configurations.
- Further work should be done on the areas of our recommendations.