ABYC TH-22 July 2022

Technical Information Report

Hull Division

Fuel & Ventilation Systems
Project Technical Committee

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ABYC reviews each standard at least every five years at which time it may be reaffirmed, revised, or withdrawn. ABYC welcomes any written comments on the standards and technical information reports.

ABYC TH-22

EDUCATIONAL INFORMATION ABOUT CARBON MONOXIDE

Origin and Development

ABYC first published this report as T-22, *Educational Information About Carbon Monoxide* in 1992 and revised it in 2000, 2002, 2008, 2012, and 2017. In 2017 the designation was changed to TH-22. The 2022 update is the work of the Fuel & Ventilation Systems Project Technical Committee.

Fuel & Ventilation Systems Project Technical Committee

This list represents the membership at the time the Committee was balloted.

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Membership on a committee shall not in and of itself constitute an endorsement of ABYC or any document developed by the committee on which the member serves.

This technical information report, which is the result of extended and careful consideration of available knowledge and experience on the subject, was developed under procedures accredited as meeting the criteria for American National Standards and is intended to provide minimum performance requirements. The Project Technical Committee that approved the technical information report was balanced to ensure that individuals from competent and concerned interests have had an opportunity to participate.

ABYC's Project Technical Committee (PTC) meetings are open to the public. All inquiries regarding standards activity, interpretations, or meeting attendance should be directed to the ABYC Technical Department at comments@abycinc.org.

ABYC and its committees do not "approve" or "endorse" any item, construction, or proprietary device.

Request for Interpretations

Upon written request the Fuel & Ventilation Systems PTC will render an interpretation of any recommendation of the report. The request for interpretation should be clear and unambiguous. Requests should be presented to the PTC in a manner in which they may be answered in a "Yes" or "No" fashion.

The committee reserves the right to reconsider any interpretation when or if additional information that might affect it becomes available to the PTC. Persons aggrieved by an interpretation may appeal to the committee for reinterpretation.

Summary of Revisions

This list indicates revisions to the report when compared with the previously published version. It is not intended to be used independently of the report. It should be used for informational purposes and as a guide to the official recommendations contained in this report. It is the responsibility of the user to read and understand the complete report.

The main changes in this revision of TH-22, *Educational Information About Carbon Monoxide* as compared with the previous edition dated 7/17, are:

- Units of Measure section was added
- Time vs concentration figure deleted

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TH-22 EDUCATIONAL INFORMATION ABOUT CARBON MONOXIDE

BACKGROUND

This technical information report provides educational material about carbon monoxide (CO) relative to boats and boating.

Carbon monoxide can accumulate in interior spaces and exterior areas. Carbon monoxide accumulation is affected by a multitude of variables (e.g., boat geometry, hatch, window and door openings, ventilation openings, proximity to other structures, swim platforms, canvas enclosures, location of exhaust outlets, vessel attitude, wind direction, boat speed, boat system performance and maintenance, etc.).

This technical information report provides information on some of the more predictable effects of CO accumulation. As this report cannot cover all conceivable variables, the reader is cautioned not to rely solely on the recommendations of this report in the prevention of CO accumulation.

INTENT

The information in this technical information report concerns all boats.

UNITS OF MEASURE

Values stated without parentheses are the recommended. Values in parentheses are explanatory or approximate.

REFERENCES

The following references form a part of this report. Unless otherwise noted the latest version of referenced standards shall apply.

ABYC - American Boat & Yacht Council, Inc., 613 Third Street, Suite 10, Annapolis, MD 21403. Phone: (410) 990-4460. Fax: (410) 990-4466. Website: www.abycinc.org

ABYC A-6, *Refrigeration and Air Conditioning Equipment*
ABYC A-24, *Installation of Carbon Monoxide Detectors and Alarms*

DEFINITIONS

For the purpose of this technical information report, the following definitions apply.

Carbon Monoxide (CO) – a gas formed by the combination of one atom of carbon and one atom of oxygen. Chemists refer to it as CO for its chemical formula, C for carbon and O for oxygen.

COHb (carboxyhemoglobin) – the molecule formed when CO, instead of oxygen, combines with blood.

Enclosed Accommodation Compartment – one contiguous space, surrounded by a permanent structure that contains all the following:

- designated sleeping accommodations,
- a galley area with sink, and
- a head compartment.

NOTE: A cuddy intended for gear storage and open passenger cockpits, with or without canvas enclosures, is not considered to be an enclosed accommodation compartment.

PPM – parts per million

PROPERTIES AND CHARACTERISTICS OF CARBON MONOXIDE

Carbon monoxide is a colorless, odorless, and tasteless gas that weighs about the same as air. This gas is almost neutrally buoyant and will disperse itself throughout the space. Do not rely on the sense of smell or sight of other gases to detect CO as it diffuses in the air much more rapidly than easily detectable vapors (i.e., visible and aromatic vapors).

WHAT MAKES CARBON MONOXIDE?

Carbon monoxide is produced any time a material containing carbon burns, such as gasoline, natural gas, oil, propane, coal, or wood. Common sources of CO are internal combustion engines and open flame appliances such as but not limited to the following:

- propulsion engines
- auxiliary engines (gensets)
- cooking ranges
- central heating plants
- space heaters
- water heaters
- fireplaces
- charcoal grills

The CO component of diesel exhaust is extremely low relative to the CO level found in gasoline engine exhaust. The use of low CO generators and catalyzed engines may reduce the risk of exposure to CO; however, proper care, maintenance, and operation of these engines should always be followed.

HOW IS A PERSON AFFECTED BY CARBON MONOXIDE?

Carbon monoxide is absorbed by the lungs and reacts with blood hemoglobin to form carboxyhemoglobin (COHb), which reduces the oxygen carrying capacity of the blood. The result is a lack of oxygen for the tissues with subsequent tissue death and, if exposure is prolonged, death of the individual. Altitude, heat, certain health related problems, and age will increase the effects of CO. Persons who smoke or are exposed to high concentrations of cigarette smoke, consume alcohol, or have lung disorders or heart problems are particularly susceptible to an increase in the effects from CO. However, all occupants' health should be considered. Physical exertion accelerates the rate at which the blood absorbs CO.

Carbon monoxide in high concentrations can be fatal in a matter of minutes. Lower concentrations must not be ignored because the effects of exposure to CO are cumulative and can be just as lethal.

Symptoms of Carbon Monoxide Poisoning

The sequence of symptoms listed generally reflects the order of occurrence in most people; however, many variables affect this order of symptom manifestation. One or more of the following symptoms can signal the adverse effect of CO accumulation:

1. watering and itchy eyes
2. flushed appearance
3. throbbing temples
4. inattentiveness
5. inability to think coherently
6. loss of physical coordination
7. ringing in the ears
8. tightness across the chest
9. headache
10. drowsiness
11. incoherence
12. slurred speech
13. nausea
14. dizziness
15. fatigue
16. vomiting
17. collapse
18. convulsions

Emergency Treatment for Carbon Monoxide Poisoning

Carbon Monoxide toxicity is a life-threatening emergency that requires immediate action. The following should be enacted if CO poisoning is suspected. Proceed with caution. The victim may be in an area of high CO concentration.

- Evaluate the situation and ventilate the area if possible.
- Evacuate the area and move the affected person(s) to a fresh air environment.
- Observe the victim(s).
- Administer oxygen, if available.
- Contact medical help. If the victim is not breathing, perform rescue breathing or approved cardiopulmonary resuscitation (CPR), as appropriate, until medical help arrives. Prompt action can make the difference between life and death.
- Investigate the source of CO and take corrective action.

MARINE CARBON MONOXIDE DETECTION SYSTEMS

Even with the best boat design and construction and scrupulous attention to inspection, operation, and maintenance of boat systems, hazardous levels of CO may, under certain conditions, be present in interior spaces and exterior areas. Vigilant observation of passengers for CO sickness symptoms should be supplemented by a marine CO detection device(s) in the accommodation space(s). Detection device(s) should be marked with "Marine Carbon Monoxide Detector" or equivalent per A-24, *Installation of Carbon Monoxide Detectors and Alarms*. Marine CO detection device(s) should be replaced as indicated by the manufacturer's end of life date and/or signal.

WHAT TO DO WHEN THE ALARM GOES OFF

Actuation of a CO alarm indicates the presence of CO. If alarm sounds, take the following actions as appropriate:

- If safe to do so, shut off sources of CO, such as engines, generators, and open flame stoves.
- Look for sources of CO that may be from other boats, and take appropriate steps, which may include moving your boat to a safe area.
- Provide fresh air through actions such as opening portlights, hatches, and doors.
- If anyone is exhibiting signs of CO poisoning, move them to fresh air and seek medical assistance.

BOAT OPERATION

Boat operators should not run the engine(s) or auxiliary generator(s) on boats with enclosed accommodation compartments unless the boat is equipped with a functioning marine CO detector that complies with ABYC A-24, *Installation of Carbon Monoxide Detectors and Alarms*.

STATIONARY OPERATION

FIGURE 1 illustrates the effects of running engine(s) or auxiliary generator(s) in confined areas.

A boat operator should be aware that dangerous concentrations of CO can accumulate when propulsion engines and/or an auxiliary generator are operated while the boat is stationary, especially when rafted or moored in a confined area such as boathouses, proximity to seawalls, or proximity to other boats (see FIGURE 1).

NOTE: The risk from CO is greatly increased when there is little or no wind present.

A boat operator should keep engine room hatches and doors closed when operating engines, including the generator set. Before running generator set, operators should consult the boat owner's manual or boat manufacturer to determine if the blowers should be operated continuously.

A boat operator should pay attention to prevailing conditions and provide for ventilation to induce fresh air and minimize exhaust re-entry. Operators should orient the boat to enable the maximum dissipation of CO and be aware that cockpit and deck drains can be a source of CO ingress into boats, especially boats with cockpit or decks enclosed with canvas or permanent boat structures.

When the propulsion engine or generator is running, CO is produced and may remain in the vicinity of the exhaust outlet (including underwater exhaust outlets such as sterndrives and outboards). Carbon monoxide accumulation may remain trapped for some time after the engine or generator is turned off (see FIGURE 2).

- Do not occupy aft lounging area(s) or swim platform.
- Do not swim under or around swim platform.
- Do not swim in the vicinity of exhaust outlet(s).

In order to minimize CO buildup, boat operators should not warm up or run propulsion engine(s) for extended periods while the vessel is stationary. Carbon monoxide production is greater when engines are cold versus when they are warm.

A boat operator should be aware that CO is emitted from any boat's exhaust. Operation, mooring, and anchoring in an area where other boats' engines or generators are running may put an operator's boat in an atmosphere containing CO, even if their boat's engine(s) are not running. Of prime concern is the operation of an auxiliary generator where boats are moored alongside each other. Boat operators should be aware of the effect their exhaust may have on other boats and be aware that the operation of other boats' equipment may affect the CO concentration on their boat (see **Error! Reference source not found.**FIGURE 3).

UNDERWAY OPERATION

Boat operators or passengers should not sit on, occupy, or hang on any stern appendages (e.g., swim platforms, boarding ladders, etc.) while underway. They should not body surf, commonly known as “teak surfing” or “platform dragging,” etc. in the wake of the boat or tow persons in close proximity to the stern of the boat (see FIGURE 4).

Backdrafting (Station Wagon Effect)

Backdrafting is caused by air movement over or around a boat creating a low pressure or suction area around the stern that can increase CO level on the boat. Backdrafting can be affected by relative wind direction, boat speed, and boat trim angle. See **Error! Reference source not found.**FIGURE 5 for an illustration of airflow over a boat and behind its transom. Under certain speeds and operating conditions, the low pressure area may form in other regions and permit CO to enter the hull through openings that are not on the back of the boat.

Other Factors That May Affect Carbon Monoxide Concentration

- Adding or removing canvas may raise or lower CO levels (see FIGURE 6).
- Intentional or unintentional excessive trim angle (e.g., high bow angle or excessive unequally distributed weight) may raise the CO level and should be avoided (see **Error! Reference source not found.**FIGURE 7).
- Opening and closing ports, hatches, doors, and windows may raise or lower CO levels on board a boat. When airflow is moving forward inside the boat, CO may be entering the boat.
- Operating a boat at slow speeds with a following wind should be avoided. Consider changing direction, adjusting speed, or both (see FIGURE 8).
- Cockpit and deck drains can be a source of CO ingress into boats, especially boats with cockpit or decks enclosed with canvas or permanent boat structures.

CABIN APPLIANCES

Boats having fuel-burning appliances in accommodation areas should be provided with adequate ventilation and the appliance should be maintained to function properly.

AIR CONDITIONING

Improper installation or lack of system maintenance may cause the air conditioner to bring CO into air conditioned spaces. Air handling ducts and plenums should be sealed from the engine room(s). Aftermarket air conditioning systems should be installed in accordance with ABYC A-6, *Refrigeration and Air Conditioning Equipment* and the manufacturer’s instructions.

VENTILATION OF OCCUPIED SPACES

Occupied spaces should be ventilated to introduce fresh air into the spaces. Ventilation methods (e.g., use of windows, hatches, doors, and blowers) used to accomplish this may, under certain conditions, bring hazardous levels of CO into the occupied spaces. Boat operators should be aware of all prevailing conditions when using these ventilating methods.

ALTITUDE AND SEA CONDITIONS

Operation at altitudes greater than 5,000 ft contributes to inefficient engine performance and may require adjustments to ignition systems, fuel systems, or changing the propeller size or gear ratio. Failure to make adjustments to ignition systems and/or fuel systems for altitude conditions may cause an increase in CO. Reduced power resulting from increased altitude may require adjustments to propeller size. Heavy seas or out of trim conditions tend to load engines resulting in reduced performance and increased CO production.

PORTABLE GENERATOR SETS

This equipment should not be used on boats. Gasoline powered portable generator sets produce CO. These sets discharge their exhaust products in locations that can lead to an increase in the accumulation of CO in occupied spaces.

MAINTENANCE

Engine Performance

Efficient engine performance is vital to minimizing CO production. The following items are those considered to have the greatest effect on increased CO production:

- Fuel that is contaminated, stale, or incorrect octane number

CARBURETORS/INJECTORS

- Dirty or clogged flame arrester
- Malfunctioning automatic choke plate or faulty adjustment of manual choke plate
- Worn float needle valve and seat
- High float level
- Incorrect idle mixture adjustment
- Dirty or worn injectors

IGNITION SYSTEM

- Fouled or worn spark plugs
- Worn points or incorrect gaps on points
- Short or open circuit high tension spark plug cables
- Incorrect ignition timing

GENERAL

- Worn piston rings and valves
- *Engine temperature* - cold running engines increase CO production. Generally, an engine produces less CO if it operates at a relatively high temperature within the manufacturer's specifications. The correct thermostat should be selected based on the manufacturer's specifications
- *Exhaust back-pressure* - certain alterations to the exhaust system may increase engine exhaust back pressure and CO production
- Restricted engine room or compartment ventilation

EXTERNAL BOAT CONDITIONS

Conditions that contribute to inefficient engine performance can include:

- Fouled hull bottom
- Damaged and fouled running gear (i.e., shaft, strut, propeller, rudder, and trim tabs)
- Incorrect selection of propeller size

EXHAUST SYSTEM INTEGRITY

Gas tight integrity of exhaust systems must be maintained to ensure prevention of leakage of CO within the boat. Disassembly may be required to carry out a thorough inspection. Components should be repaired or replaced as needed. The following should be inspected on a regular basis:

- Gaskets at cylinder head connection
- Castings and pipe fittings in the dry section
- All joints
- Hoses
- Clamps
- Mufflers and their drain plugs
- Thru-hull fittings
- Hangers and other supports

VENTILATION SYSTEMS

Boats are equipped with ventilation systems to eliminate gasoline vapors. Blowers and fans may also be provided for ventilation and to mitigate migration of CO into occupied compartments. The following actions should be performed on a regular basis:

- Keep ventilation intakes clear of debris
- Replace damaged hardware
- Maintain integrity of the ducting material and its connections
- Ensure that position of ducting intake is not obstructed or restricted, collapsed, kinked, or crushed
- Eliminate sags in ducting that can form a water trap
- Check hangers and other supports
- Ensure blower/fan is operational
- Check that airflow is present at discharge
- Inspect wiring to equipment

BULKHEAD AND DECK INTEGRITY

- Seal all visible openings (e.g., cracks, crevices, holes, including openings around wiring and piping runs) in bulkheads and decks that separate machinery compartments from occupied compartments. These openings can permit migration of CO vapors.
- Check gaskets and sealing surfaces on hatches, doors, and access panels.

CARBON MONOXIDE DETECTION SYSTEMS

Carbon monoxide detectors require periodic replacement. Check the system and its installation and maintain and/or replace in accordance with the manufacturer's instructions.

AIR CONDITIONING SYSTEMS

Air conditioning systems can be a source of CO ingress and migration of CO vapors.

- Keep return air grilles and filters clean.
- Seal bulkhead voids and openings at wiring and piping runs in return air ducting, plenums, and air handling equipment enclosures, especially those adjacent to machinery compartment bulkheads.
- Check that water traps and condensate drains are present and correctly routed. These may be in the form of a double loop in the drain line or prefabricated p-traps. Any drain that discharges below the waterline when the boat is underway is sealed, by virtue of its design, against CO intrusion.

LIQUID DRAINS

Sink, shower, and condensate drains that drain outboard above the waterline can be a source of CO ingress. Water traps be inspected to ensure they are present and contain fluid. These traps may be in the form of a double loop in the drain line or prefabricated p-traps. Any drain that terminates below the waterline is, by virtue of its design, sealed against CO intrusion. The location of drains, relative to the waterline, can be affected by the dynamics of boat motion (i.e., underway or at rest).

SAFETY AND WARNING LABELS

The following labels should be displayed in these specified locations:

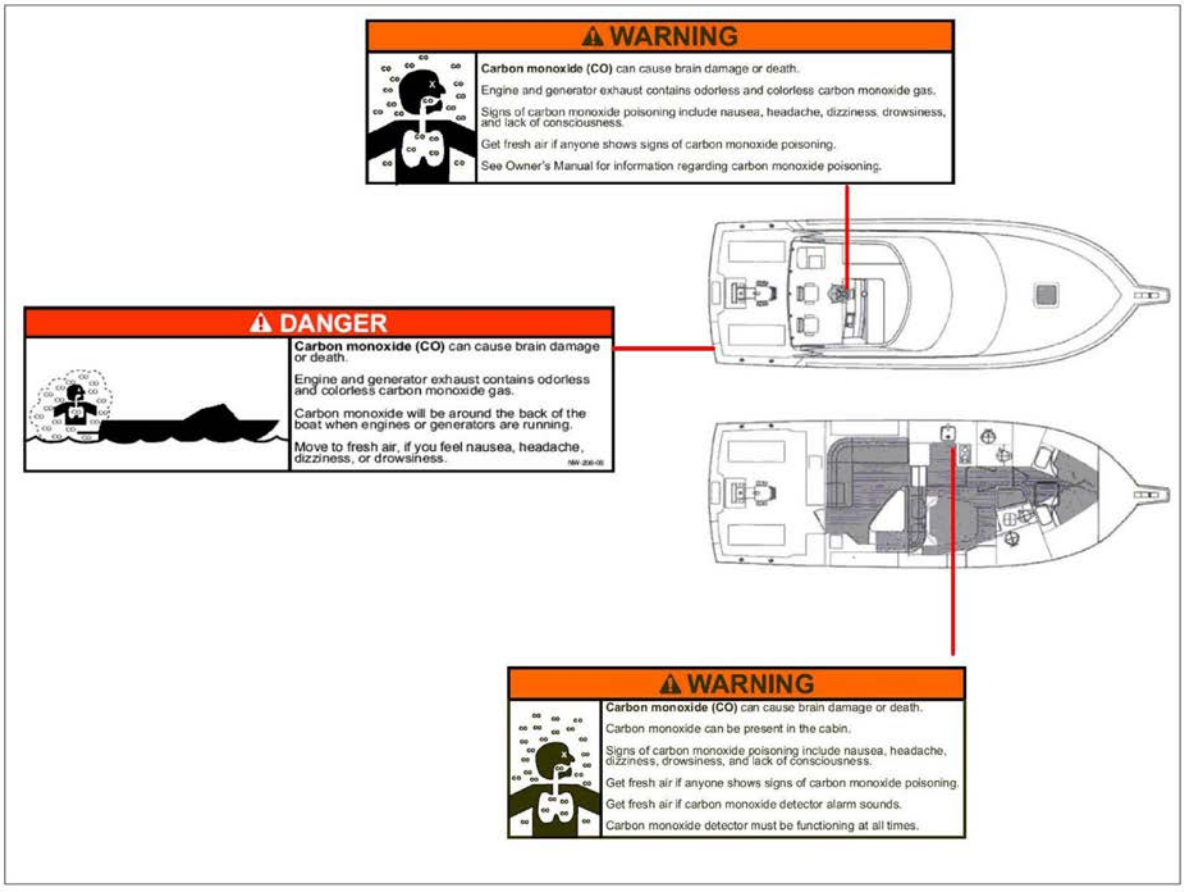
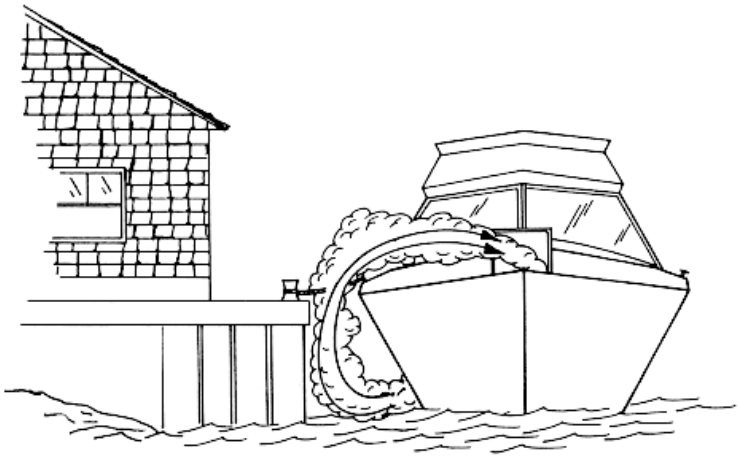


FIGURE 1 - The Effect of Sea Walls and Other Confined Spaces



This figure illustrates the effects of running engine or auxiliary generator in confined areas.

FIGURE 2 - Accumulation of Exhaust Gases at the Swim Platform

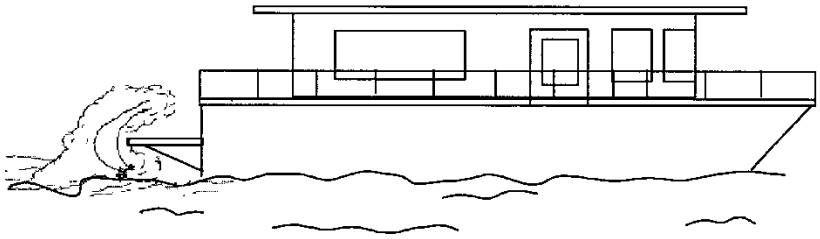
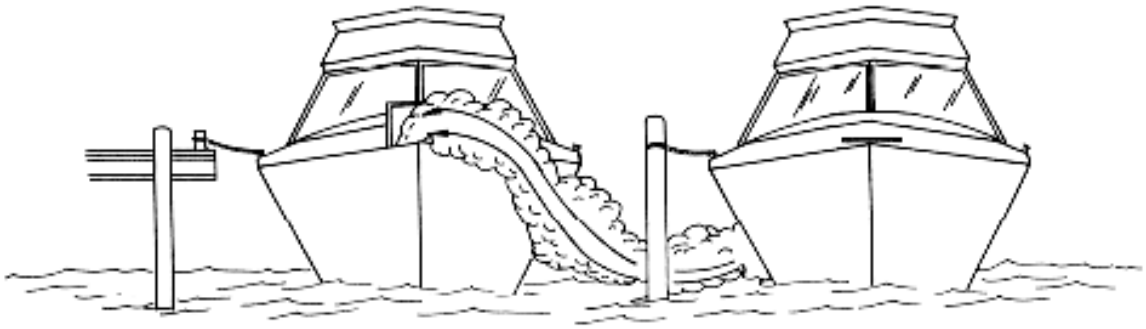


FIGURE 3 - The Effect of Boats Moored Along Side



Boats moored close together can affect each other.

FIGURE 4 - Dangerous Activity When Engine is Running

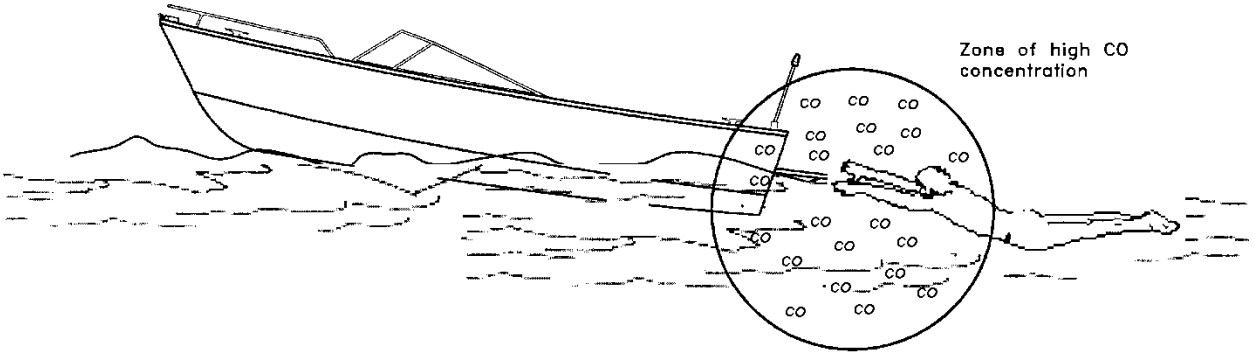
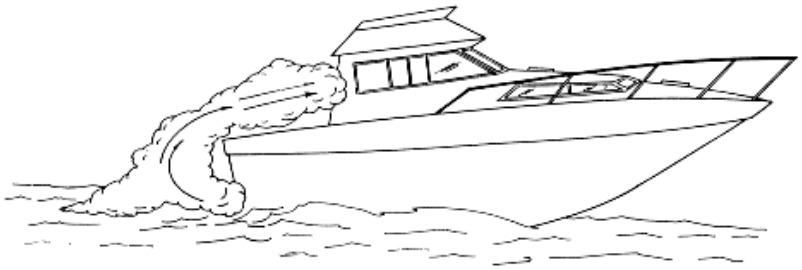


FIGURE 5 - Backdrafting (Station Wagon Effect)



This figure illustrates airflow over boat and behind the transom.

FIGURE 6 - The Effect of Canvas/Hatch Configurations

This figure illustrates desired airflow through the boat.

As shown in this figure, certain canvas configurations, such as side curtains, and position of hatches can increase backdrafting.

FIGURE 7 - Inefficient Trim Angles

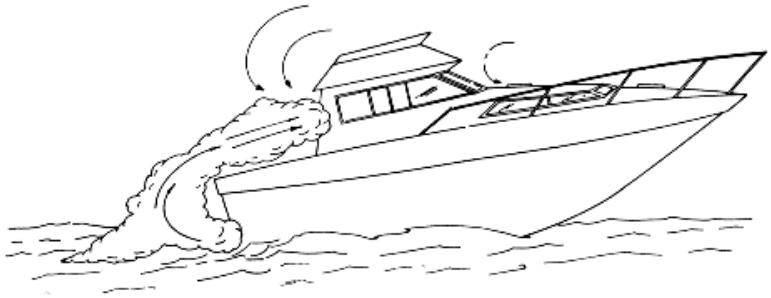


FIGURE 8 - Operating at Slow Speed with a Following Wind

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