TH-22 EDUCATIONAL INFORMATION ABOUT CARBON MONOXIDE

BACKGROUND

This technical information report provides educational material about carbon monoxide 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 maintenance, etc.)

This technical information report discusses many of these variables and enables the reader to better understand some of the more predictable effects. However, this report is limited in that it cannot cover all conceivable variables, and the reader is cautioned not to rely exclusively on it to prevent the accumulation of carbon monoxide.

INTENT

The information in this technical information report concerns all boats.

REFERENCED ORGANIZATIONS

ABYC - American Boat & Yacht Council, 3069 Solomons Island Road, Edgewater, MD 21037. Phone (410) 956-1050. Fax: (410) 956-2737. Web site: www.abycinc.org

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

Carbon Monoxide - 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 that contains the following:

a. designated sleeping accommodations,

b. a galley area with sink; and

c. a head compartment.

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

PPM - Parts per million

PROPERTIES AND CHARACTERISTICS OF CARBON MONOXIDE

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas that weighs about the same as air. It cannot be expected to rise or fall like some other gases because it will distribute 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

- cooking ranges,
- central heating plants,
- space heaters,

- water heaters,
- fireplaces, and
- charcoal grills.

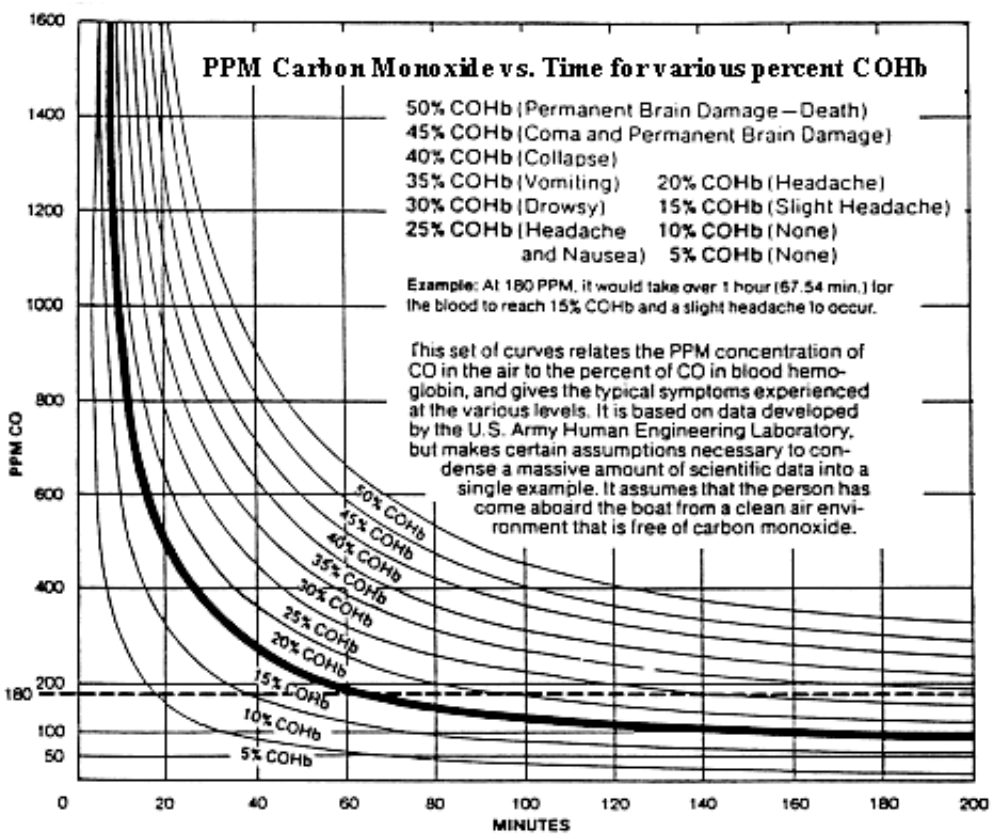
The carbon monoxide component of diesel exhaust is extremely low relative to the carbon monoxide level found in gasoline engine exhaust.

HOW IS A PERSON AFFECTED BY CARBON MONOXIDE?

Carbon monoxide is absorbed by the lungs and reacts with blood hemoglobin to form carboxyhemoglobin, which reduces the oxygen carrying capacity of the blood. The result is a lack of oxygen for the tissues with the subsequent tissue death and, if exposure is prolonged, death of the individual. Altitude, 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. (See Figure 1.)

FIGURE 1 CARBON MONOXIDE CONCENTRATION VS TIME



NOTE: Figure 1 shows the generally accepted curves of a person's absorption rate of CO at various concentrations.

Symptoms of CO Poisoning - The sequence of symptoms listed generally reflects the order of occurrence in most people; however, there are many variables that 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 CO Poisoning - CO toxicity is a life-threatening emergency that requires immediate action. The following is a list of things that should be done 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 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, and
- Investigate source of CO and take corrective action.

MARINE CO DETECTION SYSTEMS

Even with the best of 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 in the accommodation space. Detection devices should meet the requirements of ABYC A-24*, Carbon Monoxide Detection Systems on Boats*.

NOTE: There are currently no known CO detectors available for permanent installation in exterior areas.

BOAT OPERATION

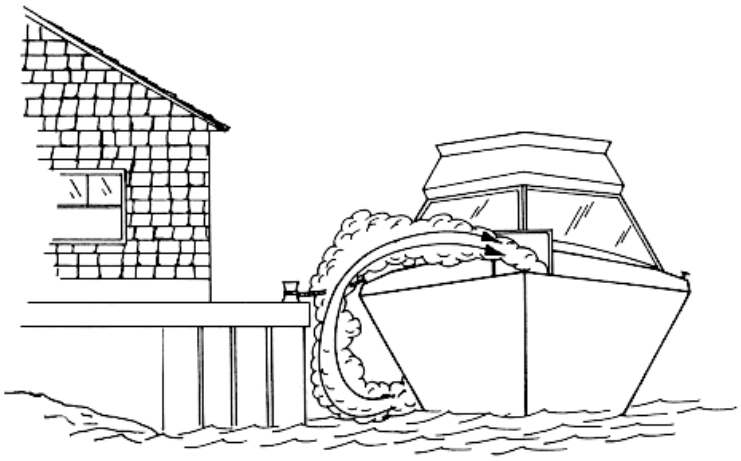
Don't run engine(s) or auxiliary generator(s) on boats with enclosed accommodation compartments unless the boat is equipped with a functioning marine carbon monoxide detector that complies with ABYC A-24, *Carbon Monoxide Detection Systems on Boats*. There are currently no known CO detectors available for permanent installation in exterior areas.

Stationary Operation

A boat operator should be aware that dangerous concentrations of CO can accumulate when propulsion engines and/or an auxiliary generator is 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 2.)

FIGURE 2 THE EFFECT OF SEA WALLS AND OTHER CONFINED SPACES

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



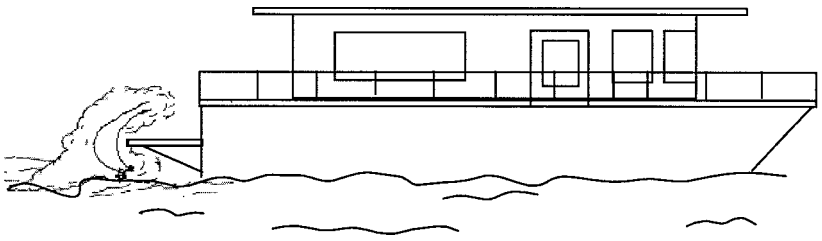
Keep engine room hatches and doors closed when operating engines, including the generator set. Before running generator set, consult boat owner's manual or boat manufacturer to determine if the blowers should be operated continuously.

Pay attention to prevailing conditions and provide for ventilation to induce fresh air and minimize exhaust re-entry. Orient boat to enable the maximum dissipation of CO. 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):

- 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 the exhaust outlet.

FIGURE 3 ACCUMULATION OF EXHAUST GASES AT THE SWIM PLATFORM



Since carbon monoxide production is greater when engines are cold versus when they are warm, a boat operator should minimize the time spent on getting underway.

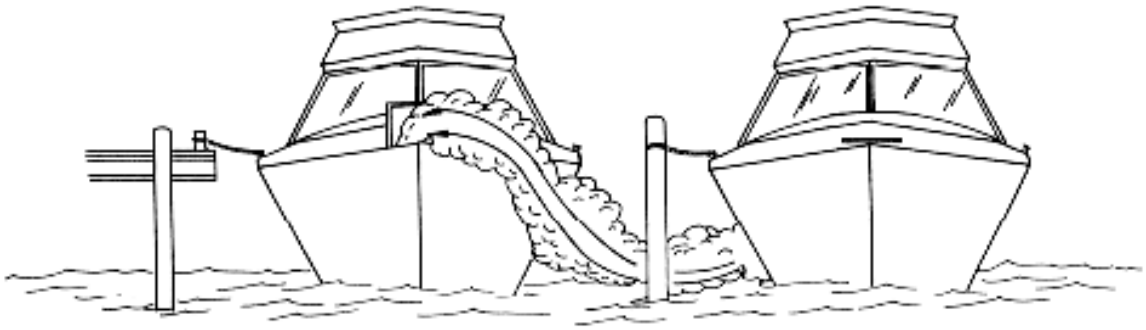
In order to minimize CO buildup, do not warm up or run propulsion engine(s) for extended periods while the vessel is stationary.

A boat operator should be aware that carbon monoxide is emitted from any boat's exhaust. Operation, mooring, and anchoring in an area where other boats' engines or generators are running may put your boat in an atmosphere containing CO, even if your boat's engine(s) is(are) not running. Boat operators need to be aware of the effect of their boat on other boats in the area. Of prime concern is the operation of an auxiliary generator where boats are moored along side each other. Be aware of the effect

your exhaust may have on other boats and be aware that the operation of other boats' equipment may affect the carbon monoxide concentration on your boat. (See Figure 4.)

FIGURE 4 THE EFFECT OF BOATS MOORED ALONG SIDE

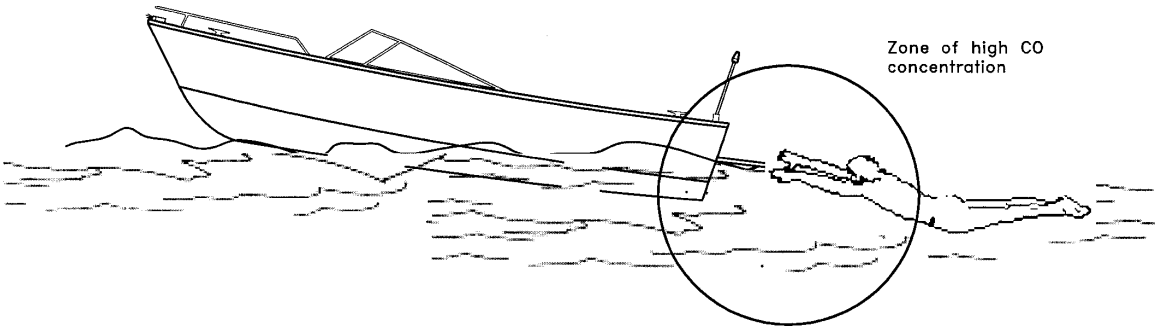
Boats moored close together can affect each other.



Underway Operation

Do not sit on, occupy or hang on any stern appendages (e.g., swim platforms, boarding ladders, etc.) while underway. Do not body surf, commonly known as "teak surfing" or "dragging", etc. in the wake of the boat. Do not tow persons in close proximity to the stern of the boat.

FIGURE 5 DANGEROUS ACTIVITY

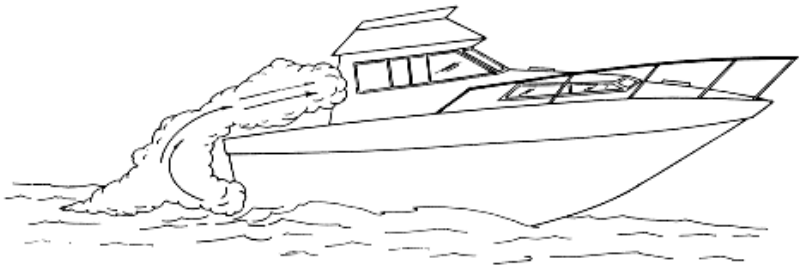


Backdrafting (station wagon effect)

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 Figure 6 for an illustration of airflow over a boat and behind its transom.) Under certain speed and operating conditions, the low pressure area may form in other regions and permit carbon monoxide to enter the hull through openings that are not on the back of the boat.

FIGURE 6 BACKDRAFTING (STATION WAGON EFFECT)

This figure illustrates airflow over boat and behind the transom.



Other factors during boat operation which may affect carbon monoxide concentration include:

- Adding or removing canvas may raise or lower CO levels. (See Figure 7.)
- 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 Figure 8.)
- 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 9.)
- 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.

FIGURE 7 THE EFFECT OF CANVAS CONFIGURATIONS

This figure illustrates desired airflow through the boat.

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

FIGURE 8 INEFFICIENT TRIM ANGLES

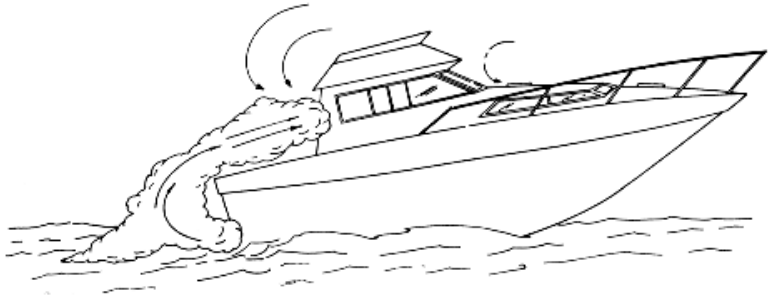


FIGURE 9 OPERATING AT SLOW SPEED WITH A FOLLOWING WIND

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 CO to be brought into the air-conditioned spaces by the air conditioner. Be sure that the air handling ducts and plenums are sealed from the engine room(s).

Ventilation of Occupied Spaces - Occupied spaces need to be ventilated to introduce fresh air into the spaces. Ventilation methods (e.g., windows, hatches, doors, and blowers) used to accomplish this may, under certain conditions, bring hazardous levels of CO into the occupied spaces. 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's 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 - Do not use this equipment on boats. Gasoline powered portable generator sets produce CO. These sets discharge their exhaust products in locations which can lead to an increase in the accumulation of carbon monoxide in the occupied space.

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 gap on points
- Shorted or opened circuit high tension spark plug cables
- Incorrect ignition timing

General

- Worn piston rings and valves
- Engine temperature - Cold running engines increase CO production. Engine cooling water system design and selection of thermostat(s) are primary considerations affecting engine operating temperature. Generally, an engine produces less CO if it operates at a relatively high temperature within 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 insure that leakage of CO within the boat does not occur. Disassembly may be required to carry out a thorough inspection. Repair or replace components as indicated. Inspect the following:

- 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. Attention should be paid to the following:

- Keeping ventilation intakes clear of debris
- Replacing damaged hardware
- Maintaining the integrity of the ducting material and its connections
- Ensuring that position of ducting intake is not obstructed or restricted, collapsed, kinked, or crushed
- Eliminating sags in ducting that can form a water trap
- Checking hangers and other supports
- Ensuring blower/fan is operational
- Checking that airflow is present at discharge
- Inspecting 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.

CO Detection Systems - Check system and its installation and maintain in accordance with the manufacturer's instructions.

Air-conditioning Systems - These 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. 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 can be a source of CO ingress. Ensure that water traps 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. Some drains that are below the waterline when the boat is underway will be above the waterline when the boat is at rest. The location of drains, relative to the waterline, can be affected by the dynamics of boat motion (i.e., underway or at rest).

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Origin and Development of ABYC TH-22, Educational Information about Carbon Monoxide

ABYC first published this report as T-22 in 1992 and updated it in 2000. This update is the work of the Fuel & Ventilation Project Technical Committee.

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