U.S. Department
of Transportation

United States
Coast Guard

JUNE 1992

Boating Safety Circular 74

CARBON MONOXIDE — THE INVISIBLE KILLER

The victims of carbon monoxide poisoning feel no particular pain except, perhaps, a severe headache which they usually attribute to some other cause. In fact, carbon monoxide will dull the senses to the point where the victims feel no fear or danger and have no will to save themselves. An hour after they drift into unconsciousness they are dead.

In **Boating Safety Circular 58** (June 84) we alerted readers to the carbon monoxide problem on recreational boats with permanently installed gasoline engines. In the article, *"A Good Way to Die"* we described some typical boating situations which result in fatalities when boat operators ignore the potential for carbon monoxide poisoning, or fail to conduct regular exhaust system inspection and maintenance.

The 1992 boating season is now underway and perhaps we can prevent a few accidents this year with an additional discussion of the carbon monoxide problem in recreational boating. Included with this article is a Technical Report,*"Educational Information About Carbon Monoxide"* , which is reprinted with the permission of the American Boat and Yacht Council, Edgewater, Maryland.

Carbon monoxide (CO) is a clear, odorless and poisonous gas that may be present even if the telltale smoke associated with exhaust emissions is not. Don't wait to feel the symptoms of carbon monoxide poisoning. If your boat has a permanently installed gasoline engine used for propulsion or as an auxiliary generator, get in the habit of inspecting the exhaust system frequently, particularly before you go for that first cruise of the season.

The "Station Wagon Effect"

Intrusion of carbon monoxide gas into the cabin and accommodation spaces on boats so equipped is another serious problem. Carbon monoxide can quickly reach dangerous levels due to aerodynamic principles which create substantial differences in the barometric pressures surrounding a boat in motion. Some boat speed and wind direction combinations can quickly raise CO concentrations to the hazardous level.

Boats moving forward generate areas of lower atmospheric pressure immediately aft of those parts of the boat which have large surfaces at right angles to a boat's direction of movement. This is sometimes called "back drafting" or the "station wagon effect". This is the same phenomenon which makes it possible for a race car to get a free ride by "drafting" close behind another car.

Back drafting worsens as the velocity of air movement from bow to stern increases relative to the velocity of the boat. The lower atmospheric areas are the result of the air streamlines being unable to flow in smooth lines around the hull and wheelhouse and further astern.

If the wheelhouse air volume is connected only to the air volume directly aft of the salon door, low pressure will develop within the wheelhouse and draw exhaust gases, including carbon monoxide into all areas having reduced air pressure.

Inside:

During tests conducted using U.S. Coast Guard Auxiliary vessels in 1985, the highest CO readings occurred when the test boats were cruising upwind with no forward ventilation sources, i.e., the forward hatch and windshield ports were closed. Reduced CO levels were achieved by opening the forward hatch and opening ports in the wheelhouse. Carbon monoxide concentrations on the flying bridges of test boats so equipped remained at acceptable levels, even when the flying bridges were enclosed.

Recent CO Research

Carbon monoxide related death and sickness cases occurring on inboard gasoline powered recreational boats were also the basis for a 1988 U. S. Coast Guard grant to the Volpe National Transportation Systems Center. A report, "The Intrusion of Engine Exhaust Into the Passenger Areas of Recreational Power Boats" was a product of the grant. The data presented in the report consists primarily of an analysis of CO sensor readings on board two cabin cruisers equipped with twin gasoline engines. The CO sensor readings were collected from many locations within the boats, with correlated relative wind direction and speed measurements. Cabin cruiser type boats were used because they are considered the most dangerous configuration for the intrusion of CO into living areas; however, cases involving other types of boats have also been reported.

The cabin cruisers used in the tests were both fitted with side mounted exhausts at the waterline. Even though the exhaust gases were mixed with seawater and a significant amount was discharged below the waterline, the testing showed that the CO was nearly insoluble in water. The test results would have been worse had the exhausts been located on the transom.

The tests demonstrated an alarming build up of carbon monoxide in living spaces on board the two cabin cruisers, especially when the relative and true wind were forward of the beam. During the tests, all forward openings were secured.

CO Concentrations and Symptoms

When carbon monoxide is inhaled, CO molecules attach to red blood cells in the same way oxygen molecules attach to red blood cells in a person breathing clean air. "Carboxyhemoglobin", the combination of carbon monoxide and hemoglobin (red blood cells), inhibits the blood's ability to combine with oxygen, resulting in oxygen deficiency.

There is no general agreement on a "safe" level of carbon monoxide exposure for humans. However, various published "acceptable concentration levels" indicate that an occupational day exposure average of 50 ppm (parts per million) would be acceptable for sea level conditions and exposures of 25 ppm for altitudes above 5,000 feet.

At an exposure level of 50 ppm for a day, a person's COHb level might reach 10 percent; victims may experience such physical effects as headaches, dizziness and diminished coordination. Levels between 10 and 15 percent CoHb cause nausea. Levels as high as 40 percent are associated with collapse and levels over 60 percent are usually fatal.

The importance of both (1) early detection, and (2) ventilation for prevention of carbon monoxide build up, are clearly evident.

Carbon Monoxide Detectors

There are several manufacturers of CO gas detectors intended for marine use, at least one of which is listed by Underwriters Laboratories. According to UL Standard 1524, "Carbon Monoxide Gas Detectors for Marine Use", a CO detector is an assembly of electrical components including a sensor and both a visual and an audible alarm.

The typical minimum COHb detection threshold is 20% (this figure is based upon military studies). Individuals with medical problems should consider using carbon monoxide detectors with lower COHb alarming capabilities.

Improvements in technology and reliability of carbon monoxide gas detectors have reached the point that their installation in accommodation spaces should be considered by all safety conscious recreational boaters. Detectors are available as single and multistation systems, fully integrated systems and self-contained units with internal batteries.

The major drawback to a unit with an internal

(continued on page 10)

The following technical report, *"Educational Information About Carbon Monoxide"* is reprinted with the permission of the American Boat and Yacht Council, 3069 Solomons Island Road, Edgewater, Maryland 21037 (Tel: (410) 956-1050).

AMERICAN BOAT AND YACHT COUNCIL, INC.

EDUCATIONAL INFORMATION ABOUT CARBON MONOXIDE (T-22)

JANUARY 14, 1992

BACKGROUND

This Technical Information Report provides educational material about Carbon Monoxide relative to boats and boating. Carbon monoxide accumulation is affected by vessel geometry; hatch, window and door openings; ventilation openings; proximity to other structures; wind direction; vessel speed; and a multitude of other variables. This Technical Information Report attempts to discuss many of these and enable 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 therefore, the reader is cautioned not to rely on it exclusively to prevent the accumulation of carbon monoxide.

INTENT: The information in this Technical Information Report concerns all vessels. An exception is vessels where diesel fuel is the only fuel source. The carbon monoxide component of diesel exhaust is extremely low relative to other exhaust products (e.g. nitrous oxide, aldehide, sulfur, etc.) and relative to the carbon monoxide produced in gasoline engine exhaust.

DEFINITIONS:

a. Carbon Monoxide - Carbon Monoxide is a gas formed by the combination of one molecule of carbon and one molecule of oxygen. Chemists refer to it as CO, its chemical formula, “C” for carbon and “O” for oxygen.
b. COHb - Carboxyhemoglobin is the molecule formed when CO combines with blood instead of oxygen.

PROPERTIES AND CHARACTERISTICS OF CARBON MONOXIDE

a. CO is a colorless, odorless and tasteless gas.
b. Its weight is about the same as air so it cannot be expected to rise or fall like some other gases but will distribute itself throughout the space.

Don’t rely on the use of smell or sight of other gases to detect carbon monoxide as CO diffuses in the air much more rapidly than easily detectable (visible and smellable) gases.

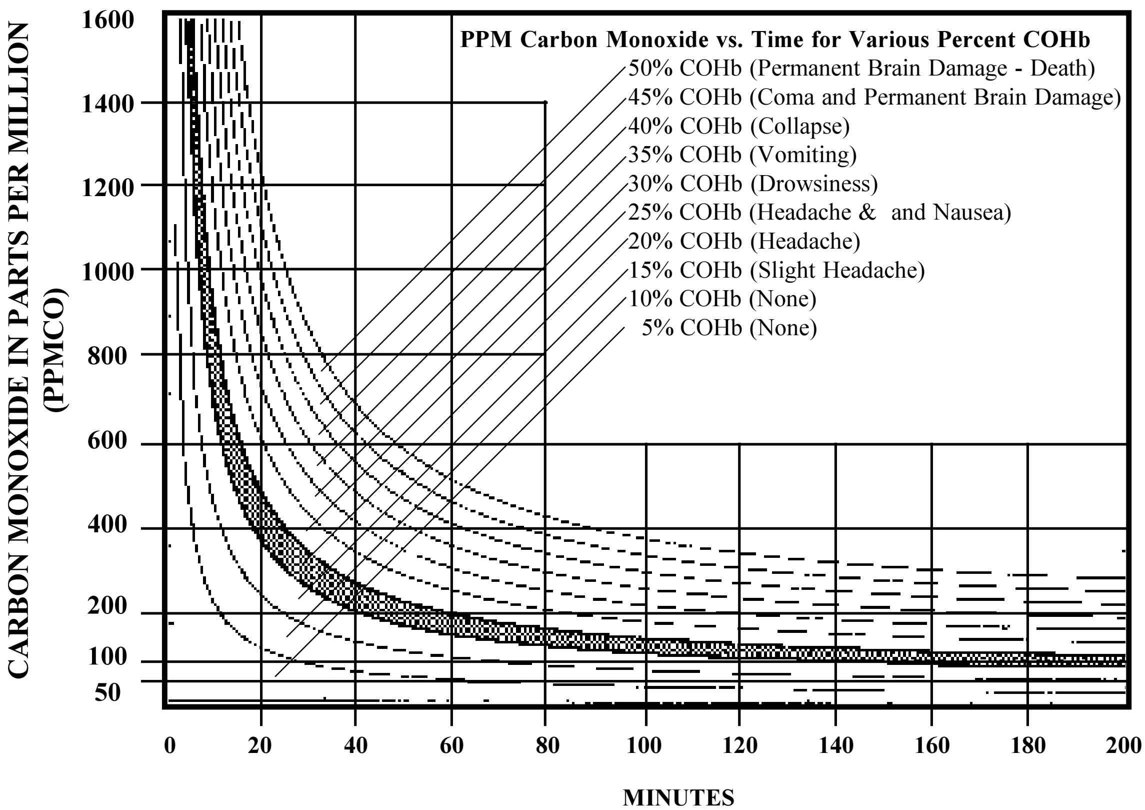
WHAT MAKES CARBON MONOXIDE: Anytime a material containing carbon burns, such as gasoline, natural gas, oil, propane, coal, or wood, CO is produced.

Common sources of CO are:

a. Internal combustion engines.

One should note that diesel engines produce substantially less carbon monoxide than gasoline engines.

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.

Example: At 180 PPM it would take over 1 hour (67.54 min.) for the blood to reach 15% COHb and a slight headache to occur.

This set of curves relates the PPM concentration of CO in the air to the percent of CO in blood hemoglobin, and gives the typical symptoms experienced at the various levels. It is based on data developed by the U.S. Army Human Engineering Laboratory, but makes certain assumptions necessary to condense a massive amount of scientific data into a single example. It assumes that the person has come aboard the boat from a clean air environment that is free of carbon monoxide.

b. Open flame devices such as:

(1) Cooking ranges,
(2) Central heating plants,
(3) Space heaters,
(4) Water heaters,
(5) Fireplaces, and
(6) Charcoal grills.

HOW A PERSON IS 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 prolonged, death of the individual.

Effects

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).

Certain health related problems and age will increase the effects of CO. People 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.

Symptoms

One or more of the following symptoms can signal the adverse effect of CO accumulation:

a. Watering and itchy eyes
b. Flushed appearance
c. Throbbing temples
d. Inattentiveness
e. Inability to think coherently
f. Ringing in the ears
g. Tightness across the chest
h. Headache
i. Drowsiness
j. Incoherence
k. Nausea
l. Dizziness
m. Fatigue
n. Vomiting
o. Collapse
p. Convulsions

One should note that the order of the above list is generally the sequence of appearance of symptoms, however the order of appearance may change for different people.

Carbon monoxide poisoning may easily be mistaken for seasickness.

TREATMENT (Evacuate, Ventilate, Investigate, take Corrective Action)

a. Move the person to fresh air.
b. Administer oxygen if available.
c. Contact Medical help.
d. If victim is not breathing, perform artificial respiration per approved CPR procedures until medical help arrives and takes over.

Prompt action can make the difference between life and death.

e. Ventilate area.
f. Investigate source of CO and take corrective action.

INSPECTION: Look and listen for leaks in exhaust systems of both generator and propulsion engine(s) Look for discoloration around joints in the system (water leaks, carbon, stains, etc.).

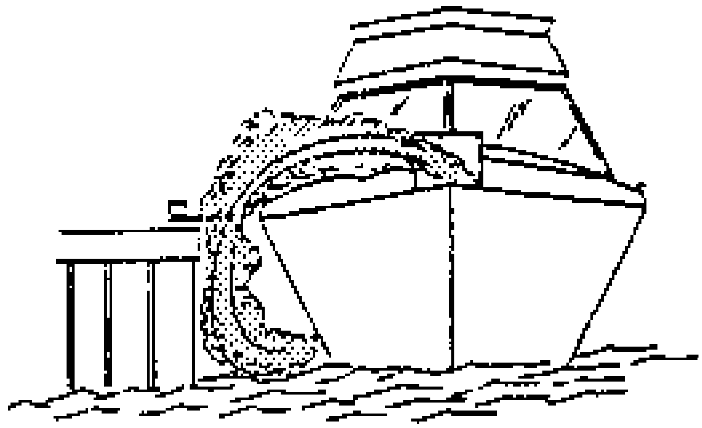
a. Make sure all exhaust clamps are in place and secured.
b. Make sure ventilation systems work and are not obstructed or restricted.
c. Make sure gaps around engine room plumbing and cableways and exhaust system doors, hatches, and access panels are minimized to reduce the opportunity for CO to enter the accommodation space(s).

OPERATION:

Cold Start vs. Warm Start - CO production is greater while combustion chamber surfaces and gas passages are cold versus when they are warm. A boat operator should:

a. pay attention to ventilating the boat,
b. orient the boat so it will allow the maximum dissipation of CO, and
c. minimize the time spent on getting underway.

Figure 2 - The Effect of Seawalls or Other Confined Spaces



Running engine or generator in confined areas

Boathouses, Sea Walls and Other Boats

A boat operator should be aware that dangerous concentrations of CO can accumulate when a boat, generator or other engine operated device is operated while the boat is moored in a confined area such as:

a. boathouses,
b. proximity to seawalls, or
c. proximity to other boats.

Orient the boat for maximum dissipation of exhaust or don,t run the boat or boat equipment for extended periods under these conditions. (See Figure 2).

A boat operator should be aware that CO is emitted from any boat's exhaust. The operation, mooring, and anchoring in an area containing other boats may be in an atmosphere containing CO not of the operator's making. An operator likewise needs to be aware of the effect of his actions on other boats. Of prime concern is the operation of an auxiliary generator with boats moored along side each other. Be aware of the effect your exhaust may have on other vessels and be aware that the operation of other vessel's equipment may affect the carbon monoxide concentration on your vessel. (See Figure 3.)

Figure 3 - How Boats Moored Close Together Can Affect Each Other

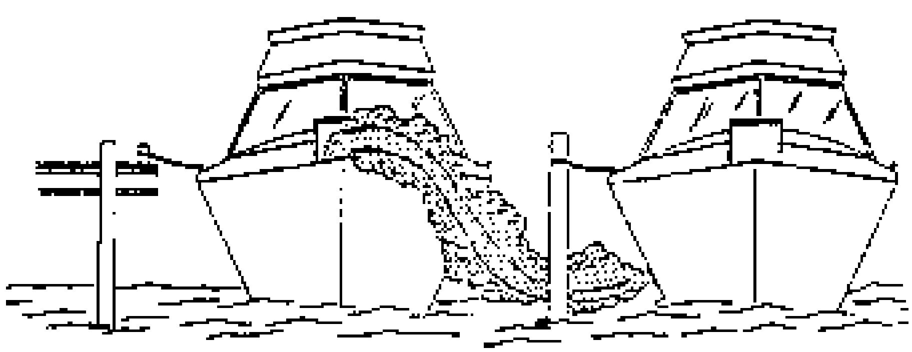
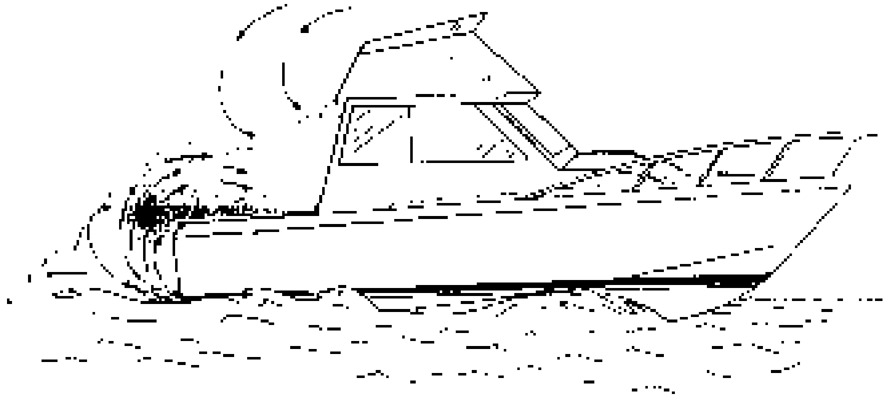


Figure 4 - Backdrafting (Station Wagon Effect)



Backdrafting (Station Wagon Effect) - Backdrafting or the “station wagon effect” is caused by air movement over or around a boat creating a low pressure area or suction area around the stern which can increase CO level on the boat. Backdrafting can be affected by relative wind direction, boat speed, and boat trim angle. See Figure 4 for “Airflow Over Boat and Behind 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 vessel. Boat factors which may affect carbon monoxide concentration:

a. Inefficient trim angle. (See Figure 6).
b. Excessive or unequally distributed weight.
c. Canvas Configurations - Under various conditions, adding or removing canvas may raise or lower CO levels. (See Figures 4, 5, 6)
d. Opening and closing ports, hatches, doors, and windows may raise or lower CO levels on board a boat.

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

Air Conditioning - It may be possible for CO to be brought into the air conditioned space by the air conditioner.

Ventilation of Accommodation Spaces - Accommodation 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 accommodation spaces. Care should be taken to be aware of all prevailing conditions when using these ventilating methods.

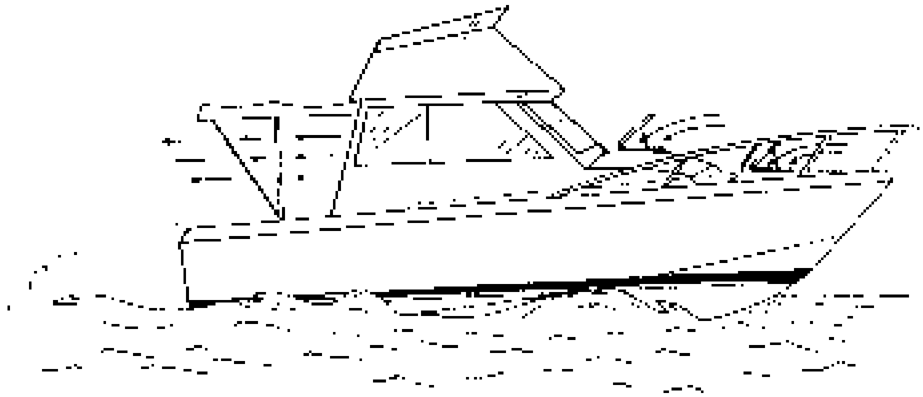
Altitude and Sea Conditions - Changes in altitude greater than 5,000 feet contribute to inefficient engine performance and may require adjustments to ignition systems, fuel systems, or changing the propeller’s size.

a. Failure to make adjustments to ignition systems, fuel systems and propeller size may cause an increase in CO production.

b. Heavy sea conditions tend to load engines resulting in reduced performance and thereby increasing their CO production.

Portable Generator Sets - 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 accommodation space. This equipment is not recommended for use on recreational vessels.

Figure 5 - The Effects of Canvas Configurations



Desired Air Flow Through The Boat

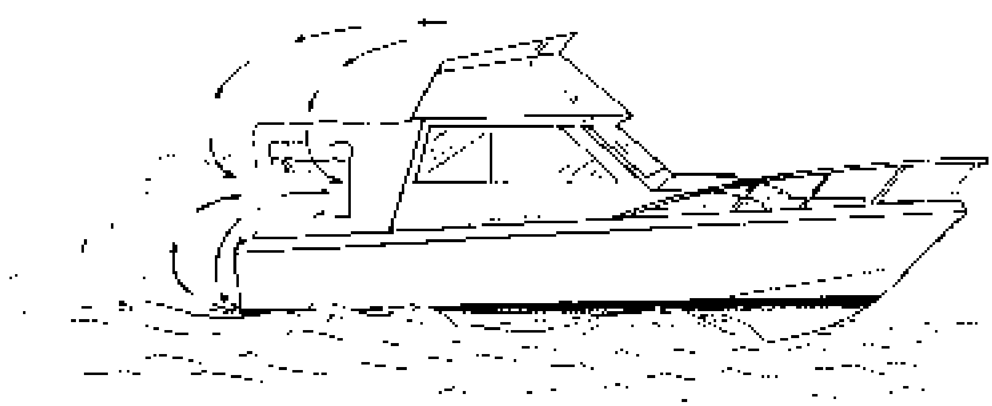
MAINTENANCE

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:

a. Fuel system - Fuel that is contaminated, stale or incorrect octane number.

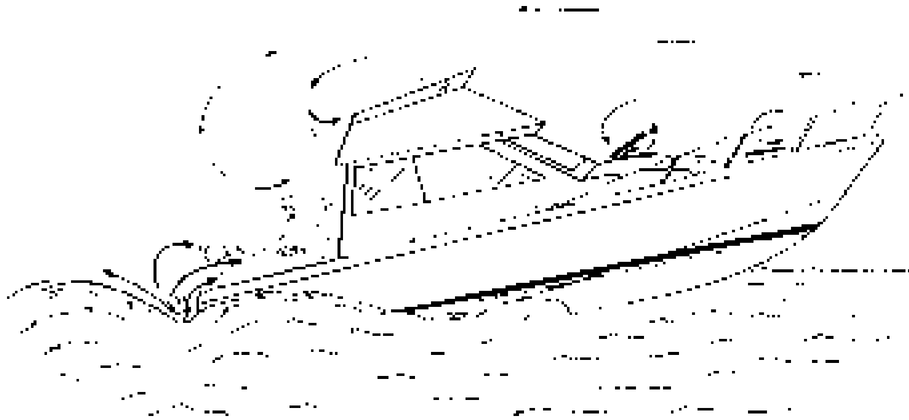
b. Carburetors/Injectors
   (1) Dirty or clogged flame arrester.
   (2) Malfunctioning automatic choke plate or faulty adjustment of manual choke plate.
   (3) Worn float needle valve and seat.
   (4) High float level.
   (5) Incorrect idle mixture adjustment.
   (6) Dirty or worn injectors.

c. Ignition System
   (1) Fouled or worn spark plugs.
   (2) Worn points or incorrect gap on points.
   (3) Shorted or opened circuit high tension spark plug cables.
   (4) Incorrect ignition timing.



Certain Canvas Configurations Can Increase Back Drafting

Figure 6 - Inefficient Trim Angles



Excessive Bow Attitude Can Increase Back Drafting

d. General

(1) Worn piston rings and valves.

(2) 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.

(3) Exhaust back-pressure - Certain alterations to the exhaust system may increase engine exhaust back pressure and CO production.

(4) Restricted engine room or compartment ventilation.

External Conditions - External conditions that contribute to inefficient engine performance are:

a. Fouled hull bottom.
b. Damaged and fouled running gear (shaft, strut, propeller, rudder and trim tabs).
c. Incorrect selection of propeller size.

CO DETECTION SYSTEMS (See ABYC A-24, "Carbon Monoxide Detectors")

General - Even with the best of boat design and construction plus utmost care in inspection, operation, and maintenance, hazardous levels of CO may still be present in accommodation spaces under certain conditions. Continuing observation of passengers for symptoms of CO intoxication can be supplemented by an alarm type CO detection device in the accommodation space.

Detectors - Current CO detector technology can be broken down into three major categories - single-point, multi-point, and fully-integrated - the difference being the degree to which each type of unit considers exposure time.

a. Single-Point Detection - The single-point detector will sound the alarm whenever the detector senses that a single pre-set PPM level of CO has been exceeded.

b. Multi-Point Detection - The multi-point detector alarm will sound at a number of selected CO levels. The multi-point detector may include several different measuring time periods with their corresponding different PPM CO level alarm settings.

c. Fully-integrated detection - The fully-integrated detector will sound an alarm to any combination of PPM CO level and exposure time that would cause a health hazard.

Detection devices should meet the requirements of ABYC A-24 "Carbon Monoxide Detection Systems on Boats".

battery is, should the battery go dead, the detector would be incapable of indicating the presence of carbon monoxide.

A draft American Boat and Yacht Council (ABYC) Standard A-24 due to be published in one to two years, will recommend CO detectors on any boat with accommodation spaces and gasoline engines or gasoline generators.

Prevention

The best way to prevent carbon monoxide problems associated with leaks from the exhaust system is with regular inspections and maintenance.

Inspect the engine and generator exhaust systems for cracks in the hot, unjacketed sections of the exhaust manifolds. Check the tightness of the bolts holding the exhaust manifolds to the engine blocks.

Be sure engineroom bulkheads are completely sealed against leaks into accommodation areas. All holes in the engineroom bulkhead for plumbing, wiring and controls should be sealed by whatever means is most convenient. Seal larger holes with pieces of plywood. Fill spaces around wiring and plumbing with caulking, electrician's putty or the nondrying putty material used by heating and ventilating contractors to seal pipes in the sides of air conditioning equipment. Sealing the holes in engineroom bulkheads will also make the cabin much quieter while the boat is underway.

Be sure that all rubber hose connections in the exhaust system are fitted with two clamps at each end. Double clamping will go a long way toward preventing the exhaust hose from coming loose due to vibration.

Make sure exhaust hoses aren't burned through or beginning to show signs of advanced age. If you replace them, be absolutely certain that they are labeled by the manufacturer for use in a marine exhaust system.

If you own a double cabin cruiser or motor yacht, the exhaust lines probably pass through the aft stateroom on their way to the transom. There may be a rubber hose connection at the transom, at the engineroom bulkhead and at each end of any muffler installed in that exhaust line. All of these joints should be accessible for a complete inspection. If you find that the exhaust lines run behind cabinetry, as they do on many boats, now is the time to provide access. Cut holes or install removable panels so that inspection is relatively easy. You will want to inspect these connections at least twice every season. A crack or leak in the exhaust line is easy to detect while the engine is running. These are wet exhaust lines. A leak or crack will cause a steady drip of water.

The best measures to take in order to prevent CO from migrating into passenger carrying areas and accommodation spaces is to provide alternate sources of air for the cockpit and cabin areas. Leave a port in the windshield open and open a deck hatch. If you can feel a flow of air coming aft through the cabin and cockpit areas, you probably won't have much of a problem with carbon monoxide being pulled forward and into the boat. Exhaust deflectors can help, but they won't totally eliminate the problem.

Other CO Sources

Don't install a portable generator below decks. No portable generators meet the Coast Guard Electrical and Fuel System Standards. The fuel tank is usually on the top of the generator directly above electrical components that are not ignition-protected, a potentially serious fire hazard on a boat. The exhaust system on a portable generator is usually constructed of nonmarine alloys that can rust through after brief exposure to a salt water environment. The carburetors on most portable generators are not intended for marine use.

Do not use any flame producing device in an unventilated area. Any heater, stove or lantern that produces an open flame uses oxygen. The argument that these devices do not produce carbon monoxide does not apply when they are used in enclosed spaces. Alcohol heaters and stoves, propane heaters and stoves, catalytic heaters, oil lamps, gasoline lanterns, even charcoal stoves consume oxygen. When the amount of oxygen in the air gets below a certain level, these devices produce carbon monoxide because of incomplete combustion of their fuel. Ventilation must be provided whenever any device producing an open flame is used in a boat cabin.

U.S. Department
of Transportation
**United States
Coast Guard**

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16751
April 2, 1992

Editor's Note: A copy of the following letter was sent to each State Boating Law Administrator alerting marine law enforcement authorities to recent changes in the Federal regulations governing acceptable backfire flame arresters. We reported on the change in the regulations in Boating Safety Circular 72.

Mrs. Elizabeth Raymond
Boating Law Administrator
Dept. of Wildlife, Fisheries
and Parks
P.O. Box 451
Jackson, MS 39205

Dear Mrs. Raymond:

In the Federal Register dated July 29, 1991, the Coast Guard Office of Marine Safety, Security and Environmental Protection published a final rule adopting industry standards in place of detailed regulations in certain sections of Titles 33 and 46 of the Code of Federal Regulations. We are bringing the publication of these particular regulations to your attention because they may affect law enforcement policies covering backfire flame arresters in your State.

Since 1968 the Coast Guard Marine Safety Program has adopted over 250 industry standards and specifications to lessen the regulatory and administrative burdens on both the Coast Guard and manufacturers. Prior to the publication of the regulations, manufacturers of backfire flame arresters had their products tested by independent test laboratories and then submitted the test results to the Coast Guard. The Coast Guard then accepted the test results as a basis for issuing a Coast Guard approval number. We included a reprint of the regulations in Boating Safety Circular 72 (September 1991). A copy of the pertinent pages is enclosed for your reference.

Under the new regulations effective August 28, 1991, an acceptable means of backfire flame control is a flame arrester complying with either Society of Automotive Engineers Standard SAE J-1928 or Underwriters Laboratories Standard UL 1111 and labelled accordingly. The possible implications of this change for State law enforcement policies were discussed at the 48th meeting of the National Boating Safety Advisory Council on November 11, 1991, and in the December/ January 1992 issue of the “Small Craft Advisory” (copy of page 5 enclosed).

After August 28, 1991, an acceptable backfire flame arrester may bear:

1. A U.S. Coast Guard approval number; or

2. The words, "complies with UL 1111 per tests by (name of testing facility)"; or

3. The words, "evidence of compliance with the standard shall be indicated by the marking SAE J-1928 with the word MARINE arranged in a suitable manner."

We hope this explains the situation sufficiently for your State to make appropriate changes to law enforcement policies, and if necessary, to State laws and/or regulations. Please let us know if you need further clarification.

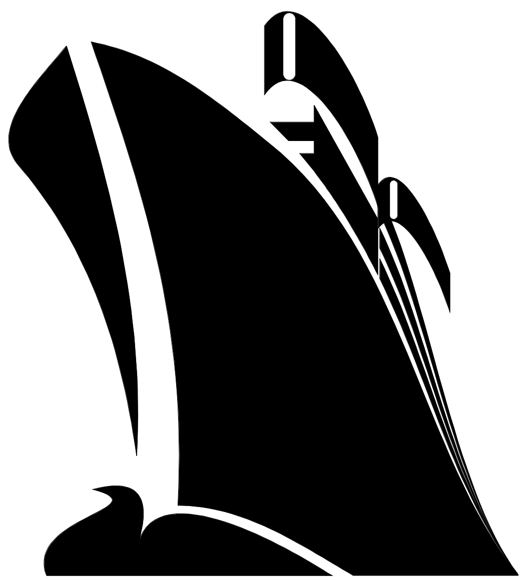
A. J. MARMO
Acting Chief, Auxiliary, Boating,
and Consumer Affairs Division
By direction of the Commandant

SMALL BOATERS -- BE WARY

In recent years the number of large commercial vessels serving the Port of Baltimore and the number of small boats sailing on the Chesapeake Bay have both increased. Every day, large ships bearing tons of cargo pass through the major shipping channel that runs the length of the bay.

Small boats should be aware of the constraints under which large commercial ships operate.

Rule 9 of the "Rules of the Road" specifically states that small craft "shall not impede the passage of a vessel which can safely navigate only within a narrow channel or fairway." Unlike most small boats, large vessels must often keep to a narrow channel. Operators of small craft should avoid ship channels where possible. When unavoidable, these channels should be crossed quickly at right angles.



Speed

On open waters, large ships may travel faster than the usual "maneuvering speed" of 10 to 13 knots. In poor visibility or in congested areas, ships often travel faster than you would expect. In low visibility, ships navigate by radar. However, small boat operators must not assume they will always be detected.

Lightly loaded ships or loaded vessels that are unevenly trimmed must keep up a fair speed to stay under control when in a channel. If they slow down too much or stop, they risk being driven aground by wind, tide or current.

It doesn't take a whole lot of time for a large ship to reach you. At 10 knots, a ship goes one nautical mile in six minutes. At 15 knots, this takes four minutes. Large, difficult to maneuver ships cannot always successfully avoid small craft in narrow channels, so it's up to the smaller boats to stay clear of these vessels.

A ship that is slowing down does not steer very well. It needs the propeller action on the rudder to respond. A pilot may sometimes choose to turn instead of slowing down to serve a particular situation.

Once a ship's engines are put "full astern," there is nothing more one can do to slow a ship. Reversing action will in most cases swing the bow to starboard, therefore, if small boats have a choice, they should try to maneuver to the port side of the larger vessel to avoid a collision. It should be kept in mind that it takes four to six minutes and 2,000 to 4,000 feet for a large ship to stop after its engines are reversed.

Vigilance

Small commercial vessels that operate on waterways should also be watched carefully. Tugs pushing barges, especially at night when the barges may be poorly lit, have to be looked out for. A partially submerged towing cable can cut a boat in two. Commercial fishing vessels, though more maneuverable, may pose a problem when hauling in large nets which can be deceptively long. Learn to recognize the mast lights of a tug towing one or more barges, and of commercial fishing vessels towing nets.

Keep a constant lookout, especially astern.

The safe sailor has a roving eye on the water. He or she uses binoculars, which can help determine ships' lights and directions with greater accuracy, especially at night.

Small boaters should keep out of the way of large ships. This doesn't mean that open waters "belong" to the big ships. What it does mean is that big ships must stay in deep channels, whereas small boats don't have to. Therefore, sailing or traveling in ship channels should be avoided whenever possible, especially in fog, rain or darkness.

Always maintain a watch, especially at night.

Even on a clear night, you will have difficulty seeing a big ship approach. You might see it first as a black shadow against a background of shore light, or as a shadow moving rapidly across still water. At that point, you are not far apart.

Remember that your lights will not be easily spotted from a larger ship. Focus attention on the ship's light. To determine whether you are in the path of a ship, note the vessel's sidelights, as well as the masthead lights. If you see only one sidelight, or if one is much brighter than the other, you can be fairly sure you are not in the direct path of the ship. This also lets you know which way to move in order to get clear altogether. If you see both sidelights, you're dead ahead - MOVE OUT FAST.

Visibility

Don't underestimate the speed of a large ship. A slow boat might not be able to take effective evasive action on a collision course with a large ship. In visibility of a quarter of a mile or less, the speed differential is simply too great.

At night, make sure that your navigation lights are bright, and not obscured by sails, flags or dinghies in davits. If you see the running lights of a ship, and you're not sure whether you've been spotted, begin to get out of the way immediately. Use flashlights on sails, a spotlight, flash bulbs or a white flare to indicate your position. (Strobe lights should be reserved for distress.) Carry a radar reflector as high on the boat as you can — a must in restricted visibility.

Whistle Signals

Know whistle signals and use them only when vessels are in sight of one another. The master or pilot of a large ship will frequently not use the port or starboard whistle signals when passing small boats, lest the signals be misunderstood and cause the smaller vessel to change course erratically.

Five or more short blasts on a whistle is a danger signal. If you should hear this, check right away and see if it is for you. If so, make way fast.

Radios

Use your radio. If you have a VHF radio aboard, remember that channel 16 is the calling and distress frequency, and channel 13 is the working frequency used to arrange safe meeting and passing between ships and other watercraft. Use channel 13 for bridge-to-bridge communication and monitor channel 16.

Anchorages and Piers

Choose safe anchorages. Each year commercial ships and fishing vessels ram and sink a few boats anchored in navigation channels or tied to marker buoys. Coast Guard buoys tell ships, "here is where you must pass." It is illegal, as well as unsafe, to tie up to them.

When navigating small craft in harbors, be particularly cautious around piers. Ships may be maneuvering in the vicinity. Sudden propeller wash or wakes generated by large ships can be extremely dangerous to small boats.

Don't pass close to ships leaving piers. You don't know what is on the other side of them, and their turbulence can cause you problems.

Remember harbor speed limits — you are responsible for your own wake.

- **Be alert - maintain watch at all times.**
- **Don't take the helm if you have been drinking.**
- **Be seen, especially at night.**
- **Carry a radar reflector.**
- **Know whistle signals.**
- **Use binoculars.**
- **Use your radio.**
- **Observe all speed limits.**

Conclusion

Whether you are a small boat operator or the master of a large container ship, it is wise to visualize any possible situation which can result when vessels of all shapes and sizes compete for the same space. Plan for it well ahead of time.

Keep in mind that few people survive collisions with ships.

Always keep clear.

Editor's Note: The previous article by Mr. Thomas J. Pettin originally appeared in the March/April 1992 issue of *Proceedings of the Marine Safety Council* .