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Small craft — Carbon monoxide (CO) detection systems and alarms

Petits navires — Systèmes de détection et d'alarme du monoxyde de carbone (CO)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 188, *Small craft*.

This second edition cancels and replaces the first edition (ISO 12133:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— in Clause 2 and throughout the text, dates to normative references have been added;

— in Clause 3, definitions have been updated;

— in 5.1.5, a low battery alarm requirement has been added;

— 5.2.3, design operating temperature range, has been added;

— requirements have been clarified in 5.3.2;

— 5.3.3 has been updated to require CO detectors without self-contained batteries to be connected to the continuously energized side of the battery switch;

— in 6.3, marking requirements have been added;

— in Figure 1 (beta curve chart) the 30 ppm line reference has been updated;

— in Figure 1, the Key has been updated;

— in Annex A, the other factors during boat operation that can affect carbon monoxide concentration have been clarified;

— EN 50291 has been moved to the Bibliography.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Small craft — Carbon monoxide (CO) detection systems and alarms

1 Scope

This document specifies requirements for the design, construction and installation of carbon monoxide detection and alarm systems in small craft.

Annex A provides essential educational material about carbon monoxide relative to small craft, and recreational boating recommendations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13297:2020, *Small craft — Electrical systems — Alternating and direct current installations*

IEC 60529:2013/Corr1:2019, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
carbon monoxide
CO
gas formed by the combination of one atom of carbon and one atom of oxygen

Note 1 to entry: In its chemical formula, C stands for carbon and O for oxygen. For the purposes of this document, the CO level is always expressed in terms of mass fraction of CO in air.

3.2
carboxyhaemoglobin
COHb
compound formed when *carbon monoxide* (3.1) combines with haemoglobin

3.3
% COHb
degree to which the oxygen carrying capacity of blood is impeded by the union of *carbon monoxide* (3.1) to the haemoglobin in blood, expressed as a percentage

3.4
enclosed accommodation compartment
contiguous space, surrounded by permanent structure, that contains all of the following:

a) designated sleeping accommodations,

b) a galley area with sink, and

c) a head compartment

Note 1 to entry: A cuddy intended for gear storage and open passenger cockpits, with or without canvas enclosures, are not considered to be enclosed accommodation compartments.

3.5
craft
small craft
recreational boat, and other watercraft using similar equipment, of up to 24 m length of hull (L_H)

[SOURCE: ISO 8666:2020, 3.15]

4 Symbols

β (beta) arbitrary variable name chosen to represent the mathematical calculation of the absolute worst case of predicted % COHb levels in a typical individual exposed to the factors [mass fraction (mg/kg) of carbon monoxide level and minutes of exposure to that CO level] used in that calculation.

5 Requirements

5.1 Design and construction

5.1.1 Detectors shall meet the requirements of relevant national standards (e.g. UL 2034 or EN 50291-2:2019).

5.1.2 An audible alarm shall be provided.

If detectors employing a COHb level algorithm, or other integrating alarm structures, include a switch to mute only the audible alarm, then warnings or other means shall be provided to protect such a switch from casual use. The switch shall not reset the detector and shall not mute the alarm for more than 6 min.

5.1.3 There shall be no power switch on the detector.

5.1.4 A non-mechanical indicator, e.g. some type of visual electrical indicator (lamp, LED, LCD, etc.), shall be provided on the detector to indicate that it is in operation.

5.1.5 A circuit self-check shall be provided that shall also give alarms for an electrically defective sensor or low battery condition. A testing procedure or test switch shall be provided for checking the alarm circuitry.

5.1.6 Detectors shall be designed and marked as drip proof or watertight in accordance with IP rating 42, as specified in IEC 60529:2013/Corr1:2019.

5.1.7 Detectors shall be powered by the craft's electrical system, or by a self-contained battery.

5.2 Performance specifications

5.2.1 The detector shall be tested to the relevant national standard including the following:

— β (beta) = 10 % maximum;

— an alarm condition shall occur at some point within the shaded area of the beta curve as illustrated in Figure 1.

5.2.2 β is calculated from the following expression:

$$\beta = 218 \times \left(0{,}000\,3 + \frac{w_{co}}{1\,316} \right) \times \left(1 - e^{-t/96{,}879\,2} \right) \quad (1)$$

where

w_{co} is the mass fraction of CO, in mg/kg (ppm);

e is the base natural logarithm, approximately equal to 2,718 28;

t is the time of exposure, in minutes.

NOTE For reference purposes, the β (beta) formula solved for t or w_{co} is as follows:

$$w_{co} = \frac{6{,}036\,7\beta}{1 - e^{-t/96{,}879\,2}} - 0{,}394\,8 \quad \text{and} \quad t = -96{,}879\,2 \times \ln\left[1 - \frac{\beta}{0{,}065\,4 + 0{,}166 w_{co}} \right]. \quad (2)$$

5.2.3 The design operating temperature range of CO detectors shall be -40 °C to 70 °C.

5.3 Installations

5.3.1 A carbon monoxide detection system shall be installed on all craft with an enclosed accommodation compartment(s).

5.3.2 Detectors shall be located to monitor the atmosphere in a continuous cabin space and additionally in each sleeping space separated by solid bulkheads/structure and permanent doors/partitions.

NOTE Sleeping spaces separated only by curtains do not need additional CO detector(s).

5.3.2.1 The detector shall be mounted and located to avoid areas subject to physical damage, including harm from rain, water or sunlight, and dilution of sampled air (e.g. near hatches, ports or forced ventilation openings), and inadequate natural air circulation, (e.g. in corners).

5.3.2.2 The d.c. electrical system of the detector system shall be installed in accordance with ISO 13297:2020, except for detectors powered by a self-contained battery.

5.3.3 If a circuit breaker is installed, it shall include a block or other multi-step means to prevent it from being inadvertently turned off.

CO detectors without a self-contained battery shall be connected to the continuously energized side of the battery switch.

5.3.4 The craft's manufacturer shall draw attention to the hazards of carbon monoxide when boating, as well as provide instructions on what actions should be taken when the CO alarm sounds. Craft manufacturers should reference the information provided in Annex A.

5.4 Instructions

Instructions covering the installation and operation shall be provided with each detector. The following information shall be included in the instructions:

— mounting location requirements consistent with the requirements in 5.3;

— actions to be taken when the alarm system sounds, wherein the order of action is evacuate, ventilate, investigate, and take corrective action;

— the manufacturer's service policy;

— the manufacturer's recommendation for overcurrent protection shall specify the current rating and type of overcurrent protection device in the connected branch circuit;

— if a fuse is used, the fuse current rating shall be permanently marked to be visible if the fuse is replaced;

— the manufacturer's recommendation for operational testing and frequency for such testing, in accordance with Clause 5;

— general educational material about carbon monoxide;

— the detector's performance specifications, in accordance with this document;

— information on the detector's ability to sense only the air in the vicinity of the detector's sensing element.

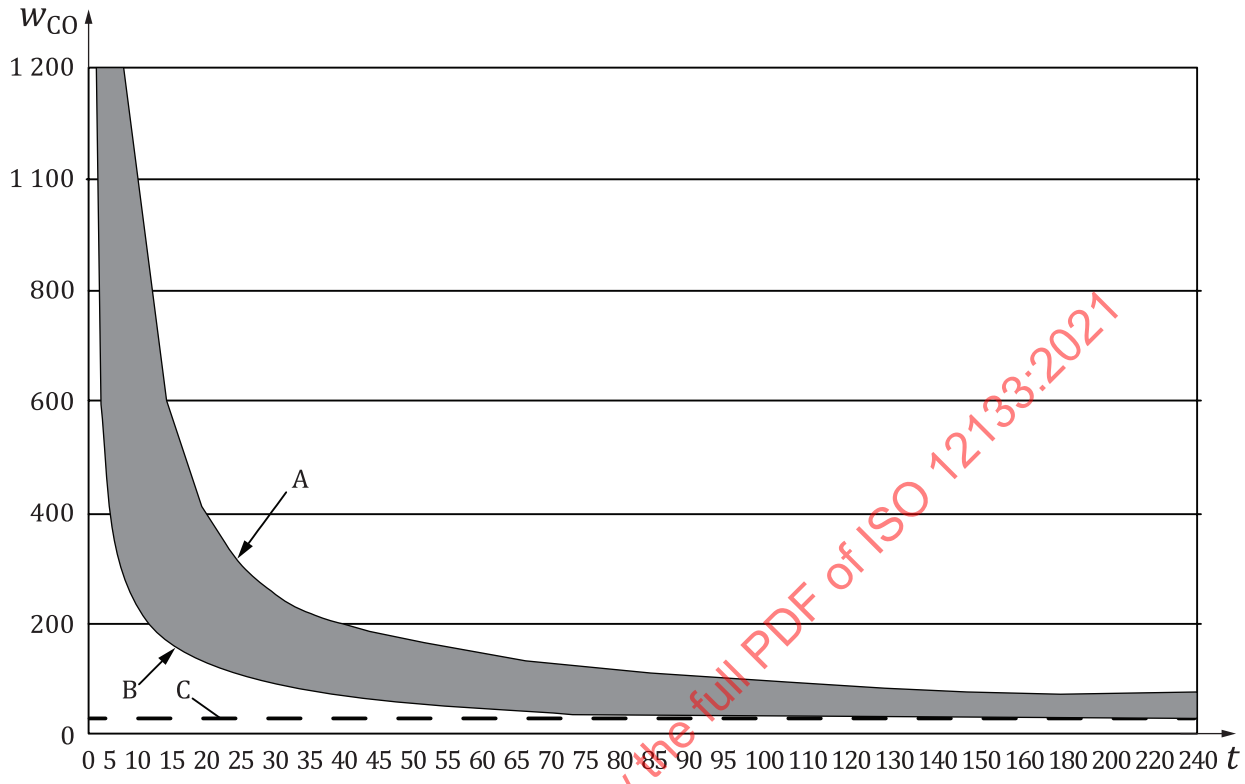
6 Markings

6.1 Detectors shall be marked with "Marine carbon monoxide alarm" or equivalent, as tested to the relevant national standard.

6.2 Detectors that have been certified by a certification body shall be marked with the name of the certifying body. The markings shall be clearly visible as installed.

NOTE These markings are in addition to markings required under the relevant national standard.

6.3 Detectors shall be marked with a “Replace by date” or “Replace by XX months after retail sale”, as determined by the manufacturer.



Key

t	time (min)
w_{co}	mass fraction of CO in mg/kg (ppm)
A	10 % COHb curve
B	2,5 % COHb curve
C	30 mg/kg (ppm)

NOTE 1 This figure is for illustrative purposes only.

NOTE 2 The β formula given in 5.2.2 is used to determine β.

Figure 1 — Beta curve for 2,5 % to 10 % COHb level — CO mass fraction in mg/kg (ppm) vs. time in minutes

Annex A
(informative)

Educational information about carbon monoxide

A.1 General

This annex provides essential educational material about carbon monoxide relative to small craft, and recreational boating recommendations.

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).

This annex discusses many of these variables and enables the reader to better understand some of the more predictable effects. However, this annex 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.

A.2 Properties and characteristics of carbon monoxide

Carbon monoxide (CO) is a colourless, odourless and tasteless gas that weighs about the same as air. It cannot be expected to rise or fall like some other gases because it distributes 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 vapours (i.e. visible and aromatic vapours).

A.3 What makes carbon monoxide?

Carbon monoxide is produced any time a material containing carbon burns, such as petrol, 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,

— propulsion engines,

— auxiliary engines (gensets),

— 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 petrol engine exhaust.

A.4 How is a person affected by carbon monoxide?

A.4.1 General

Carbon monoxide is absorbed by the lungs and reacts with blood haemoglobin to form carboxyhaemoglobin, 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 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 should not be ignored because the effects of exposure to CO are cumulative and can be just as lethal. The use of low CO generators and catalyzed engines can reduce the risk of exposure to CO, however, proper care, maintenance, and operation of these engines should always be followed.

A.4.2 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:

a) watering and itchy eyes;

b) flushed appearance;

c) throbbing temples;

d) inattentiveness;

e) inability to think coherently;

f) loss of physical coordination;

g) ringing in the ears;

h) tightness across the chest;

i) headache;

j) drowsiness;

k) incoherence;

l) slurred speech;

m) nausea;

n) dizziness;

o) fatigue;

p) vomiting;

q) collapse;

r) convulsions.

A.4.3 Emergency treatment for CO poisoning

CO toxicity is a life-threatening emergency that requires immediate action. The following is a list of actions that should be done if CO poisoning is suspected. Proceed with caution. The victim can 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.

— Investigate the source of CO and take corrective action.

A.5 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 can, 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.

A.6 What to do when the alarm goes off?

Actuation of a CO alarm indicates the presence of carbon monoxide (CO) which can be lethal. If the alarm sounds, take the following actions as appropriate.

— Shut off sources of CO, such as engines (if safe to do so), generators and open flame stoves.

— Look for sources of CO that can be from other boats, and take appropriate steps, which can include moving the boat to a safe area.

— Provide fresh air through actions such as opening port lights, hatches and doors.

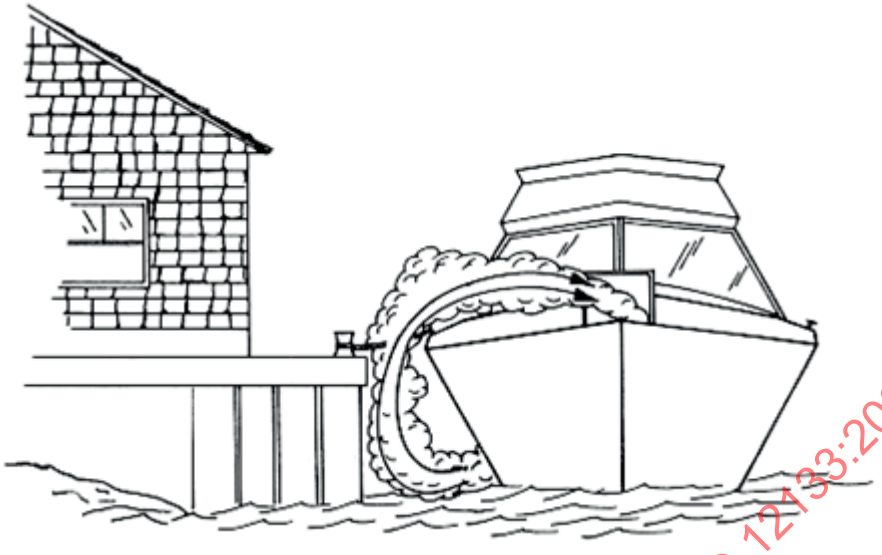
— If anyone is exhibiting signs of CO poisoning, move them to fresh air and seek medical assistance.

A.7 Boat operation

Do not 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 this document or equivalent.

A.8 Stationary operation

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



NOTE This figure illustrates the effects of running an engine or auxiliary generator in confined areas. The risk from CO is greatly increased when there is little or no wind present.

Figure A.1 — Effect of sea walls and other confined spaces

Keep engine room hatches and doors closed when operating engines, including the generator. Before running the generator, consult the 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 the boat to enable the maximum dissipation of CO. Be aware that the 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 can remain in the vicinity of the exhaust outlet (including underwater exhaust outlets such as sterndrives and outboards). CO accumulation can remain entrapped for some time after the engine or generator is turned off (see Figure A.2).

Do not occupy aft lounging area(s) or the swim platform.

Do not swim under or around the swim platform.

Do not swim in the vicinity of exhaust outlet(s).

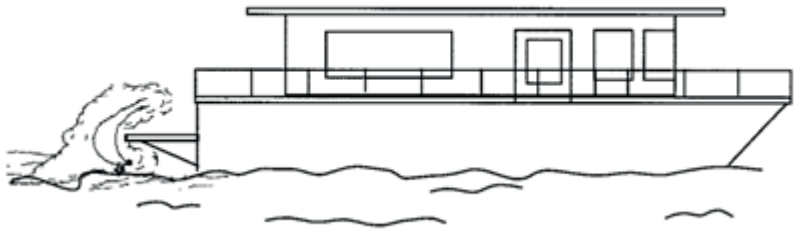


Figure A.2 — Accumulation of exhaust gases at the swim platform

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

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

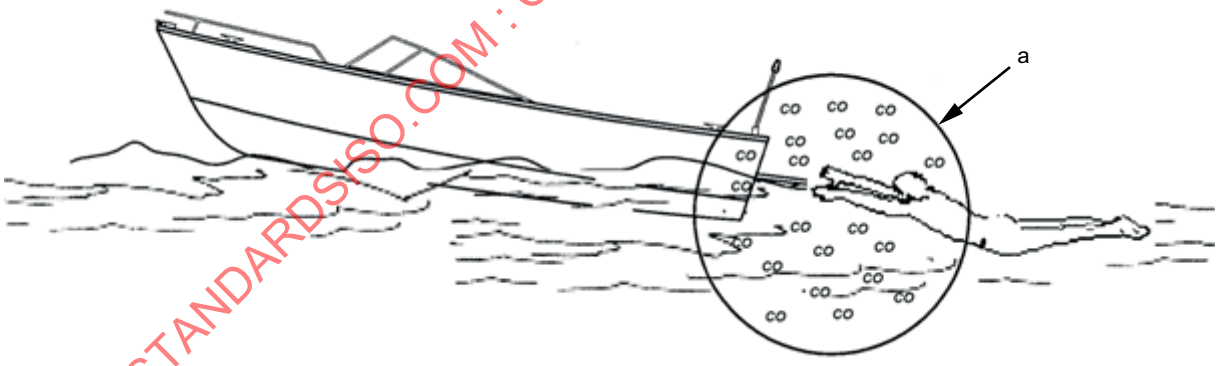
A boat operator should be aware that carbon monoxide is emitted from any boat's exhaust. Operation, mooring and anchoring in an area where other boats' engines or generators are running can put a boat in an atmosphere containing CO, even if the boat's engine(s) is (are) not running. Boat operators need 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 alongside each other. Be aware of the effect the exhaust can have on other boats, and be aware that the operation of other boats' equipment can affect the carbon monoxide concentration on one's boat (see Figure A.3).

NOTE Boats moored close together can affect each other.

Figure A.3 — The effect of boats moored alongside

A.9 Underway operation

Do not sit on, occupy or hang on any stern appendages (swim platforms, boarding ladders, etc.) while underway. Do not body surf, commonly known as “teak surfing”, “platform dragging”, etc. in the wake of the boat. Do not tow persons in close proximity to the stern of the boat (see Figure A.4).



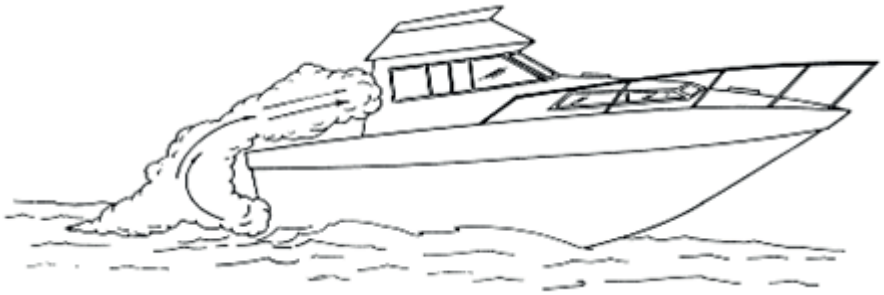
Key

a zone of high CO concentration

Figure A.4 — Dangerous activity when engine is running

There is a need to be aware of 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 the CO level on the boat. Backdrafting can be affected by relative wind direction, boat speed and boat trim angle. See Figure A.5 for an illustration of airflow over a boat and behind its transom. Under certain speeds and operating conditions, the low pressure area can form in other regions and permit carbon monoxide to enter the boat through openings that are not on the back of the boat.



NOTE This figure illustrates airflow over the boat and behind the transom.

Figure A.5 — Backdrafting (station wagon effect)

Other factors during boat operation which can affect carbon monoxide concentration include the following.

— Adding or removing canvas can raise or lower CO levels (see Figure A.6).

— Intentional or unintentional excessive trim angle (e.g. high bow angle or excessive unequally distributed weight) can raise the CO level and should be avoided (see Figure A.7).

— Opening and closing ports, hatches, doors and windows can raise or lower CO levels on board a boat. When airflow is moving forward inside the boat, CO can 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 A.8).

— 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.

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

— Improper installation or lack of system maintenance can 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). Aftermarket air conditioning systems should be installed in accordance with ISO 13297.

— 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 can, under certain conditions, bring hazardous levels of CO into the occupied spaces. Be aware of all prevailing conditions when using these ventilating methods.

— Operation at altitudes greater than about 1 500 m contributes to inefficient engine performance and can 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 can cause an increase in CO. Reduced power resulting from increased altitude can require adjustments to the propeller size. Heavy seas or out-of-trim conditions tend to load engines, resulting in reduced performance and increased CO production.

— Petrol powered portable generators produce CO. Do not use this equipment on boats. These generators discharge their exhaust products in locations which can lead to an increase in the accumulation of carbon monoxide in occupied spaces.

a) Desired airflow through the boat

b) Increased backdrafting

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

Figure A.6 — The effect of canvas/hatch configurations

Figure A.7 — Inefficient trim angles

Figure A.8 — Operating at slow speed with a following wind

A.10 Maintenance

Efficient engine performance is vital to minimize CO production. The following items can have an effect on increased CO production.

a) Fuel that is contaminated, stale, or of incorrect octane number.

b) Carburettors/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, and

   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, and

   4) incorrect ignition timing.

d) Engine:

   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 can increase engine exhaust back-pressure and CO production, and