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Small craft — Carbon monoxide (CO) detection systems

Petitis navires — Systèmes de détection du monoxyde de carbone (CO)

Reference number
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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 12133 was prepared by Technical Committee ISO/TC 188, *Small craft*.

Small craft — Carbon monoxide (CO) detection systems

1 Scope

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

Annex A provides educational material about carbon monoxide relative to boats and boating.

2 Normative references

The following referenced documents are indispensable for the application 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 7240-6, *Fire detection and alarm systems — Part 6: Carbon monoxide fire detectors using electro-chemical cells*

ISO 7240-8, *Fire detection and alarm systems — Part 8: Carbon monoxide fire detectors using an electro-chemical cell in combination with a heat sensor*

ISO 10133, *Small craft — Electrical systems — Extra-low-voltage d.c. installations*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

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

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

NOTE In its chemical formula, C stands for carbon and O for oxygen. For the purposes of this International Standard, the CO level is always expressed in terms of mass fraction of CO in air.

3.2
carboxyhaemoglobin
COHb
stable combination of carbon monoxide and haemoglobin formed in the blood when carbon monoxide is inhaled

NOTE Also called carbonmonoxy-haemoglobin, CO-haemoglobin, blood-COHb, and blood-CO. It is the molecule formed when carbon monoxide, instead of oxygen, combines with blood.

3.3
% COHb
degree to which the oxygen carrying capacity of blood is impeded by the union of carbon monoxide to the haemoglobin in the blood

NOTE Expressed as a percentage.

3.4
enclosed accommodation compartment
contiguous space, surrounded by permanent structure that contains

a) designated sleeping accommodation,

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 compartments.

4 Symbols

β (Beta) An arbitrary variable name chosen to represent the mathematical calculation of the absolute worst case 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 ISO 7240-6 or ISO 7240-8, or relevant national standard (e.g. UL 2034 or EN 50291-2).

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 will also give an alarm for an electrically defective sensor. 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 defined in IEC 60529.

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

5.2 Performance specifications

5.2.1 The device shall be tested to the relevant national standard (e.g. UL 2034) including the following:

— β (Beta) = 10 % maximum;

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

5.2.2 β is calculated from the following expression:

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

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) equation solved for t or w_{CO} is as follows:

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

5.3 Installations

5.3.1 A carbon monoxide detection system shall be installed on all boats with an enclosed accommodation compartment(s) and a petrol generator set or an inboard petrol propulsion engine.

5.3.2 Detectors shall be located to monitor the atmosphere in the main cabin and each sleeping area.

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).

The d.c. electrical system of the detector system shall be installed in accordance with ISO 10133, 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.

The power source for the detector may be the continuously energized side of the battery switch.

5.3.4 The boat manufacturer shall provide instructions in the owner's manual as to what action should be taken when the CO alarm sounds.

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 to be used, the fuse current rating shall be permanently marked where it will 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 International Standard;

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

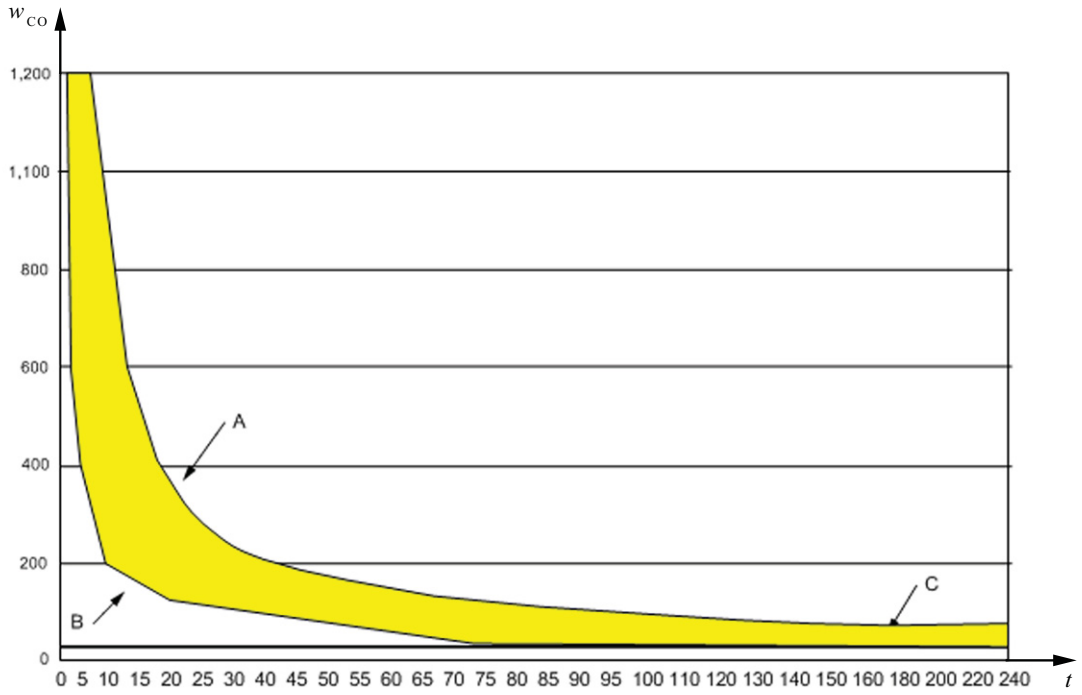
6 Markings

Detectors shall be marked with “Marine Carbon Monoxide Alarm” or equivalent, as tested to the relevant national standard.

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 legislation.



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 (Beta) formula given in 5.2.2 is used to determine β (Beta).

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

NOTE The information in this annex concerns all boats.

A.1 General

Carbon monoxide can accumulate in interior spaces and exterior areas. Carbon monoxide accumulation is affected by a multitude of variables (e.g. boat geometry, hatches, 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 engine performance and maintenance).

This annex discusses many of these variables and enables the user to better understand some of the more predictable effects. However, this annex is limited in that it cannot cover all conceivable variables, and the user 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 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 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 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

— 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 gasoline 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 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 should not be ignored because the effects of exposure to CO are cumulative and can be just as lethal.

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 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.

— 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 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 as specified in Clause 6.

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

Actuation of a CO alarm indicates the presence of carbon monoxide (CO) which can kill you. 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 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 port lights, hatches and doors.

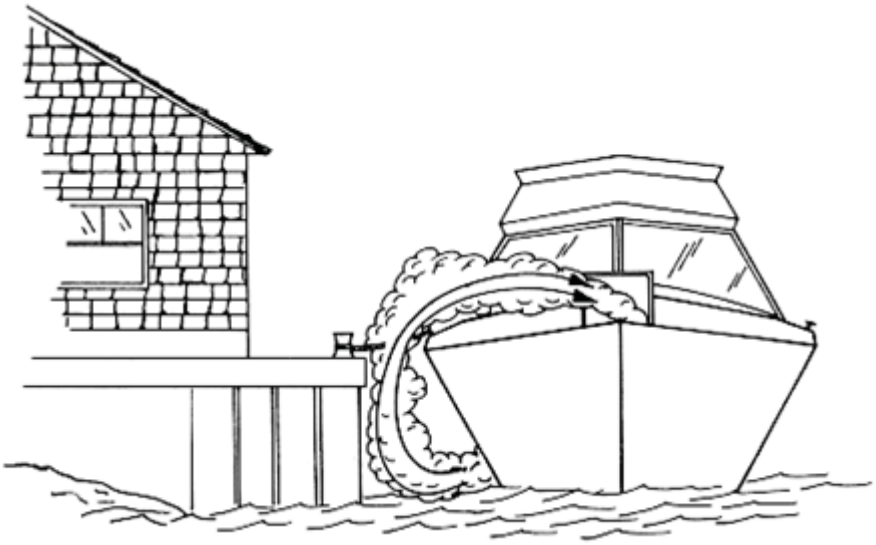
— If anyone is exhibiting signs of CO poisoning, move them to fresh air and seek medical assistance.

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 International Standard or equivalent.

A.8 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 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 — The effect of sea walls and other confined spaces

Keep engine room hatches and doors closed when operating engines, including the generator set. Before running the generator set, 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 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). CO accumulation may 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 swim platform.

Do not swim under or around swim platform.

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

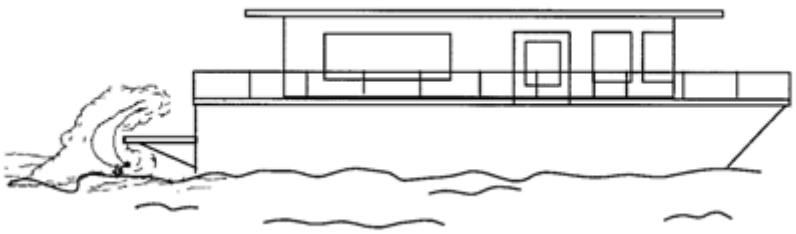
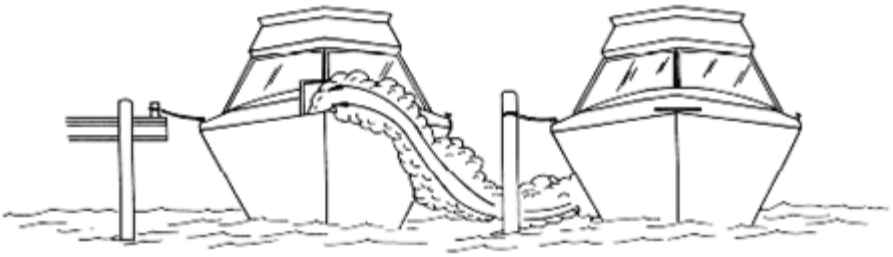


Figure A.2 — Accumulation of exhaust gases at the swim platform

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 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 alongside 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 A.3).

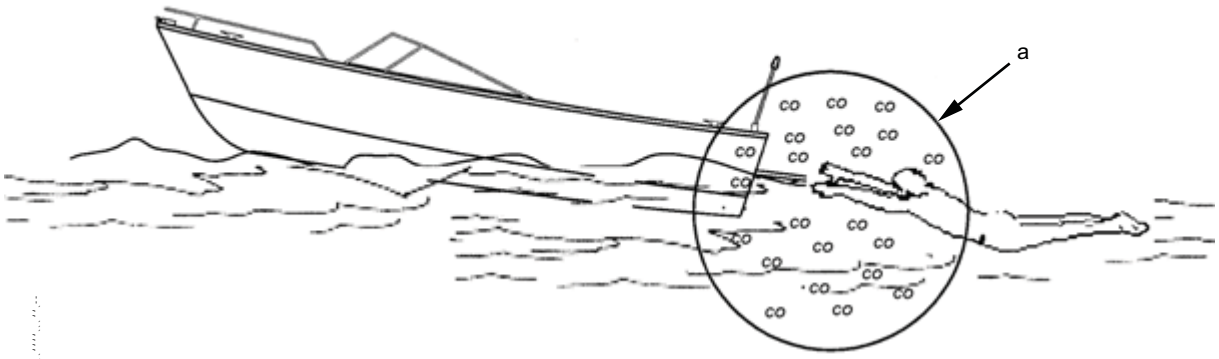


NOTE Boats moored close together can affect each other.

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).

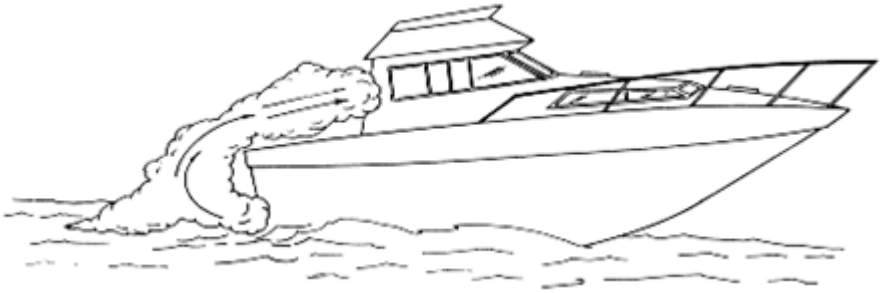


a Zone of high CO concentration.

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 speed and operating conditions, the low pressure area may 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 may affect carbon monoxide concentration include the following.

— Adding or removing canvas may 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) may raise the CO level and should be avoided (see Figure A.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 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.

NOTE 1 This figure illustrates desired airflow through the boat.

NOTE 2 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

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). Aftermarket air conditioning systems should be installed in accordance with ISO 13297[1].

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 about 1 500 m 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 occupied spaces.

A.10 Maintenance

Efficient engine performance is vital to minimize CO production. The following items may have the greatest 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 may increase engine exhaust back-pressure and CO production, and

   4) restricted engine room or compartment ventilation;

e) External boat conditions. Conditions that contribute to inefficient engine performance can include:

   1) fouled hull bottom,

   2) damaged and fouled running gear (i.e. shaft, strut, propeller, rudder, and trim tabs), and

   3) incorrect or damaged propeller;

f) Exhaust system integrity. Gas tight integrity of exhaust systems should be maintained to ensure 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:

   1) gaskets at cylinder head connection,

   2) castings and pipe fittings in the dry section,

3) all joints,

4) hoses,

5) clamps,

6) mufflers and their drain plugs,

7) thru-hull fittings, and

8) hangers and other supports;

g) Ventilation systems. Boats are equipped with ventilation systems to eliminate gasoline vapours. 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:

1) keeping ventilation intakes clear of debris,

2) replacing damaged hardware,

3) maintaining the integrity of the ducting material and its connections,

4) ensuring that position of ducting intake is not obstructed or restricted, collapsed, kinked or crushed,

5) eliminating sags in ducting that can form a water trap,

6) checking hangers and other supports,

7) ensuring blower/fan is operational,

8) checking that air flow is present at discharge, and

9) inspecting wiring to equipment;

h) Bulkhead and deck integrity:

1) 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 vapours, and

2) check gaskets and sealing surfaces on hatches, doors and access panels;

i) CO detection systems. CO detectors require periodic replacement. Check the system and its installation and maintain and/or replace in accordance with the manufacturer's instructions;

j) Air-conditioning systems. These systems can be a source of CO ingress and migration of CO vapours:

1) keep return air grilles and filters clean,

2) 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, and

3) 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;

k) 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).

Bibliography

[1] ISO 13297, *Small craft — Electrical systems — Alternating current installations*

[2] UL 2034, *Single and Multiple Station Carbon Monoxide Alarms*, Section 75, *Carbon Monoxide Alarms for Use on Recreational Boats*

[3] EN 50291-2*, Electrical apparatus for the detection of carbon monoxide in domestic premises — Part 2: Electrical apparatus for continuous operation in a fixed installation in recreational vehicles and similar premises including recreational craft — Additional test methods and performance requirements*

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