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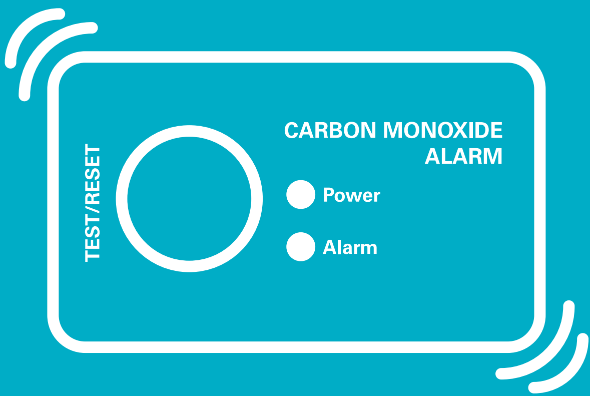
UK Civil Aviation Authority



CARBON MONOXIDE **SAFETY**

FOR GENERAL AVIATION

SAFETY SENSE

SS34

YOUR SAFETY SENSE LEAFLET FOR:
CARBON MONOXIDE SAFETY

Carbon monoxide (CO) poisoning has been cited as a factor in multiple fatal General Aviation (GA) accidents. Although such accidents are rare, CO poisoning remains a persistent background threat to pilots and passengers flying in piston engine aircraft.

This leaflet provides guidance to GA pilots on how they can protect themselves and their passengers from CO by employing effective prevention via maintenance and detection measures. The leaflet also includes guidance on the range of CO detectors available, fitting one in your aircraft, and responding to alerts from your device.

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What is carbon monoxide?

Carbon monoxide (CO) is a colourless and odourless gas that is impossible for humans to detect unaided and can be extremely harmful when inhaled, even in relatively small quantities. It is formed by the incomplete combustion of carbon-based fuel and is produced by virtually all internal combustion engines, since even very efficient engines will not completely burn their fuel.

Most piston engine aircraft exhaust gas typically contains about 5% CO so the risk of poisoning is significant. In normal operation, CO is directed away from the aircraft via the exhaust, but it can sometimes find its way into the cabin, posing a threat to pilots and passengers.

Effects of exposure

CO is toxic to humans as it inhibits the ability of red blood cells to carry oxygen around the body. Consequently, tissue and organs do not receive the oxygen they need to function, resulting in damage to the brain, heart and nervous system.

Susceptibility to CO poisoning increases with altitude due to the reduced oxygen density of the air, making those who fly particularly vulnerable.

The symptoms of CO poisoning are not always obvious and can be easily dismissed as something much less severe such as a cold or flu. Mild poisoning may not present any symptoms at all.

The physiological effects of CO poisoning are cumulative and take time to disperse. The severity of symptoms and the time needed to recover depend on the level of CO exposure, measured in parts per million (PPM) of oxygen, and the duration of exposure. Even relatively low CO concentrations over several hours can be enough to cause impaired judgement and degrade pilot performance.

The following table shows the most common symptoms associated with mild, moderate, and severe CO poisoning based on CO concentration and the duration of exposure.

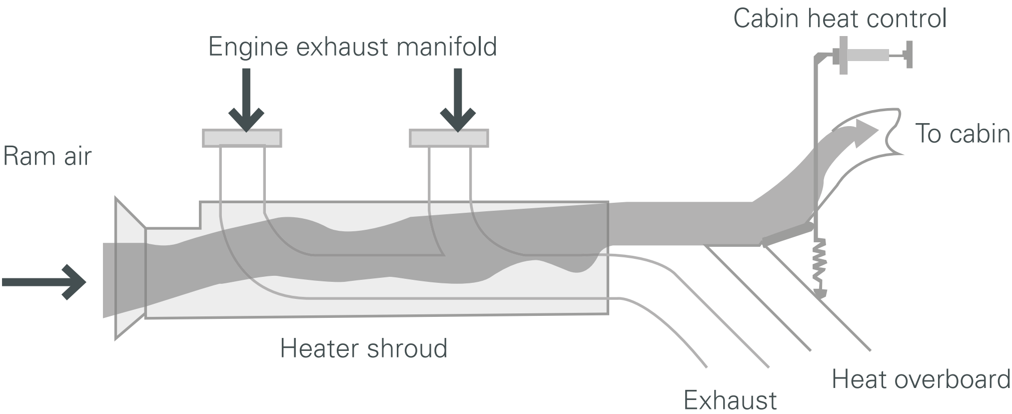
Severity	CO parts per million	Exposure Time	Typical symptoms
Mild	50	8 hr	None or slight headache
Moderate	200	2-3 hr	Bad headache, nausea, fatigue, dizziness, increased respiration, impaired judgement, drowsiness, blurring vision, difficulty breathing, stomach pain
Severe	400	1-2 hr	Pounding headache, confusion, marked shortness of breath, marked drowsiness, increasing blurred vision, unconsciousness, heart attack, life threatening after 3 hr
	800	45 min	Symptoms as above, unconscious within 2 hr, death within 2-3 hr
	1600	20 min	Symptoms as above, death within 1 hr

How does CO enter the cabin?

There are various ways that CO can enter the cabin, which can be broadly split into two categories; internal migration and external ingestion.

Internal migration

For many light aircraft cabin heat is provided via a heat exchanger that takes advantage of the hot air flowing through the exhaust system and uses it to heat air that is directed to the cabin. In normal operation the exhaust gas and air for the cabin are kept separate. However, in the event of a failure in the exhaust manifold (e.g. cracks, worn seals, etc.) exhaust fumes can escape and enter the cabin via the heater vents. Research indicates that CO poisoning incidents are more prevalent in colder months when cabin heater use is high.



CO that may be circulating in the engine compartment due to a fault in the exhaust system can also enter the cabin via poor sealing of the bulkhead between the engine compartment and the cabin.

If the aircraft has a separate combustion heater, this is also a potential source of CO within the aircraft.

External ingestion

CO ingestion into the cabin can also occur externally – there is usually a stream of exhaust gas flowing down the outside of the fuselage that could enter the cabin via poorly fitting doors, windows, panels, or vents. The extent may vary at different angles of attack. In an unpressurised aircraft the interior air pressure is typically slightly lower than outside, which can have the effect of sucking flowing fumes inside through external gaps.

Changes/modifications to the position and configuration of the exhaust system can also notably affect the amount of CO entering the cabin.

Aircraft maintenance

The best way to prevent CO poisoning in piston engine aircraft is to avoid exposure by adhering to a thorough and regular maintenance programme.

Since many CO occurrences are in some way related to exhaust system failures, vigilance from pilots and maintenance personnel to recognise the hallmarks of exhaust system failure is crucial in avoiding CO poisoning. A smell of smoke/fumes in the cabin and/or a large drop in engine rpm when applying carburettor heat are often associated with an exhaust system requiring attention. The heat exchanger shroud may also show black, sooty deposits and discolouration, which should not be ignored.

Older aircraft with higher operating hours are more likely to be affected by exhaust system issues as well as degraded sealing, but CO can be an issue for any piston engine aircraft, irrespective of age.

Key maintenance points include:

- Exhaust components should be periodically inspected as part of the aircraft maintenance programme (AMP) for any signs of damage or corrosion that could allow gases to escape from other than the intended exit point.
- Both external and bulkhead seals should be checked.
- For aircraft with an exhaust heat exchanger, there should be a specific CO concentration check item in the AMP – this is now a requirement in the Minimum Inspection Programme for aircraft maintained under UK Part-ML.
- CO concentration measurements exceeding 50 ppm should prompt further investigation to identify the cause so that rectification action can be taken.

Maintenance references:

- For aircraft maintained under the Minimum Inspection Programme (MIP), owners and maintenance staff should refer to the applicable entry for CO detection in the AMC material to UK Reg (EU) No. 1321/2014 Annex Vb (Part-ML).
- CAAIPS Leaflet B-190, as included in CAP 562 Civil Aviation Airworthiness Information and Procedures contains maintenance related measures to minimise the likelihood of contamination.
- FAA AC-43-13-1B (Section 3 paragraphs 8-45 to 8-52) provides valuable information on typical failures and inspections including pressure checks, repairs and replacement recommendations for exhaust systems.
- Transport Canada Airworthiness Directive CF-90-03 and its accompanying Safety Alert document CASA 2019-07 (see para 3) includes an example of an inspection and test regime for aircraft exhaust and heater components.
- Generic Requirement 11 (GR11) of CAP747 contains mandatory airworthiness requirements for combustion heaters fitted in aircraft.

Active detection

Even though CO itself is odourless, other exhaust gases that have a distinctive smell may indicate the presence of CO, so if you do smell exhaust gases inside the aircraft it is highly likely that CO is also entering. However, this should not be relied on as a method of detection since significant quantities of CO may still enter without any smell of exhaust fumes. For this reason, having a suitable CO detector is vital.

The CAA recommends that GA pilots flying piston engine aircraft have an electronic CO detector capable of providing audible and/or visible alerts that actively engage pilot's attention when elevated CO levels are detected; these devices are known as 'active CO detectors'.

CO detectors that simply change colour in the presence of CO have been used by GA pilots for many years, but their lack of any attention-getting capability and short life span make them problematic given the nature of CO.

Safety Directive SD-2024/001

From January 2025, operators of piston engine aircraft are required to have a functioning active carbon monoxide detector on board when operating with passengers who do not hold a recognised pilot qualification. To facilitate compliance, the CAA allows both aviation standard and commercial-off-the-shelf (COTS) active CO detectors as an acceptable means of compliance. The requirement to have an active CO detector does not apply to some types of aircraft/operation – see SD-2024/001 for further details.

Although the safety directive prioritises the protection of passengers who are not expected to be aware of the risk posed by CO, all pilots of piston engine aircraft at risk of CO are strongly encouraged to fly with an active CO detector.

ACTIVE DETECTION

Active CO detectors

Active CO detectors typically alert when CO levels reach 50 ppm although some devices alert at lower thresholds; the trigger level for alerts can sometimes be adjusted, depending on the device. The CAA considers 50 ppm as an appropriate threshold that minimises excessive low-level alerting whilst also giving the pilot time to respond to a CO event. However, some pilots may prefer to fly with a more sensitive active CO detector that alerts at lower thresholds.

Some devices feature a digital display showing CO levels in real time, making it clear to pilots how much CO is present and whether it is increasing or decreasing. Active CO detectors with digital displays should be in line-of-sight of the pilot.

The effectiveness of any active CO detector is largely dependent on variables such as the alarm trigger level and the detector's location in the aircraft. Adherence to the manufacturer's general guidance for installation, usage and maintenance should maximise effective operation.

It is important that pilots find a device that best suits their needs considering factors such as device size, alert threshold, audibility, sensor/battery life, and ease of fitment.

Active CO detectors broadly fall into two categories as follows:

Aviation standard active detectors

These devices are approved for aircraft use in accordance with a recognised aviation standard (e.g. EASA ETSO-2C48a) and can therefore be permanently installed in aircraft. They are available from a variety of reputable pilot/aircraft equipment suppliers.

These detectors tend to cost more, typically around £300 plus installation, but often come with additional functions and better aircraft integration. Active CO detectors are increasingly being built into other aviation equipment as standard, including ADS-B devices and headsets.

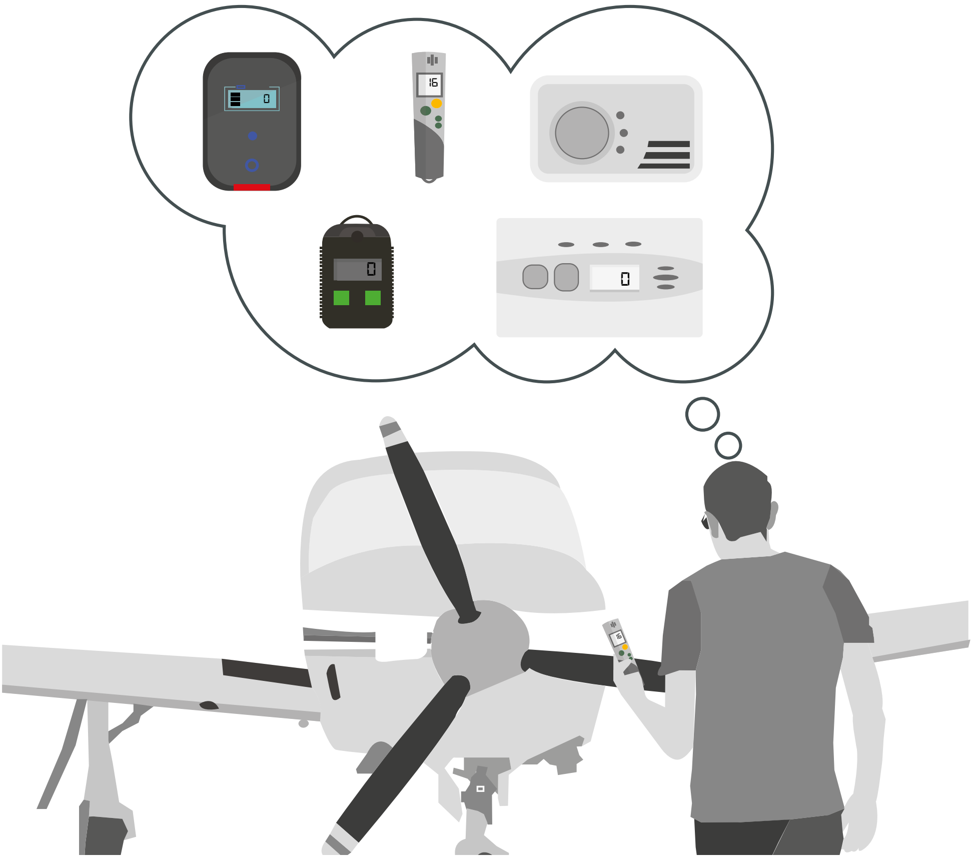
ACTIVE DETECTION

Commercial off the shelf (COTS) active detectors

There is a wide range of low cost (around £20) active CO detectors designed for domestic use. Although these devices are not designed for use in aircraft, findings from the CAA 12-month study of COTS detectors suggest that they can function reasonably well at typical GA altitudes (up to 5,000 ft). The CAA published a list of the five most popular COTS devices used in the CAA 12-month study.

Opting for a device that meets a commercial standard (e.g. EN 50291-2) can result in improved durability and reliability. With sensor lives of up to 7 years and battery lives up to 10 years, these devices can be very cost-effective.

Active CO detectors designed for industrial applications are also available. These devices often cost more (typically starting at around £100) than domestic COTS detectors, but tend to be more accurate and durable, making them a good option for GA aircraft.



Fitting an active CO detector

Aviation standard active detectors

- These devices can be installed in UK-registered aircraft as ‘standard changes’ under the provisions of CS-STAN (Standard Change CS-SC107a).
- This removes the need for direct CAA involvement, including avoiding the cost and time of applying for a formal modification.
- These detectors are most often mounted on the instrument panel and must be installed by a suitably qualified individual who is able to release the aircraft to service.

COTS active detectors

- No airworthiness approval is required for COTS active CO detectors that are independently powered i.e. not powered by the aircraft electrical system.
- Pilots should assess the suitability and condition of the detector before flight to ensure that an aural CO warning is audible even when wearing noise-cancelling headsets, but not so loud as to create a distraction in flight.
- Pilots should also be familiar with the aural alert produced by their device so as not to confuse it with other onboard warnings.
- Most participants in the 12 month CAA study of COTS detectors kept their device attached to the instrument panel. Other popular locations for devices were the centre console, side pocket and side panel. Devices should not be located near fresh air vents as this could affect their ability to detect CO.
- COTS active CO detectors can be installed in aircraft cabins by various means such as suction mounts/cradles, velcro, clips, or strong adhesive tape. Whatever means is used, pilots should ensure that the device is securely held in place for the flying being undertaken.
- By keeping the device in the pilot’s line of sight, alerts are more likely to be noticed.
- Do not keep your detector inside a flight bag or compartment where it will not be able to sample the cabin air.
- Although CO is slightly lighter than air, mounting a detector high up in the cabin may not result in better detection as air circulation in the cabin can affect CO distribution.

Responding to a CO alert

In the event of an in-flight CO alert, you should:

- Keep flying the aircraft – the alert will likely come as a surprise and could be a distraction, particularly at critical phases of flight;
- Turn off the cabin heat supply and maximise fresh air entry into the cabin – this will normally be by use of fresh air vents rather than opening a window;
- Make a PAN or MAYDAY call if appropriate (e.g. high CO reading or experiencing CO poisoning symptoms);
- Land as soon as possible – do not wait for things to get worse. Consider that the nearest airfield may not be your planned destination; return to the departure airfield if that is closer. (off-aerodrome) may need to be considered in the event of a persistent high CO reading or if experiencing CO poisoning symptoms;
- Seek medical attention on the ground if experiencing CO poisoning symptoms (e.g. headache, dizziness, nausea);
- Ensure the problem is identified and rectified before further flight; and
- Report the occurrence to the CAA using the Mandatory Occurrence Report (MOR) scheme.

In the event of a CO alert while on the ground:

- Turn off the cabin heat supply and maximise fresh air entry into the cabin;
- If the alert does not clear prior to takeoff, do not take off with the alert;
- Inform the Air Traffic Service of the issue, taxi back to the parking area or apron and shut down the engine;
- Seek medical attention if experiencing CO poisoning symptoms (e.g. headache, dizziness, nausea);
- Ensure the problem is identified and rectified before further flight; and
- Report the occurrence to the CAA using the Mandatory Occurrence Report (MOR) scheme.

Recommended additional reading

The following sources contain useful information concerning the nature and effects of carbon monoxide, the causes of contamination and means by which the likelihood of exposure can be reduced:

- Safety Directive SD-2024/001
- CAA webpage, Carbon monoxide in general aviation
- Piper PA-46 Malibu (N264DB) AAIB Special Bulletin S2/2019 and Final Report
- CAA Safety Notice, SN-2020/003
- CAA Carbon Monoxide Detector Trial Summary Report, July 2023
- LAA 'Light Aviation' magazine article 'The Canary & the Silent Killer', July 2017
- FLYER article 'Top Gear; Carbon Monoxide Monitors'; Summer 2019
- EASA European Technical Standard Order ETSO-2C48a Carbon Monoxide Detector Instruments
- Australian Civil Aviation Safety Authority Airworthiness Bulletin, AWB 02-064 Issue 5 – 30 June 2023, 'Preventing Carbon Monoxide Poisoning in Piston Engine Aircraft'
- FAA report DOT/FAA/AR-09/49 'Detection and Prevention of Carbon Monoxide Exposure in General Aviation Aircraft', 2009
- EASA Safety Information Bulletins 2010-19 'Exhaust Mufflers Inspection for piston engine Helicopters and Aeroplanes'

Queries

Any queries or requests for further guidance should be addressed to **GA@caa.co.uk**