Australian Government
Australian Transport Safety Bureau

Partial crew incapacitation involving Cessna 172, VH-YXZ

44 km south of Adelaide Airport, South Australia, 22 December 2019

ATSB Transport Safety Report
Aviation Occurrence Investigation (Short)
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Addendum

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Safety summary

What happened

On 22 December 2019, the crew of a Cessna 172R aircraft, registered VH-YXZ and operated by Hartwig Air, was conducting aerial shark patrols. The aircraft departed Parafield, South Australia for the second flight of the day and flew along the coast to Goolwa Murray Mouth, returning along the same route.

About 2 hours into the flight, the crew started to experience symptoms typically associated with carbon monoxide (CO) poisoning, and subsequently observed a localised discolouration on the disposable CO chemical spot detector. The pilot notified air traffic control, who offered the pilot to land at Adelaide Airport. The pilot initially agreed, but as their symptoms resulted in confusion about the runways at Adelaide Airport, they subsequently decided to fly to Parafield, due to their familiarity with that airport.

The aircraft was landed safely and the three crew were taken to hospital for assessment. Blood tests confirmed all crew had mildly elevated carboxyhaemoglobin levels.

What the ATSB found

The ATSB found that, despite having only mildly elevated carboxyhaemoglobin levels, the crew's physical symptoms and cognitive effects likely resulted from exposure to elevated CO levels in the aircraft cabin. The CO source within the aircraft could not be established. Further, the discrepancy between the low carboxyhaemoglobin levels and severity of experienced effects could not be resolved.

Safety message

Carbon monoxide is a colourless and odourless gas, and its presence may not be detected until the physical symptoms and cognitive effects are more developed. Therefore, operators and owners of piston-engine aircraft are strongly encouraged to install a CO detector with an active warning to alert pilots to the presence of elevated levels of CO in the cabin. Should any smell or sensation of illness develop, pilots should check their CO detector, ensure cabin heat has been turned off, open all fresh air vents and windows, make prompt decisions to land as soon as possible, and use all available resources for assistance. Further information on CO poisoning and detectors can be found at the following:

Are you protected from carbon monoxide poisoning?

Carbon Monoxide: A Deadly Menace

The investigation

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope investigation was conducted in order to produce a short investigation report, and allow for greater industry awareness of findings that affect safety and potential learning opportunities.

The occurrence

On the morning of 22 December 2019, the crew of a Cessna 172R aircraft, registered VH-YXZ and operated by Hartwig Air, was being operated on an aerial shark patrol flight under visual flight rules.[1] The three crew on board included the pilot, a communications officer[2] and an observer.

The morning consisted of two flights, flying the same route along the coast. At about 1000 Central Daylight-saving Time,[3] the first flight departed Parafield Airport, South Australia, and proceeded along the coast to Goolwa Murray Mouth, before returning along the same route (Figure 1). This flight went for about 2.75 hours, which was longer than expected. This resulted in limited time for the crew to refuel the aircraft, conduct all the checks and ground runs, and have a lunch break prior to the second flight.

At about 1330, the aircraft departed Parafield Airport for the next flight. While overhead Sellicks Beach on the return leg, and about 2 hours into the flight, the communications officer became sick, followed shortly thereafter by the pilot. The crew discussed their sickness and dismissed it on the assumption that it was likely due to turbulence encountered while flying across the hills.

After passing Port Noarlunga, the pilot looked down and observed a localised discolouration on the disposable carbon monoxide (CO) chemical spot detector. The communications officer, sitting in the front right seat, verified the discolouration on the detector and all the crew confirmed they were feeling light-headed.

The crew immediately opened the windows and confirmed that the aircraft's heating was turned off. The crew reported that, due to smoke haze in the area from the Cudlee Creek bushfire, they experienced no relief from this action and began to feel worse. The pilot noted losing periods of time, had begun to lose feeling in their legs, experienced chest pains, and had a tingling feeling in their hands.

The pilot contacted Adelaide air traffic control, notified the controller of potential CO poisoning and requested a clearance to fly direct to Parafield. The controller offered the pilot direct to Adelaide Airport for runway 30, to which the pilot initially agreed. The pilot then decided to fly to Parafield due to their familiarity with the airport, as their light-headedness had become worse and resulted in confusion about the runways at Adelaide.

The pilot continued to experience confusion for the rest of the flight, including with radio calls, however, the aircraft was landed safely at Parafield. The three crew were subsequently taken to hospital for a medical examination (refer to section titled *Medical information*).

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1 Visual flight rules: a set of regulations that permit a pilot to operate an aircraft only in weather conditions generally clear enough to allow the pilot to see where the aircraft is going.

2 The communications officer's role was to contact the police in the event a shark was spotted.

Figure 1: Aircraft's flight path (in white)

Source: Google earth, annotated by the ATSB

Context

Medical information

Physical symptoms and cognitive effects experienced

The crew all reported experiencing nausea, headaches, fatigue and light headedness. Individually, the pilot experienced memory loss, confusion, a numbness/tingling sensation in their extremities, chest pains and mildly blurred vision. The observer reported experiencing chest pains, fatigue and breathlessness, while the communications officer reported vomiting.

The crew did not experience any eye irritations and did not detect a strong smoke smell while flying. They also did not identify a significant difference in the strength of the smoke odour while on the ground, compared with in the air. Both the communications officer and the observer did not recall a smoke odour on their clothing after the flight, however, the pilot recalled a slight odour on their shirt when they got home.

General health and fitness

With respect to their health and fitness, the crew reported that:

- All crew felt well, were well-rested prior to the first flight, and were fit and healthy.
- Both the pilot and the observer had a light breakfast. The communications officer could not recall if, or what they had for breakfast. The crew all had a light lunch prior to the second flight.
- The crew were non-smokers, were not taking any medication, and did not have any pre-existing conditions that could have contributed to the incident.

- The communications officer reported being prone to motion sickness, particularly on an empty stomach.
- The observer felt a bit more tired than usual after the first flight. The pilot felt okay after the first flight, but recalled having a slight headache. The communications officer felt fine.

Dehydration

The crew reported drinking minimum amounts of water prior to the flight and only having small sips during the flight. Specifically, the pilot had some water before the flight and also sipped water during the flight. The observer had not drunk any water during the morning before the flight, but took regular small sips during the flight. It was unknown if the communications officer had drunk any water prior to the flight.

In addition, the pilot and observer reported having not consumed any alcohol or drugs in the 24 hours leading up to the flight. The communications officer had a slight headache from drinking alcohol the night before, but was fit to fly.

Dehydration is caused by excessive water loss. Causes include alcohol and caffeine consumption; and as both create a diuretic effect, working in the heat before flying and by not drinking enough water (Flight Safety Foundation, 2001). Symptoms of dehydration can include fatigue, nausea, elevated pulse and respiratory rate, headache, dizziness and confusion.

Medical examinations

Blood samples were taken approximately 3 hours after the crew's initial physical symptoms and cognitive effects were detected. The results of these tests established that the crew had mildly elevated levels of carboxyhaemoglobin (COHb). Both the pilot and communications officer had levels of 1.2 per cent and the observer had 1 per cent. The crew declined the administration of oxygen while at hospital.

Carbon monoxide is an odourless, colourless and tasteless gas formed by the incomplete combustion of carbon-containing materials. When inhaled, it preferentially binds to haemoglobin, the oxygen carrying molecule in red blood cells. This creates COHb compounds and prevents oxygen from binding to the molecule and being transported, resulting in oxygen starvation.

According to Baselt (2014), normal endogenous levels of COHb are generally reported to fall within the range of 0.4-0.7 per cent. Smokers, and those living in an urban area, may have higher than average levels of COHb. Carbon monoxide has a half-life of 4-5 hours at sea level, meaning that the COHb will reduce to half its initial value within that time, after the source of CO has been removed. The CO half-life can be reduced to 80 minutes with the administration of pure oxygen.

The physical symptoms and cognitive effects of CO poisoning can worsen with an increasing level of COHb, however, different individuals' reactions to a given COHb level can vary (Lacefield et al., 1982). Typically, COHb levels of 10-20 per cent can result in symptoms of a mild headache. Levels of 20-40 per cent can result in increasing severity of headaches, irritability, mental changes, fatigue, weakness, nausea, dizziness, visual problems and confusion (Knobeloch & Jackson, 1999; Lacefield et al., 1982). Though physical symptoms do not generally show at levels below 10 per cent, researchers have found that a person's ability to perform complex tasks can be adversely affected at levels of 10 per cent or less (Baselt, 2014). It has also been found that the effects of CO can begin to show with the deterioration of psychomotor function at COHb levels of about 3 per cent (Hawkins, 1993).

Given the half-life of CO and elapsed time since the symptoms and effects were first detected, it was likely that the crew's COHb levels were a maximum of approximately 2 per cent. For the crew to have obtained a saturation level of 2 per cent COHb, according to Baselt (2014), they would have been exposed to 200 parts per million (ppm)[3] for about 2 hours, not taking into account the

[3] The concentration of CO in the air is represented as parts per million.

break between flights. The maximum exposure level, as recommended by Safe Work Australia, is 30 ppm over an 8-hour period.

Aircraft maintenance

A new engine was installed on the aircraft 10 days prior to the incident. An inspection was conducted during this process and no faults were found that would relate to a possible exhaust leak.

Immediately after the incident, an inspection was carried out on the aircraft, focusing on the exhaust system and airframe, including the firewall and door seals. No faults or exhaust gas leaks were found. The aircraft was not tested for CO leaks prior to the inspection. However, there were no reports or maintenance release entries made prior to the incident that indicated a possible exhaust leak. Further, the pilot who operated the aircraft the day before the incident reported not feeling any adverse health effects during the flight.

After the inspection, ground runs were conducted with a digital CO detector in the aircraft cabin. No indications of CO were found during the ground runs or during a subsequent check flight.

Environmental conditions

Bureau of Meteorology

The Bureau of Meteorology 1-minute observation data at Adelaide Airport, indicated the surface wind was variable, blowing to the south-west with wind speeds between 5-13 kt, and the temperature was 24 °C.

On the day of the incident, a bushfire was burning at Cudlee Creek, 16 km south-east from Parafield Airport and 40 km from the coast. The fire had grown to 25,000 hectares in size. There were also two small fires burning on Kangaroo Island to the south-west of Adelaide. However, given the wind conditions on the day, it was unlikely that these fires would have contributed to the smoke haze in Adelaide.

Throughout the flight, the crew reported the visibility was approximately 6 km due to smoke haze from the bushfire and that this remained constant. The visibility in the routine aerodrome weather report[4] for Adelaide and Parafield were recorded as CAVOK[5] and above 10 km respectively, throughout the day. The Adelaide Airport automatic terminal information service[6] reported smoke haze to the north-east of the airport.

The South Australian Environment Protection Authority recorded CO levels in the Adelaide central business district at ground level of 0.46 ppm at 1500. The average was 0.29 ppm from 1000 to 1600.

Bushfire smoke

The ATSB engaged the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Climate Science Centre who were conducting research into the effects of bushfire smoke on firefighters. CSIRO reported that CO disperses in the air and high CO concentrations of about 400 ppm are generally correlated with low visibility of only a few metres. They noted that, to have CO poisoning with the effects the crew reported after 3 hours, the crew would have been exposed to very high levels. They also advised that, given the distance to the fire and the fact that there was

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4 METAR: a routine aerodrome weather report issued at routine times, hourly or half-hourly.

5 CAVOK ceiling and visibility okay: visibility, cloud and present weather are better than prescribed conditions. For an aerodrome weather report, those conditions are visibility 10 km or more, no significant cloud below 5,000 ft, no cumulonimbus cloud and no other significant weather.

6 Automatic terminal information service (ATIS): continuous broadcast of recorded aeronautical information. ATIS broadcasts contain essential information, such as current weather information, active runways, available approaches, and any other information required by flight crew.

no strong smell of smoke experienced by the crew, the CO concentrations in the plume would not have been elevated enough to cause adverse health effects.

The ATSB also engaged the South Australian Country Fire Service to determine if any of their aircrew had experienced similar symptoms while conducting aerial firefighting on the day of the incident. They reported that none of their aircrew had experienced any CO effects during this fire or during any other fires in the past.

The possibility of other toxins in the bushfire smoke that may have potentially led to the crew's partial incapacitation were also considered. CSIRO advised that typically, if the concentrations were high enough to cause adverse health effects, one of the main symptoms would be irritation in the eyes and throat. The crew did not report any irritations nor a strong smoke smell, therefore, it was unlikely that other toxins in the smoke led to their symptoms.

Carbon monoxide detector

The aircraft was fitted with an Aviation Supplies and Academics disposable CO chemical spot detector, attached to the centre of the instrument panel. The detector consisted of an orange-coloured circle (spot) in the middle of the card, which was designed to change colour to grey/black following a chemical reaction with CO in the immediate vicinity. The spot then returns to normal (orange) after it has been exposed to fresh air. The chemical reaction depends on the concentration of CO in the air and the time of exposure. This detector was designed to react to a minimum of 50 ppm of CO within 30 minutes, 100 ppm within 10 minutes and 200 ppm within 4 minutes.

A limitation of this type of detector is that it does not actively alert the pilot to the presence of CO. Therefore, its effectiveness relies on the pilot regularly monitoring the detector throughout the flight. It is also dependent on the detector being easily visible and accessible, in a well-lit position. In a low ambient light environment, the discolouration of the chemical spot, from orange to a grey/black colour, can be difficult to see.

Similar occurrences

ATSB investigation (AO-2017-118)

On 31 December 2017, the pilot and five passengers of a de Havilland Canada DHC-2 floatplane, registered VH-NOO, boarded the aircraft for a charter flight from Cottage Point to Rose Bay, New South Wales. The aircraft taxied for about 7 minutes. Shortly after take-off, the aircraft deviated from the standard flight path, stopped climbing, and entered a confined area (Jerusalem Bay) below the height of the terrain. The aircraft continued along the bay before making a very steep right turn and colliding with the water. All on board were fatally injured and the aircraft destroyed.

Toxicology results identified that the pilot and passengers had higher than normal levels of COHb in their blood. This was almost certainly due to elevated levels of CO in the aircraft cabin. The ATSB's wreckage examination established that several pre-existing cracks in the exhaust collector ring, very likely released exhaust gas into the engine/accessory bay. This then very likely entered the cabin through holes in the main firewall where three bolts were missing from the magneto access panels.

ATSB investigation (AO-2020-055)

On 23 September 2020, the pilot of a Piper PA-28 aircraft, registered VH-TBB, departed Moree, New South Wales on a private ferry flight to Tamworth. Shortly after take-off, the pilot started to experience dizziness, breathlessness, and a warm feeling in the chest. The pilot conducted a visual scan and observed a discolouration on the disposable CO chemical spot detector that was gradually getting darker. The pilot opened the air vents and storm window, and returned to Moree. The investigation is ongoing.

National Transportation Safety Board investigation (CEN17LA101)

On 2 February 2017, shortly after take-off, the pilot of a Mooney M20C aircraft became incapacitated. The aircraft continued flying until running out of fuel and then collided with terrain near Ellendale, Minnesota, United States. The pilot survived the accident but had no recollection of events between becoming incapacitated and waking up on the ground. The National Transportation Safety Board investigated the accident and concluded that the pilot's incapacitation was due to CO poisoning.

The pilot reported using the aircraft's heater throughout the day and having a headache and experiencing 'butterflies' in their stomach by the end of the first flight. The symptoms subsided after the first flight but returned after landing on the second flight. The symptoms were still present on the third flight and the last event the pilot remembered was being cleared to climb to 6,000 ft by air traffic control.

A post-accident inspection revealed several cracks in the exhaust muffler. The pilot's COHb level, taken 4.5 hours after the accident, was 13.8 per cent. However, given the half-life of CO, the pilot's level would have been at least 28 per cent at the time of the accident. In response to the experience, the pilot stated that:

> Current technology has made portable CO detection very accurate and expensive. A high resolution detector would have not only prevented this accident flight, but may have alerted me to a comprimise [compromise] in my exhaust system many flight hours before the incedent [incident].

Analysis

Partial crew incapacitation

The observed physical symptoms reported by the crew were consistent with CO poisoning. This was supported by their blood tests, which established that they had mildly elevated levels of COHb adjusted to 2 per cent, and the positive indication on the CO detector in the aircraft's cabin. Although, the extent of these symptoms was inconsistent with the literature and would generally be associated with COHb levels between 20-40 per cent. However, research has shown that adverse effects on cognitive functions can occur as low as 3 per cent and different individuals' reactions to a given COHb level can vary.

While it was noted that a level of dehydration and possible motion sickness may have exacerbated the crew's symptoms, this would not account for the elevated COHb levels.

Source of carbon monoxide

The ATSB considered the likely sources of CO, including cigarette smoke, bushfire smoke, and the aircraft. None of the crew were smokers and the reported visibility throughout the day indicated a relatively modest amount of smoke pollution. Further, as high concentrations of CO in bushfire smoke are generally associated with low visibility of only a few metres, it was unlikely that the smoke haze observed by the crew was sufficient to result in adverse health effects. This was consistent with the low CO levels recorded in Adelaide.

Therefore, the most likely source of CO was from the aircraft. There were no indications of a potential exhaust leak prior to the flight and the post-flight testing found no fault with the aircraft. Although it was possible that, by disassembling the aircraft prior to testing, an existing problem was masked. However, despite the unresolved inconsistency with measured CO levels and in the absence of other sources, it was likely that the crew were exposed to elevated levels of CO in the aircraft cabin. Therefore, it was likely that the crew's symptoms were associated with CO poisoning.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the partial incapacitation of the crew involving a Cessna 172R, registered VH-YXZ that occurred 44 km south of Adelaide Airport, South Australia on 22 December 2019.

Contributing factors

- It was likely that the flight crew were exposed to elevated levels of carbon monoxide in the aircraft cabin, which likely contributed to them experiencing mild incapacitating symptoms and effects.

Other findings

- The source of the carbon monoxide could not be determined.

Safety actions

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. All of the directly involved parties are invited to provide submissions to this draft report. As part of that process, each organisation is asked to communicate what safety actions, if any, they have carried out to reduce the risk associated with this type of occurrences in the future. The ATSB has so far been advised of the following proactive safety action in response to this occurrence.

Carbon monoxide education

As a result of this incident, the operator has advised the ATSB that they will:

- Install additional CO detectors in all aircraft, in both the cockpit and in the back of the cabin.
- Brief all pilots on the effects of CO poisoning, using the audio of the incident pilot's radio calls to help demonstrate these effects.
- Instruct pilots to monitor both the instrument panel-mounted CO detector and the domestic electronic detector, with the instruction to land as soon as possible should the presence of CO be detected,
- Adjust the rosters to ensure that shark patrol flights were split into two shifts and separated by a few hours to assist in the dissipation of any CO that may have started to accumulate in the flight crew's bodies.

Sources and submissions

Sources of information

The sources of information during the investigation included:

- the crew
- Hartwig Air
- Gulfstream Aviation (aircraft maintainer)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)

- South Australian Country Fire Service.

References

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Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the following directly involved parties:

- the crew
- Hartwig Air
- Gulfstream Aviation.

Submissions were received from:

- the crew.

The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

General details

Occurrence details

Date and time:	22 December 2019 – 1545 CDT	
Occurrence category:	Serious incident	
Primary occurrence type:	Flight crew incapacitation	
Location:	44 km S of Adelaide, South Australia (Sellicks Beach)	
	Latitude: 35º 19.80' S	Longitude: 138º 26.88' E

Aircraft details

Manufacturer and model:	Cessna 172R	
Registration:	VH-YXZ	
Operator:	Hartwig Air	
Serial number:	17280885	
Type of operation:	Aerial work	
Activity:	Other	
Departure:	Parafield, South Australia	
Destination:	Parafield, South Australia	
Persons on board:	Crew – 3	Passengers – N/A
Injuries:	Crew – Nil	Passengers – N/A
Aircraft damage:	None	

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- independent investigation of transport accidents and other safety occurrences
- safety data recording, analysis and research
- fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, international agreements.

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.