Australian Government
Australian Transport Safety Bureau

Partial pilot incapacitation involving Piper PA-28, VH-TBB

19 km south-east of Moree, New South Wales, on 23 September 2020

ATSB Transport Safety Report
Aviation Occurrence Investigation (Short)
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Addendum

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Safety summary

What happened

On 23 September 2020, the pilot of a Piper PA-28 aircraft, registered VH-TBB, was conducting a ferry flight from Moree to Scone, New South Wales. Shortly after take-off, the pilot began to feel unwell with a warm feeling in their chest, dizziness, breathlessness, some confusion and disorientation. The pilot then observed a localised discolouration on the disposable carbon monoxide (CO) chemical spot detector. As the pilot looked closer at the detector, they noticed the spot rapidly getting darker. The pilot immediately returned to the airport, reduced engine power and opened all the fresh air vents and the side window. The aircraft landed safely at Moree and the pilot was subsequently taken to hospital for medical examination.

What the ATSB found

The ATSB found that the positive indications on two separate disposable CO chemical spot detectors, both during the flight and prior to the post-incident inspection, indicated that the pilot was likely exposed to elevated levels of CO in the aircraft cabin. Despite the pilot's carboxyhaemoglobin level being mildly elevated, it was likely that their physical symptoms and cognitive effects were associated with CO poisoning.

Safety message

Carbon monoxide is a colourless and odourless gas, and its presence may not be detected until the development of physical symptoms and cognitive effects. 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

Detection and Prevention of Carbon Monoxide Exposure in General Aviation Aircraft

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 23 September 2020, the pilot of a Piper PA-28 aircraft, registered VH-TBB, was conducting a ferry flight from Moree to Scone, New South Wales. At about 1418 Eastern Standard Time,[1] the pilot started the engine, carried out engine run-ups[2] and then taxied the aircraft to the runway for departure. The pilot reported the engine was running for about 10 minutes while on the ground in Moree, with the side window, fresh air vents open and the heater off. Prior to take-off, the pilot closed the window and vents.

Shortly after take-off, the pilot began to feel unwell, with a warm feeling in their chest, dizziness, breathlessness, some confusion and disorientation. The pilot then conducted a visual scan of the flight instruments and observed a localised discolouration on the disposable carbon monoxide (CO) chemical spot detector. As the pilot looked closer at the detector, they noticed the spot rapidly getting darker. The pilot immediately turned the aircraft back toward the airport, reduced engine power, and opened all the fresh air vents and the side window.

The aircraft was landed safely at Moree and the engine shut down at 1435. The pilot was subsequently taken to hospital for a medical examination. While receiving supplemental oxygen, the pilot was starting to feel better after about 2 hours.

Context

Medical information

General health and fitness

The pilot was well rested and felt fit to fly on the day of the incident. They had completed two flights in a different aircraft prior to the incident, one of which was from Tamworth to Moree. The pilot felt normal throughout those flights and only became unwell during the incident flight.

The pilot was a non-smoker, was not taking any medication, and had no pre-existing medical condition that could have contributed to the incident.

Carboxyhaemoglobin

A blood sample taken from the pilot about 1.5 hours after engine shut down, indicated a carboxyhaemoglobin (COHb) level of 1 per cent. The pilot was administered oxygen at the hospital, starting about 15 minutes before the blood sample was taken. In total they were on supplemental oxygen for about 5 hours, until their oxygen saturation levels were at 100 per cent.

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.

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[1] Eastern Standard Time (EST): Coordinated Universal Time (UTC) + 10 hours.

[2] Run-up: a high-power run-up check is carried out in a piston-engine aircraft to check the aircraft's ignition and other systems before commencing an initial take-off.

As previously discussed in ATSB investigations AO-2020-026 and AO-2017-118, normal endogenous levels of COHb are generally within the range of 0.4-0.7 per cent. However, smokers, and those living in an urban area, may have higher than average levels of 1-6 per cent (Baselt, 2014).

After the source of CO has been removed, COHb will reduce to half its initial value within 4-5 hours at sea level. This can decrease to 80 minutes with the administration of pure oxygen. Taking into account the CO half-life, the elapsed time since the symptoms and effects were first detected, and the pilot's brief time on oxygen prior to the blood test, the ATSB estimated that the pilot's COHb levels were likely between 1.5 to 2 per cent.

Although individuals' reactions can vary, the physical symptoms and cognitive effects of CO poisoning tend to worsen with an increasing level of COHb (Lacefield et al., 1982). Typically, COHb levels of 10-20 per cent can result in symptoms of breathlessness, while levels of 30-40 per cent can result in mental changes, dizziness and confusion (Knobeloch & Jackson, 1999; Lacefield et al., 1982). While 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). Hawkins (1993) also noted that the effects of CO can begin to show with the deterioration of psychomotor function at COHb levels of about 3 per cent.

Aircraft maintenance

Post-incident aircraft inspection

After the incident, and prior to any maintenance activity, engineers conducted ground runs and confirmed that CO was leaking into the cabin with a positive indication on a new, disposable CO chemical spot detector. The engineers then inspected the aircraft, focusing on the engine exhaust system and airframe. The inspection revealed 4-5 pinholes in the exhaust stack that were not covered properly and unserviceable scat (air duct) hoses. No breaches were found in the firewall or the aircraft belly, and the cabin heat valve was functioning correctly. The pinholes were repaired and the scat hoses were replaced. Ground runs were conducted after the repairs and the chemical spot detector showed no indication of CO in the cabin.

Most recent periodic inspection

The last periodic maintenance inspection was completed on 22 May 2020, about 4 months prior to the incident, where the exhaust system was visually inspected using a torch and mirror. The inspection of the exhaust system included the removal of the muffler shroud, security of the baffle cones and the cabin heat flexible hoses. The engineer reported that, exhaust stains on the engine and/or cowling can indicate the existence of an exhaust leak, which was something they looked for during inspections. However, in this case, there were no exhaust system defects recorded in the maintenance documentation.

The owner, who operated the aircraft a few days prior to the incident, reported never having observed a positive indication on the CO detector, nor had they felt unwell during or after a flight. However, they would sometimes smell exhaust fumes when they turned the heater on. The owner advised that they typically never left it on for very long, as CO was always in the back of their mind.

A study conducted by the United States Federal Aviation Administration (2009) noted that a small crack or imperfection can be difficult to see during a visual inspection, which is further impeded by densely packed engine compartments. Further, defects can form after the inspection from erosion and internal fatigue.

Carbon monoxide detector

The aircraft was fitted with an Aviation Supplies and Academics disposable CO chemical spot detector, attached to the instrument panel (Figure 1). The detector was only 4 months old, which was within the manufacturer's 12-month replacement period. It 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 parts per million (ppm) of CO within 30 minutes, 100 ppm within 10 minutes and 200 ppm within 4 minutes.

The ATSB's investigation and corresponding safety advisory notice for AO-2017-118, highlighted the limitations of these types of detectors. Although commonly used in general aviation, they are a passive device that rely on the pilot regularly monitoring the changing colour of the detector throughout the flight. Further, identifying a positive indication is also dependent on the detector being easily visible and accessible, in a well-lit position particularly when operating in a low ambient light environment.

Figure 1: Slightly discoloured carbon monoxide detector, after engine shutdown and the detector being exposed to fresh air

Source: Pilot

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, were fatally injured when the aircraft collided with water in Jerusalem Bay, New South Wales. The occupant's toxicology results identified that they 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-2020-026)

On 22 December 2019, the crew of a Cessna 172R aircraft, registered VH-YXZ, were conducting aerial shark patrols. About 2 hours into the second flight of the day, the crew started to experience symptoms typically associated with CO poisoning, and subsequently observed a localised discolouration on the disposable CO chemical spot detector. Soon after, the aircraft was landed safely and the three crew were taken to hospital for assessment. While blood tests confirmed all crew had mildly elevated COHb levels, their 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 COHb levels and severity of experienced effects could not be resolved.

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, but the pilot survived. 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. A post-accident inspection of the aircraft identified several cracks in the exhaust muffler. In response to the experience, the pilot stated that:

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

Safety analysis

Elevated levels of carbon monoxide

The post-incident aircraft ground runs produced elevated levels of carbon monoxide (CO) in the aircraft cabin, which was resolved once repairs to the exhaust stack and the scat hoses were complete. This indicated that the source of the CO was associated with the items repaired. No obvious breaches were identified that would have allowed CO to enter the cabin and therefore, it was not immediately clear how the exhaust gasses entered the cockpit on this occasion.

However, the observed physical symptoms and cognitive effects reported by the pilot were more likely associated with CO poisoning. This was further supported by the positive indications on the CO chemical spot detector and the blood test indicating a mildly elevated level of carboxyhaemoglobin (COHb). While the extent of the pilot's symptoms for the recorded COHb level were inconsistent with the literature, research has shown that adverse effects on cognitive functions can occur at levels as low as 3 per cent and that individuals can react differently to COHb.

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 pilot incapacitation involving a Piper PA-28, registered VH-TBB that occurred 19 km south-east of Moree Airport, New South Wales, on 23 September 2020.

Contributing factors

- An exhaust leak likely exposed the pilot to elevated levels of carbon monoxide in the aircraft cabin, resulting in mild incapacitation.

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- pilot
- aircraft owner
- repairer for VH-TBB
- maintenance organisation for VH-TBB.

References

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Knobeloch, L & Jackson, R. (1999). Recognition of Chronic Carbon Monoxide Poisoning. *Wisconsin Medical Journal, 98(6):26-9*. Retrieved from https://www.researchgate.net/publication/12696822_Recognition_of_chronic_carbon_monoxide_poisoning

Lacefield, D. J., Roberts, P. A., & Grape, P. M. (1982). *Carbon monoxide in-flight incapacitation: An occasional toxic problem in aviation* (FAA-AM-82-15). Oklahoma City, Oklahoma: Federal Aviation Administration.

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:

- pilot
- aircraft owner
- repairer for VH-TBB
- maintenance organisation for VH-TBB.

A submission was received from the pilot. The submission was reviewed and, where considered appropriate, the text of the report was amended accordingly.

General details

Occurrence details

Date and time:	23 September 2020 – 1418 EST	
Occurrence category:	Serious incident	
Primary occurrence type:	Flight crew incapacitation	
Location:	19 km south-east of Moree, New South Wales	
	Latitude: 29° 37.020' S	Longitude: 149° 58.800' E

Aircraft details

Manufacturer and model:	Piper Aircraft Corp PA-28	
Registration:	VH-TBB	
Serial number:	28R-7737153	
Type of operation:	Private – Test and ferry	
Activity:	General aviation - Other general aviation flying - Ferry flights	
Departure:	Moree, New South Wales	
Destination:	Scone, New South Wales	
Persons on board:	Crew – 1	Passengers – 0
Injuries:	Crew – 0	Passengers – 0
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.