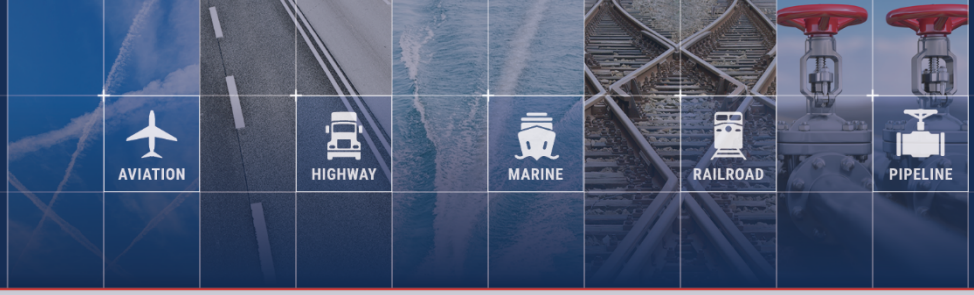

Aviation Investigation Final Report

Location:	Guthrie Center, Iowa	**Accident Number:**	WPR19FA022
Date & Time:	November 9, 2018, 17:15 Local	**Registration:**	N91770
Aircraft:	Piper PA28	**Aircraft Damage:**	Substantial
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	4 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

About 45 minutes into the cross-country flight, the student pilot passenger reported to air traffic control that the pilot was having a heart attack and that he was going to take control of the airplane and divert to an airport about 20 miles away; however, another airport was much closer, and controllers received no further communications from the pilot. The student then reported over the nearby airport's common traffic advisory frequency that he would attempt to divert there. GPS flight track data indicated that, a short time later, the airplane began to fly in an erratic manner, climbing and descending over the area of the diversion airport. The airplane subsequently collided with terrain in a wings-level attitude.

All four occupants sustained fatal injuries, and toxicology testing indicated that all had high levels of carboxyhemoglobin, which is caused by the inhalation of carbon monoxide (CO), an odorless, tasteless, colorless, nonirritating gas formed by hydrocarbon combustion. Levels in both pilots and one passenger where high enough to have caused confusion, seizures, or loss of consciousness. There was no evidence the pilot had a heart attack, so his symptoms were likely due to the CO poisoning.

The engine was equipped with three identical exhaust mufflers. Examination of the aft muffler revealed a crack that allowed engine exhaust gases to enter the cabin through the cabin heating system.

The muffler's crack developed as a result of corrosion and thinning of the muffler wall. The crack and small perforations in the muffler wall were likely present at the time of the last inspection, which occurred shortly before the accident; however, due to damage from impact, it could not be determined if the extent of cracking was readily visible at the time of inspection. Also, the crack could have opened just before the accident flight due to an engine backfire that occurred during startup.

Use of a pressure check during an inspection could help identify cracks and small perforations that can be obscured by oxides and deposits during a visual inspection; however, the manufacturer's service manual only recommended a pressure check when a visual inspection could not be accomplished.

The manufacturer and Federal Aviation Administration (FAA) both recommended that the mufflers be replaced at or near 1,000 hours time in service (TIS). Although maintenance records revealed that three mufflers were replaced over the previous 27 years, the records did not indicate if the cracked muffler was one of those that had been replaced. Review of the available records indicated that the cracked muffler likely had at least 752 hours TIS, but due to missing records, it could have had over 1,033 hours TIS. Additionally, one of the mufflers was replaced at 549 hours TIS, well before the manufacturer's recommended interval, and likely an indication of premature failure.

The hazard of CO poisoning via leaks in reciprocating engine exhaust systems that are used to provide cabin heat has long been known to the industry. In 2004, the NTSB issued a safety recommendation to the FAA to require the installation of CO detectors in all single-engine airplanes such as the accident type.

In response, the FAA undertook extensive research on the detection and prevention of CO exposure in general aviation aircraft, created a technical standard order specifying minimum performance standards for CO detectors, and recommended, but did not require, that all operators install CO detectors.

The FAA concluded that the primary method to prevent CO contamination in the cabin is through proper inspection and maintenance of mufflers and exhaust system components and that CO detectors are a secondary method of preventing CO exposure. The FAA further stated that since a lack of a CO detector alone is not unsafe, installing a CO detector would not correct an unsafe condition.

Because the FAA did not require installation of CO detectors, the safety recommendation was classified "Closed – Unacceptable Action."

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

Pilot incapacitation due to carbon monoxide poisoning as a result of an undetected crack in an engine exhaust muffler, which permitted entry of exhaust gasses into the cabin via the cabin heat system.

Findings

Personnel issues	Carbon monoxide - Pilot
Personnel issues	Carbon monoxide - Student/instructed pilot
Aircraft	(general) - Fatigue/wear/corrosion
Aircraft	Directional control - Attain/maintain not possible
Aircraft	(general) - Not installed/available

Factual Information

History of Flight

Enroute-cruise	Powerplant sys/comp malf/fail (Defining event)
Enroute-cruise	Loss of control in flight
Uncontrolled descent	Collision with terr/obj (non-CFIT)

On November 9, 2018, about 1715 central standard time, a Piper PA28-236, N91770, was substantially damaged when it was involved in an accident near Guthrie Center, Iowa. The private pilot and three passengers were fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* (*CFR*) Part 91 personal flight.

The pilot was flying the three passengers, one of whom was a student pilot and co-owner of the airplane, from Le Mars Municipal Airport (LRJ), Le Mars, Iowa, to Osceola Municipal Airport (I75), Osceola, Iowa, for a hunting trip.

Two witnesses reported observing the initial engine start. Both stated that the pilot made multiple attempts to start the engine, which resulted in loud popping and "backfire" sounds, but the engine would either not start or would not maintain idle power and would sputter to a stop. The restart attempts continued for about 1 minute, and on the final attempt, the engine started and rapidly accelerated to a speed so high that one witness was concerned that it could damage the cold engine. Both stated that the pilot then taxied the airplane to the fuel island at what they considered to be a high engine idle speed. After fueling, the passengers boarded. One witness stated that the takeoff and departure were uneventful, but he did notice before the airplane began its taxi that the insides of the windows were covered in mist.

According to air traffic control radar and voice communication information provided by the Federal Aviation Administration (FAA), about 1700 a controller observed a radar target squawking the 7700 emergency transponder beacon code, about 40 miles west of Des Moines International Airport (DSM), close to the town of Guthrie Center. Controllers established contact with the pilot of an airplane using a call sign of "Dakota 770" on the Guthrie County Regional Airport (GCT) common traffic advisory frequency. The pilot reported that he was a student, and that he was diverting to Perry Municipal Airport (PRO; about 20 miles east of the airplane's location) because the pilot who was flying the airplane was having a heart attack. No other communication from that airplane was received directly by the controllers; however, the pilots of two other aircraft on the frequency advised the controllers that they were able to communicate with the pilot, who reported that he was instead going to attempt to land at GCT.

By 1730, the airplane had not landed at either GCT or PRO, and an FAA Alert Notice (ALNOT) was issued.

The wreckage was located the following morning in an area of rolling hills and pastures at an elevation

of 1,200 ft mean sea level (msl) 6 miles southwest of GCT.

Review of flight track data recorded by an onboard GPS receiver indicated that after departing LRJ, the airplane followed an almost direct southeast track for about 40 minutes at an altitude of about 4,000 ft msl, before reaching the Guthrie Center area. At 1701, the airplane made a 90° left turn towards the general direction of GCT, followed by a counter-clockwise (left-turning) 3-mile-wide orbit around GCT at an altitude of about 3,500 ft msl (1,300 ft agl). The airplane then proceeded to fly southwest towards the town of Guthrie Center, and after passing east of the town, it initiated a descending right turn, reaching an altitude of 1,513 ft (400 ft agl), about 2 miles to the south of town. It then proceeded to fly north and make a right turning orbit around the town climbing, descending, and then climbing again until it reached 2,800 ft at 1713. The airplane then turned to a southwest track and descended to the last recorded location. That location was at an altitude of 2,560 ft, about 2 1/2 miles northeast of the accident site (Figure 1). Ground speeds during the maneuvers over Guthrie Center ranged between 83 and 174 knots.

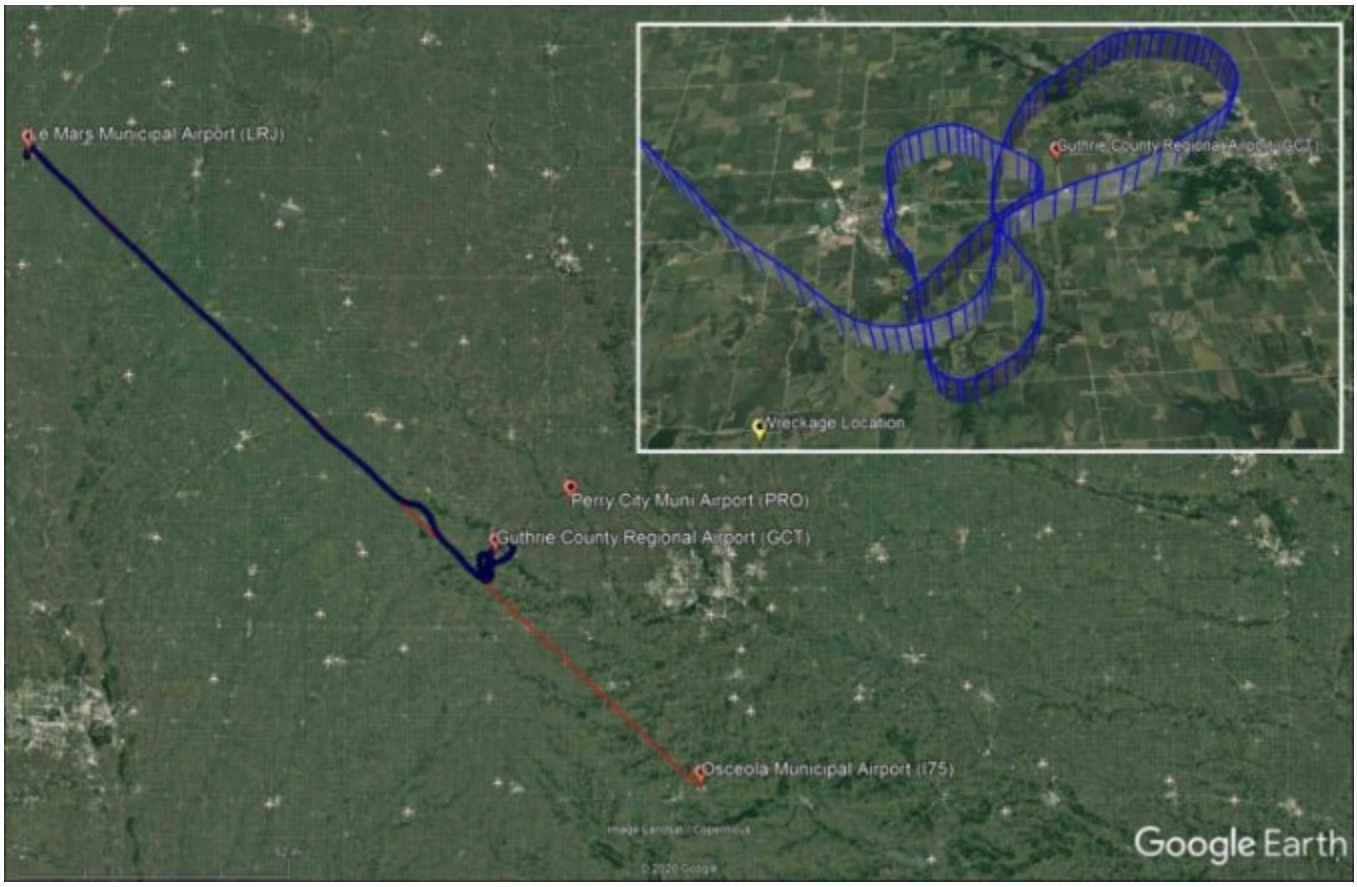

Figure 1 – GPS ground track and final stages of flight (inset). Projected flight track in red (North up).

Pilot Information

Certificate:	Private	**Age:**	49,Male
Airplane Rating(s):	Single-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 3 None	**Last FAA Medical Exam:**	February 8, 2016
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	August 10, 2018
Flight Time:	(Estimated) 1130 hours (Total, all aircraft), 500 hours (Total, this make and model), 60 hours (Last 90 days, all aircraft), 30 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Student pilot Information

Certificate:	Student	**Age:**	36,Male
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	None	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 3 With waivers/limitations	**Last FAA Medical Exam:**	May 29, 2018
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	
Flight Time:	(Estimated) 100 hours (Total, all aircraft), 100 hours (Total, this make and model), 1 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Piper	**Registration:**	N91770
Model/Series:	PA28 236	**Aircraft Category:**	Airplane
Year of Manufacture:	1979	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	287911174
Landing Gear Type:	Tricycle	**Seats:**	4
Date/Type of Last Inspection:	November 3, 2008 Annual	**Certified Max Gross Wt.:**	3000 lbs
Time Since Last Inspection:	1 Hrs	**Engines:**	1 Reciprocating
Airframe Total Time:	2955 Hrs at time of accident	**Engine Manufacturer:**	Lycoming
ELT:	C91A installed, not activated	**Engine Model/Series:**	O-540-J3A5D
Registered Owner:		**Rated Power:**	
Operator:	On file	**Operating Certificate(s) Held:**	None

The student pilot had purchased the airplane in June 2018. According to the other co-owner, the airplane had accumulated about 100 hours total flight time during the period between purchase and the accident, and the student had flown the airplane solo on multiple occasions.

Maintenance and Muffler History

According to the airplane's maintenance records, a new logbook was created on August 27, 1991, because the previous logbooks were lost. At the time the logbook was created, the airframe had accrued a reported 1,922.58 hours time in service (TIS).

A logbook entry indicated that two of the three mufflers were replaced on August 12, 2002, at 2,203.64 hours airframe TIS (752 flight hours before the accident), but the positions of those two replaced mufflers were not specified. Subsequent entries noted that the forward muffler was replaced on January 23, 2008, at 2,689 airframe hours TIS, and the middle muffler was replaced on March 1, 2012, at 2,752 airframe hours TIS. Therefore, at least one of the mufflers installed in 2002 was replaced at less than 549 hours TIS.

None of the maintenance log entries in the 1,033 hours since 1991 specifically mentioned replacement of the aft muffler. The forward muffler was the only one that displayed a part and serial number. Each of the mufflers were constructed slightly differently, suggesting that they were likely from different manufacturers.

The airplane's most recent annual inspection was completed on November 3, 2018, at an airframe time of 2,955 hours. The mechanic who performed the most recent annual inspection stated that he spent about 22 hours inspecting and servicing the airplane. He provided a copy of the Piper maintenance manual that he used to perform the inspection, which included a section devoted to exhaust system examination. He specifically recalled disassembling the heat exchanger assembly and exhaust mufflers and stated that the accident pilot helped him remove the heat exchanger shroud. He stated that he checked the mufflers and shroud for cracks, deformation, and discoloration, and found none.

Based on statements provided by the airport manager and the mechanic, the accident flight was likely the first since the inspection.

The airplane was not equipped with any type of CO detector, nor was it required to be. The last time the cabin heat was likely used was on October 12, 2018. The pilot who flew it that day reported that he did not notice the smell of exhaust fumes during the flight or experience any symptoms of what he considered to be CO poisoning, such as headaches or dizziness.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Dusk
Observation Facility, Elevation:	KADU,1287 ft msl	**Distance from Accident Site:**	18 Nautical Miles
Observation Time:	23:15 Local	**Direction from Accident Site:**	285°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	Broken / 4400 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	9 knots / 18 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	310°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.4 inches Hg	**Temperature/Dew Point:**	-7°C / -12°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Le Mars, IA (LRJ)	**Type of Flight Plan Filed:**	None
Destination:	Osceola, IA (I75)	**Type of Clearance:**	None
Departure Time:	16:18 Local	**Type of Airspace:**	

According to the National Oceanic and Atmospheric Administration, sunset in Guthrie Center occurred at 1703.

Temperatures for area airports around the time of the accident were about –7°C, with clear skies, broken cloud conditions, and visibilities of 10 miles or greater.

Airport Information

Airport:	Guthrie County Rgnl GCT	**Runway Surface Type:**	
Airport Elevation:	1220 ft msl	**Runway Surface Condition:**	Dry
Runway Used:		**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:	2 Fatal	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	4 Fatal	**Latitude, Longitude:**	41.620277,-94.521942

The main wreckage, which included the cabin, both wings and the empennage, came to rest facing uphill on a heading of about 270° magnetic. The first identified point of impact was located about 25 ft southeast of the main wreckage and comprised three 18-inch-long by 8-inch-wide divots, the relative positions of which matched the main landing and nose gear. A crater several feet away displayed two matching linear impact marks extending from either side, the total length of which corresponded to the airplane's wingspan.

The fuselage sustained crush damage from the nose aft to the leading edge of the vertical stabilizer. The cabin flight controls, instrument panel, and avionics were heavily fragmented and compressed. The firewall had folded underneath the instrument panel, which was obscuring the engine. The right side of the cabin walls, along with the cabin roof, had peeled back, exposing the aft seats and baggage area.

The emergency locator transmitter (ELT) was found still mounted to the airframe behind the baggage compartment. The antenna cable remained attached and the ELT power switch was found in the "OFF" position. The rear baggage access panel for the ELT was intact and there was no indication that the ELT had been accessed by first response personnel, nor were there any reports that the ELT had activated.

Cabin Heat System

Cabin heat was extracted from the engine exhaust system via a heat exchanger shroud mounted around the engine's three exhaust mufflers. Hot air from inside this shroud was routed to the cabin via supply tubes and a heat distributor assembly. The three mufflers were all the same design, with a common part number.

The shroud, mufflers, and their respective risers were bent and crushed during impact. Examination of the aft exhaust muffler revealed a crack in the outer skin. The forward and middle mufflers were crushed, but neither exhibited any evidence of cracks. The inner surface of the heat exchanger shroud was coated in tan- and grey-colored particulate deposits. Similar deposits were also present on the inner surface of the cabin heat tube that ducted air from the shroud to the cabin heat distributor box.

The three exhaust mufflers and their respective risers, along with the heat exchanger shroud, heat exchanger intake tube, and cabin heat supply tube were further examined at the NTSB Materials Laboratory.

Aft Muffler

At the upper forward side of the aft muffler, shown in Figure 2, a longitudinal crack extended 2.75 inches at the location of a longitudinal seam weld. The crack was gapped open, and portions of wall material were missing at the crack opening.

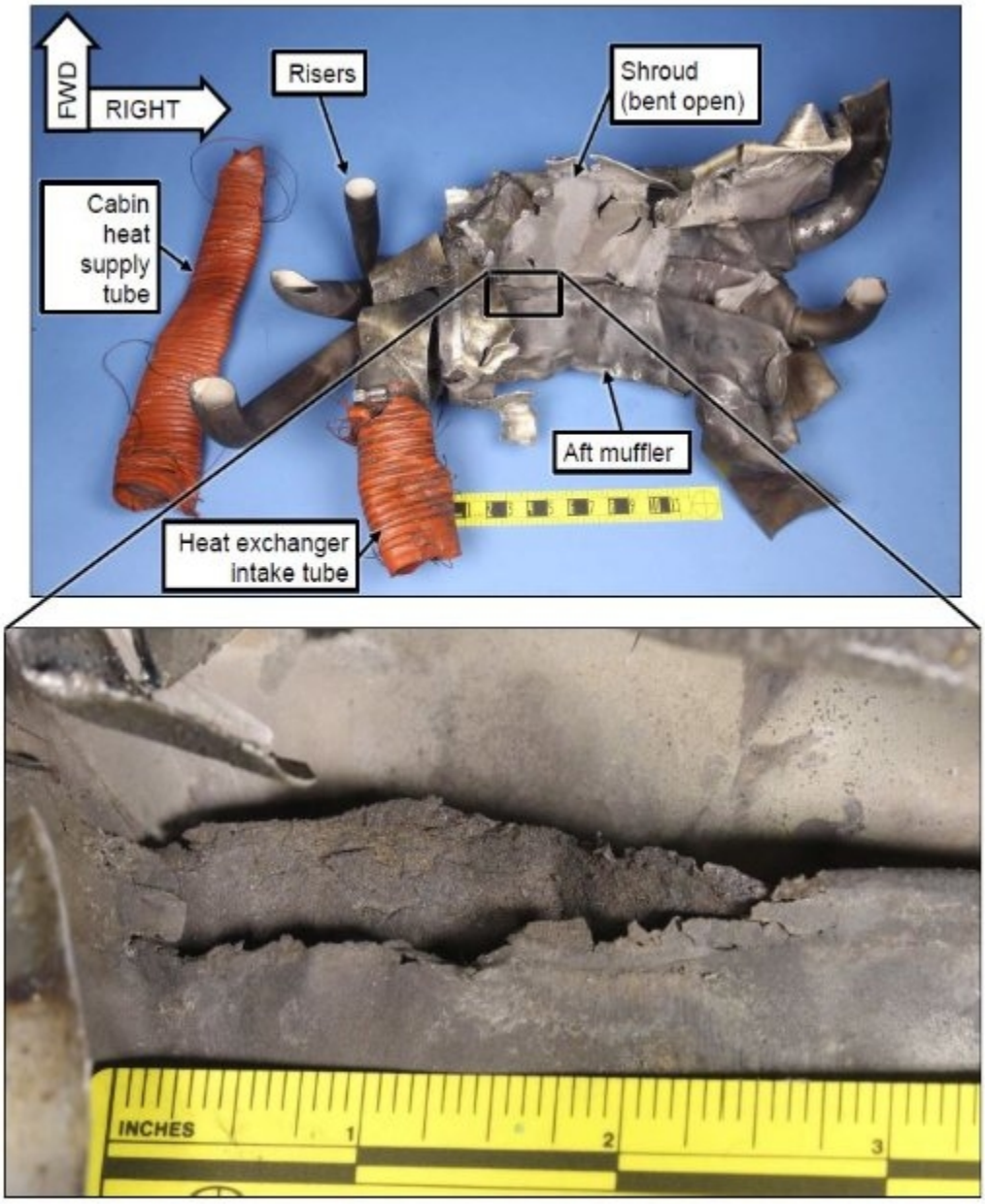

Figure 2 - Overall view of the muffler assembly with a closer view of an open crack at the upper forward side of the aft muffler (lower image)

A circumferential crack extended about 3/4 of the circumference of the muffler adjacent to the left end face, and the lower side exhibited perforations and another longitudinal crack; the muffler wall was crushed and folded at the location of that crack.

The longitudinal crack fracture surface at the upper forward side exhibited oxidation with dark-colored deposits on the surface, consistent with a preexisting crack.

The muffler wall fracture features associated with the circumferential crack had dark oxidation and deposits across much of the thickness, but a thin portion of the fracture at the exterior surface was in a slightly different fracture plane and had a light gray appearance consistent with final fracture at impact.

The cracks and perforations in the wall at the lower side were generally associated with wrinkles, folds, and deformation on the muffler wall. Sliding contact marks on the lower surface were also observed associated with the longitudinal crack opening on the lower side. Oxidized fracture surfaces were observed adjacent to the interior surfaces of the perforations and cracks, and light gray fracture features were generally observed adjacent to the exterior surface.

The thickness of the muffler wall adjacent to the longitudinal crack at the upper forward side was 0.018 inch, with the loosely adhering oxides and deposits removed. For comparison, the wall thickness near the middle of the muffler adjacent to the crack was 0.109 inch thick.

Shroud and Tubes

Tan deposits were observed covering the interior surface of the heat exchanger shroud and on the interior surface of the cabin heat supply tube. Analysis revealed that the tan deposits had high levels of lead and bromine, consistent with engine exhaust deposits.

Additional Information

Airplane Manufacturer's CO and Exhaust System Information

Piper service letter (SL) 324C, issued in 1969, included the PA-28 series and provided instructions for ongoing maintenance of exhaust systems and heat exchangers, and stated, "Adequate inspection and maintenance in many instances is not being accomplished on the exhaust and heat exchanger systems." The SL recommended more critical inspections as the aircraft ages, with a recommendation that consideration should be given to replacing components after 1,000 hours of use.

The manufacturer's maintenance manual made similar recommendations to SL 324C, including the requirement that the entire exhaust system be inspected at each annual inspection, and that mufflers be replaced at or near 1,000 hours TIS. It further recommended that if a complete visual inspection cannot be accomplished, either a pressure check be performed on the exhaust system, or the cabin environment should be tested for the presence of CO while the engine is operating on the ground.

FAA CO and Exhaust System Guidance

On November 24, 1972, the FAA issued advisory circular (AC) 20-32B "Carbon Monoxide (CO) Contamination in Aircraft—Detection and Prevention." The AC provided information on the potential

dangers of carbon monoxide contamination from faulty engine exhaust systems or cabin heat exchangers. It also discussed means of detection and procedures to follow when contamination is suspected.

In October 2009, the FAA issued report DOT/FAA/AR-09/49, "Detection and Prevention of Carbon Monoxide Exposure in General Aviation Aircraft." The report documented research on detection and prevention of CO exposure in general aviation aircraft, with the objective of identifying exhaust system design issues related to CO exposure, evaluating inspection methods and maintenance practices with respect to CO generation, and the identification of protocols to quickly alert users to the presence of excessive CO in the cockpit and cabin.

On March 17, 2010, the FAA published Special Airworthiness Information Bulletin (SAIB) CE-10-19 R1. It recommended that owners and operators of general aviation aircraft consider the information in the DOT/FAA/AR-09/49 report and use CO detectors while operating their aircraft. The SAIB also recommended a cabin CO level check during every 100-hour or annual inspection, along with continued inspection of the complete engine exhaust system during 100-hr or annual inspections and at inspection intervals recommended by the aircraft and engine manufacturers in accordance with the applicable maintenance manual instructions.

On August 16, 2010, the FAA also published Special Airworthiness Information Bulletin SAIB CE-10-33R1, which reiterated the recommendation to use CO detectors as documented by SAIB CE-10-19R1. It recommended the replacement of mufflers on reciprocating engine-powered airplanes that use an exhaust system heat exchanger for cabin heat with more than 1,000 hours TIS and at intervals of 1,000 hours TIS. It further recommended following guidance for exhaust system inspections and maintenance provided in SAIB CE-04-22, dated December 17, 2003, and Advisory Circular (AC) 43-16A, Aviation Maintenance Alert, issued October 2006. The FAA also recommended continuing to inspect the complete exhaust system during annual inspections and at intervals recommended by the aircraft and engine manufacturers.

SAIBs are for information only, their recommendations are not mandatory. Likewise, compliance with manufacturer-issued SLs is not mandatory.

NTSB CO and Exhaust System Guidance

On June 24, 2004, the NTSB issued Safety Recommendation A-04-028 to the FAA to require installation of CO detectors in all single-engine airplanes with forward-mounted reciprocating engines and enclosed cockpits that are already equipped with systems needed to operate the CO detector. In response, the FAA undertook the creation of the DOT/FAAIAR-09/49 report and recommended the use of CO detectors in SAIB CE-10-33R1. However, in 2011, the FAA concluded that the primary method to prevent CO contamination in the cabin is through proper inspection and maintenance of mufflers and exhaust system components, and CO detectors are a secondary method to prevent CO exposure. The FAA referenced the subsequent publication of SAIB CE-10-19 R1, and further stated that, since a lack of a CO detector alone is not unsafe, installing a CO detector does not correct an unsafe condition as defined by 14 *CFR* Part 39.

Because the FAA did not require installation of CO detectors, Safety Recommendation A-04-028 was classified by the NTSB as "Closed – Unacceptable Action".

Medical and Pathological Information

According to the autopsy performed by the Iowa Department of Public Health, Iowa Office of the State Medical Examiner, the cause of death for the pilot and student pilot was multiple blunt force injuries. Internal examination was unremarkable, but the carboxyhemoglobin levels were found to be 59.2% for the pilot and 45.3% for the student pilot/passenger.

Toxicology testing performed by the FAA's Forensic Sciences Laboratory identified carboxyhemoglobin at 58% for the pilot and 48% for the student pilot/passenger. Testing did not identify the presence of any screened drug substances in either occupant. Blood from the two rear-seat passengers demonstrated carboxyhemoglobin levels of 41% and 20%.

Carbon monoxide (CO) is an odorless, tasteless, colorless, nonirritating gas formed by hydrocarbon combustion. In the body, CO binds to hemoglobin with much greater affinity than oxygen, forming carboxyhemoglobin; elevated levels result in impaired oxygen transport and utilization. Nonsmokers may normally have up to 3% carboxyhemoglobin in their blood; heavy smokers may have levels of 10 to 15%. Low levels of CO may cause vague symptoms like headache and nausea but increased levels (40% and above) lead to confusion, seizures, loss of consciousness, and death.

Administrative Information

Investigator In Charge (IIC):	Simpson, Eliott		
Additional Participating Persons:	James Konig; Federal Aviation Administration FSDO; Des Moines, IA Kathryn Whitaker; Piper Aircraft Company; Phoenix, AZ Mike Childers; Lycoming Engines; Williamsport, PA		
Original Publish Date:	December 3, 2020	**Investigation Class:**	2
Note:	The NTSB traveled to the scene of this accident.		
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=98621		

The National Transportation Safety Board (NTSB), established in 1967, is an independent federal agency mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The Independent Safety Board Act, as codified at 49 U.S.C. Section 1154(b), precludes the admission into evidence or use of any part of an NTSB report related to an incident or accident in a civil action for damages resulting from a matter mentioned in the report. A factual report that may be admissible under 49 U.S.C. § 1154(b) is available here.