National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: June 23, 2004

In reply refer to: A-04-25 through -28

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On December 17, 2000, about 1821 central standard time, a Beech BE-23, N2324J, impacted hilly, wooded terrain en route from Spirit of St. Louis Airport (SUS), Chesterfield, Missouri, to Tulsa, Oklahoma.[1] The commercial-rated pilot, the sole occupant of the airplane, was killed, and the airplane was destroyed. Radar data indicate that about 1 hour after its departure from SUS, the airplane's heading and altitude became erratic. Between 1809 and 1821, the airplane descended from 8,500 feet mean sea level (msl) to 2,500 feet msl, and its flightpath was a series of irregular descending turns in an easterly direction. The last radar return was about 0.5 mile from the accident site. Visual meteorological conditions prevailed, and no flight plan was filed for the 14 *Code of Federal Regulations* (CFR) Part 91 flight.

The National Transportation Safety Board determined that the probable cause of this accident was, in part, "the pilot's incapacitation due to carbon monoxide [CO] and [a] fractured muffler." Postaccident examination of the airplane's muffler at the Safety Board's materials laboratory revealed oxidation that penetrated the wall of the muffler shroud and extended around at least 20 percent of the muffler's circumference. The metallurgical report stated that the oxidized areas of the fracture appeared black, which was consistent with a preexisting fracture that was exposed to the environment for an extended period of time.

At the time of the accident, the airplane had accumulated 2,082 hours since its manufacture in 1963 and approximately 6 hours since its last annual inspection in August 2000. A review of the airplane's maintenance records found that the muffler had been replaced on

[1] The description of this accident, CHI01FA052, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

November 26, 1973, (1,218 flight hours before the accident). These records also indicate that the muffler weld and assembly had been inspected "for leaks and deterioration" during an annual inspection on May 21, 1999, (23 flight hours before the accident) and that they were found to be "ok."

A similar accident occurred on January 17, 1997, when a Piper PA-28-236 crashed near Alton, New Hampshire, killing the pilot and pilot-rated passenger.[2] About 25 minutes after the airplane's departure from Farmingdale, New York, the passenger reported to air traffic control (ATC) that the pilot was unresponsive. ATC tracked the airplane and another aircraft tried to provide assistance, but, almost 2 hours after the passenger contacted ATC, the airplane crashed. The flight was being conducted under 14 CFR Part 91.

The Safety Board determined that the probable cause of this accident was "an exhaust gas leak due to inadequate maintenance, which resulted in carbon monoxide poisoning, and incapacitation of the pilot." Postaccident examination of the accident airplane revealed a large crack in the airplane's muffler that extended around about two-thirds of the muffler circumference. At the time of the accident the airplane had accumulated 1,626 hours since its manufacture in 1970 and 88 hours since its last annual inspection in January 1996. There was no entry in the airplane or engine logs that indicated whether the muffler had been replaced since the manufacture of the airplane.

The Piper PA-28-236 service manual recommends that all airplanes be fitted with a new muffler at or near 1,000 hours of muffler use and that the muffler, heat exchange shroud, and all exhaust connections be rigidly inspected at each annual or 100-hour inspection. The Piper service manual also suggests that the exhaust system be inspected more carefully as the number of hours increases and before winter operation, when cabin heat will be in use.[3] It also recommends that, if any component is inaccessible for a visual inspection, a submerged pressure check of the muffler and exhaust stack be performed at 2 pounds per square inch (psi) pressure or that a ground test be conducted using a CO indicator while the engine is running and the cabin heat valves are open. The manual further states that if CO concentrations exceed 0.005 percent, the muffler must be replaced.

Although the Piper manual recommends pressure testing and muffler replacement, the Safety Board notes that there is no requirement to pressure test single-engine airplane mufflers nor is a life limit imposed on these components. Further, there is no requirement for a detailed inspection of airplane mufflers. Title 14 CFR Part 43, Appendix D states, in part, that "each person performing an annual or 100-hour inspection shall inspect (where applicable) components of the engine and nacelle group as follows: exhaust stacks—for cracks, defects, and improper attachment."

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[2] The description of this accident, IAD97FA043, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[3] Most single-engine reciprocating-powered airplanes use a muffler/heat exchanger to heat the airplane cabin and systems.

A query of the Safety Board's accident database found 125 accidents or incidents from 1964 to the present that involved muffler failure in single-engine reciprocating-powered airplanes (models include Piper, Cessna, Beech, Aero Commander, Bellanca, Luscombe, Navion, and Aeronca), resulting in 42 fatalities and 27 serious injuries. Of the 54 exhaust system failures that occurred between 1983 and 2002, 25 occurred within 40 hours of the airplane's most recent annual inspection.[4] The Board also found that the mufflers involved in these accidents had accumulated an average of 2,200 hours and that 60 percent of the mufflers had accumulated between 1,000 to 2,000 hours when the accidents occurred.

The Safety Board notes that not all of the muffler-related accidents and incidents in the Safety Board's database were the result of pilot incapacitation due to CO exposure. Some of these accidents and incidents occurred when muffler failure resulted in damage to critical airplane systems; for example, on September 24, 1985, the pilot of a Bellanca 17-30A, N6627V, executed a forced landing on rough, uneven terrain after he smelled smoke and the engine lost power during initial climb near Burlington, Washington. The airplane struck a ditch and was substantially damaged.[5] Postaccident examination of the airplane's exhaust system revealed that the left exhaust muffler had eroded at the muffler outlet and hot exhaust fumes had damaged the voltage regulator, alternator, and magneto wires. The exhaust system had been visually inspected on August 18, 1982, which was 50 hours before the accident flight.

A similar accident occurred on October 29, 1999, when a Piper PA-22-150 crashed near Newberry, South Carolina.[6] Thirty minutes into the flight, the pilot noticed smoke entering the cabin. He elected to make an emergency landing at the nearest airport. About 3 miles from the airport, the pilot noticed fire at the right rudder pedals. He decreased power and started descending toward a field. The airplane sustained substantial damage and the pilot was seriously injured. Postaccident examination of the muffler revealed two areas of burn-through damage. In addition, a 14-inch-diameter area of insulation at the airplane's firewall exhibited indications of severe overheating. At the time of the accident, the airplane had accumulated 1,845 hours. The airplane's maintenance records indicated that the muffler was last inspected on April 8, 1999.

A review of records between 1974 and 2001 in the Federal Aviation Administration's (FAA) Service Difficulty Report (SDR) system found 232 reports of cracked or leaking mufflers on single-engine reciprocating-powered airplanes. Many of the SDRs indicated that visual inspection of the exhaust system did not or would not have detected cracks. For example, an entry on a Cessna 182 SDR, dated October 15, 1998, stated, "performed pressure test per Cessna Service Bulletin 98-78-02[7] and found a 1-inch crack along edge of weld attaching flange to

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[4] The Safety Board's database does not contain detailed maintenance information for accidents that occurred before 1983; therefore, it is not known how many hours elapsed since the last inspection before these accidents occurred.

[5] The description for this accident, SEA85LA230, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[6] The description for this accident, MIA00LA018, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[7] SB 98-78-02 recommends that the Cessna 182 exhaust system be pressure tested during each annual inspection using a vacuum cleaner and soapy water to detect any leaks in the exhaust system.

forward end plates. Cracks cannot be visually seen unless muffler is removed." The entry also stated that the airplane had gone through an annual inspection just 14.7 flight hours before the defect was found. An SDR from 1981 (the date of submission is unavailable) for a Beech F33A stated, "Mechanic detected exhaust fumes on ground run. Found heater muffler cracked. Last inspection was only 28 hours earlier." A Piper PA28 SDR, dated February 18, 1994, stated, "Pilot reported exhaust fumes in cockpit…Found hole worn in muffler by flange of muffler shroud…Recommend closer inspection of muffler shroud assembly at each inspection."

Since 1962, the FAA has issued more than 20 airworthiness directives (AD) that address leaking mufflers, requiring visual inspections or pressure testing at varying intervals to identify cracks and prevent CO and hot exhaust leaks in single-engine reciprocating-powered airplanes. Despite these requirements, muffler failures and leaks continue to occur, suggesting that these ADs have not been completely effective. Although the SDR statements cited earlier indicate that pressure testing mufflers on single-engine reciprocating-powered airplanes can be a more reliable method for detecting cracks and leaks than visual inspection, the Safety Board notes that pressure testing only identifies cracks and leaks that have already perforated the muffler. Accordingly, muffler inspections and pressure testing cannot be relied upon to detect and correct muffler and exhaust system leaks before they become hazardous. Therefore, the Safety Board believes that the FAA should evaluate the inspection methods that could be used to determine the integrity of the exhaust systems and require additional procedures that are effective. The Safety Board further believes that the FAA should establish a recommended replacement time interval for exhaust systems in general aviation aircraft with reciprocating engines and cabins, taking into consideration the factors that cause or contribute to the deterioration or erosion of exhaust systems. After the establishment of this recommended replacement time interval, the FAA should issue a notice to all 14 CFR Part 91 owners and operators advising them of these recommended replacement time intervals and require adherence to the replacement time intervals for 14 CFR Part 135 owners and operators.

As demonstrated by the December 17, 2000, and January 17, 1997, accidents cited in this letter, CO poisoning is often the result of eroded or cracked exhaust systems.[8] A search of the Safety Board's database for accidents or incidents involving CO poisoning from 1964 to the present found 58 accidents or incidents, which resulted in 84 fatalities and 5 serious injuries. Because CO cannot be seen or smelled, its presence in the airplane can easily go undetected, impairing the judgment of airplane occupants or incapacitating them in flight. Exposure to CO at levels greater than those permitted by the Federal Aviation Regulations[9] can cause oxygen deficiency, the effects of which may be exacerbated by flight conditions. The physiological effects of CO poisoning may include shortness of breath, headache, fatigue, nausea, disorientation, unconsciousness, and respiratory failure, depending on CO concentration levels and duration of exposure.

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[8] The Safety Board notes that CO poisoning as a result of muffler failures is primarily of concern in single-engine reciprocating-powered airplanes with forward-mounted engines and enclosed cockpits.

[9] Title 14 CFR 23.831 states that "each passenger and crew compartment must be suitably ventilated" and that "carbon monoxide concentration may not exceed one part in 20,000 parts of air."

Although many general aviation pilots use CO detection devices, there is currently no requirement to do so, nor is there any standard for the type of CO detection that would be best suited for general aviation use. The Safety Board is aware of a variety of CO detectors that are available for use in general aviation airplanes. Many are plugged into a lighter socket, while others are battery-operated and can be mounted anywhere in the cockpit. Some indicate the presence of CO by changing color and others provide an aural and visual alert. The ability to detect the presence of CO before a pilot's judgment is impaired is necessary to the continued safe operation of the aircraft. Therefore, the Safety Board believes that the FAA should evaluate CO detector technology for use in general aviation aircraft. The Board also believes that the FAA should develop specific standards to ensure any detection device used in general aviation aircraft quickly and distinctly alerts the user to the presence of CO in the cockpit before the CO reaches a level that would impair a pilot's ability to safely operate an aircraft. The FAA should also require the installation of CO detectors meeting the standards developed as a result of the preceding recommendation in all single-engine reciprocating-powered airplanes with forward-mounted engines and enclosed cockpits that are already equipped with any airplane system needed for the operation of such a CO detector.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Evaluate the inspection methods that could be used to determine the integrity of the exhaust systems and require additional procedures that are effective; establish a recommended replacement time interval for exhaust systems in general aviation aircraft with reciprocating engines and cabins, taking into consideration the factors that cause or contribute to the deterioration or erosion of exhaust systems. After the establishment of this recommended replacement time interval, issue a notice to all 14 *Code of Federal Regulations* (CFR) Part 91 owners and operators advising them of these recommended replacement time intervals and require adherence to the replacement time intervals for 14 CFR Part 135 owners and operators. (A-04-25)
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> Evaluate carbon monoxide detector technology for use in general aviation aircraft. (A-04-26)
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> Develop specific standards to ensure any detection device used in general aviation aircraft quickly and distinctly alerts the user to the presence of carbon monoxide (CO) in the cockpit before the CO reaches a level that would impair a pilot's ability to safely operate an aircraft. (A-04-27)
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> Require the installation of carbon monoxide (CO) detectors meeting the standards developed as a result of Safety Recommendation A-04-27 in all single-engine reciprocating-powered airplanes with forward-mounted engines and enclosed cockpits that are already equipped with any airplane system needed for the operation of such a CO detector. (A-04-28)

Chairman CONNERS, Vice Chairman ROSENKER and Members CARMODY, GOGLIA, and HEALING concurred with these recommendations.

Original Signed

By: Ellen Engleman Conners
Chairman