

GENERAL INFORMATION

Identification number:	2007043
Classification:	Accident
Date, time ¹ of occurrence:	12 May 2007, 20.33 hours
Location of occurrence:	Waddenzee, West of Harlingen, the Netherlands
Aircraft registration:	D-EBAA
Aircraft model:	Reims Aviation F182Q
Type of aircraft:	Single engine piston
Type of flight:	Cross-country
Phase of operation:	En-route
Damage to aircraft:	Severely damaged
Cockpit crew:	One
Passengers:	None
Injuries:	Pilot deceased
Other damage:	None
Lighting conditions:	Daylight

SUMMARY

The aircraft, a Reims Aviation F182Q, crashed in the Waddenzee in the Netherlands. The pilot, the sole occupant of the aircraft, died in a hospital in the evening. He had departed from Heringsdorf airport with the intention to fly to Emden airport in Germany. Approximately 1 hour and 15 minutes after German air traffic control received the last transmission from the pilot, the aircraft entered Dutch airspace at approximately 9000 feet. The aircraft had passed the intended destination airport in Germany. No contact could be established with the pilot.

FACTUAL INFORMATION

On 11 May 2007 the pilot had made three flights with the aircraft. After the second flight he refuelled the aircraft at Emden airport, Germany (EDWE). The third flight was made to Heringsdorf airport, Germany, (EDAH). The next day the pilot planned to fly the aircraft back to EDWE. On 12 May 2007 the flight departed at 16.21 hours. The pilot was the only person on board. He had filed an IFR² flight plan in which Bremen airport, Germany (EDDW) was used as the alternate airport. The flight plan indicated that the flight was planned at FL60³ with a true airspeed of 130 knots and

¹ All times in this report are local times.

² IFR stands for instrument flight rules.

³ FL = flight level. FL60 equals approximately 6000 feet.

a total estimated elapsed time⁴ of 2 hours. The fuel endurance was 4 hours.

At 16.23 hours Berlin Radar cleared the flight to point EMPIT⁵ via the flight plan route and to climb to FL60. At 16.29 hours the pilot requested a climb to FL90 which was approved by Berlin Radar after which he climbed to this level. At 18.14 hours the pilot made initial contact with Hamburg radar. This was the last audible radio telephony transmission that was made by the pilot. After this transmission the pilot did not reply to calls from the air traffic controller anymore.

The aircraft entered Dutch airspace at FL90 at approximately 19.30 hours. Because no radio contact could be established with the pilot, the Royal Netherlands Air Force scrambled two F-16 fighters from Leeuwarden air base to intercept the aircraft. It was reported by the pilots that the head of the pilot of the F182Q hung down and he did not react to signals. The speed of the aircraft was estimated to be between 80 and 100 knots. A military radar plot indicates that at 20.07 hours the aircraft left FL90 and started a descent. According to the pilots the aircraft was flying straight



Figure 1: The flown route by D-EBAA.

⁴ For IFR flights, the term 'total estimated elapsed time' is defined as the estimated time required from take-off to arrive over that designated point, defined by reference to navigation aids, from which it is intended that an instrument approach procedure will be commenced, or, if no navigation aid is associated with the destination aerodrome, to arrive over the destination aerodrome.

⁵ This (navigation)point is located near the city Leer in Germany.

and wings level in a gradual descent. The radar plot indicates the last aircraft position at time 20.33 hours with an altitude indication of 400 feet. Shortly thereafter the aircraft crashed into the Waddenzee⁶ in the Netherlands. According to the pilots the aircraft touched the water smoothly, did not tumble and stayed afloat. At 20.59 hours the pilot was picked up by a lifeboat, which was brought into action by the Netherlands Coastguard as part of the rescue operation, and brought to a hospital where he died.

A weather report of the Royal Netherlands Meteorological Institute (KNMI) indicated that the freezing level was at FL60. At FL50 the temperature was 2 degrees Centigrade and at FL100 it was -6 degrees Centigrade.

INVESTIGATION AND ANALYSIS

General

Radio transmissions between the pilot and several air traffic control units were available for the investigation.

Pathological investigation

The Dutch Forensic Institute performed a pathological investigation on the body of the pilot. The corresponding toxicological report notes that *"atropine and carbon monoxide were detected in the blood. No signs of alcohol, drugs or medicines were found in the blood. Neither were signs of alcohol found in the urine. The concentration of carbon monoxide in the blood was high (60%). This will have contributed to the decrease of the consciousness of the pilot. Possibly the high concentration contributed to the death of the pilot."*

The final pathological investigation report concludes that the death of the pilot is explained by a recent coronary caused by carbon monoxide intoxication and the occurring complications and damage to tissue.

Technical investigation

General inspection and damage

To get the pilot out of the aircraft, the windscreen was broken by the rescue services. The airfoil at the position of both wing roots⁷, the left and right wing tip, the rudder and the left-hand stabilizer had been damaged by the salvage operation. In both the left and right wing tanks no fuel was found. The underside of the aircraft nose, the spinner, the engine mounts, the fire bulkhead and the nose wheel strut had been distorted due to the ditch in the water. No evidence for serious pre-existing damage prior to impact was found and the propeller blades showed low rotations per minute impact damage.

The flaps were found in the "up" position consistent with the position of the flap selector. The elevator trim wheel and the elevator trim tab were found in the neutral position. The rudder trim wheel and the rudder were found in a slightly right position. The ailerons were found in a neutral position. It is concluded the flight control systems were intact and serviceable.

⁶ Position: 53-11.06N 005-17.37E.

⁷ The wing root is the part of the wing that is connected to the fuselage.

Cabin and equipment

In addition to standard equipment required for IFR flights also a global positioning system (GPS), RNAV⁸ and an autopilot had been installed. It seems electrical power was available during flight as the master switch of the electrical system was found in the “on” position after the accident. Post accident investigation revealed the autopilot switch was also found in the “on” position and the heading function and altitude pitch stabilisation function had been selected. Only the auto pilot circuit breaker was found in the popped position.

By extracting data from electronic memories from the navigation/communication unit (KX155) it was found that 113.10 MHz of the Hamburg VORTAC⁹ had been the last active frequency selected by the pilot for navigation. Similarly, the last selected active radio frequency was 123.12 MHz, which is an ATIS¹⁰ frequency of Hamburg airport. This frequency cannot be used to communicate with air traffic control (ATC), but is used to receive operational aerodrome information. The last selected active frequency of the (KY196A) communication unit was 124.225 MHz of Bremen Radar. The frequency of the active waypoint of the RNAV was 110.40 MHz. The selected frequency of the ADF¹¹ was 200 KHz. Both frequencies are not allocated to navigation aids in Germany.

The cabin air control was in the “off” position, meaning that no ambient air (scooped air from the right front side of the aircraft) was mixed with heated air from the exhaust shroud.¹² The cabin heat control was found in the closed or almost closed position. The cabin heat valve was intact. In some aircraft a tell-tale sticker may warn pilots for carbon monoxide, however, this was not the case in D-EBAA and it was not a requirement.

To ventilate the cabin the overhead vents have to be opened allowing ambient air to flow in the cabin by pulling out the adjustable ventilator tubes. Inspection demonstrated that both the left and right vents were in the closed position during flight.

Engine controls

The throttle, propeller pitch and air fuel mixture levers were found pushed in. The fuel selector valve was in the position ‘both’ and both magneto systems had been selected. Those selections correspond with which can be expected during cruise flight.

The connection between the propeller pitch control lever and the pitch control mechanism which drives the propeller blades, was still intact and functioned. The throttle lever was pushed out of the dashboard when throttle movement was tested. Except the lever the connection appeared to be intact and functioned. However, taking into account that the throttle cable runs through the engine upper area of the fire wall and that the engine mounts were bent down during impact, it seems likely the lever separated from the cable when it came under too high tension.

The carburettor heat lever was found in the “on” position (pulled out) but had been bent to the right, probably during either impact or the rescue operation. After it had been bent back the

⁸ RNAV (Area Navigation) can be defined as a method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self contained system capability, or a combination of these.

⁹ VOR (VHF omnidirectional radio range) and TACAN (UHF tactical air navigation aid) combination.

¹⁰ Automatic terminal information service.

¹¹ ADF stands for automatic direction finding equipment.

¹² The shroud (heater cuff) surrounds the exhaust muffler and works as a heat exchanger to warm up the air for the cabin.

carburettor heat lever could be moved and consequently the position of the valve in the carburettor air intake changed. The mechanism was still functioning.

Laboratory engine exhaust assembly investigation

A visual inspection showed some cracks around the exhaust muffler end plates. The exhaust was distorted by impact. The engine exhaust assembly¹³, excluding the heater cuff, was investigated in a laboratory.¹⁴ The corresponding report mentions that the muffler *'is damaged by scaling of the steel used. The effect of the corrosion by the hot exhaust gas is aggravated by the flaking of the protecting scale layers when the muffler cools down. Possibly the destruction of the sensibitized austenitic steel is additionally supported by electrolytic corrosion when the engine is out of operation. In the opinion of the investigator the steel type [...] is absolutely unqualified for the conditions in the muffler. The concentration of the scaling (crack formation) to the both ends of the cylindrical muffler probably results from the highest temperature in the entrance regions of the exhaust gas and from the mechanical stresses induced by the side cover plates'*.

Based on this report, Cessna Aircraft Company concluded that the engine exhaust assembly did not match their type design. Therefore, Cessna Aircraft Company stated there is no verification the part was the correct part, manufactured using the correct materials. Cessna Aircraft Company also concluded that the corrosion is not the result of a few hours of use, rather a prolonged process, which should have been detected using established inspection intervals and procedures.



Some cracks in the exhaust muffler



D-EBAA during technical investigation

Maintenance

The Service Manual for the model 182 and T182 series mentions: *Since exhaust systems of this type are subject to burning, cracking and general deterioration from alternate temperature extremes and vibrations, inspection is important and must be accomplished every 50 hours of operation. Also a thorough inspection of the engine exhaust system should be made to detect cracks causing leaks which could result in loss of engine power. To inspect the engine exhaust system, proceed as follows:*

- *Remove engine cowling as required so that ALL surfaces of the exhaust assemblies can be visually inspected.*
- *After visual inspection, an air leak check should be made on the exhaust system [...]*
- *Where a surface is not accessible for a visual inspection, or for a more positive test, the following procedure is recommended:*

¹³ See page 8 for a drawing of the exhaust system and the names of its components.

¹⁴ Institute for materials ('Institut für Werkstoffe'), Technical University Braunschweig, Germany.

- Remove exhaust stack assemblies.
- Use rubber expansion plugs to seal openings.
- Using a manometer or gauge, apply [...] air pressure while each stack assembly is submerged in water. Any leak will appear as bubbles and can be readily detected.

One maintenance company had performed the yearly checks and another maintenance company the scheduled maintenance of the aircraft. The exhaust system was inspected during those turns. As part of a yearly check the last carbon monoxide test was performed on 22 September 2006. For this test a carbon monoxide detector was used during an engine ground run; it was being held close to the cabin heat outlets inside the cabin. No discrepancies were found. The aircraft had flown 3313 hours (TTAF)¹⁵ and made 4217 landings at that time. The two previous yearly checks were performed on 8 September 2005 and on 16 September 2004; the TTAF on both dates was 3251 hours and 3195 hours respectively. No discrepancies were found.

The last two scheduled maintenance turns of the aircraft were performed on 30 June 2005 (a 50 hours inspection) and on 5 December 2005 (a 200 hours inspection). The exhaust system was inspected for cracks and security and an air leak check was performed. The TTAF on both dates were 3231 hours and 3274 hours respectively. No discrepancies were found. During above-mentioned inspections the heater cuff was not removed. See table 1 for an overview of the inspections.

<i>Date:</i>	<i>Type of inspection:</i>	<i>TTAF (hours):</i>	<i>Number of hours of operation after previous inspection:</i>
22 September 2006	Yearly check	3313	39
5 December 2005	200 hours	3274	23
8 September 2005	Yearly check	3251	20
30 June 2005	50 hours	3231	36
16 September 2004	Yearly check	3195	-

Tabel 1: Inspections of D-EBAA during the period from September 2004 up to and including September 2006.

Maintenance records from 1998 onwards were reviewed, but no replacements or problems related to the engine exhaust assembly were found. As no identifying information was found on the exhaust muffler it was not possible to trace the origin and history of this part.

At the time of the accident no Airworthiness Directives, Service Bulletins or Service Letters existed regarding the F182Q exhaust system.

Analysis

Although the cabin heat switch of D-EBAA was found in a position close to "off", based on the findings of the pathological investigation, the investigation of the exhaust muffler and the fact that the aircraft was flying at FL90 in cold air, it would make sense that the pilot selected the cabin heat to "on" during flight. Subsequently the carbon monoxide gas entered the cabin heating system as a result of the cracks in the engine exhaust muffler. Subsequently gas entered the cabin. As both overhead vents were closed, no fresh air entered the cabin which deteriorated the situation. This resulted in incapacitation of the pilot. The last contact between the pilot and air traffic control was at 18.14 hours. As he sounded confused during this last transmission it is likely that his consciousness had started to decrease at that time due to carbon monoxide. As the autopilot had

¹⁵ TTAF = Total Time Air Frame (aircraft).

been selected on the aircraft maintained level and continued on a more or less steady track for one hour and 53 minutes after the last transmission had been made. Thereafter the aircraft started a descent after it had ran out of fuel and finally crashed in the Waddenzee.

The positions of the throttle, propeller pitch and mixture levers, as found, were not investigated in detail, neither was the behaviour of the autopilot after the engine ran out of fuel. It could not be determined why the auto pilot circuit breaker had popped.

The history of the exhaust muffler could not be traced by the Board. The maintenance records from 1998 onwards did not reveal abnormalities. On the basis of maintenance documentation it can be concluded that inspection of the exhaust system of D-EBAA had been accomplished in accordance with the Service Manual every 50 hours of operation since September 2004.¹⁶ The Board is of the opinion that it is striking that cracks were present in the exhaust muffler but not detected during the last inspection, which was performed eight months before the accident occurred.

Since carbon monoxide cannot be seen or smelled it is difficult to identify the subtle onset of carbon monoxide poisoning. Therefore the Board encourages the use of carbon monoxide detectors in the cockpit.

Similar occurrences

The National Transportation Safety Board (NTSB) investigated an accident on 17 December 2000, involving a Beech BE-23. The airplane impacted hilly, wooded terrain while en route from Spirit of St. Louis Airport, Chesterfield, Missouri, to Tulsa, Oklahoma in the United States. The NTSB determined that the probable cause of this accident was, in part, the pilot's incapacitation due to carbon monoxide and a fractured muffler. As part of this investigation the NTSB's database for accidents and incidents and the Federal Aviation Administration's (FAA) Service Difficulty Report (SDR) system were reviewed. These databases only contain reports concerning US registered aircraft.

As a result of the investigation by the NTSB four safety recommendations were issued to the FAA in 2004. The results of the databases review and the recommendations are reproduced in annex A and the FAA response in annex B of this report.

On inquiry about cracks in exhaust systems of single-engine reciprocating-powered airplanes with sixteen European states, it appeared that since 1991 seventeen occurrences have been reported.

CONCLUSION

The Board concludes that:

- Cracks in the engine exhaust muffler enabled carbon monoxide to enter the cabin. This incapacitated the pilot and resulted finally in loss of control and the aircraft crashing in the Waddenzee.
- The materials used for the exhaust muffler were not according the design specifications.
- The last inspection of the exhaust muffler did not reveal the cracks.

¹⁶ The period before this month was not investigated by the Board.

Note: This report has been published in English and Dutch language. If there are differences in interpretation the Dutch text prevails.

MODEL 182 & T182 SERIES SERVICE MANUAL

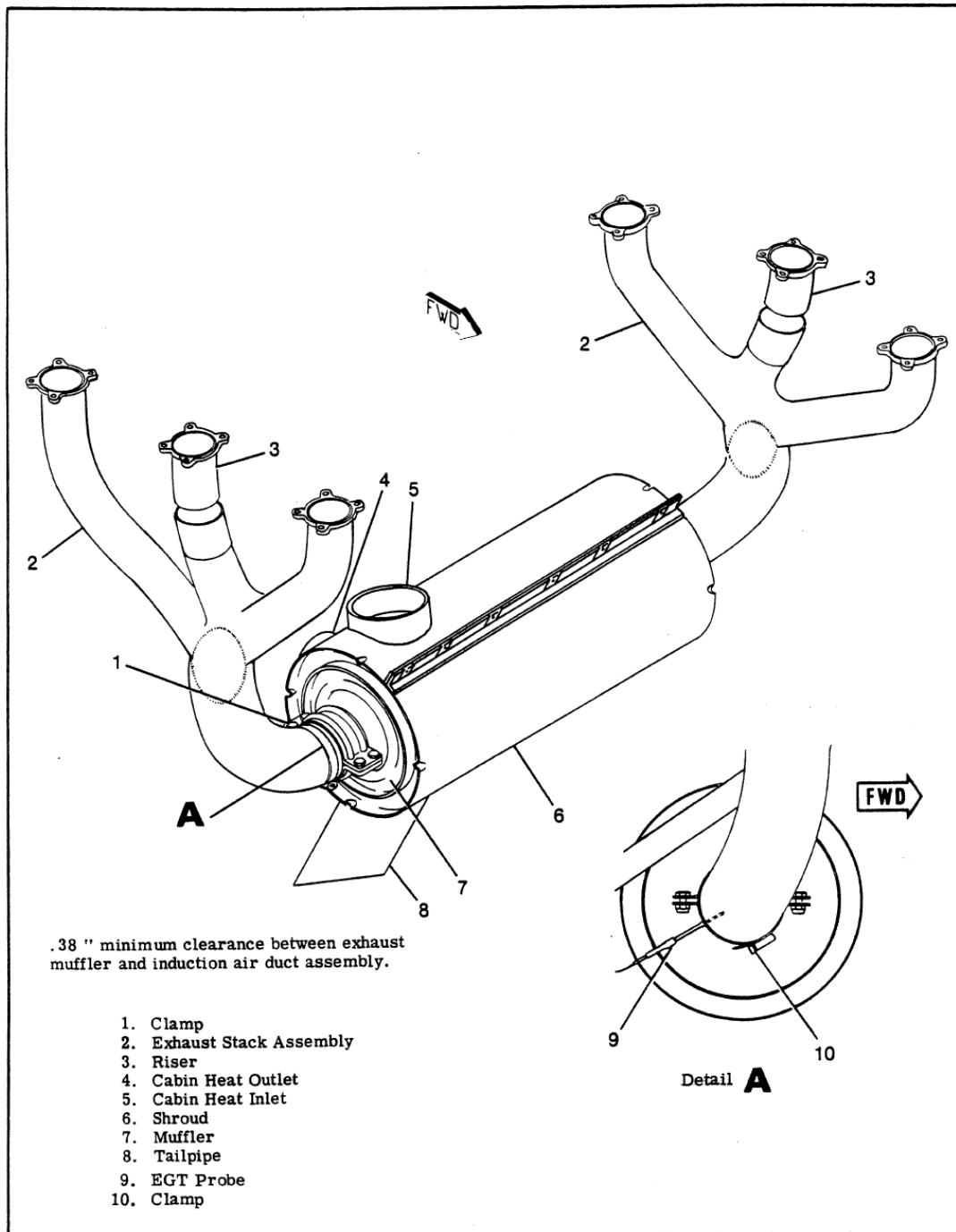


Figure 11-8. Exhaust System

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Figure 2: Drawing of the exhaust system.

Appendix A: National Transportation Safety Board, safety recommendations



National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: June 23, 2004

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

Honorable
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.nts.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.”

² The description of this accident, IAD97FA043, can be found on the Safety Board’s Web site at <<http://www.nts.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 98-78-02⁷ and found a 1-inch crack along edge of weld attaching flange to

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.nts.gov>>.

⁶ The description for this accident, MIA00LA018, can be found on the Safety Board's Web site at <<http://www.nts.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 Regulations⁹ 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.

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)

Evaluate carbon monoxide detector technology for use in general aviation aircraft. (A-04-26)

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)

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 , Vice Chairman and Members
, and concurred with these recommendations.

Original Signed

By:
Chairman

Appendix B: FAA response to safety recommendations A-04-25 up through -28, issued by the NTSB



U.S. Department
of Transportation

**Federal Aviation
Administration**

MAY 15 2008

Office of the Administrator

800 Independence Ave., S.W.
Washington, D.C. 20591

REC'D MAY 28 2008

MC20802 TO
NOT 7559A

The Honorable
Chairman, National Transportation
Safety Board
490 L'Enfant Plaza East, SW.
Washington, DC 20594

Dear Chairman

This is in further response to Safety Recommendations A-04-25 through -28 issued by the Board on June 23, 2004, and supplements our letter dated September 9, 2004. These safety recommendations were issued as a result of the Board's investigation of an accident on December 17, 2000, involving a Beech BE-23, N2324J. The airplane impacted hilly, wooded terrain while en route from Spirit of St. Louis Airport, Chesterfield, Missouri, to Tulsa, Oklahoma. The commercial-rated pilot and sole occupant of the airplane was killed, and the airplane was destroyed. Radar data indicate that about 1 hour after its departure from St. Louis, the airplane's heading and altitude became erratic. Between 1809 and 1821, the airplane descended from 8,500 feet mean sea level to 2,500 feet mean sea level, 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.

A-04-25. 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.

FAA Comment. During the type certification process, type certificate and supplemental type certificate holders are required by 14 CFR section 23.1529 to create Instructions for Continued Airworthiness that are reviewed and accepted by the Flight Standards Aircraft Evaluation Group in coordination with the responsible Aircraft Certification office. These design approval holders are also required by 14 CFR section 21.50 to make this information available to aircraft owners for maintaining the airworthiness of the product. To specifically address this safety recommendation, we reviewed several type design holder's maintenance manuals for inspection

and maintenance procedures for exhaust systems. The manuals reviewed contained effective procedures for determining exhaust system integrity and airworthiness.

The design of an exhaust system varies among aircraft manufacturers, making it difficult to establish a consistent replacement interval for all type designs. Some manufacturers recommend replacement of an exhaust system every 1,000 hours while other manufacturers maintain that “on condition” replacement of exhaust system components is adequate if the exhaust system is inspected per the maintenance manual procedures. If an inspection reveals an unairworthy condition of an exhaust system component, the aircraft must be made airworthy before being returned to service by a certificated mechanic or maintenance organization. This entails properly repairing or replacing the unairworthy exhaust system component. If the manufacturer’s recommended maintenance program includes a replacement time interval for the exhaust system, part 135 operators are required to comply within the time interval unless otherwise approved by the Administrator. There is no requirement for part 91 operators to comply with such replacement time intervals recommended in the maintenance manual.

We continue to stress to the aviation community the importance of proper exhaust system maintenance. In October 2006, we published an article in Advisory Circular 43-16A, “Aviation Maintenance Alerts,” (Enclosure 1) describing good exhaust system maintenance practices that can prevent entry of carbon monoxide (CO) into the cabin. We will also use aviation maintenance alerts and other forms of communication to advise the public of recommended exhaust system maintenance practices and the manufacturers’ recommended exhaust system component replacement intervals.

I believe that the Federal Aviation Administration has effectively addressed this safety recommendation, and I consider our actions complete.

A-04-26. Evaluate carbon monoxide detector technology for use in general aviation aircraft.

FAA Comment. The FAA tasked Wichita State University to conduct research that focuses on the carbon monoxide issues as they apply to general aviation products and that research is ongoing. Enclosed is a copy of the Project Statement of Work (Enclosure 2).

Under this cooperative research grant “Detection and Prevention of Carbon Monoxide Exposure in General Aviation Aircraft,” researchers created a database by surveying technical information on 43 CO detectors commercially available from two dozen manufacturers. CO detectors can be grouped into five sensor technology types: biomimetic, electrochemical, spot, infrared, and semiconductor. Each type of sensor technology has advantages and limitations. Considering the requirements for detecting accuracy, response time, false alarms, and power consumption, electrochemical sensor-based carbon monoxide detectors appear to be the most suitable for use in general aviation environment.

Based on the technical information provided by the manufacturers, the researchers developed a list of performance parameters and specifications and categorized them into four different groups:

- Tier 1: imperative performance parameters within a general aviation environment;
- Tier 2: useful performance parameters within a general aviation environment;
- Tier 3: not necessarily useful performance parameters within a general aviation environment; and
- Tier 4: miscellaneous parameters.

Users will be able to use the database of commercially available detectors and the categorized list of performance parameters to assist them in selecting CO detectors best suited for their aircraft.

This database and the list of parameters will be included as an appendix in the final project report scheduled to be completed in December 2008.

I will keep the Board informed of the FAA's progress on this safety recommendation.

A-04-27. 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.

FAA Comment. Technical Standard Order (TSO) C-48, "Carbon Monoxide Detector Instruments," establishes the performance standards for carbon monoxide detector instruments. The FAA is updating the TSO by adopting the current version of the Society of Automotive Engineers Aviation Standard AS412, Rev B, "Carbon Monoxide Detector Instruments." Enclosed is a copy of TSO C-48 and AS412, Rev B (Enclosure 3) for the Board's information.

Under the research grant described in Safety Recommendation A-04-26, Wichita State University was tasked to perform research and testing to determine the most effective method to select the CO detector and its placement in a typical GA aircraft so that it quickly alerts the pilot if the presence of CO exceeds the § 23.831 requirement of 50 ppm. This research includes installation of electrochemical sensor-based detectors with data logging capability in a fleet of Cessna Model 172 aircraft. Potential detector locations will be based on parameters such as: early detection, visibility, and accessibility. The results of this research will be published in the final project report to be completed in December 2008 and will be used to develop a revision to the TSO.

I will keep the Board informed of the FAA's progress on this safety recommendation.

A-04-28. 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.

FAA Comment. Through the research described in our response to Safety Recommendation A-04-26, we will pursue engineering guidance for proper installation procedures for carbon monoxide detectors meeting FAA TSO C-48, "Carbon Monoxide Detector Instruments." The

ongoing research project includes development of a streamlined method of installing carbon monoxide detectors meeting TSO C-48 in general aviation products and possible regulatory considerations for carbon monoxide detectors. The technical report from this research is scheduled to be completed by the end of 2008.

When this research is completed, the FAA will determine if a change to 14 CFR Part 23 is necessary to mandate installation of CO detectors as required equipment on newly designed aircraft. The FAA will also determine the need for airworthiness directive action if an unsafe condition exists with any specific type design in the existing general aviation fleet.

I will keep the Board informed of the FAA's progress on this safety recommendation.

Sincerely,

Acting Administrator

Enclosures