FLIGHT SAFETY FOUNDATION

Accident Prevention

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Loss of Engine Power Sets Stage For Ditching on a Moonless Night

The left engine failed and the right engine malfunctioned when a Piper Chieftain was being flown over a gulf in Australia. The airplane did not have — and was not required to have — life vests aboard for the scheduled flight. None of the eight occupants survived the ditching.

FSF Editorial Staff

About 1906 local time May 31, 2000, a Piper Chieftain operated by Whyalla Airlines as Flight WW904 on a regular public transport service flight from Adelaide to Whyalla, both in South Australia, was ditched in Spencer Gulf after the left reciprocating engine failed and the right engine malfunctioned. The pilot and seven passengers were killed.

The Australian Transport Safety Bureau (ATSB) said, in its final report, that the following factors contributed to the outcome of the flight:

- "The pilot responded to the failed left engine by increasing power to the right engine;
- "The resultant change in operating conditions of the right engine led to loss of power from, and erratic operation of, that engine;
- "The pilot was forced to ditch the aircraft into a 0.5-meter to 1.0-meter [1.6-foot to 3.3-foot] swell in the waters of Spencer Gulf, in dark, moonless conditions;
- "The absence of upper-body restraints and life [vests] or flotation devices reduced the chances of survival of the occupants; [and,]
- "The emergency locator transmitter [ELT] functioned briefly on impact but ceased operating when the aircraft sank."

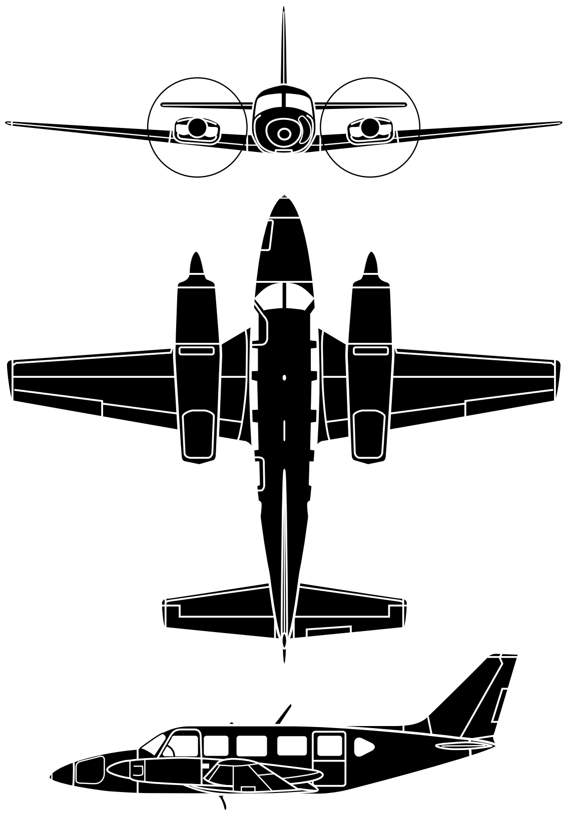
The report said that the airline's engine-operating practices — which complied with procedures included in the U.S. Federal Aviation Administration (FAA) approved operating manual for the airplane — also were a contributing factor.

"The engine-operating practices of Whyalla Airlines including leaning [the fuel-air mixture] at climb power and leaning to near 'best economy' during cruise," the report said. "High-power piston-engine operating practices of leaning at climb power and leaning to near 'best economy' during cruise may result in the formation of deposits on cylinder [surfaces] and piston surfaces that could cause preignition."

[Preignition occurs when a deposit in a cylinder or on a piston becomes hot enough to glow (i.e., to become incandescent) and prematurely ignites the fuel-air mixture (i.e., before the spark plugs fire). Preignition produces excessive heat that can burn a hole in a piston and cause detonation (also called autoignition or "knock") — an abnormal combustion of the fuel-air mixture that creates excessive pressure and heat, which can damage pistons, cylinder heads and valves.][1]

The accident airplane was manufactured in 1981 and had accumulated about 11,838 flight hours. The airplane had turbocharged, six-cylinder Lycoming TIO-540 engines. The left engine had been operated about 262 hours since overhaul, and the right engine had been operated about 1,395 hours since overhaul.

The pilot, 22, held a commercial license and had 2,212 flight hours, including 1,133 flight hours in type. He earned a private license, a commercial license and a flight instructor rating in 1996.



Piper PA-31-350 Chieftain

The Chieftain is a derivative of the PA-31-300 Navajo and PA-31-310 Turbo Navajo, both introduced in 1967 with naturally aspirated 300-horsepower (224-kilowatt) Lycoming IO-540 reciprocating engines and turbocharged 310-horsepower (231-kilowatt) TIO-540 engines, respectively.

Piper Aircraft Co. developed several other versions of the airplane, including the PA-31P Pressurized Navajo in 1970 and the Navajo C/R, which has counter-rotating propellers, in 1974. The Navajo's airframe also was used in the development of the twin-turboprop PA-31 Cheyenne, introduced in 1973.

The Navajo Chieftain was introduced in 1972 with a fuselage that is two feet (0.6 meter) longer than the fuselage of the Navajo, Turbo Navajo and Navajo C/R, and with 350-horsepower (261-kilowatt) TIO-540 engines driving three-blade, constant-speed, counter-rotating Hartzell propellers. "Navajo" later was dropped from the Chieftain's name.

Six seats are standard; 10 seats were available as an option. Maximum takeoff weight and maximum landing weight are 7,000 pounds (3,175 kilograms). Maximum rate of climb at sea level is 1,120 feet per minute (fpm). Maximum single-engine rate of climb at sea level is 230 fpm.

Maximum certified altitude is 24,000 feet. Cruise speed at 75 percent power is 221 knots at 20,000 feet and 205 knots at 12,000 feet. Stall speed with landing gear and flaps extended is 74 knots.♦

Source: *Jane's All the World's Aircraft*

The chief pilot of a company that hired the pilot as an instructor described him as conscientious and as having above-average ability. Colleagues said that the pilot was an excellent instructor who developed a good rapport with students. The company began to assign the pilot to charter flights and ferry flights in 1997. He was endorsed to fly Chieftains in 1998.

The pilot was hired by Whyalla Airlines in January 1999. At the time, he had 895 flight hours, including 383 flight hours in multi-engine airplanes and 46 flight hours in Chieftains.

During a flight in the accident airplane on Jan. 7, 2000, the left engine failed catastrophically. The pilot, who was conducting a scheduled flight from Cleve to Adelaide [which is about 122 nautical miles (225 kilometers) southeast of Cleve] with eight passengers aboard, diverted to Maitland [about 68 nautical miles (125 kilometers) southeast of Cleve] and conducted a successful emergency landing. The left engine was replaced with a factory-overhauled engine.

The company, which maintained a staff of six pilots, had a high pilot-turnover rate, which was typical of low-capacity regular-public-transport operators, the report said. During the 18 months preceding the accident, five of the six pilots had left the company and had been replaced.

"At the time of the accident, the pilot and another pilot, who had joined Whyalla Airlines about the same time, were the [airline's] two most senior line pilots," the report said. "They had been with the company for approximately 17 months."

The pilot had logged 82 flight hours during the 30 days preceding the accident and 242 flight hours in the 90 days preceding the accident.

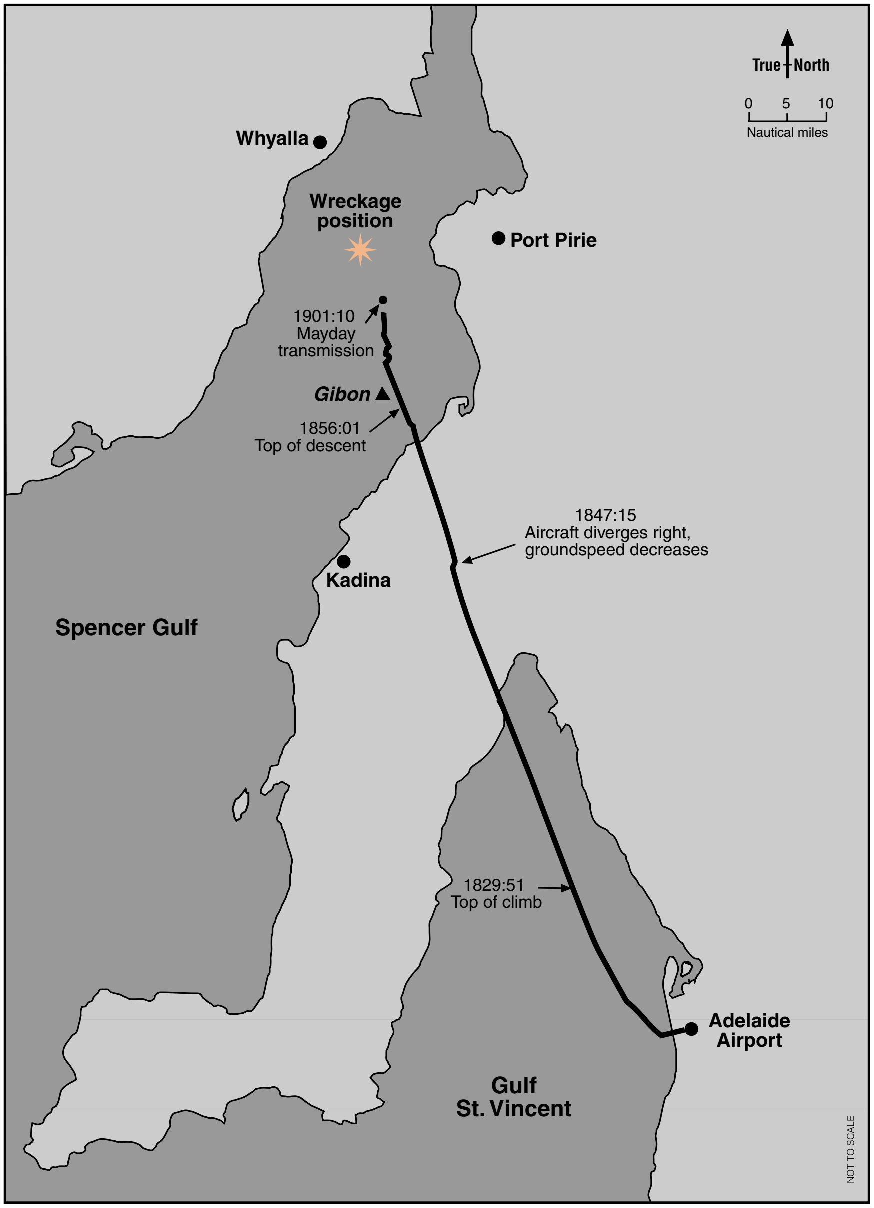
"During the 72 hours before the accident, the pilot was reported to have slept [normally] and eaten normally," the report said. "The pilot was apparently well rested prior to commencing duty on the afternoon [of the accident]."

Weight and balance were within certified limits when the airplane departed from Adelaide about 1823 for the flight to Whyalla [which is about 124 nautical miles (230 kilometers) north-northwest of Adelaide (Figure 1, page 3)].

"After being radar vectored a short distance to the west of Adelaide for traffic-separation purposes, the pilot was cleared to track direct to Whyalla at 6,000 feet," the report said. "A significant proportion of the track from Adelaide to Whyalla passed over the waters of Gulf St. Vincent and Spencer Gulf. The entire flight was conducted in darkness."

At 1856, the pilot told Adelaide Flight Information Service (FIS) that the airplane was 35 nautical miles (65 kilometers) south-southeast of Whyalla and that he was beginning a descent from 6,000 feet. The pilot said that the estimated time of arrival at Whyalla was 1908.

Flight Path of Whyalla Airlines Flight WW904; Piper Chieftain; May 31, 2000



Source: Australian Transport Safety Bureau

Figure 1

At 1901, the pilot declared "mayday," a distress condition, and told the Adelaide FIS specialist that both engines had failed.

"We're going to have to ditch," the pilot said. "We're trying to make Whyalla at the moment. We've got no engines, so we'll be ditching. We have eight POB [people on board]. I repeat again, eight POB. And, most likely, we're currently about one five miles [28 kilometers] off the coast of Whyalla on the Gibon [intersection to] Whyalla track. Request someone come out and help us, please."

The FIS specialist asked the pilot whether he was flying the airplane toward Whyalla or toward the nearest coast. The pilot said that he was flying the airplane toward Whyalla.

The specialist told the pilot that if a loss of direct radio communication with the FIS occurred, he should relay messages to the FIS through the crew of an aircraft that had been diverted toward the Chieftain.

"The pilot's acknowledgement was the last transmission heard from the aircraft," the report said. "A few minutes later, the crew of [the other] aircraft heard an [ELT] signal for 10 [seconds to] 20 seconds."

Search-and-rescue (SAR) personnel said that weather conditions included cloud tops at about 5,000 feet and bases between 2,000 feet and 2,500 feet, with some lower patches of cloud.

"Rain showers were present in the area, particularly to the west over land," the report said. "[SAR] crews commented that there was a light southerly wind, with no turbulence. They also indicated that it was a particularly dark night with no moon."

The report said that in these conditions, the pilot would have had difficulty observing the horizon and the water surface. The right engine likely produced sufficient hydraulic pressure to extend the landing gear, on which the landing lights were attached, but the pilot did not extend the landing gear.

"Lowering the landing gear and switching on the landing lights may have provided some surface definition," the report said. "However, the pilot would have had to weigh any potential advantage provided by the landing lights against the possible disadvantages of ditching with the gear extended."

Early the next morning, SAR personnel found two bodies and some wreckage near the last reported position of the airplane.

"The aircraft, together with five deceased occupants, was located several days later on the seabed," the report said. "One passenger remained missing [and was presumed to have been killed]."

The report said that autopsies revealed the following:

- "One passenger died from multiple injuries;
- "Six of the occupants (the pilot and five passengers) died from salt water drowning;
- "Four of the passengers suffered injuries that may have affected their ability to egress from the aircraft and/or survive in the water for any length of time;
- "One passenger suffered no major physical injuries; [and,]
- "The pilot suffered no major physical injuries."

Of the 10 seats in the airplane, two — the front seats — had lap belts and shoulder harnesses; the other eight seats had only lap belts. When the airplane was manufactured, U.S. Federal Aviation Regulations (FARs) Part 23 — the certification standards for normal, utility, acrobatic and commuter category airplanes — required shoulder harnesses only for the front seats. The regulation later was revised to require shoulder harnesses for all seats in airplanes built after 1986.

No life vests, life rafts or other flotation devices were aboard the airplane. Australian regulations — Civil Aviation Orders (CAOs) Part 20, *Air Service Operators*, Section 20.11, "Emergency and Lifesaving Equipment and Requirements for Passenger Control in Emergencies," paragraph 5.1.2 — did not require this equipment in multi-engine airplanes with fewer than nine passenger seats that are flown within 50 nautical miles (93 kilometers) of land.

"It is highly likely that the chances of survival for the occupants would have been enhanced if the passenger seats had been fitted with upper-body restraints and if the aircraft had been carrying life [vests] or individual flotation devices," the report said.

On June 9, 2000, a marine-salvage operator recovered the wreckage from the seabed and transported it to land for examination by ATSB investigators.

"Contact with the water caused disintegration of the nose section and the cockpit area."

The examination indicated that the airplane was in a shallow nose-down attitude and that the wings were level or banked slightly right on impact. The outboard section of the right wing struck the water first.

"Contact with the water caused disintegration of the nose section and the cockpit area," the report said. "Rapid and forceful ingress of water is considered to have further aggravated the initial impact damage and contributed to rapid sinking.

"A combination of fuselage deformation and inrushing water forced the doors, most windows and the emergency escape hatch to come out of their respective retaining frames. Both engines … were torn from their wing nacelles."

The engines were the only components of the airplane found to have pre-impact damage.

"Aside from the engines, no fault was found in the aircraft that might have contributed to the accident," the report said. "Both engines had malfunctioned due to the failure of components of the engines."

The report said that the following factors contributed to the failure of the left engine:

- "The accumulation of lead oxybromide compounds on the crowns of pistons and cylinder head surfaces;
- "Deposit-induced preignition resulted in the increase of combustion-chamber pressures and increased loading on connecting-rod bearings;

Examination of the wreckage indicated that the airplane likely slewed right severely after the right wing struck the water and was torn off. (Photo: Australian Transport Safety Bureau)

- "The connecting-rod big-end-bearing-insert retention forces were reduced by the inclusion, during engine assembly, of a copper-based anti-galling compound [intended to reduce wear];
- "The combination of increased bearing loads and decreased bearing-insert-retention forces resulted in the movement, deformation and subsequent destruction of the bearing inserts;
- "Contact between the edge of the damaged no. 6 connecting-rod-bearing insert and the no. 6 crankshaft journal fillet resulted in localized heating and consequent cracking of the nitrided surface zone;
- "Fatigue cracking in the no. 6 journal initiated at the site of a thermal crack and propagated over a period of approximately 50 flights; [and,]
- "Disconnection of the two sections of the journal following the completion of fatigue cracking in the journal, and the fracture of the no. 6 connecting-rod big-end housing most likely resulted in the sudden stoppage of the left engine."

The report said that the left engine probably continued to operate for eight minutes to 10 minutes after the no. 6 connecting-rod housing fractured.

"It is likely that the engine would have displayed signs of rough running and some power loss during this time," the report said. "The final disconnection of the crankshaft resulted in a loss of drive to the magnetos, fuel pump, camshaft and, consequently, the sudden stoppage of the engine. The left propeller was in the feathered position when the aircraft struck the water, confirming that the engine was not operating at that time."

The report said that loss of power from the left engine likely began during "the first third of the cruise segment of the flight" and that when the left engine eventually failed, the pilot increased power from the right engine.

Recorded air traffic control radar data showed that at 1847, the airplane's ground track changed approximately 19 degrees right of the direct track to Whyalla and groundspeed decreased from about 177 knots to about 167 knots. The report said that the track change might have resulted from the pilot's reaction to the failure of the left engine.

The report said that radar data indicated that the pilot had been flying the airplane on autopilot, with the altitude-hold mode engaged. When the left engine failed, the autopilot was disengaged and the pilot began to hand-fly the airplane.

"In asymmetric flight, at night, with changing engine-operating conditions and indications, the pilot's workload in flying the aircraft would have been very high," the report said.

At the time, there were two airports nearby that were suitable for landing the airplane: Kadina and Port Pirie.

"Both [airports] were equipped with pilot-activated runway lighting," the report said. "Neither was equipped with a ground-based navigation aid or an associated instrument approach procedure."

The report said that the following factors might have influenced the pilot's decision to continue the flight to Whyalla, rather than to divert to Kadina or Port Pirie:

- A determination that weather conditions precluded a visual approach to either Kadina or Port Pirie;
- A perception that the passengers and the airline expected the airplane to be landed at Whyalla; and,
- The pilot was not overly concerned with the airplane's performance until the right engine began malfunctioning during the descent.

After the pilot increased power from the right engine, detonation caused temperatures to increase in the combustion chambers, and portions of the no. 6 cylinder head and piston melted.

"The damaged piston would have caused a loss of engine oil and erratic engine operation, particularly at high power settings," the report said. "Engine lubrication was still effective at impact, indicating that oil loss was incomplete and that the piston holing occurred at a late stage of the flight."

The right propeller was not feathered before the airplane was ditched.

"It could not be confirmed that the right engine was operating when the aircraft struck the water, although it most probably was operating when radar contact was lost as the aircraft descended through 4,260 feet when 25.8 nautical miles [47.8 kilometers] from Whyalla," the report said.

The report said that the following factors contributed to the malfunction of the right engine:

- "Detonation of combustion end-gas;
- "Disruption of the gas boundary layers on the piston crowns and cylinder head surface, increasing the rate of heat transfer to these components;
- "Increased heat transfer to the no. 6 piston and cylinder head resulted in localized melting; [and,]
- "The melting of the no. 6 piston allowed combustion gases to bypass the piston rings."

During examinations of eight other Lycoming engines that failed between January 2000 and November 2001, investigators found deposits of lead oxybromide on combustion-chamber surfaces in seven engines and a copper-based anti-galling compound in connecting-rod-bearing inserts in three engines. Lead oxybromide deposits also were found on components from two Teledyne Continental TIO-520 engines that had failed.

The report said that there is a "strong association between engine fuel-leaning practices and the creation of lead oxybromide deposits."

The pilot's operating handbook for the Chieftain said that the engines may be operated at peak exhaust-gas temperature (EGT) or lean of peak EGT "as long as stable engine operation results without exceeding any engine limitations during steady state or transient conditions."

Lycoming Service Instruction 1094D, issued in March 1994, said, however, that Lycoming does not recommend operating engines at mixture settings lean of peak EGT.

The manager of Whyalla Airlines said that he had demonstrated lean-of-peak engine operations to his pilots.

"[The manager showed the pilots] that the exhaust manifold did not glow as brightly (at night) when operating lean of peak," the report said. "However, he was insistent [when interviewed by investigators] that company pilots had not been instructed to operate the engines lean of peak. The manager was not aware of the engine manufacturer's recommendation against operating the engine on the lean side of peak, nor was he required to be."

None of the company's pilots was aware of Lycoming's recommendation against using lean-of-peak EGT mixture settings.

"It was clear that company Chieftain aircraft engines were being operated lean of peak EGT on some occasions," the report said.

Company pilots told investigators that the manager closely monitored fuel usage.

"The manager would regularly monitor the fuel usage of each pilot to ensure that excess fuel was not being used and was reported to use that as an indicator to judge the performance of pilots," the report said.

Investigators examined the mixture-setting techniques of 12 other Chieftain operators and found that no two operators used the same procedure, especially during climb and cruise.

"Anecdotal reports indicated that there were fewer engine problems (including component failures) in engines that were operated full rich during climb and [at] 'best power' during cruise, compared with those where the mixture was leaned during climb and 'best economy' cruise power was used," the report said.

The report said that at the time of the accident, the Australian Civil Aviation Safety Authority (CASA) had not published official guidance material on ditching, except for an article on a ditching in the September 1997 edition of *Flight Safety Australia*.

"However, that [article] did not address ditching techniques in much detail, and night ditching was not discussed," the report said.

Based on these findings, ATSB made the following recommendations and received the following responses to the recommendations:

- "[FAA should] review the certification requirements of piston engines with respect to the operating conditions under which combustion-chamber deposits that may cause preignition are formed."

  FAA in August 2002 told ASTB that it was conducting an evaluation of the detonation characteristics of high-performance reciprocating engines and that data from the evaluation will be used to assess the adequacy of engine-certification requirements.

- "[FAA should] review the practice during assembly of applying anti-galling compounds to the backs of connecting-rod-bearing inserts with respect to its effect on the safety margin for engine operation of the bearing-insert-retention forces achieved."

  FAA in August 2002 said that it would "review the effect of anti-galling compound relative to connecting-rod-bearing insert retention and rotation on Lycoming engines."

- "[Lycoming should] review the practice during assembly of applying anti-galling compounds to the backs of connecting-rod-bearing inserts with respect to is effect on the safety margin for engine operation of the bearing-insert-retention forces achieved during assembly."

  [The report did not indicate whether Lycoming responded to the recommendation.]

- "[CASA should] review the operating and maintenance procedures for high-powered piston engines fitted to Australian-registered aircraft to ensure adequate management and control of combustion-chamber deposits, preignition and detonation."

  [The report did not indicate whether CASA responded to the recommendation.]

- "[CASA should] alert operators of aircraft equipped with turbocharged engines to the potential risks of engine damage associated with detonation and encourage the adoption of conservative fuel-leaning practices."

  CASA in March 2001 said that it published an article on the topic in the January–February 2001 issue of *Flight Safety Australia* and was "considering further action on this matter [and] consulting with the [airplane manufacturers] and engine manufacturers with a view to … improving their engine-leaning procedures."

- "[CASA] should educate industry on procedures and techniques that may maximize the chances of survival of a ditching event. Part of that education program should include the development of formal guidance material."

  CASA in April 2003 published Civil Aviation Advisory Publication (CAAP) 253-1(0), *Ditching*. CASA said that the publication contains information "to assist pilots and operators to plan for and execute a ditching, [and] on the subsequent issues associated with survival while waiting for rescue."

- "[CASA should revise CAOs Section 20.11, paragraph 5.1.2] to remove the restriction that [the requirement for life vests or other flotation devices aboard multi-engine aircraft] only applies to aircraft authorized to carry more than nine passengers."

  CASA in January 2003 revised the regulation to require all "land aircraft that carry passengers and are engaged in regular public transport operations or charter operations" to be equipped with a life vest or flotation device for each occupant "on all flights where the takeoff or approach path is so disposed over water that, in the event of a mishap occurring during the departure or the arrival, it is reasonably possible that the aircraft would be forced to land onto water."

- "[CASA should] ensure that CAOs provide for adequate emergency and lifesaving equipment for the protection of fare-paying passengers during overwater flights where an aircraft is operating beyond the distance from which it could reach shore with all engines inoperative."

  CASA in March 2001 said that it was "sympathetic" with the recommendation but would "consult more widely with the aviation community and other stakeholders, including ATSB, before taking further action."

- "[CASA should] mandate the compliance of all manufacturers' service bulletins relating to the provision of upper-body restraint to occupants of FARs Part 23 certified aircraft engaged in fare-paying passenger operations and emphasize compliance with their instructions on the correct use of the restraint systems."

  CASA in August 1999 said that its airworthiness branch would research this issue. "Mandating the installation of upper-body restraint in small aircraft would require substantiation to support [a] proposed rule," CASA said. "CASA therefore intends to gather the appropriate accident [data], research data and cost data to determine if the requirement can be justified in a [notice of proposed rulemaking]."

  CASA in October 2001 said that it prepared a draft discussion paper proposing that "all small aircraft that carry fare-paying passengers be fitted with a shoulder restraint in all seats occupied for takeoff or landing."

The accident report was issued by ATSB in December 2001. From July 2002 to July 2003, the South Australian state coroner conducted a public inquest on the accident. ATSB, which reopened its accident investigation in November 2002 and issued a supplementary accident report in October 2003, said that the coroner concluded that the *right* engine failed first and that the subsequent failure of the left engine was independent of the failure of the right engine. (In the initial report, ATSB said that the engine failures were dependent — that is, the right engine malfunctioned as a consequence of the power increase by the pilot in response to the failure of the left engine.)

"The coroner concluded that the left and right engines had failed independently," ATSB said. "He found that the right engine overheated and was damaged during the climb from Adelaide, and developed a hole in the no. 6 piston eight minutes into the cruise phase of the flight. He concluded that the left engine subsequently independently failed because of fatigue cracking initiated by a sub-surface manufacturing defect in the crankshaft."

The supplementary report includes the coroner's findings and ATSB's responses to the corner's findings.

"The ATSB does not agree with the coroner's findings and is strongly of the view that the engine-failure mechanisms and the sequence of events contained in [the initial accident report] remain the most likely explanation of the circumstances of the accident, based on the limited factual information that was available," the supplementary report said.

In July 2002, ATSB recommended that CASA examine the potential safety benefits of requiring devices that monitor fuel system operation and engine operation to be installed in general aviation aircraft engaged in air transport operations.

"CASA advised that it did not consider [that] the safety benefits of those devices warranted their fitment being made mandatory," the supplementary report said. "However, CASA did not have any concern with operators [voluntarily] fitting such equipment."

The supplementary report said that CASA in December 2002 issued two airworthiness directives (ADs) — AD/LYC/107 amendment 2 and AD/LYC/108 — requiring Australian operators to comply with Lycoming Service Bulletins (SBs) 552 and 553. [SB 552, issued in August 2002, recommends the replacement of crankshafts in specific TIO-540 engines.[2] SB 553, issued in September 2002, recommends inspections of crankshafts in specific IO-540 and TIO-540 engines.[3]]♦

[FSF editorial note: This article, except where specifically noted, is based on: Australian Transport Safety Bureau (ATSB) Aviation Safety Report 20002157, *Piper PA31-350 Chieftain VH-MZK, Spencer Gulf SA, 31 May 2000*, (140 pages with illustrations and appendixes); and ATSB Supplementary Aviation Safety Investigation Report 200002157-A, *Piper PA31-350 Chieftain VH-MZK, Spencer Gulf SA, 31 May 2000*, (174 pages with illustrations and appendixes).]

Notes

1. Lycoming. "Detonation and Preignition" and "Induced Engine Damage." *Key Reprints*. <www.lycoming.textron.com/main.jsp?bodyPage=/support/publications/keyReprints/general.html> Jan. 5, 2004.
2. Lycoming Service Bulletin (SB) No. 552, "Crankshaft Replacement in Lycoming TIO and LTIO-540 Engines Rated at 300 Horsepower and Higher." Aug. 16, 2002.
3. Lycoming SB No. 553, "Crankshaft Inspection for Lycoming Six Cylinder Turbocharged Engines." Sept. 16, 2002.

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