National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 7, 2004
In reply refer to: A-03-58 through -61

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

On October 16, 2002, a Pilatus PC-12/45 airplane, N96WF, overran the runway during a forced landing at Trenton Mercer County Airport (TTN), Trenton, New Jersey.[1] The pilots reported that shortly after takeoff from TTN, they heard "bangs" coming from the single engine, a Pratt & Whitney Canada (PWC) PT6A-67B turbopropeller, and that there were flames and sparks coming from the engine's left-side exhaust. The pilots turned back toward the airport, extended the landing gear and flaps, shut down the engine, and feathered the propeller.[2] The airplane landed long, about two-thirds down the 4,800-foot-long runway, and fast, with a 20-knot tailwind, on a wet runway. The airplane overran the runway and continued for about 300 feet before impacting a chain link fence; the airplane sustained substantial damage.

The airplane was on an instrument flight rules flight plan from TTN to Washington Dulles International Airport (IAD), Sterling, Virginia, and was operating under the provisions of 14 *Code of Federal Regulations* Part 91. Two pilots and two passengers were on board; one passenger sustained a minor injury. Although the Safety Board's investigation of this accident is ongoing, the investigation to date has identified several issues that the Board believes warrant action by the Federal Aviation Administration (FAA).

Background

The PWC PT6A-67B engine, which is installed in Pilatus PC-12 and PC-12/45 airplanes, consists of a gas generator section and a power turbine section. The gas generator section produces the power to drive the power turbine section, which drives the propeller through the reduction gearbox (RGB). The gas generator section also drives the accessory gearbox (AGB), which drives the gearbox components, such as the starter-generator, hydraulic pump, oil pump, and oil scavenge pumps.

[1] The description of this accident, NYC03FA008, can be found on the National Transportation Safety Board's Web site at <http://www.ntsb.gov>.
[2] Feathering a propeller means adjusting the pitch of the blades so that the leading edge points into the wind, thus reducing the frontal area to a minimum, and minimizing or stopping rotation of the blades, which reduces the drag caused by the propeller.

The PT6A-60 series engine's oil system is equipped with a magnetic chip detector (MCD) that is installed in the RGB. The MCD uses a dipole magnet, which attracts magnetic material that may be in the engine's oil. When enough magnetic (or other conductive) material has collected to bridge the two poles, the material completes an electrical circuit that then generates a warning light in the cockpit to alert the crew of an impending engine problem. Such metallic material in the engine's oil typically indicates a bearing or gearbox component beginning to wear. On the Pilatus PC-12 and PC-12/45 airplanes, this warning is displayed on the central advisory and warning system (CAWS) in the cockpit.

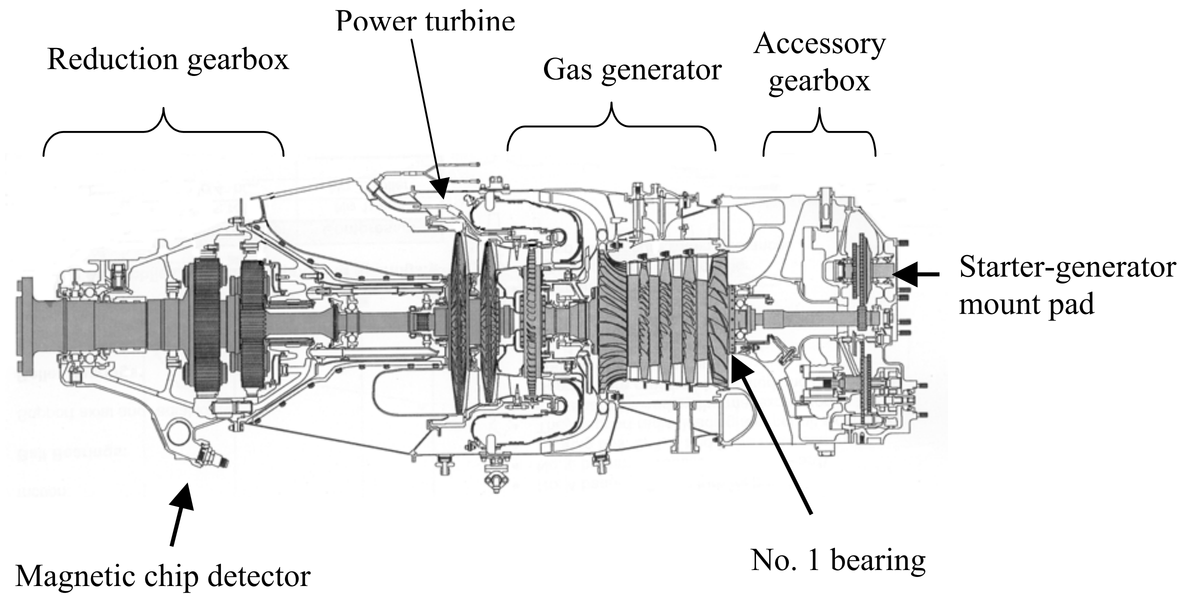

Figure 1. Cross-section of PT6 engine

The disassembly of the engine revealed that its No. 1 bearing ball cage was fractured into several pieces, which allowed the balls to be loose in the bearing compartment. The disassembly also revealed that the interior surfaces of the AGB were coated with metallic particles and that there was metallic debris in the oil filter. Although some metallic debris was found in the RGB, there was not enough debris to bridge the two poles of the MCD dipole magnet.

A metallurgical examination of the AGB components conducted at PWC's Materials Laboratory, Longueuil, Canada, under the observation of the Transportation Safety Board of Canada and Transport Canada,[3] revealed numerous areas of pitting on the gear teeth. Metallographic cross-sections of the pitted areas revealed heat-affected zones[4] in the adjacent material. PWC's Materials Laboratory report stated that the postaccident magnetic readings of and

[3] Because the PWC PT6A-67B engine was certificated in Canada, the Transportation Safety Board of Canada and Transport Canada are assisting the Safety Board with this investigation under the provisions of Annex 13 to the Convention of International Civil Aviation.
[4] A heat-affected zone is that portion of the base metal in which the structure or material properties have been altered by heat.

the surface pitting and adjacent heat-affected zones found on the AGB components are consistent with electrical discharge damage (EDD).[5]

A review of maintenance records revealed that approximately 704 hours before the event, the accident airplane's starter-generator, a Lucas Aerospace model 23085,[6] failed while the airplane was en route to a 100-hour inspection. The generator was reset and remained on line for the rest of the flight.[7] The starter-generator was then replaced and the airplane returned to service. According to documents from Pilatus, the examination of the failed starter-generator revealed heavy burn marks on the armature and stator vanes, which are consistent with high current flow from a short circuit.

Role of Starter-Generator Failures in Causing Engine Failures in PT6A-60 Series Engines

On PT6A-60 series engines, the starter-generator is mounted on the back of the AGB. The rotational drive between the AGB and the starter-generator is transmitted by a splined drive shaft. When the starter-generator is installed, the splined end of the drive shaft connects to the starter-generator drive gear in the AGB. There is a direct link from the starter-generator drive gear to the No. 1 bearing, through the other gears in the AGB. Further, testing of various AGB gear components with a magnetometer revealed that the starter-generator drive gear had a reading of between 18 and 20 Gauss.[8] Other AGB gear components also registered Gauss readings, which were lower the further away they were from the starter-generator drive gear. Typically, an AGB gear component would not register any Gauss readings. The trail of AGB parts in the accident engine between the starter-generator and the failed No. 1 bearing that had been magnetized and had EDD suggests that the failure of the No. 1 bearing was related to the earlier failure of the starter-generator.

The Safety Board is aware that the Australian Transport Safety Bureau (ATSB) has investigated five occurrences of No. 1 bearing failures in PT6A-60 series engines caused by EDD.[9] On June 19, 2002, the ATSB released safety recommendations to the FAA, Transport Canada, and PWC. The ATSB recommended that the FAA, "examine the circumstances of electrical discharge damage to the number-1 bearing of the Pratt and Whitney (Canada) PT6A engine models equipped with TRW Lucas starter-generators and develop an appropriate safety assurance strategy."

On February 19, 2003, in response to the ATSB's recommendation, the FAA issued Special Airworthiness Information Bulletin CE-03-24 to alert the owners and operators of PWC PT6A-60

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[5] EDD is caused by the flow of high current across a component. The high current flow could be caused by lightning, static electricity discharge, or a short circuit from one of the installed electrical components. EDD weakens the metal, and increases its susceptibility to wear damage.

[6] The starter-generator operates as a starter motor to turn the gas generator section of the engine during startup. After the engine has started, the starter-generator operates as a generator to provide the airplane with a continuous supply of 28 volts Direct Current. The starter-generator was manufactured by Lucas Aerospace, which was acquired by TRW Aeronautical Systems, which was later acquired by Goodrich.

[7] Another unscheduled starter-generator removal occurred 1284 hours prior to the accident when the starter-generator failed to accelerate the engine during start and was replaced.

[8] A Gauss is a unit of magnetic flux density.

[9] Those events occurred on Shorts Brothers 360 and Beech 1900 series airplanes.

series engines[10] to the possibility of engine failure caused by deterioration of the No. 1 bearing. The bulletin stated that there have been a total of 17 PT6A-60 series engine failures worldwide, including the five involving Australian operators, attributed to the failure of the No. 1 bearing because of EDD. The Safety Board has learned that in all of the events for which records are available (about half the events), the engine failure was preceded by the failure of the starter-generator.

Accordingly, it appears that a starter-generator failure can cause EDD that can damage the accessory gearbox components and No. 1 bearing which may result in a No. 1 bearing failure and subsequent engine failure. This result could be avoided if the starter-generator were electrically isolated from the rest of the engine so that, in the event of a failure of the starter-generator, the high current that causes the EDD could not flow into the engine. Therefore, the Safety Board believes that the FAA should require that PWC PT6A-60 series engine starter-generators be electrically isolated from the rest of the engine.

Adequacy of Current MCD System on Pilatus PC-12 and PC-12/45 Airplanes

As stated previously, on Pilatus PC-12 and PC-12/45 airplanes, if the poles of the MCD dipole magnet are bridged by conductive material, the electrical circuit will be closed, and a warning light will be illuminated on the CAWS in the cockpit. However, the CAWS on early serial-numbered PC-12 and PC-12/45 airplanes, including the accident airplane, was designed so that such engine MCD warnings would be enabled only when the airplane was on the ground. The CAWS receives a signal from the weight-on-wheels (WOW) switch on the left main landing gear. As soon as the airplane takes off and the WOW switch is opened, MCD warnings are disabled.[11] The Safety Board is concerned that having the MCD warnings disabled in flight negates the purpose of the system – to warn the flight crew of potential engine problems.

The Safety Board notes that when PC-12 and PC-12/45 airplanes were registered for use in Canada, Transport Canada required that they be modified so that the installed CAWS would display any engine MCD warnings throughout all phases of flight. Pilatus issued Service Bulletin (SB) No. 04-002, "Canadian Registration of PC-12 and PC-12/45 Aircraft," which called for the replacement of the CAWS in these airplanes with a system that would not inhibit any engine MCD warnings when the airplane was in flight. When PC-12 and PC-12/45 airplanes were registered in the United States, the FAA did not impose a similar requirement.

The Safety Board concludes that receiving an MCD warning in flight would warn pilots of a potential engine problem and enable them to take the appropriate action (for example, making a precautionary landing to determine the cause of the problem) and could prevent in-flight engine failures and resultant forced emergency landings or accidents. Therefore, the Safety Board believes that the FAA should require that Pilatus PC-12 and PC-12/45 airplanes be equipped with a CAWS that will display engine MCD warnings during all phases of flight.

[10] PWC PT6A-60 series engines can be installed on, but are not limited to, Raytheon (Beech) 1900, Raytheon B300 (Super King Air 300), Raytheon T-6A Texan II, Short Brothers Limited SD3-60 (Shorts 360), and Pilatus PC-12 and PC-12/45 airplanes.

[11] PC-12 and PC-12/45 airplanes up to serial number (SN) 231 incorporated this CAWS design; the accident airplane was SN 139. PC-12 and PC-12/45 airplanes SN 232 and above incorporate a revised system design which does not disable the MCD in flight.

The PWC PT6A-60 series engine MCD monitors the oil scavenged from the RGB; the MCD does not monitor the oil scavenged from the AGB and main engine bearings. After the oil is scavenged from the AGB and bearings, it is pumped back into the engine's oil tank and passed through the main oil filter, which traps any debris in the oil scavenged from these areas before the oil is reused by the engine. Therefore, the MCD installed in the RGB will not detect debris from the AGB and bearings and, accordingly, the pilots will not be alerted to potential engine problems that might be indicated by such debris. As previously mentioned, the disassembly of the accident airplane's engine revealed that the AGB and oil filter were coated with metallic debris, but the MCD, which is downstream of the filter, did not have enough material to bridge the poles of the magnet that would have completed the electrical circuit and initiated a warning light in the cockpit.

On August 20, 2001, Pilatus issued SB No. 79-005, "Oil-Indicating, Introduction of Chip Detector in Engine Accessory Gearbox," which made available the installation of an MCD in the AGB to monitor the gearbox oil-drain for metal particles. According to Pilatus, the MCD for the AGB oil-drain is currently available. Pilatus has also advised the Board that it has developed an oil debris monitor (ODM) that is mounted on the engine and continuously monitors the oil for any metallic debris and, if any debris is detected, sends a warning to the cockpit. The ODM is being installed on new production aircraft and is retrofittable to later model PC-12 and PC-12/45 aircraft. Pilatus is looking into ODM retrofits for earlier models.

Following the failure of the accident airplane's starter-generator, the oil system patch test specified by the PT6A-67B Maintenance Manual (MM)[12] if there is a starter-generator failure was not accomplished; however, the 100-hour spectrometric oil analysis program (SOAP)[13] checks were accomplished. A review of the SOAP records, including the last one that was performed about 32 hours before the crash, showed no discernible trend for metal in the oil. PWC advised the Safety Board that in the PT6 series engine, SOAP checks are unreliable for detecting impending bearing failures. Furthermore, PWC advised that an impending bearing failure has never been detected by the oil system patch test.

Because the existing SOAP and patch tests cannot reliably detect impending bearing failures, it is imperative that the Pilatus PC-12 and PC-12/45 airplanes have an on-board oil monitoring system that will detect metal particles in all areas of the engine's oil system and send a warning to the cockpit to alert the pilots of a potential engine malfunction. The installation of an MCD in the AGB oil-drain or an equivalent device, such as the ODM, will allow the engine's entire oil system to be monitored. Therefore, the Safety Board believes the FAA should require on Pilatus PC-12 and PC-12/45 airplanes the installation of an MCD, in accordance with Pilatus SB No. 79-005, or an equivalent device, in the AGB oil-drain to monitor the Pratt & Whitney Canada PT6A-67B engine's entire oil system, as soon as the necessary parts become available.

Need for MCDs on Other Single-Engine Airplanes

[12] PT6A-67B MM, Section 72-00-00, "Engine, Turboprop – Inspection," Page 648, states that the patch test requires the engine oil filter be removed and flushed with a solvent. The solvent is poured through a paper filter, the patch, to capture any debris that may have been rinsed. The filtrate is then analyzed by x-ray energy spectroscopy that produces an illumination spectra that would identify the type and quantity of any material that might be in the oil.

[13] With SOAP, a sample of engine oil is collected from the oil tank and then burned in a spectrometer, which measures the resultant illumination spectra and intensity to determine the type and quantity of any material in the oil.

In the case of turbopropeller engines installed on twin-engine general aviation airplanes, if one of the engines should fail in flight, the redundancy offered by the second engine permits a successful emergency landing. However, with airplanes such as the Pilatus PC-12 and PC-12/45, which have only a single engine, it is imperative that the engine's oil system be monitored completely and continuously, and that warnings be generated in the cockpit during all phases of flight so that the pilots can make a precautionary landing before the single engine fails. As a result of its findings regarding the PC-12 and PC-12/45 airplanes during this investigation, the Safety Board is concerned that there may be other single-engine, turbopropeller-powered airplanes that have MCDs that are not enabled during all phases of flight and/or that do not monitor the engine's entire oil system. Therefore, the Safety Board believes that the FAA should evaluate all single-engine, turbopropeller, normal-category airplanes to ensure that the MCDs, or equivalent devices, are installed to monitor the engine's entire oil system, and that warnings are enabled during all phases of flight.

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

> Require that Pratt & Whitney Canada PT6A-60 series engine starter-generators be electrically isolated from the rest of the engine. (A-03-58)
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> Require that Pilatus PC-12 and PC-12/45 airplanes up to serial number (SN) 231 be equipped with a central advisory and warning system that will display engine magnetic chip detector warnings during all phases of flight. (A-03-59)
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> Require on Pilatus PC-12 and PC-12/45 airplanes the installation of a magnetic chip detector, in accordance with Pilatus Service Bulletin No. 79-005, or an equivalent device, in the accessory gear box oil-drain to monitor the Pratt & Whitney Canada PT6A-67B engine's entire oil system, as soon as the necessary parts become available. (A-03-60)
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> Evaluate all single-engine, turbopropeller, normal-category airplanes to ensure that the magnetic chip detectors (MCD), or equivalent devices, are installed to monitor the engine's entire oil system, and that warnings are enabled during all phases of flight. (A-03-61)

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

Original Signed

By: Ellen Engleman Conners
Chairman