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ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2010-005
Final

Total power loss, VH-UMV near Cairns Airport, Queensland 31 December 2009

Abstract

On 31 December 2009, a Cessna Aircraft Company model 208, registered VH-UMV, was engaged in parachuting operations from Cairns Airport, Queensland. While climbing through 12,500 ft in preparation for a parachute drop, the engine failed. The parachutists exited the aircraft and the pilot completed a glide approach and uneventful landing at Cairns Airport.

The failure of the Pratt and Whitney PT6A-114 engine was probably precipitated by fracture of the compressor turbine blades. Federal Aviation Administration (FAA) parts manufacturing approval information indicated that part number T-102401-01 compressor turbine blades that had been installed in the engine during the most recent overhaul were not approved for the PT6A-114 model.

As a result of this occurrence, the Civil Aviation Safety Authority (CASA) released Airworthiness Bulletin AWB 72-005, alerting all operators and maintainers of PT6A engines, of the potential for installation of these compressor turbine blades in unapproved PT6A engine variants, and to raise awareness of the restrictions placed on the use of approved after-market blades.

FACTUAL INFORMATION

On 31 December 2009 at approximately 1030 EST[1], a Cessna Aircraft Company model 208, registered VH-UMV (UMV), departed Cairns Airport, Queensland, on the first of several planned parachuting operation flights. The pilot and 15 parachutists were on board.

Climbing through 12,500 ft, the aircraft's engine lost all power. After performing an initial check and scan of the engine instruments, the pilot advanced the emergency power lever[2], but the engine was unresponsive.

The pilot turned the aircraft back towards Cairns and issued a MAYDAY[3] radio call to air traffic control, requesting an immediate track back to the airport and a clearance to drop the parachutists. Both actions were approved and the parachutists subsequently exited the aircraft and landed safely. The pilot feathered[4] the propeller and set the aircraft up for a glide approach to the

1 The 24-hour clock is used in this report to describe the local time of day, Australian Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) +10 hours.

2 The emergency power lever allowed a pilot to manually maintain fuel flow to the engine in the event of a failure of the fuel control unit.

3 Mayday is an internationally recognised radio call for urgent assistance.

4 The term used to describe rotating the propeller blades to an angle edge on to the air flow that minimises aircraft drag following an engine failure or shut-down in flight.

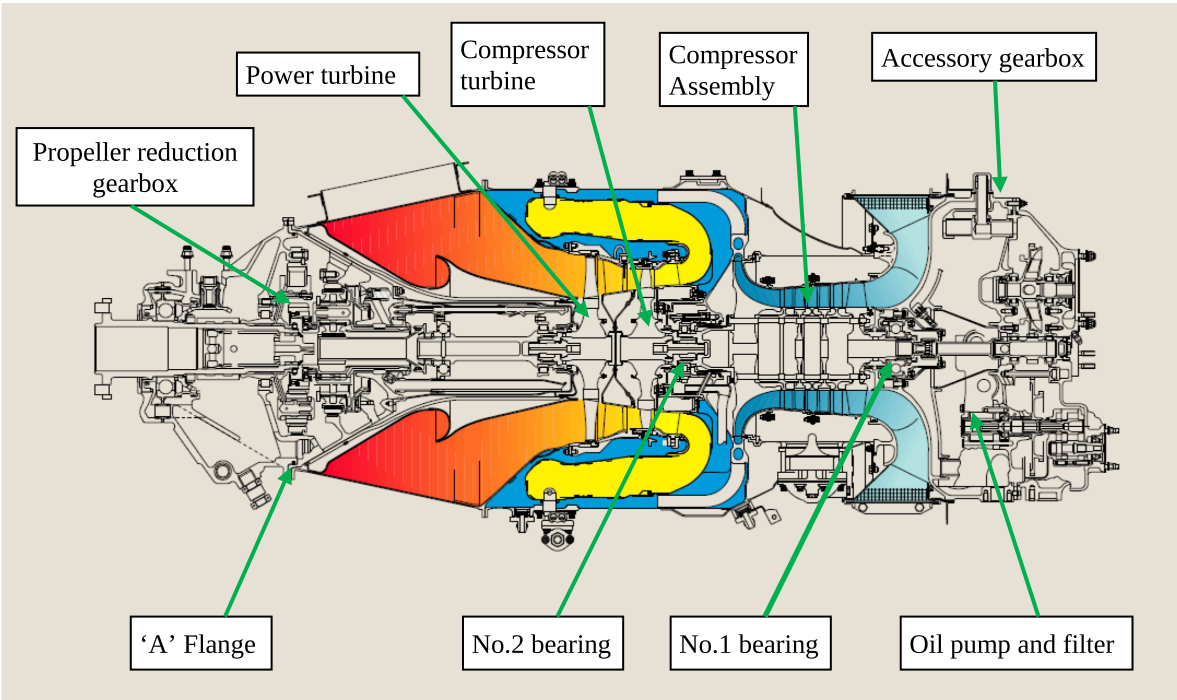
airport. The emergency checklist was consulted and the pilot attempted, but was unable to restart the engine. The aircraft landed on runway 15 without further incident.

The pilot reported that there were no cockpit warnings, vibrations or other indications of the impending engine failure. The pilot also reported that the propeller had continued to rotate until it feathered (approximately 15 seconds). However, once on the ground, the pilot found that the engine had seized and the propeller could not be rotated by hand.

Engine information

The aircraft was fitted with a 600 shaft horsepower (SHP) Pratt and Whitney Canada PT6A-114 free-turbine, turboprop engine, serial number PC-E 17154. The engine had accumulated 10,397 hours/12,561 cycles since new, and 1,926.4 hours/3,002 cycles since last overhaul, which was within the manufacturer's normal recommendation of 3,600 hours. The last engine hot section inspection was conducted 657.4 hours prior to the occurrence. A typical PT6A engine cross section is shown in Figure 1.

Figure 1: Typical PT6A engine arrangement



Engine disassembly and inspection

The engine was removed from the aircraft and shipped to the manufacturer's facility in Brisbane, where a detailed disassembly and inspection was completed in the presence of Australian Transport Safety Bureau (ATSB) investigators as well as representatives from the engine manufacturer and the Civil Aviation Safety Authority (CASA).

Hot Section

Separation of the hot section revealed significant damage to the compressor turbine (CT) rotor assembly (Figure 2). All of the blades were fractured through the airfoil section; the majority close to the blade platform. Many of the blade sections exhibited deformation, cracks and nicks associated with impacting circulating blade debris. The compressor turbine shroud and vane ring had also sustained extensive impact damage and gouging. The anti-rotation lugs on the vane ring were fractured.

Some of the CT blade fracture surfaces were obscured by metal smearing, but the remaining fractures were typical of ductile rupture in cast superalloy components (Figure 3) and did not show any evidence of progressive cracking, corrosion or other pre-existing defects.

Figure 2: Compressor turbine rotor assembly

Figure 3: Typical CT blade fracture surfaces

The power turbine (PT) vane ring, disk and blades showed damage consistent with the downstream passage of the CT blade debris. The PT blades were fractured through the airfoil section near the blade tips and had sustained general leading edge nicks and dents. The tips of the inter-turbine temperature (ITT) thermocouple probes protruding into the gas path appeared to have been burned away to a point flush with the PT vane ring surface.

Compressor Section

Axial movement of the compressor shaft had resulted in contact damage between the trailing edge of the first stage compressor blades and first stage stators.

The number-1 bearing inner race showed a localised area of metal flow and associated spalling, as well as surface discolouration and chromatic heat-tinting (Figure 4). This was consistent with electrical arcing across the bearing, commonly referred to as electrical discharge damage (EDD). Several of the rolling elements also exhibited minor surface pitting. The bearing had not failed during operation and the point at which the EDD occurred was not able to be conclusively determined by this investigation.

Figure 4: Number-1 bearing inner race showing electrical discharge damage

Oil System

The oil-to-fuel heater had fractured at the mounting lugs, allowing separation of the oil transfer tube (Figure 5). The pressure oil transfer elbow mounted on the A-flange had also sustained a fracture of the mounting lug (Figure 6). Examination of the mounting lug fracture surface revealed no evidence of pre-existing cracking or other defects.

The main oil pressure pump housing had fractured, exposing the pump gears (Figure 7). In this condition, oil pressure could not have been maintained during engine operation. When examined under the Scanning Electron Microscope (Figure 9), approximately two thirds of the pump housing fracture surface presented with a highly crystallographic morphology; consistent with a low-stress, high-cycle fatigue cracking mechanism. The remaining area of fracture presented as ductile overstress (Figure 8).

Figure 5: Fracture of oil-to-fuel heater mounts

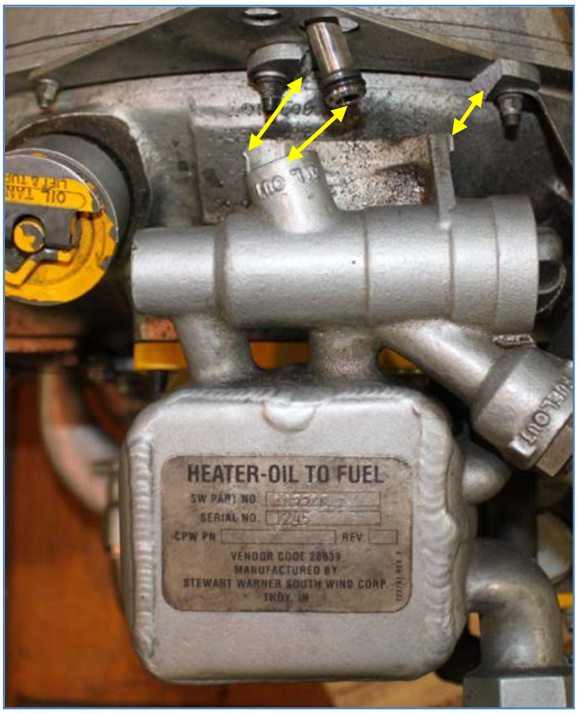


Figure 6: Fractured oil transfer tube mounting lug

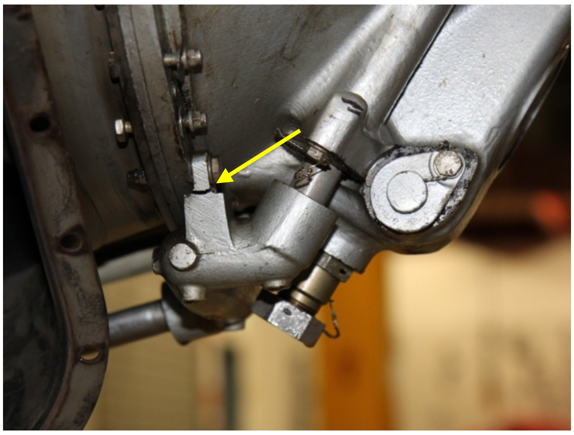


Figure 7: Fracture of oil pump housing

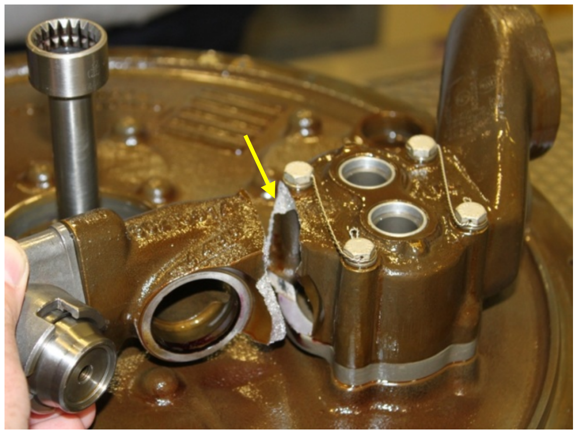


Figure 8: Oil pump housing fracture surface

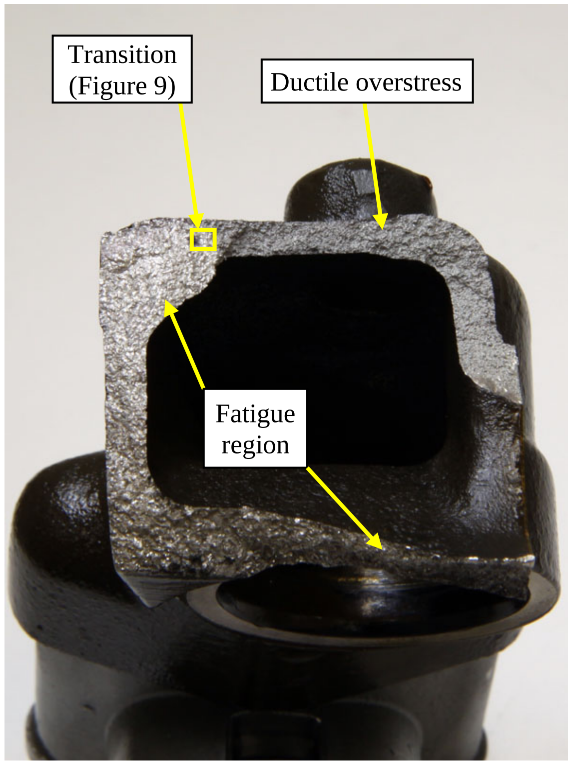
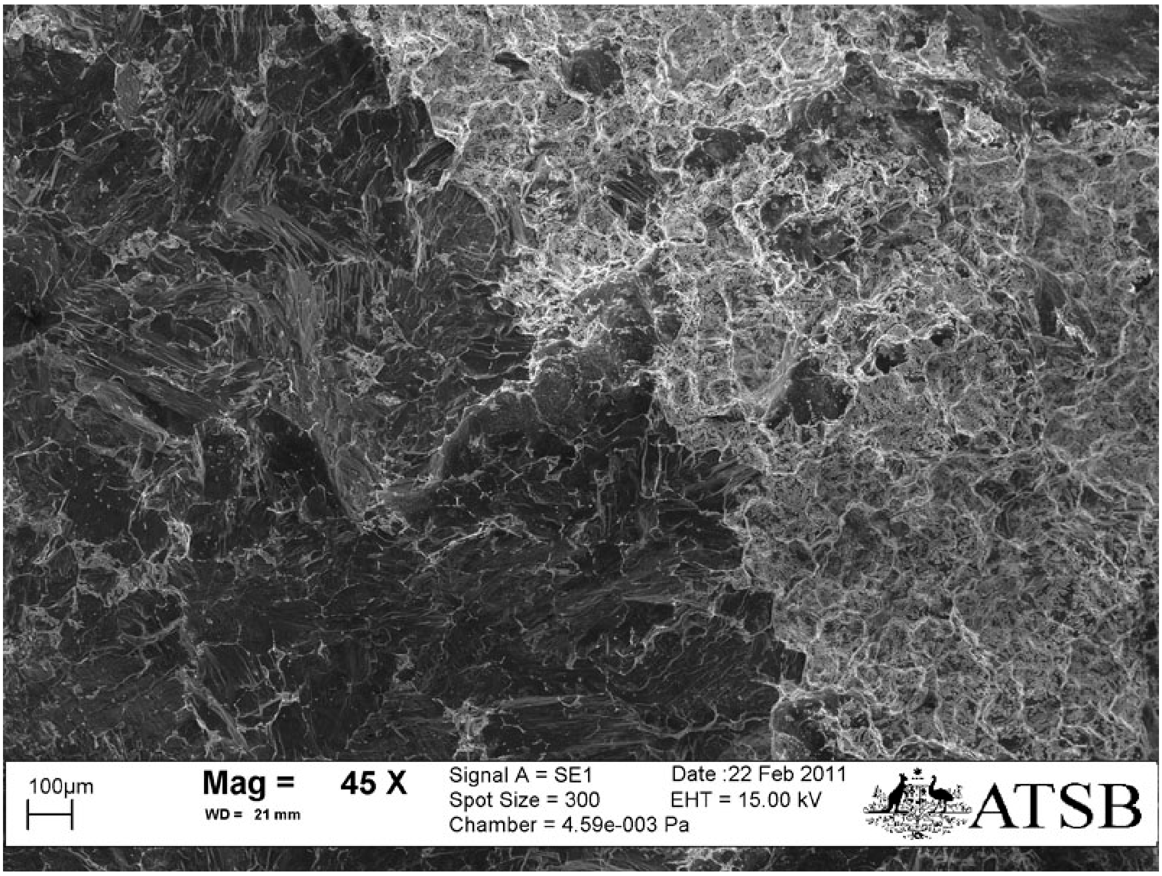


Figure 9: SEM image showing fatigue/overstress transition region

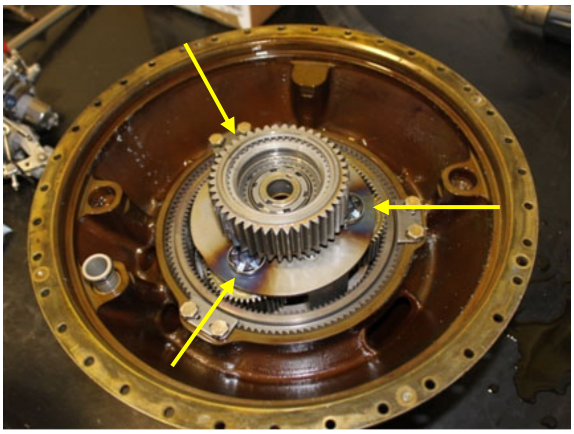


Reduction gearbox (RGB)

The propeller shaft was unable to rotate due to overtemperature-induced seizure of the three, first-stage planet gears - evidenced by localised chromatic heat tinting of the gear carrier (Figure 10). Seizure of the gears was likely related to disruption of the oil system and oil starvation to the RGB.

The magnetic plug from the RGB had retained small amounts of chromium flake and carbonaceous deposits. The oil drained from the RGB looked clean and of the correct colour, and also contained carbonaceous material. No debris was identified in the RGB finger filter.

Figure 10: Overheating of the three planet reduction gears



Compressor turbine blades

Engine maintenance logs indicated that a new set of 58 CT blades were installed in the engine at the last overhaul, which was conducted by a US-based maintenance provider in March 2005.

The installed blades were part number T-102401-01 and were manufactured under Federal Aviation Administration (FAA) Parts Manufacturer Approval[5] (PMA) as a replacement for the original equipment manufacturer (OEM) part number 3102401-01. However, PMA information obtained from the FAA showed that the T-102041-01 blades were only approved for installation on PT6A-11, 11AG, 15AG, 21, 25, 25A, 27, 28, 110 and 112 engine variants, and were therefore not approved for installation on the PT6A-114 engine fitted to UMV.

The damaged CT blades removed from the engine during disassembly matched the PMA part number from the maintenance logs – confirming the substitution error. However attempts to determine the reason for the incorrect blade installation error were unsuccessful.

During the ATSB's examination of this issue, it was found that the PT6A engine variants approved for PMA blade installation operated with lower engine SHP ratings and correspondingly lower turbine temperatures than the unapproved PT6A variants (including the PT6A-114). A review of PT6 CT blade materials indicated that the OEM 3102401-01 parts were manufactured from an IN-100 alloy, while the PMA T-102401-01 blades were manufactured from IN-738. Chemical analyses of one of the fractured T-102401-01 blades and an exemplar 3102401-01 blade were consistent with IN-738 and IN-100 alloys respectively.

Physical property data showing the effect of temperature on stress-rupture strengths for the two alloys indicated that IN-100 retained higher strength after extended exposure to temperatures in the region of approximately 750 to 800°C. Those temperatures typically reflected the operating range of higher-rated PT6A engines, such as the PT6A-114.

5 The Federal Aviation Administration can approve a manufacturer for the design and manufacture of modified and replacement parts for type-certified products.

Previous occurrences

PT6 compressor turbine blade events

The National Transportation Safety Board (NTSB) investigated a 2008 occurrence (NTSB ID: MIA08LA133) involving a Rockwell International S-2R aircraft that experienced a loss of power and subsequently crashed, injuring the pilot and substantially damaging the aircraft.

The NTSB report indicated that the PT6A-34AG engine installed in the S-2R lost power as the result of fatigue cracking and fracture of the CT blades. The engine was fitted with PMA T-102401-01 blades during repair of the CT disk in March 2005[6]. FAA PMA information showed that the T-102401-01 blades were not approved for installation in the PT6A-31AG.

Another loss of power event, involving an Ayres S2RT-34RE aircraft, was investigated by the NTSB in 1998 (NTSB ID: LAX98LA129). In that occurrence, three of the 58 CT blades installed in the PT6A-34AG engine were part number T-102401-01. The remaining blades were part number T-102401-792, which were approved for use in the PT6A-34AG engine. One of the T-102401-01 blades was reported as having sustained a fatigue fracture, which had ultimately resulted in the engine failure.

Other PT6 engine failure occurrences, attributed to creep or fatigue failure of CT blades have also been investigated, where the occurrences were not related to the installation of PMA CT blades.

In response to the number of in-flight shut down events and service difficulty reports relating to CT blade failures, Transport Canada released Service Difficulty Advisory AV-2007-06; the purpose of which was to advise owners, operators, maintainers, and overhaul shops of the importance of proper engine maintenance and engine power management.

AV-2007-06 stated that:

> One of the primary reasons for CT blade fractures and resultant engine power loss

6 The engine maintenance facility that installed the PMA blades into the PT6A-34AG was not the same facility that installed the same blades into the PT6A-114 engine (S/N: 17154) from this occurrence investigation.

is operating the engine beyond the power settings specified in the respective Aircraft Flight Manual (AFM). Not following the specified AFM requirements has largely contributed to incidents of blade creep and reduced blade life

Electrical discharge damage

Numerous PT6A engine failures and in-flight shutdown occurrences in the world-wide fleet have been attributed to failure of the number-1 bearing as a result of electrical discharge damage (EDD).

EDD results from high electrical current passing from the starter generator through the accessory drive train, creating arcing damage to the gears and resulting in pitting damage to the number-1 bearing. Continued engine operation can lead to spalling and eventual failure of the bearing.

Detailed analysis of a 2006 engine failure that resulted from EDD of the number 1 bearing in a PT6A-114 engine was documented in ATSB investigation report 200600563, which can be found on the ATSB website (www.atsb.gov.au).

The manufacturer's service and maintenance recommendations relating to EDD are included in service information letter (SIL): Gen PT6-024, titled *No. 1 Bearing Electrical Discharge Damage.*

ANALYSIS

Damage sustained by engine serial number 17154 was consistent with the fracture and collapse of the compressor turbine blade set. It was found that the FAA-PMA T-102401-01 CT blades installed during the last overhaul were not approved for a PT6A-114 engine. The fact that the unapproved blade part number was documented in the engine maintenance logs indicated that the maintenance provider was unaware, or did not detect, that the incorrect parts were installed or that those parts were not approved for that engine.

A review of PT6A operating parameters indicated that PT6A engine variants not approved for installation of the T-102401-01 blades, (including the PT6A-114), typically exhibit maximum operating temperatures higher than the other engine variants that were approved for the PMA blades. Considering that the IN-738 alloy data indicated the T-102401-01 blades were likely to be more susceptible to thermally-induced microstructural decay than the IN-100 alloy 3102401-01 OEM blades, operation of the higher-rated, higher ITT engines with unapproved T-102401-01 CT blades could be likened to operating the engine beyond the specified maximum power settings, which, as stated in AV-2007-06, would contribute to incidents of blade creep and reduced blade life.

Overheating of the first stage planet reduction gears was the only physical evidence of engine damage resulting from interruption to the oil supply. The pilot also reported that there were no oil pressure warnings in the minutes leading up to the engine failure and that the propeller continued to rotate after the event, until feathered.

The engine manufacturer indicated that the first components to show distress due to loss of oil supply would be the first stage planet gears, which would occur after only a few seconds. This was consistent with oil supply interruption to the RGB after the initial engine failure. Final fracture of the oil pump housing therefore probably occurred due to vibrations resulting from disruption to the turbomachinery.

The engine manufacturer was not aware of any engine failure events resulting from fatigue cracking of the oil pump housing. Non-destructive inspection of pump housing was specified during overhaul and it was possible that the crack initiated after this time.

FINDINGS

Context

From the evidence available, the following findings are made with respect to the total power loss occurrence involving the Cessna 208 aircraft registered VH-UMV, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- FAA PMA T-102-401-01 compressor turbine blades that were unapproved for the PT6A-114 engine were installed during the last overhaul and the error was not detected by the maintenance service provider.

- The loss of engine power was probably brought about by failure of the compressor turbine blades.

Other safety factors

- Seizure of the reduction gearbox first stage planet gears was the result of oil starvation, precipitated by fractures of oil system components.

Other key findings

- The number-1 bearing showed evidence of electrical discharge damage but was still operational at the time of the occurrence.

SAFETY ACTION

Any safety issues identified during the conduct of an investigation are listed in the Findings and Safety Actions sections of the report. However, whereas an investigation may not identify any particular safety issues, relevant organisation(s) may proactively initiate safety action in order to further reduce their safety risk.

All of the relevant organisations identified during this investigation were given a draft report and invited to provide submissions. Although no safety issues were identified during this investigation, the following proactive safety action was submitted.

Civil Aviation Safety Authority (CASA)

As a result of this occurrence, CASA released Airworthiness Bulletin AWB 72-005, alerting all operators and maintainers of PT6A engines of the potential for installation of FAA PMA compressor turbine blades in unapproved PT6A engine variants, and to raise awareness of the restrictions placed on the use of FAA PMA blades.

CASA recommended that operators and maintainers of PT6A engines check engine maintenance logs to ensure that the compressor turbine blade part number(s) installed are correct for the engine variant according to FAA PMA approval information.

SOURCES AND SUBMISSIONS

Sources of Information

Pilot of VH-UMV

Owner of VH-UMV

Pratt and Whitney Canada

Civil Aviation Safety Authority

National Transportation Safety Board

Federal Aviation Administration

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the pilot of VH-UMV, the owner of VH-UMV, the engine manufacturer, the Civil Aviation Safety Authority, the Federal Aviation Administration and the US National Transportation Safety Board.

Responses were received from the pilot of VH-UMV, the engine manufacturer, the Civil Aviation Safety Authority, and the US National Transportation Safety Board. There were no submissions seeking amendment to the draft report.