

**NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594**

December 12, 2019

POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB ID No.: CEN17LA254

A. ACCIDENT

Location: Alpine, Texas
Date: July 3, 2017
Time: 1815 Central Daylight Time
Aircraft: Cessna 208B, Registration: N9714B

B. POWERPLANTS GROUP

Group Chairman: Harald Reichel
National Transportation Safety Board
Washington, DC

Member: Leslie Ederer
Pratt & Whitney Canada
Montreal, Quebec, Canada

Member: Andrew Hall
Textron Aviation
Wichita, Kansas

Member: Patrick Jemison
Martinaire
Addison, Texas

C. SUMMARY

On July 3, 2017, about 1815 central daylight time, a Cessna 208B airplane, N9714B, was substantially damaged during a forced landing near Alpine, Texas. The commercial pilot, who was the sole occupant, sustained minor injuries. The airplane was registered to and operated by Martinaire Aviation LLC under the provisions of 14 Code of Federal Regulations Part 135 as a cargo flight. Day visual meteorological conditions prevailed for the instrument rules (IFR) flight, which departed about 1812 from Alpine-Casparis Municipal Airport (E38), Alpine, Texas, with an intended destination of Maverick County Memorial International Airport (5T9), Eagle Pass, Texas.

While climbing through about 500 ft above ground level (AGL), the pilot heard a loud bang, followed by a squealing noise and an immediate loss of engine power. According to the pilot, he released back pressure on the flight controls, he did not move the power lever, but pulled only the propeller control to feather. During the forced landing, the right and left wings were damaged due to impact with power poles and the airplane came to rest in a field. The emergency power lever (EPL) was not used and Martinaire confirmed that the witness wire was still intact. The witness wire is broken when the EPL is activated, indicating it had been used.

The airplane was recovered and stored at Air Salvage of Dallas, in Lancaster Texas. After July 20th the engine was removed from the airframe and transported to the Pratt & Whitney Canada (PWC) facilities in St. Hubert, Quebec, Canada for examination. The teardown examination occurred on October 17-20, 2017.

D. DETAILS OF INVESTIGATION

D.1 Powerplant Information

D.1.1 Engine Description¹

The engine was a Pratt & Whitney Canada PT6A-114A which produces a takeoff power of 675 horsepower. The PT6A engine is a 2-spool turbo-shaft engine. One power turbine stage drives the propeller through a 2-stage gearbox. The gas generator consists of a compressor section, which has 3 axial, and 1 centrifugal stages driven by a single compressor turbine. The combustion chamber is a reverse-flow annular type. The constant-speed, variable pitch propeller is a single-acting type and is hydraulically controlled. The engine power management system consists of a hydro-mechanical fuel

¹ All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF) as is the convention. The direction of rotation of the engine is clockwise. All numbering in the circumferential direction starts with the No. 1 position at the 12:00 o'clock position or immediately clockwise from the 12:00 o'clock position and progresses sequentially clockwise ALF.

control unit (FCU), which governs the gas generator speed, and a propeller governor, which governs the power turbine speed.

D.1.2 Engine History & Maintenance

The accident engine was a model PT6A-114A, part number (P/N) 3044000, serial number (S/N) PCE19373 ([Photo 1](#)).

According to the Martinaire maintenance records, the engine times were:

Units	Time/Cycles	Date	Notes
Total Time Since New (TTSN)	12,426.1 hours	7/3/2017	
Cycles Since New (CSN)	14,020 cycles	7/3/2017	
Time Since Overhaul (TSO)	4,866 hours	7/3/2017	
Cycles Since Overhaul (CSO)	6899 cycles	7/3/2017	
Last Hot Section Inspection (HSI)	12,329.8 hours	12/4/2017	C/W AD2014-17-08R1
Fuel Nozzle Inspection	12,329.8 hours	12/4/2017	No anomalies noted
Previous HSI TTSN	11,776.8 hours	3/16/2016	C/W AD2014-17-08R1

Table 1 – Review of Maintenance Records for S/N PCE19373

According to Martinaire, their fleet of P&WC PT6A-114 engines have an FAA approved 8000-hour TBO. The HSI interval is on-condition, depending on trend monitoring and borescope inspection results.

The raw trend monitoring data is manually collected by Martinaire pilots during cruise and is monitored by Camp EHM Trend Group, who inform and advise Martinaire of engine health and maintenance. Camp EHM did not report any trend changes, since the last inspection interval, significant enough to alert Martinaire. Although trend monitoring has occasionally been able to detect a CT rotor in which all the blades that have significant creep, it cannot detect cracked CT blades. It cannot detect cracks in a single blade.

The last maintenance activity on the engine was a special phase 1 inspection, 400-hour inspection, done on-wing, on April 12, 2017, 96.3 hours before the accident event, under work order number 21703029. At this time, an engine hot section borescope inspection was performed in accordance with the Pratt & Whitney PT6 maintenance manual, revision 31.1, dated 02-03-2107, chapter 72-00-22, paragraph D(1), D(2) and D(3). No compressor turbine blade defects were noted in the engine log. The log states that this HSI was also intended to satisfy Airworthiness Directive (AD) 2014-17-08 R1 (e) paragraph (1)(i) and (1)(ii).

The FAA issued AD 2014-17-08 to prevent failure of CT blades, prompted by several previous incidents of compressor turbine (CT) blade failure, causing power loss, and engine failure. It stated that if an engine contained pre-SB PT6A-72-1669 turbine

blades part numbers (P/Ns) 3072791-01, 3072791-02, or 3079351-01 (IE. non single-crystal blades) as was the case in this event, compliance required a borescope inspection of the leading and trailing edges of the compressor turbine blades at recurring intervals.

Additionally, AD (e) paragraph (1)(iii) required: At the next hot section inspection (HSI) after the effective date of the AD, and each HSI thereafter, replace the complete set of CT blades with any of the following:

(A) New CT blades

(B) CT blades that have passed a two-blade metallurgical inspection, per paragraph 3.B., Accomplishment Instructions, of P&WC Service Bulletin (SB) No. PT6A-72-1669, Revision 9, dated June 28, 2013, to do the inspection; or

(C) P&WC single crystal CT blades, P/Ns 3072791-01, 3072791-02, or 3079351-01.

Replacement of the complete set of CT blades with single crystal CT blades, P/Ns 3072791-01, 3072791-02, or 3079351-01 was the terminating action for the requirements of paragraph (e)(1) of the AD.

The AD also required the replacement of the complete set of CT blades with P&WC single crystal CT blades, P/Ns 3072791-01, 3072791-02, or 3079351-01 by October 8, 2017.

D.2 Details of the Teardown Examination

D.2.1 General External Condition

The engine was received in a wooden container with many airframe accessories attached. The engine was generally intact and clean ([Photo 2](#) & [Photo 3](#)). There was minor corrosion on the aluminum and magnesium parts. There were indications of impact distress on the airframe and external components such as a fractured horse collar engine mount ([Photo 4](#)), bent oil cooler brackets, buckled starter cooling shroud. The oil scavenge lines at the exhaust duct location were bent and deformed.

An examination through the exhaust duct, revealed fractured power turbine blades with varying lengths of remaining blades ([Photo 5](#)). When the power turbine wheel was turned by hand, the propeller shaft turned in unison, which is consistent with RGB internal continuity. The RGB front flange bolts were deformed at the 3 o'clock position, which corresponded to the location of the oil cooler mount brackets.

An examination of the oil dip stick revealed that there was no oil remaining in the tank, consistent with its draining in preparation for transport. Oil was seen to exit various ports during the disassembly of the engine.

One ignitor cable was not attached to the ignitor plug, additionally, there was no lockwire on the connection. It was reported that this cable was not attached to the plug during the post-accident examination of the wreckage.

The pneumatic (Px) lines to the FCU, propeller governor (PCU) or constant speed unit (CSU) and torque limiter were tight and secured with safety wire. The P3 filter was dry and clean ([Photo 6](#)). The propeller reversing linkage forward link and carbon block assembly were not received. The PCU was intact and undamaged.

The accessory gearbox (AGB) was intact and undamaged. The fuel control unit (FCU) housing was fractured at approximately 1½ inches from the mount flange, exposing the internal flyweight components ([Photo 7](#)). The compressor could be turned with some hand effort, revealing a small internal resistance, however, a corresponding rotation was seen on the oil pump and starter spline, consistent with mechanical continuity of the AGB gearshafts.

Examination of the RGB and AGB chip detectors revealed only a small amount of fine magnetic material ([Photo 8](#)).

Examination of the oil filter indicated that it was oil wetted and contained a small amount of soft non-magnetic material ([Photo 9](#)). The debris was sent to the P&WC materials laboratory where the particles were identified as a magnesium alloy.

D.2.2 Reduction Gearbox (RGB)

The RGB housing and propeller shaft were intact. The propeller could easily be rotated by hand and corresponding rotation of the power turbine was observed, consistent with mechanical continuity and integrity within the RGB. The propeller governor was in place, intact and undamaged.

The RGB was not disassembled any further.

D.2.3 Power Section

The 'C' flange (the flange joining the power and the gas generator sections) was split, and the power section module was removed with normal effort.

D.2.3.1 Power Turbine (PT) Blades

The PT blades were all present, but fractured, with varying lengths of blade span remaining ([Photo 10](#)). A visual examination of the fracture surfaces revealed evidence of only overload at the ends of the remaining blades. The power turbine wheel was sent to the P&WC laboratory for detailed analysis. The P&WC material laboratory report stated that no evidence of fatigue was found, confirmed the teardown findings.

D.2.3.2 Power Turbine Vane Ring (PTVR)

The PTVR was identified as P/N ASSY: 3024862, S/N 012048, CL12.99, W/O 0296R13, STI 72-50-4962 R00, was intact but battered in various locations. There were 11 thumbnail sized fractures at the leading and trailing edges with associated missing material ([Photo 11](#)). Additionally, there was one through hole, approximately 0.100 inches diameter, near the trailing edge. According to P&WC, this was a PMA part ([Photo 12](#)), not an original equipment manufacturer (OEM) part.

D.2.4 Combustor Section

D.2.4.1 Combustor

The combustion chamber liner was intact and undamaged and therefore not removed from the combustor housing ([Photo 13](#)). The inner and outer exit ducts were intact and undamaged.

D.2.4.2 Fuel Nozzles

Despite not being near them, fuel nozzles are an important engine component that can affect the life of the CT blades. Flow rates that are too high or too low can affect the one-per-rev vibration amplitude on the CT blades and cause premature cracking.

The fuel 14 nozzles were removed and functionally tested. The report indicated that most nozzles were found to be moderately streaky. Nine consecutive nozzles displayed a slightly low flow rate. No conclusions could be made concerning the fuel nozzle conditions that would have affected the condition of the turbine blades.

D.2.5 Compressor Section

D.2.5.1 Compressor

The forward conical section of the compressor housing was torque buckled and fractured, ([Photo 14](#)) which is consistent with a sudden stoppage of the compressor turbine. Initially, the compressor could only be rotated with some effort. After the hot section was removed, the compressor could be rotated with light normal effort. Rotation of the compressor also revealed a corresponding rotation of the accessory gearbox starter spline, indicating mechanical continuity with the accessory gearbox gearshafts. An in-situ examination of the 1st stage compressor rotor blades, revealing no significant foreign object damage.

The compressor was not disassembled or examined further.

D.2.5.2 Compressor Turbine Vane Ring (CTVR) and CT Shrouds

There were four locations on the CT shroud, of deep impact marks, consistent with a blade release. The remaining surfaces of the CT shrouds were heavily battered, consistent with contact against smaller fragments ([Photo 15](#)).

The CTVR was P/N 3029051 and the S/N was unreadable. An additional identification number, 13-769 0531R13 was vibro-peened on the part. According to P&WC, this was not an OEM part. Records from Martinaire were insufficient to ascertain the origin of the CTVR.

A visual examination of the CTVR revealed dimensional differences that did not conform to an OEM part. The vane cooling air exit slots differed in shape and size from an exemplar P&WC vane ([Photo 16](#)). The vane sealing plates welding differ from the P&WC vane ([Photo 17](#)). Additionally, upon visual examination the axial locations of the vane trailing edges, which should all be on the same plane, appeared to be staggered. A hand measurement between the rear mount plane to the aft position of the trailing edge using a depth gauge indicated that they varied by approximately 0.03 inches ([Photo 18](#)). When a new OEM exemplar CVTR was examined, no variation of the vanes axial position could be observed. A variation of the axial stagger of the compressor turbine vanes would induce a flow variation to the CT blades, thereby increasing their one-per-rev vibration amplitude. It is unknown how large an effect on CT blade longevity this variation would have on pre-SB1669 blades. Because the event CTVR was damaged, it could not be tested.

D.2.5.3 Compressor Disk and Blades

The compressor turbine blades were all present, but fractured, at varying heights ([Photo 19](#)). They were original P&WC parts. A visual inspection of the fracture surfaces of the CT blades revealed only evidence of overload.

The last CT borescope blade inspection, was performed at the phase 1 inspection on April 12, 2017, 96.3 hours prior to this event (See [Table 1](#)) and no defects were reported by the inspector. The video recording of the inspection was reviewed by the team on Oct. 18, 2017 and an anomaly in one the CT blade, not previously noted at the time of the inspection, was now observed. Still images of the video which revealed that one blade was cracked at the time of the hot section borescope inspection were recorded ([Figure 1](#)). The technician who performed the task stated that during the borescope inspection, he was paying attention to the tip clearance of the blades and did not notice the cracks.



Figure 1 - Still of Inspection Video Taken on April 12, 2017 – Training Edge Crack

Martinaire counselled the inspector on Oct. 18, 2017 and began an internal process to review past video recordings of all recent CT blade borescope inspections. No adverse blade conditions were discovered from this review. They also reviewed their inspection process and will make changes to prevent future occurrences.

All the blades were sent to the P&WC laboratory for detailed analysis. A total of 11 blades were identified with P/N 3045741-01C with the remaining blades showing P/N 3045741-01A. The latter blades exhibited significant hot corrosion (blistering) along the leading-edge platform (Figure 2).

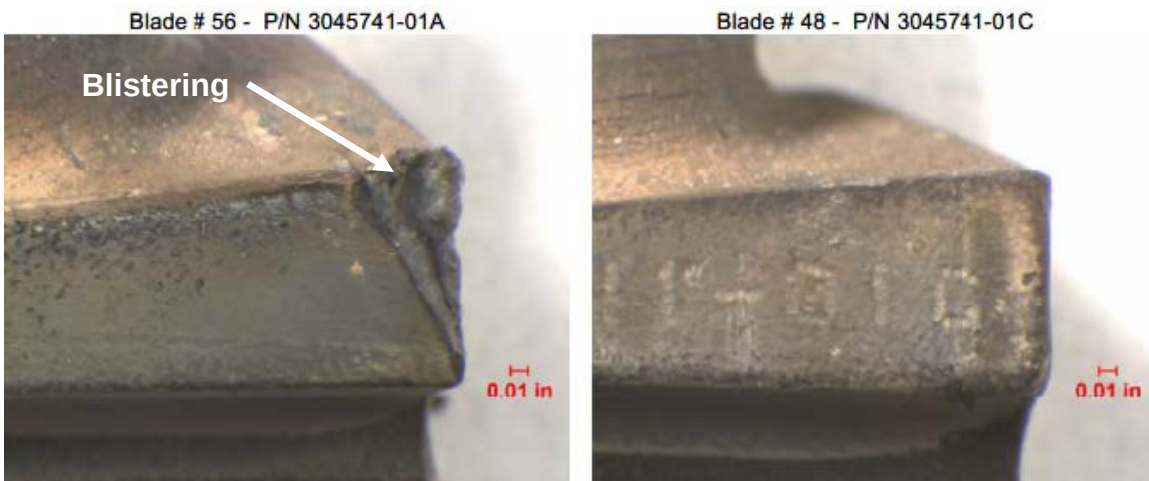


Figure 2 – Differences between Leading Edge Platforms of -01A & -01C blades

The fracture surfaces of all the blades showed exposure to elevated temperatures, causing the coating of some blades to delaminate from the base material (Figure 3).

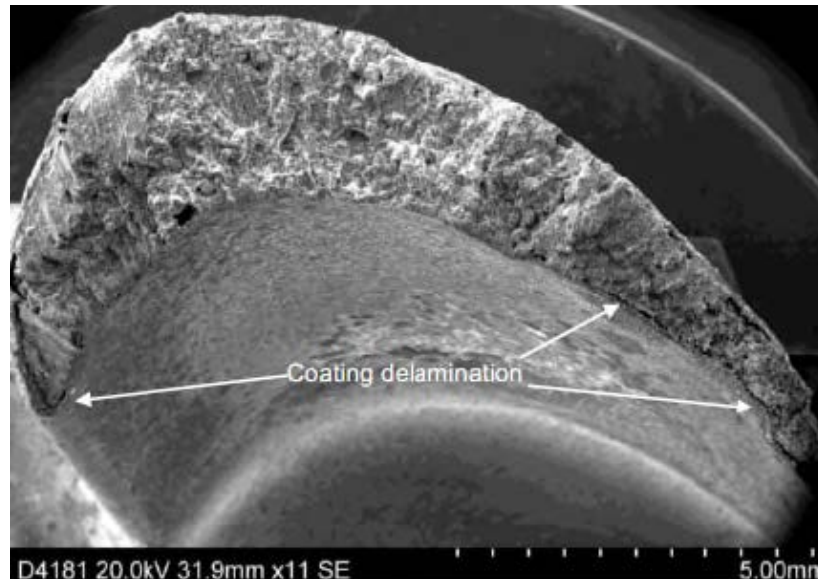


Figure 3 – Delamination of Coating from Base Material

A cross-section through the airfoil span-axis of the trailing edges of four CT blades showed similar results as shown in Figure 4. The findings were:

- 1) The root microstructure used for comparison of the microstructure in the remnant of the airfoil, consisted of unaltered cuboidal gamma prime precipitates.
- 2) At 2 mm above the root platform no significant alteration of the microstructure was observed.
- 3) At 5 mm above the root platform partial solutioning of the gamma prime precipitates was observed.
- 4) At 9 mm above the root platform, the microstructure, in the region of the micro voids, shows a partial to complete solutioning of the gamma prime precipitates. Micro-voids along grain boundaries oriented perpendicular to the axis of stress, indicative of creep².
- 5) The region next to the fracture showed complete solutioning of the gamma prime precipitates.

² Creep is the tendency of a solid material to deform permanently under the influence of long-term mechanical stress that are still below the yield strength of the material and is more severe in materials that are subjected to heat for long periods. Creep is more severe and generally increases as they near their melting point.

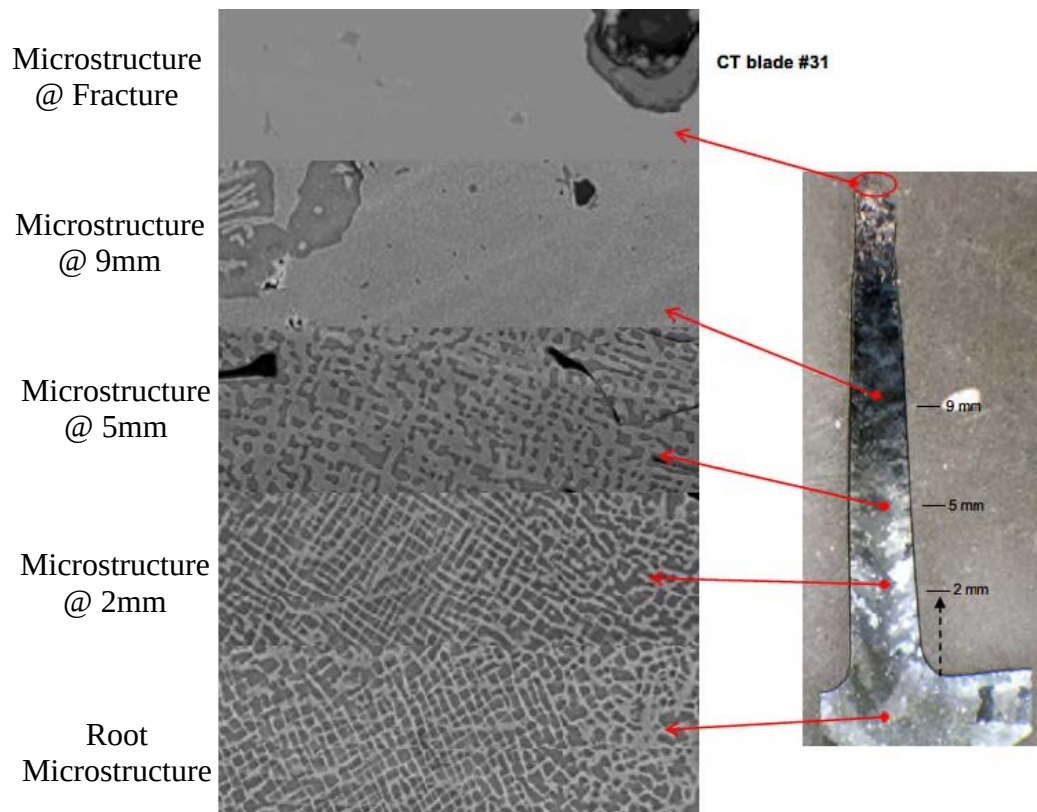


Figure 4 – Typical Cross Section Results from Four Sample CT Blades

In a new CT blade or in one that is operated under normal conditions, the microstructure of the entire blade is the same as that in the root. As the blade is in operation, creep will slowly accumulate along the blade in a slow, consistent, and understood manner, causing a permanent stretch. Maintenance inspection at prescribed intervals, such as HSI, will identify stretched blades by simple measurement and those blades that have reached the creep limit must be removed from service. Additional blade inspections required by P&WC and the FAA AD include a materials lab section and inspection of two sample blades from a set being inspected that identifies creep and microstructure anomalies that result from time in service or over temperature operation.

The CT blade condition seen in Figure 4, is consistent with having been operated above operational limits for an extended period.

The CT blade condition seen in Figure 2, is consistent having been installed in a blistered condition during the last CT repair. Hours in operation are not tracked on CT blades; they are inspected and returned to service if they are in good condition. The 47 P/N 3045741-01A CT blades were possibly marginally serviceable at the last overhaul.

D.2.6 Accessory Gearbox (AGB)

The accessory gearbox (AGB) was intact and undamaged. It was split at the 'G' flange, revealing an intact and undamaged gear train. It was not further disassembled.

D.2.7 Controls and External Accessories

D.2.7.1 Fuel Control Unit (FCU)

The FCU, a Honeywell unit P/N 3244809-7, S/N B10280, was brought to the P&WC fuel lab for disassembly and examination. It could not be functionally tested because the drive body was fractured ([Photo 20](#)).

When removed from the fuel pump, the polymeric coupling was found sheared ([Photo 21](#)), consistent with a sudden stoppage of the compressor shaft.

The Py and Px cavities, which pass pneumatic feedback airflow from the engine and the propeller governor to the FCU were inspected and were found to be clear of debris.

The bypass valve diaphragm was marked 1Q08 indicating that it had been manufactured in the 1st quarter of 2008 and was not within the 6-year life limit recommended by Honeywell at the time of the event. The rubber of the diaphragm was pliable and there were no leak-paths visible.

The governor lever was bent ([Photo 22](#)), consistent with impact. The flyweights turned smoothly, and the flyweight driveshaft was intact and undamaged. All internal bearings were undamaged and rotated freely. The ratio levers and torque tube were intact and undamaged ([Photo 23](#)).

The acceleration bellows length was 0.13 inches from nominal or 0.07 above the allowable maximum. An analysis of the bellows by the P&WC engine control clinic confirmed that the acceleration and governing bellows were not leaking. The torque tube was tested and confirmed to have no leaks.

D.2.7.2 Fuel Pump

The fuel pump was sessile to the FCU and was separated. The exterior of the fuel pump was dirty, and brown staining was present at the drive shaft cavity ([Photo 24](#)). Lockwire was present at all locations. The outlet filter element was inspected revealing a brown dust in the fuel residue, but no significant debris was found in the outlet filter element.

D.3 Findings

- 1) The last HSI inspection did not capture the cracks in the trailing edges of some CT blades. Had they been found; the CT rotor would have been removed and the blades replaced.
- 2) The material analysis of the blades confirmed extreme operational overtemperature conditions in the blades.
- 3) The material analysis confirmed significant creep in the micro-structure of the CT blades, consistent with imminent cracking probability.
- 4) Different blistering patterns on the blade leading edge platforms implies that the blades that displayed platform blistering were not properly inspected and repaired during the last overhaul.
- 5) Because CT blades are not serialized, they can be overhauled and re-used until an inspection limit is reached. Their operational hours cannot be determined.
- 6) The last fuel nozzle replacement time could not be determined from the Martinaire records supplied. Several sequential nozzles were found to be flowing low, but it could not be determined how much they contributed to the crack initiation of the CT blades.
- 7) The CTVR was a PMA part and had features that were significantly different to the OEM part. The cooling air ducts were a different size than the OEM; however, it could not be determined if the cooling air performance was compromised. The vane axial positioning likely increased the vibrational loads on the CT blades, but it could not be determined how much they contributed to the crack initiation of the CT blades.

Harald Reichel
Aerospace Engineer – Powerplants

Photo 1 – PT6A-114A Engine S/N PCE-19373 – Data Plate

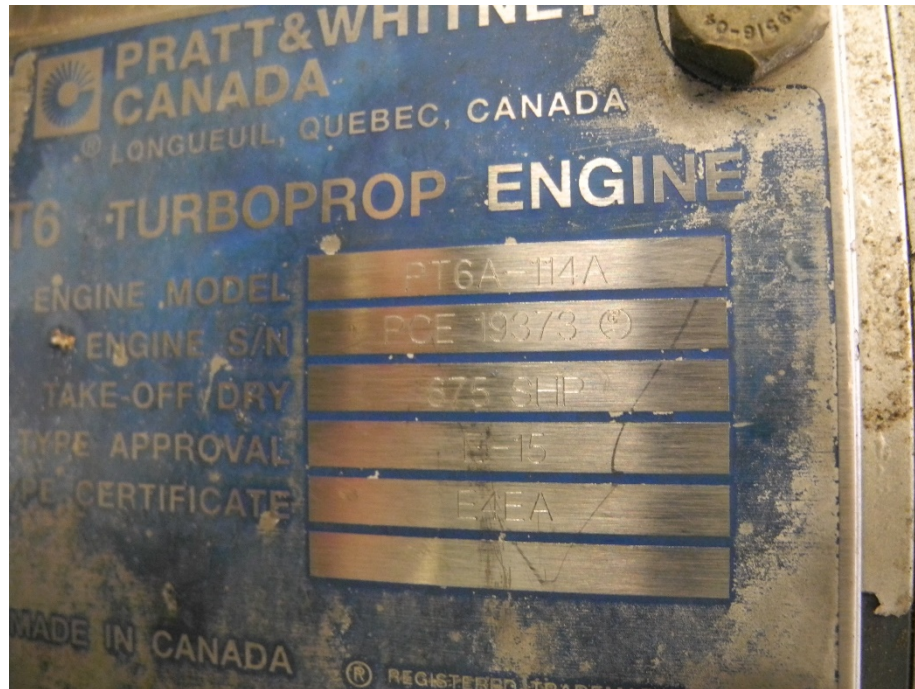


Photo 2 – PT6A-114A Engine S/N PCE-19373 – Right Front View



Photo 3 – PT6A-114A Engine S/N PCE-19373 – Right Aft View



Photo 4 – Engine Top View - Fractured Airframe Horse Collar

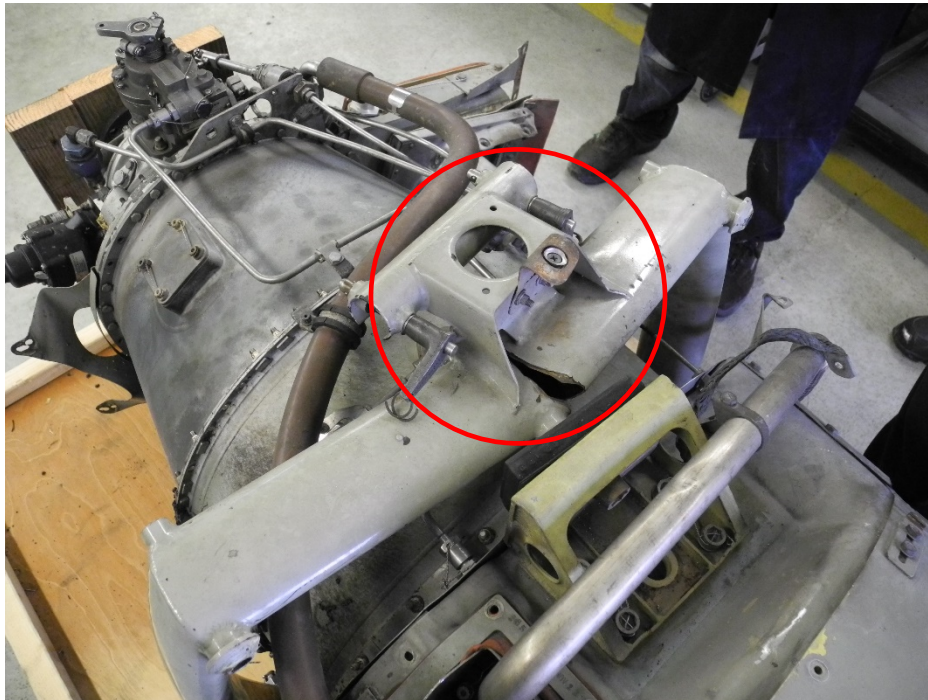


Photo 5 – Power Turbine Blades - Fractured



Photo 6 – P3 Filter and Housing - Clean



Photo 7 – Fuel Control Unit – Fractured



Photo 8 – Chip Detectors - Clean



Photo 9 – Oil Filter



Photo 10 – Power Turbine – Upstream View



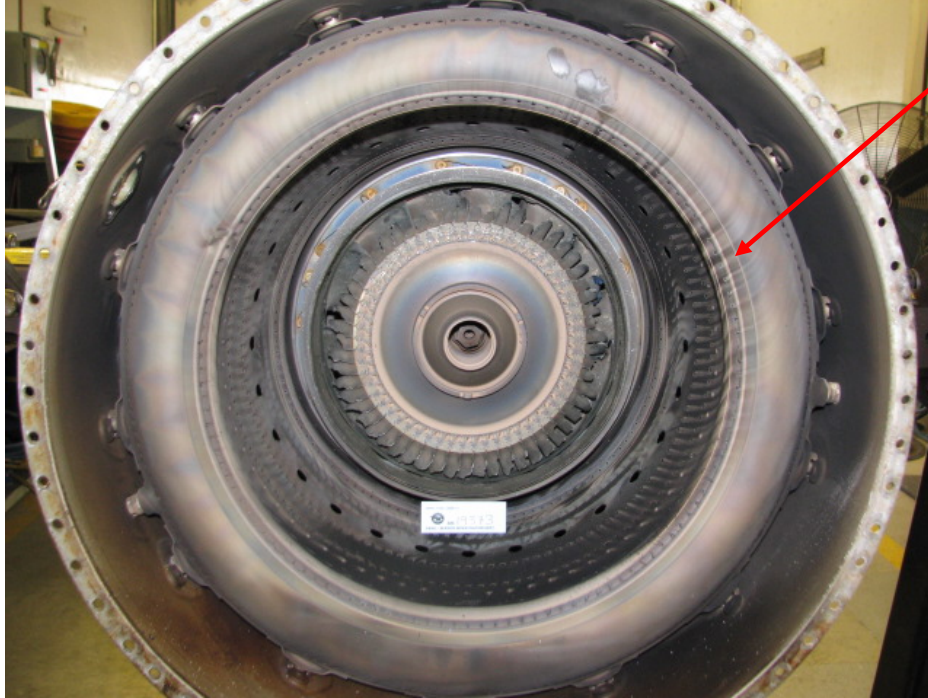
Photo 11 – Power Turbine Vane Ring – Trailing Edge Damage



Photo 12 – Power Turbine Vane Ring - Markings

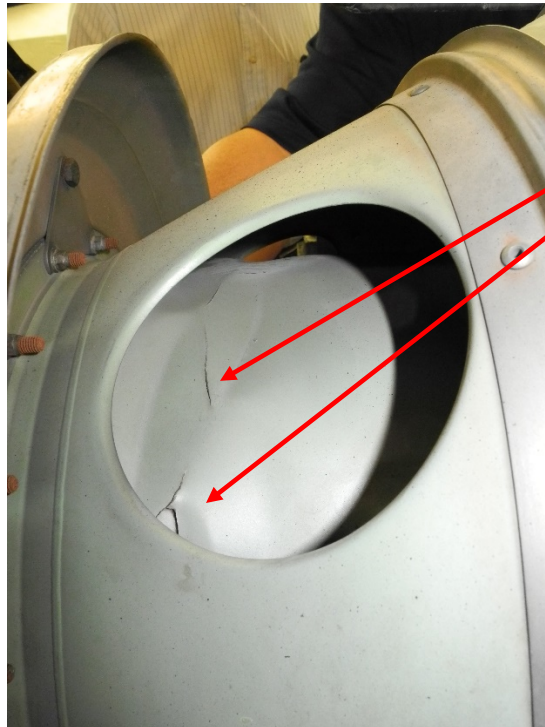


Photo 13 – Combustor Liner in Housing



Combustion
Chamber
Liner

Photo 14 – Compressor Housing – Torque Buckled



Torque buckles
and fractures

Photo 15 - CT Blade Shrouds

General
Battering Marks

Deep Impact
Mark



Photo 16 – Event CTVR vs OEM Cooling Air Exit Slots

CTVR Cooling
Air Exit Slots

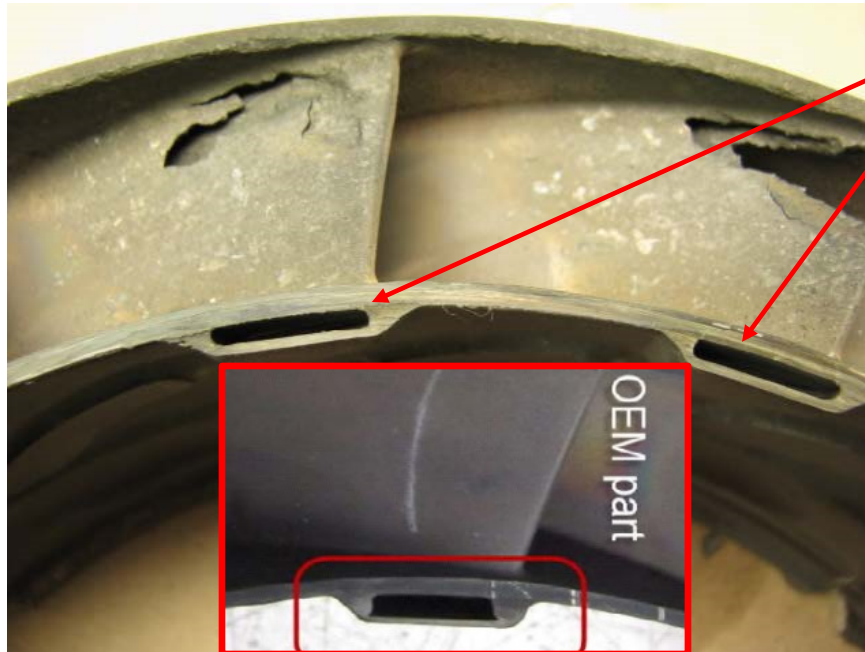


Photo 17 – Event CTVR vs OEM Vane Sealing Plates Welds



Photo 18 – Event CTVR Axial Stagger of Vanes Depicted

Dimension
Measured

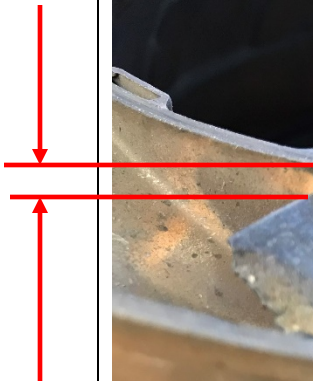


Photo 19 – Compressor Turbine Blades

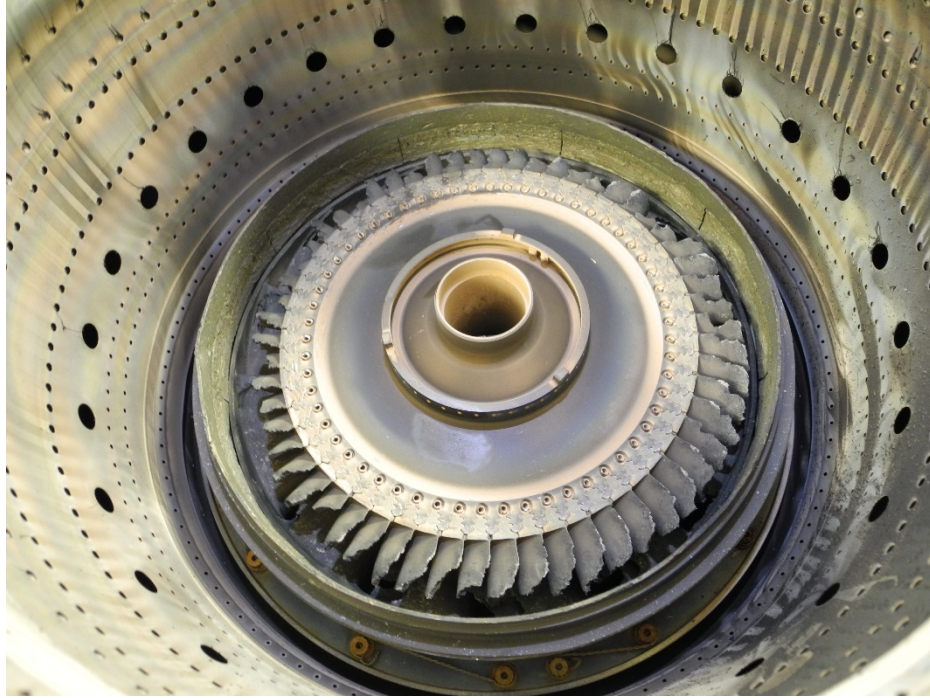


Photo 20 – FCU – Fractured Drive Body

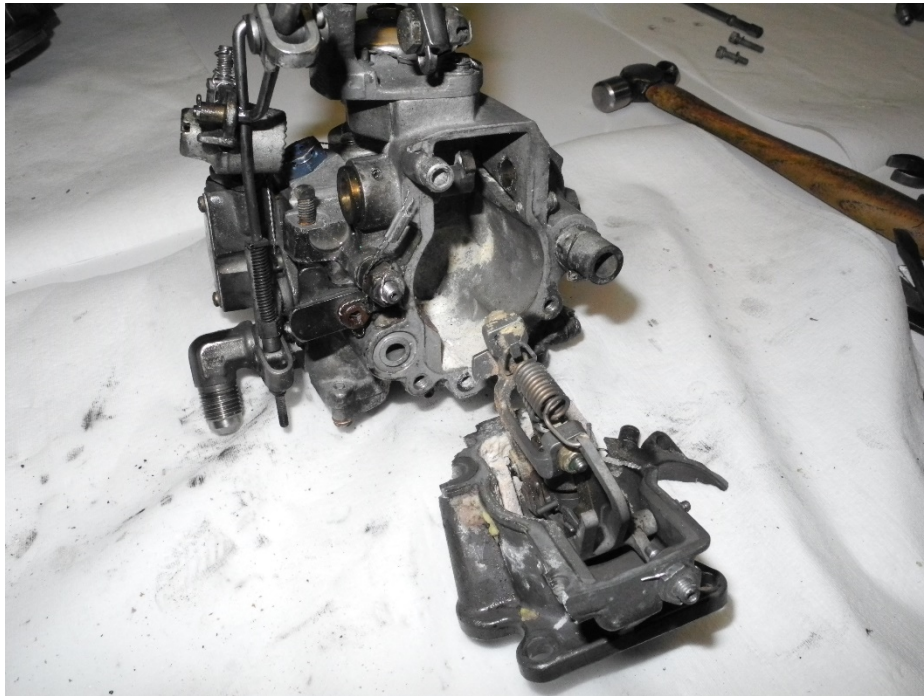
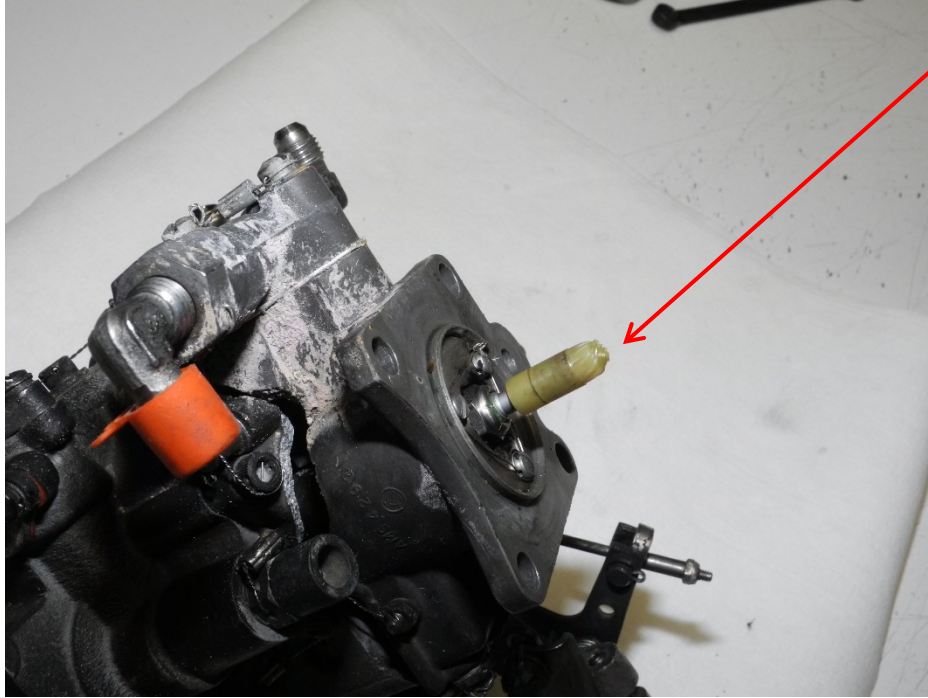


Photo 21 – FCU Polymeric Coupling - Sheared



Sheared
Coupling

Photo 22 – FCU - Governor Lever - Bent

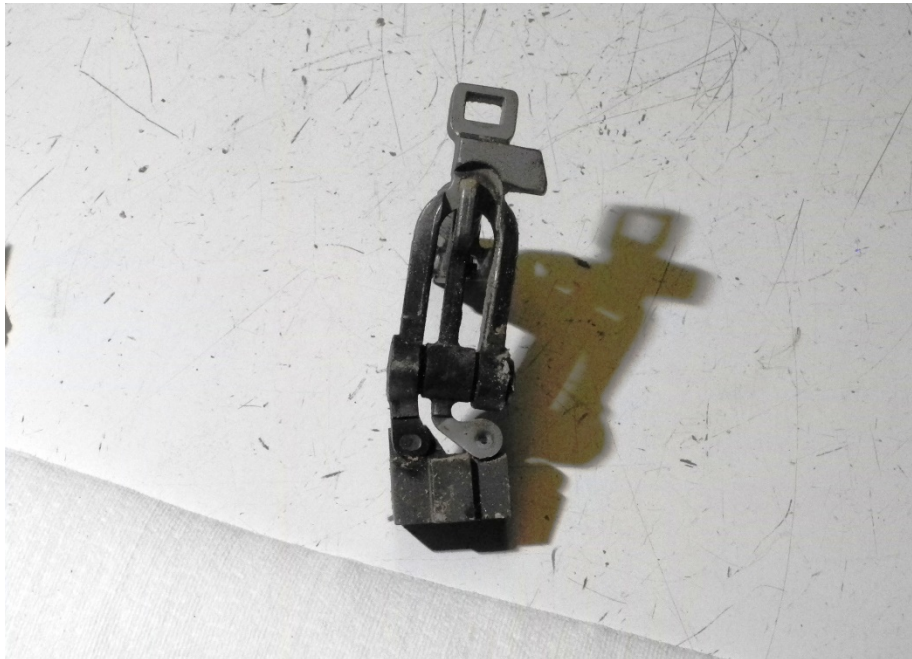


Photo 23 – FCU Ratio Levers and Torque Tube - Undamaged



Photo 24 – Fuel Pump

