

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



CEN22LA312

POWERPLANTS

Group Chair's Factual Report

October 25, 2023

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A. ACCIDENT

Location: Decatur, Illinois
Date: July 11, 2022
Time: 0630 central daylight time
1130 Universal Coordinated Time
Airplane: Air Tractor AT-502B, N5850R

B. POWERPLANTS GROUP

Group Chair Robert Hunsberger
National Transportation Safety Board
Washington, DC

Technical Advisor Mike Hodge
(Canada) Pratt & Whitney Canada
Bridgeport, West Virginia

C. SUMMARY

On July 11, 2022, about 0630 central daylight time, an Air Tractor AT-502B, N5850R, was substantially damaged when it was involved in an accident at Decatur Airport (DEC), Decatur, Illinois. The pilot was not injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 137 agricultural flight.

The accident engine was shipped to Pratt & Whitney Canada (PWC) in Bridgeport, West Virginia for examination and disassembly. Investigation party members from Pratt & Whitney Canada, and the National Transportation Safety Board completed the teardown examination from January 11-12, 2023.

The engine teardown examination revealed that all compressor turbine (CT) rotor blades were fractured at the midspan. The power turbine (PT) rotor blades immediately downstream of the CT exhibited impact damage and were fractured at varying spanwise locations. Circumferential rub was observed on multiple components, most notably the PT vane ring, consistent with engine rotation at impact.

The CT rotor blades were removed and shipped to the PWC Materials Laboratory in Longueuil, Québec, Canada for materials analysis. A microstructure analysis of sampled blades identified alloy solutioning consistent with exposure to temperatures in excess of engine operating limits. A scanning electron microscope

analysis of the compressor turbine blades revealed micro-voids along the material grain boundaries, indicative of creep.

The fuel control unit (FCU) was bench tested and partially disassembled. Multiple test points were outside of the maintenance manual limits but were within the expected range of permissible field adjustment. The fuel nozzles were visually examined and tested and although there were minor spray pattern irregularities noted, they were consistent with other fuel nozzles with similar operating history. There were no issues identified during the FCU or fuel nozzle testing that would have precluded normal engine operation.

D. DETAILS OF THE INVESTIGATION

1.0 Engine Information

1.1 Engine Description

The PWC PT6A-34AG is a reverse flow turboprop engine featuring a three-stage axial compressor, a single-stage centrifugal compressor, an annular combustion chamber, a single-stage compressor turbine, a single-stage independent power turbine, and a hydromechanical fuel control (**Figure 1**). According to the FAA type certificate data sheet E4EA, Revision 28, July 17, 2020, the engine has a takeoff dry power rating of 750 shaft horsepower¹.

¹ The engine ratings are based on static sea level condition 29.92 in Hg pressure, compressor intake screen installed, no external accessory loads and no air bleed.

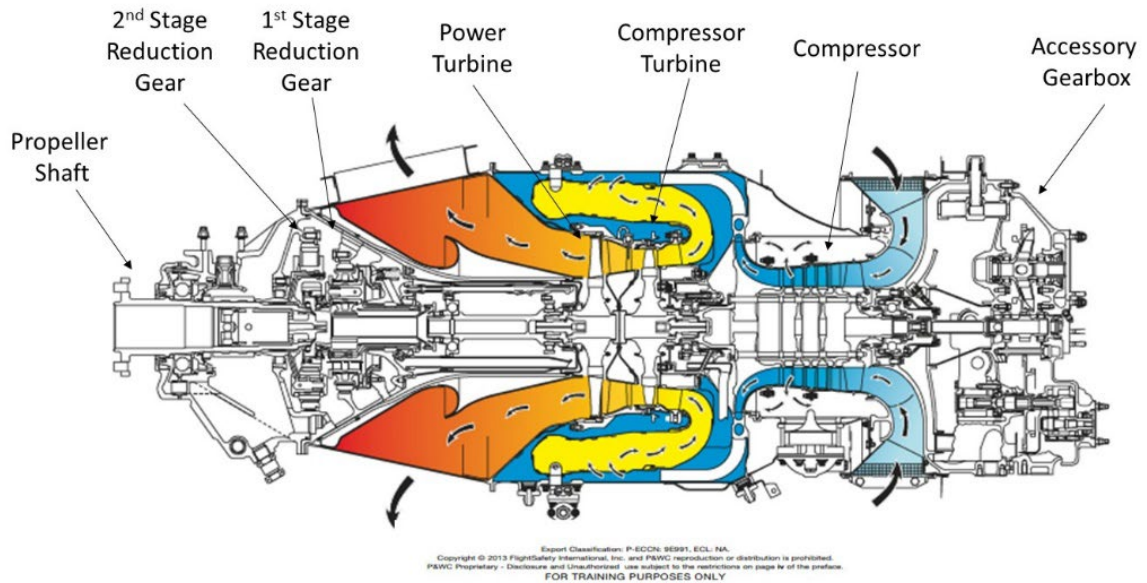


Figure 1- Pratt & Whitney Canada PT6-30 Series Engine

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF).

1.2 Engine Operating History and Maintenance

According to NTSB Form 6120.1 Pilot/Operator Aircraft Accident/Incident Report, the engine had accumulated 5,975 hours time since new (TSN) at the time of the accident. The last routine engine related annual inspection/maintenance was performed on November 16, 2021, at which time the engine had accumulated 5,924.0 hours TSN (**Photo 1**).

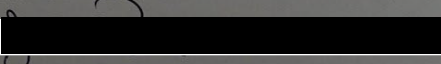
Date: November 16, 2021 Tail Number N5850R Aircraft AT-502B Serial number 502B-0685 Aircraft total time 5924.0 hours total time (Hobbs meter)	Engine
1. Performed annual inspection in accordance with Air Tractor Publications. 2. Cleaned engine oil filter, replaced engine fuel filter, cleaned airframe fuel filter. (Note: No anomalies noted in any filters) 3. Lubricated propeller. 4. Checked engine chip detector. 5. Checked igniter plugs. 6. Checked P3 filter. 7. Drained and reserviced engine oil with 8 quarts of Exxon 2380 oil. 8. Replaced fuel nozzles with overhauled exchange kit provided by Covington Engine Repair. (See documentation on file for part number and serial numbers) 9. Checked engine mount torque. 10. Replaced fuel differential pressure sensor. 11. Checked Air filter differential pressure sensor. 12. Replaced air filters with two new P/N P182043.	
Researched all AD's and find this aircraft to be in compliance with all applicable to it to this date. This aircraft is returned to service for the work performed this date.	
Signature	

Photo 1- November 2021 Engine Logbook Entry

An engine hot section inspection (HSI) was completed on December 14, 2018, at Dallas Airmotive in Chesterfield, Missouri. As part of the HSI, the compressor turbine (CT) rotor blades were inspected. Fifty-seven (57) CT blades were removed, inspected, and reinstalled and 1 blade was replaced. The engine had 4,770.2 hours TSN when the HSI was completed. A copy of the FAA Form 8130-3 Airworthiness Approval Tag is shown below in **Photo 2**.

1. Approving Civil Aviation Authority/Country FAA/United States		2. AUTHORIZED RELEASE CERTIFICATE FAA Form 8130-3, AIRWORTHINESS APPROVAL TAG			3. Form Tracking Number: RPR50941	
4. Organization Name and Address  DallasAirmotive Airmotive company		Dallas Airmotive, Inc. 567 Bell #100 Spirit of St. Louis Airport Chesterfield, MO 63005-3602 Certificate Number: YRR7491L			5. Work Order/Contract/Invoice Number: RPR50941	
6. Item	7. Description	8. Part Number	9. Quantity	10. Serial Number	11. Status/Work	
1	C.T. DISK ASSY.	3013411	1	A001E2WT	REPAIRED	
12. Remarks TT: 4770.2 TSO: N/A CSN: 2454 CSO: N/A DE-BLADED DISK TO PERFORM S.B. 1303R13. PERFORMED 5060HR STRECH CHECK AND NDT INSPECTION ON 57EA. CT BLADES P/N 3120751-01. PERFORMED CT OVERTEMP INSPECTION 1EA. CT BLADES P/N 3120751-01. INSTALLED 1EA. FN CT BLADE P/N 3120751-01. INSTALLED 58EA. FN CT REVITS P/N 3018240. TRUED AND BALANCED C.T. DISK ASSY. ENGINE S/N PCE-PH0288 ALL WORK PERFORMED AS PER PRATT & WHITNEY OHM P/N 3021243 REV. 45 DATED 08/OCT/2018 AND OTHER DATA AND METHODS ACCEPTABLE TO THE ADMINISTRATOR.						
13a. Certifies the items identified above were manufactured in conformity to: ☐ Approved design data and are in a condition for safe operation ☐ Non-approved design data specified in Block 12			14a. ☒ 14 CFR 43.9 Return to Service ☐ Other regulation specified in Block 12 Certifies that unless otherwise specified in Block 12, the work identified in Block 11 and described in Block 12 was accomplished in accordance with Title 14, Code of Federal Regulations, part 43 and in respect to that work, the items are approved for return to service.			
13b. Authorized Signature:		13c. Approval/Authorization No.:		14b. Authorized Signature:		14c. Approval/Certificate No.: 
13d. Name (Typed or Printed):		13e. Date:		14d. Name (Typed or Printed): 		14e. Date (dd-mm-yyyy) 14-Dec-2018
User/Installer Responsibilities It is important to understand that the existence of this document alone does not automatically constitute authority to install the part/component/assembly. Where the user/installer performs work in accordance with the national regulations of an airworthiness authority different than the airworthiness authority of the country specified in Block 1, it is essential that the user/installer ensures that his/her airworthiness authority accepts parts/components/assemblies from the airworthiness authority of the country specified in Block 1. Statements in Blocks 13a and 14a do not constitute installation certification. In all cases, aircraft maintenance records must contain an installation certification issued in accordance with the national regulations by the user/installer before the aircraft may be flown.						
FAA Form 8130-3 (02-14)				NSN: 0052-00-012-9005		

Photo 2- FAA 8130-3 Form Following Hot Section Inspection- December 2018

2.0 ESN PCE-PH0288 Examination and Disassembly

2.1 Visual Examination

The engine was secured in a banded cardboard shipping container when the investigation team arrived at PWC-Bridgeport, West Virginia (**Photo 3**). There was no evidence of engine fire damage or radial uncontainment (**Photos 4, 5, and 6**). The exhaust case had deformation around the engine circumference. Loose metal fragments were collected in the exhaust duct at the 6 o'clock position aft of the PT blades (**Photo 7**). All PT rotor blades were broken at varying spanwise locations.



Photo 3- Engine Shipping Container, as Received



Photo 4- Engine, Left Side, as Received



Photo 5- Engine, Right Side, as Received



Photo 6- Engine Data Plate



Photo 7- Metal Fragments Collected in Exhaust Duct

The rigging connections between the FCU, cam box assembly, and constant speed unit (CSU) were secure and unremarkable. The Py² line and P3³ line fittings were torqued. The beta plunger retracted and extended smoothly when moved by hand. All engine accessory components were covered in dirt/earthen debris but appeared intact.

The Ng⁴ spool was seized and could not be rotated through the accessory gearbox (AGB). The PT was also seized and could not be rotated by hand. The AGB magnetic chip detector was free of debris accumulation. There was no debris in the oil filter and the residual oil in the filter pleats smelled normal (**Photo 8**). The oil drained from the AGB, reduction gearbox (RGB), and oil tank were filtered and a small amount of fine debris was observed.

² The Py line is a pneumatic pressure air line between the Nf (propeller governor) and the FCU used for overspeed control. In the event of an overspeed, the prop governor can bleed Py pressure. The reduction in Py line pressure moves the FCU metering valve in the closed direction and reduces fuel flow.

³ P3 is compressor discharge pressure.

⁴ The Ng spool is comprised of the compressor and compressor turbine.



Photo 8- (L) Magnetic Chip Detector, (R) Oil Filter

2.2 Power Section

The PT vane ring baffle had circumferential rub around the outer diameter, center bore lip, and on the center bore of the vane ring (**Photo 9**). Coincidental rubs were present on the aft side of the CT rotor disk. As noted during the visual inspection, all PT rotor blades were broken at varying spanwise locations. When the PT vane ring was separated there was circumferential rub and impact damage between the suction side of the PT vane and the forward face of the PT rotor disk (**Photo 10**).

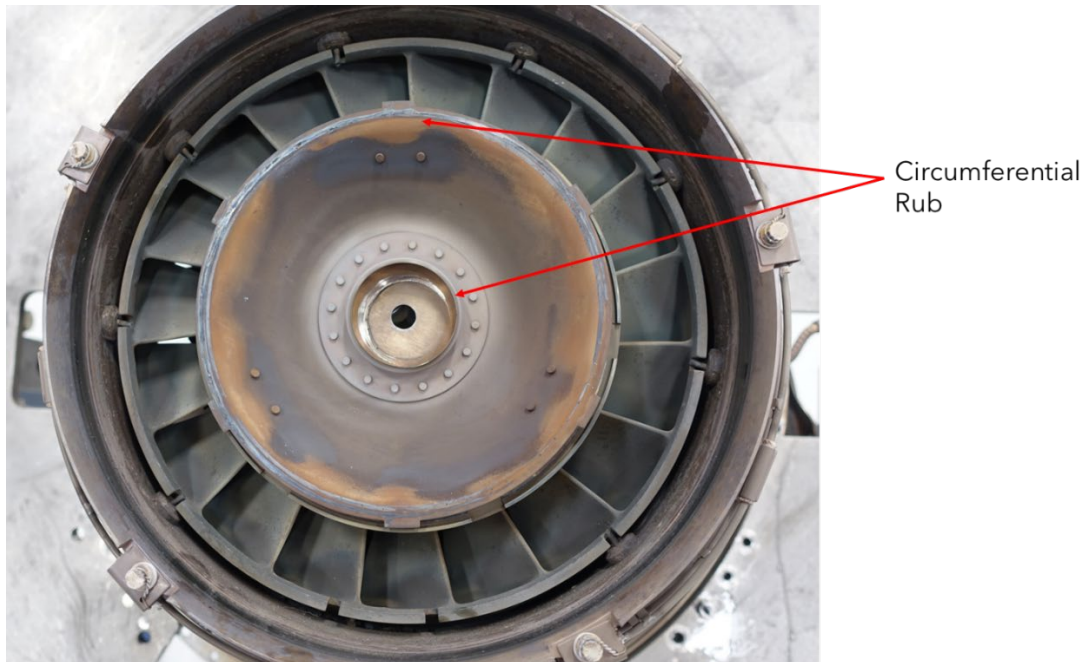


Photo 9- PT Vane Ring, Pressure Side with Circumferential Rub Indications

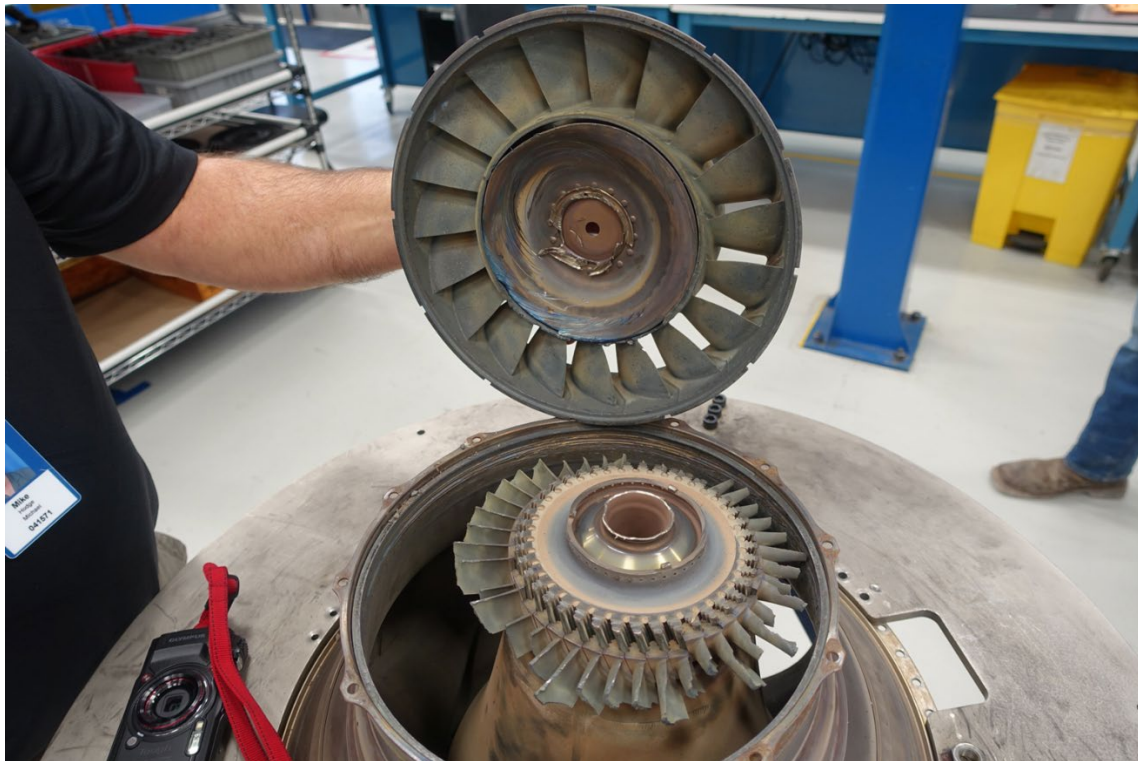


Photo 10- PT Vane, Suction Side and PT Rotor, Leading Edge

Following removal of the PT rotor, the propeller flange could be rotated by hand and continuity through the RGB was confirmed. The RGB was not further disassembled because there were no indications of internal damage.

2.3 Gas Generator and Combustor

The CT rotor blades were all fractured at varying spanwise locations. The remaining CT blade stubs exhibited impact damage and were discolored/gray (**Photos 11 and 12**). A shim check was performed in accordance with the engine overhaul manual⁵ to measure the gap between the blade platforms in the disk (**Figure 2**). The CT blade shroud had 360 degree impact damage and gouging.



Photo 11- CT Rotor, Trailing Edge, and Combustion Liner

⁵ According to the EOM the gap between the CT blade platforms should be between 0.003 and 0.005."

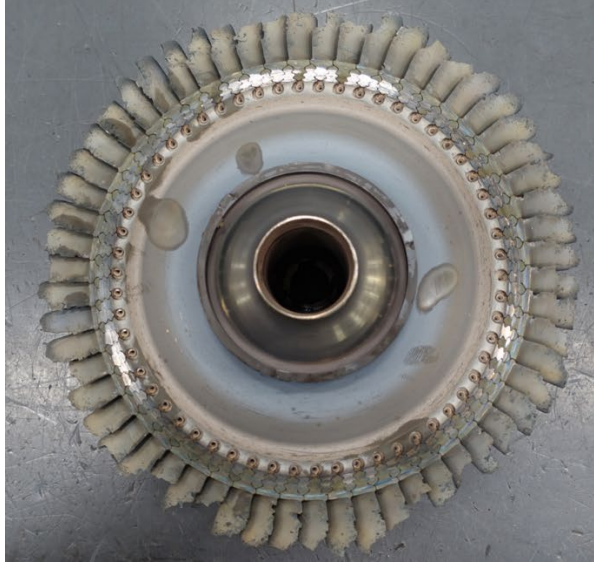


Photo 12- CT Rotor Blades, Trailing Edge, (R) CT Blade Fracture Surfaces

DISASSEMBLY HISTORY SHEET

DHS - 500997 SALES ORDER NO: 232442 Page 10 of 11

CT Blade Platform Gap PH0288 Inspector Done By

~~CONFIDENTIAL - NEW PROGRAM~~

BLADE POSITION	SHIFT (INCH)	BLADE POSITION	SHIFT (INCH)
1	.003	33	.004
2	.004	34	.006
3	.005	35	.004
4	.006	36	.004
5	.004	37	.004
6	.004	38	.005
7	.004	39	.003
8	.004	40	.004
9	.004	41	.004
10	.005	42	.006
11	.003	43	.004
12	.007	44	.004
13	.004	45	.0025
14	.004	46	.006
15	.004	47	.004
16	.004	48	.005
17	.004	49	.005
18	.004	50	.004
19	.007	51	.002
20	.004	52	.0045
21	.005	53	.003
22	.004	54	.003
23	.004	55	.004
24	.004	56	.004
25	.005	57	.006
26	.003	58	.004
27	.003	59	
28	.0065	60	
29	.0015	61	
30	.007	62	
31	.004	63	
32	.004	64	

Figure 2- CT Rotor Blade Gap Check

The CT vane ring airfoils were all impact damaged and missing material, most concentrated along the trailing edge outer diameter (**Photo 13**). The remaining vane airfoils exhibited minor thermal discoloration. The CT vane lugs on

the No. 2 bearing cover plate were all fractured and coincidental impact marks were observed on the inner diameter of the CT vane assembly on the pressure/forward side (**Photo 14**).



Photo 13- CT Vane Ring, Suction Side

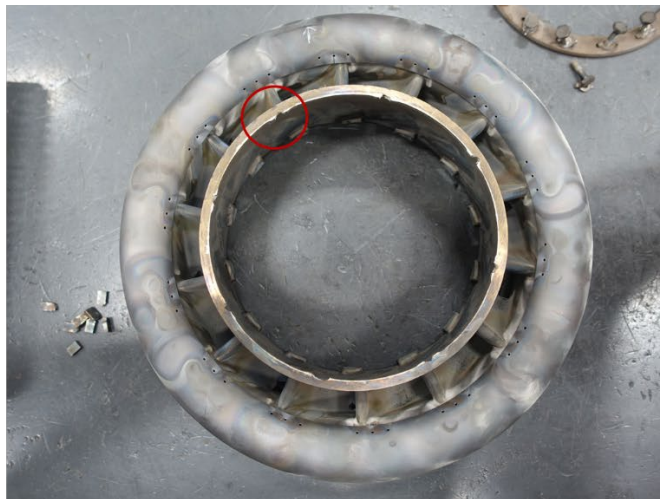


Photo 14- (L) No. 2 Bearing Cover CT Vane Lug Fractures, (R) Impact Marks

The combustion liner was intact and unremarkable. There was no evidence of fuel nozzle streaking or uneven wear. Fuel nozzles Nos.11-14, positioned between the 9 and 11 o'clock positions in the engine, had more carbon buildup than the other nozzles but the nozzle orifices were unobstructed (**Photo 15**).



Photo 15- Fuel Nozzle No. 13

2.4 Compressor

The Ng spool rotated by hand after the power section was separated. The compressor first stage blade leading edges were inspected with a mirror and a fingertip was run along the leading edge of each blade. Minor leading edge roughness was noted but there was no evidence of foreign object damage. According to PWC, the blades were typical of service run engines. The compressor bleed valve was removed to visually inspect the compressor third stage blades. The compressor bleed valve piston moved freely. All blades were complete and appeared unremarkable.

There was visible case deformation as viewed through the compressor case compartment (**Photo 16**). According to PWC, compressor case buckling is common during CT rotor blade separation events.

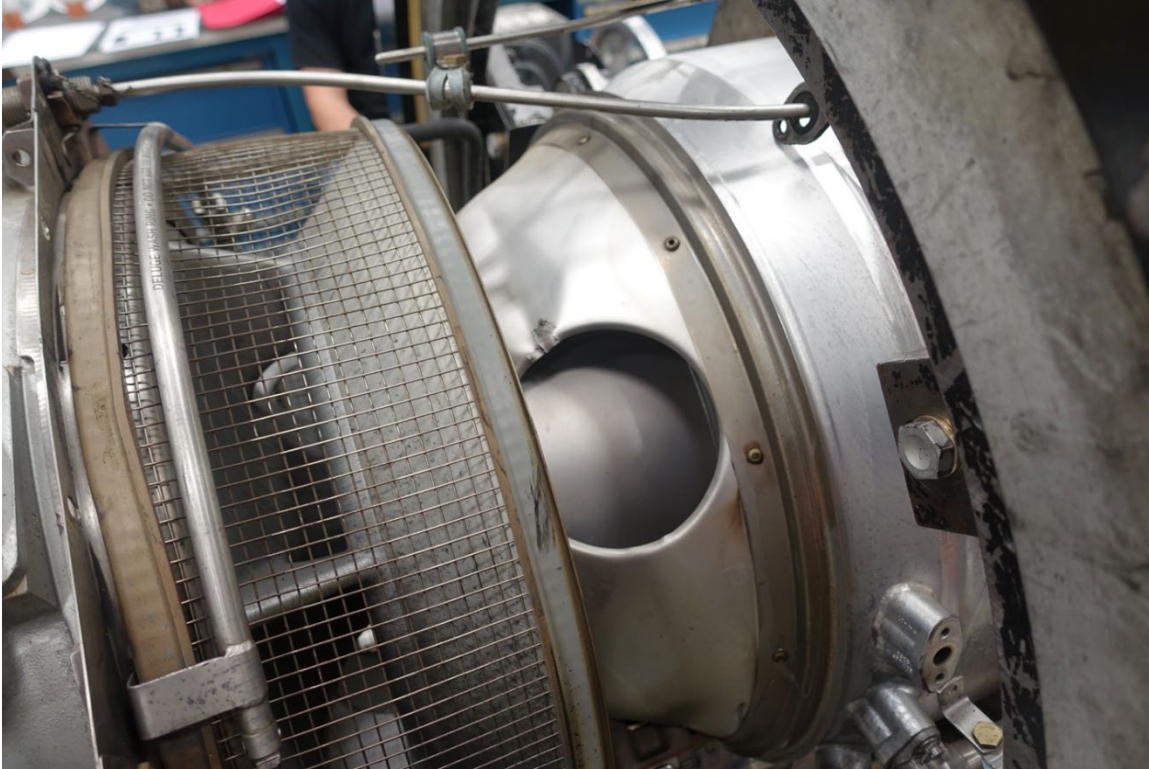


Photo 16- Compressor Case Deformation

2.5 Accessory Gearbox

Continuity was confirmed through the AGB by rotating the compressor and observing rotation of the accessory drive splines. The AGB rotated smoothly and there was no evidence of internal damage, so the AGB was not further disassembled.

3.0 Engine Accessories Testing

The FCU, manufactured by Honeywell, part number 4138008-3, serial number C75144, and the fuel nozzle set, manufactured by PWC, were shipped to PWC in Saint-Hubert, Québec, Canada for testing and partial disassembly. The accessories investigation was initiated on April 26, 2023, under the oversight of a Transportation Safety Board of Canada representative. The PWC accessories investigation report is available in the docket as "Attachment 1- PWC Service Investigation Accident/Incident Report No.: 23ECN00007, Engine Accessories Investigation."

3.1 Fuel Control Unit

The FCU external surfaces were observed to be dirty and discolored during the as received visual inspection (**Photo 17**). The idle speed adjustment lockwire was a different size than the other lockwire present on the FCU, consistent with a permissible field adjustment at some point in the service history. The identification plate revealed that the FCU was overhauled at International Governor Services (IGS) in Broomfield, Colorado on December 2, 2020. IGS was contacted and provided a copy of the post-overhaul test run sheets to assist with the investigation.

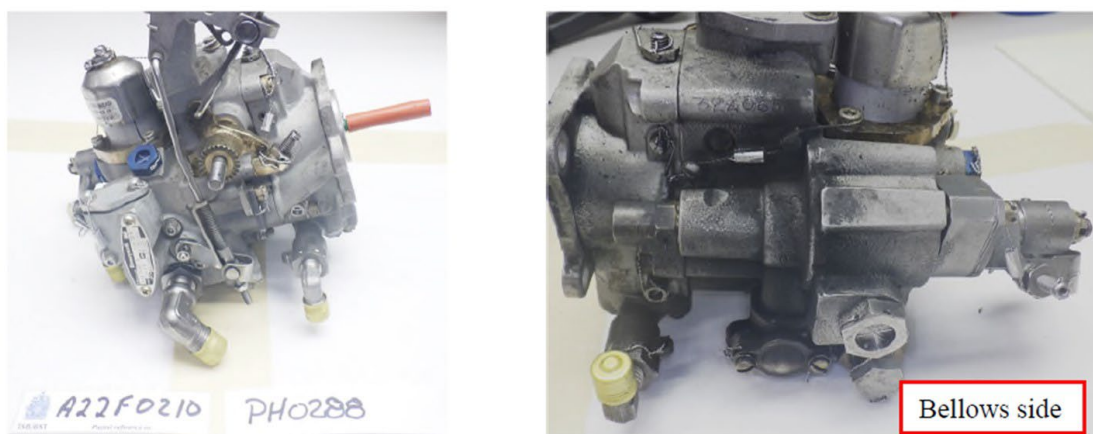


Photo 17- FCU, as Received at PWC, Saint-Hubert Facility (Photos Courtesy of PWC)

All FCU levers rotated across the full range of travel and the input driveshaft rotated smoothly with typical resistance. The FCU was installed on a test bench and tested per Honeywell Component Maintenance Manual (CMM) 73-20-64 Revision 2. The acceleration schedule including the minimum fuel flow were above the CMM limit. The maximum Ng speed and idle speed were also adjusted above the CMM limit. The idle reset spring was adjusted low. The manual override fuel flow output was above CMM limits. According to PWC, all FCU adjustments were within the expected and permissible range of similar service run units.

The FCU was partially disassembled, and the bellows and governing system appeared unremarkable. There were no anomalies identified during testing or disassembly that would have precluded normal operation.

3.2 Fuel Nozzles

The as received visual inspection of the set of 14 fuel nozzles identified a light film of black discoloration on the fuel nozzle tips from position Nos. 10 to 14 (**Photo 18**). The fuel locking tab washers were not installed in accordance with the CMM at position Nos. 3, 8, and 13. The fuel nozzles were flow tested and minor spray quality issues were noted including streaks and voids on several nozzles

that were typical of nozzles with similar run time (**Photo 19**). The fuel nozzles pressure test was satisfactory. There were no fuel nozzle anomalies identified that would have precluded normal operation.



Photo 18- Fuel Nozzle Set, Nozzle Position Identification Diagram (Photo Courtesy of PWC)

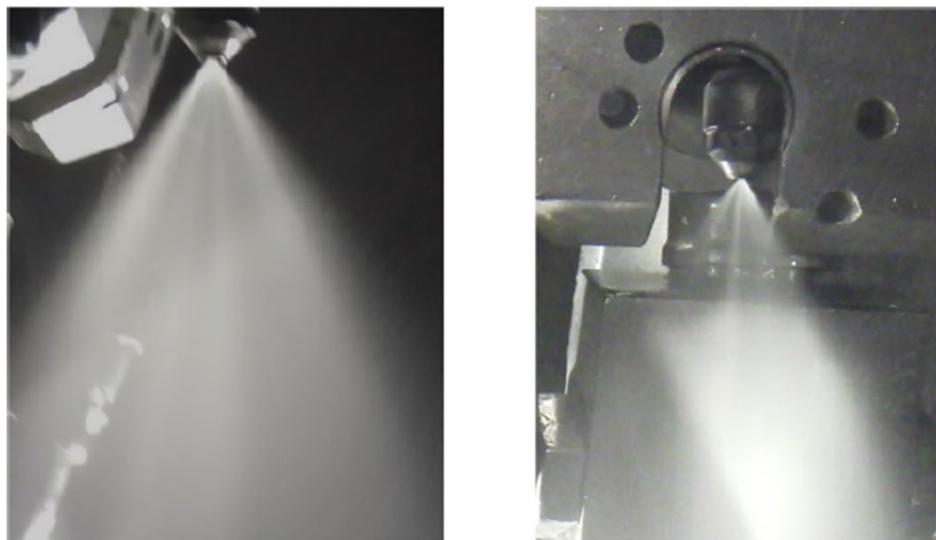


Photo 19- Fuel Nozzle Spray Pattern During Test

4.0 Materials Analysis

The complete set of 58 CT rotor blades were shipped to the PWC Materials Laboratory in Montreal, Québec, Canada for failure analysis (**Photo 20**). Blades No. 1 and No. 20 were sectioned to evaluate microstructure. Both blades exhibited solutioning of the gamma prime⁶ (**Photo 21**). The PWC Materials Laboratory was unable to determine maximum temperature exposure or duration but stated that the solutioning observed in the microstructure occurs at temperatures above the published operating limits. A cross section of Blade No. 20 was examined 0.25 inches from the trailing edge with a scanning electron microscope. Micro-voids were observed perpendicular to the airfoil axis at the material grain boundaries (**Photo 22**). Micro-voids along the grain boundaries suggest creep⁷. Similar voids along the material grain boundary were observed when a cross section of blade No. 39 was viewed under the scanning electron microscope (SEM).

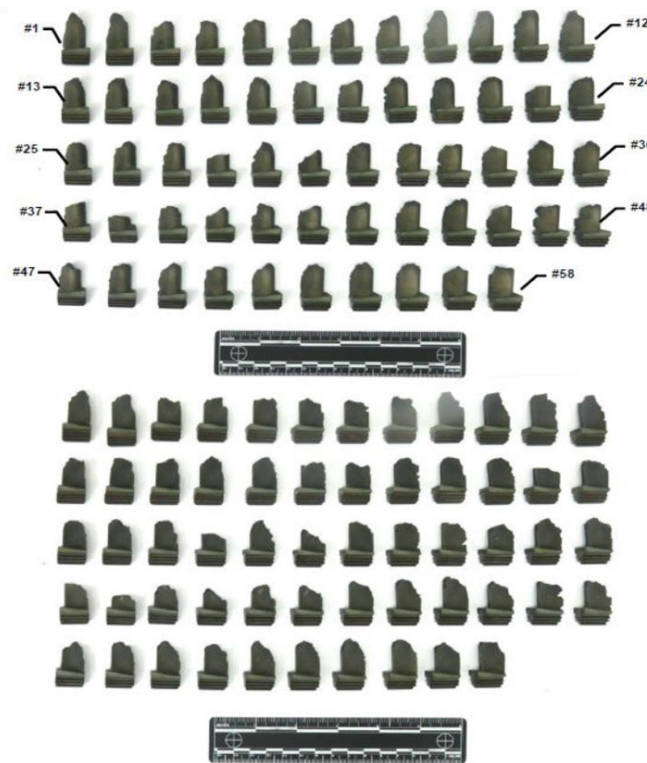


Photo 20- Compressor Turbine Blade Set, as Received at the PWC Materials Laboratory, (Top) Suction Side, (Bottom) Pressure Side (Photos Courtesy of PWC)

⁶ Gamma prime is the primary strengthening phase in nickel-based alloys. When the blade alloy is exposed to temperatures above operating limits, the gamma prime precipitates return into solution.

⁷ Creep is defined as time dependent deformation under constant load usually at high temperature.

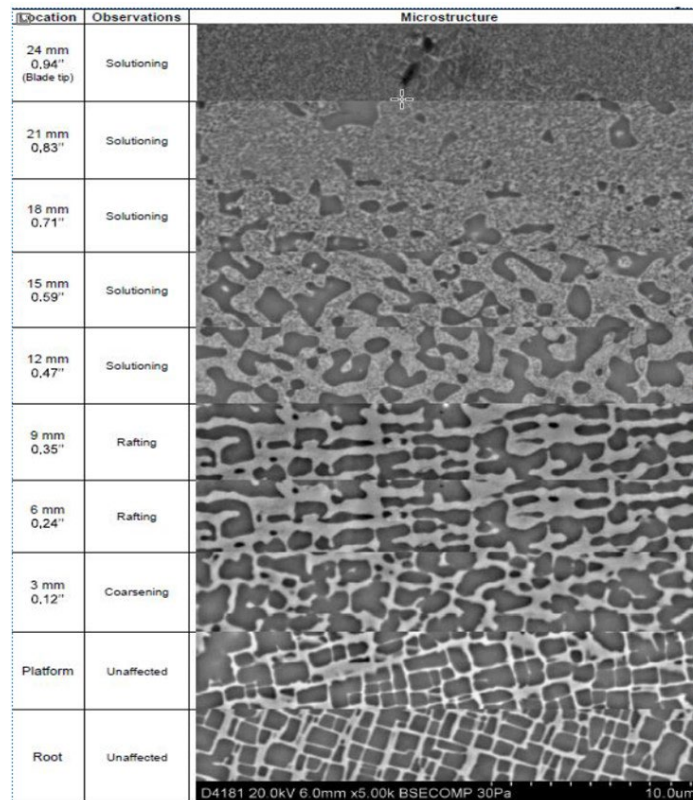


Photo 21- CT Blade No. 1 Microstructure Analysis (Photos Courtesy of PWC)

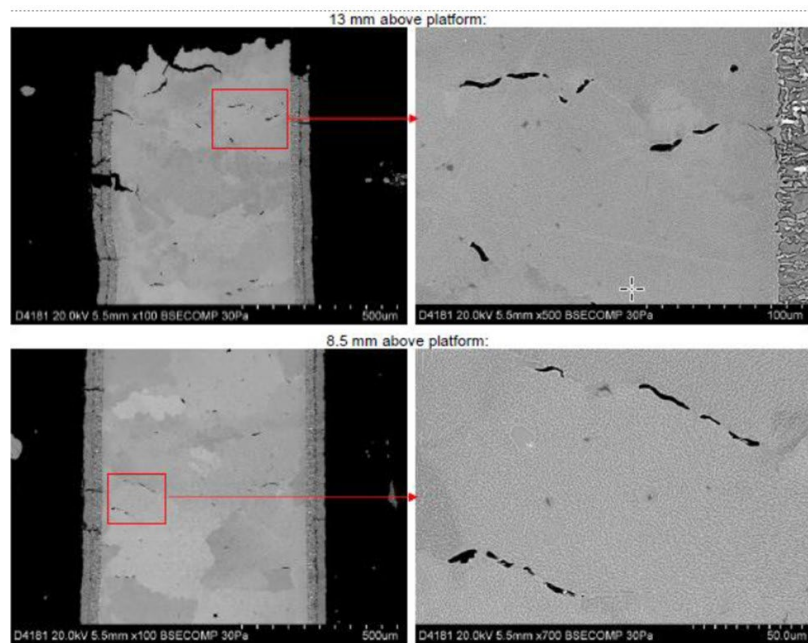


Photo 22- CT Blade No. 39, Micro-voids Perpendicular to the Airfoil Axis Along Grain Boundaries (Photos Courtesy of PWC)

A SEM analysis of the fracture surface of blade No. 23 showed features typical of overload failure with no evidence of fatigue. The CT blade material composition was found to meet the PWC drawing specification. An NTSB Materials Engineer consulted with PWC on the materials analysis workscope and concurred with PWC's findings. The PWC Materials Laboratory report is available in the investigation docket as "Attachment 2- PWC Service Investigation Accident/Incident Report No.: 22-118, Materials Laboratory Analysis."

5.0 Corrective Actions

On July 30, 2015, PWC released service bulletin (SB) PT6A-72-1767 with recommended compliance category 5 or 6⁸. The most recent revision 5, was released on July 16, 2020. The summary section of the SB states: *"There can be blade creep at the Compressor Turbine (CT) area when the engine is operated at higher temperatures and power than the Pilot Operating Handbook (POH) recommended power settings. To prevent creep-related events, introduce a new Compressor Turbine Disk Balancing Assembly which incorporates redesigned turbine blades made from a different material and increased gap at the blade inter and under platform. Also to increase vibratory stress margin, a new blade platform seal was added."* The new CT blade design features single crystal material which is comprised of a continuous crystal lattice that eliminates grain boundaries. The SB was not mandated by Transport Canada or the Federal Aviation Administration, so SB compliance is at the discretion of the owner/operator.

Engines with pre-SB PT6A-72-1767 CT blades are inspected in accordance with the engine maintenance manual (EMM) periodic table (72-00-00, Table 601, 2B/C) (**Figure 3**). The CT blade initial inspection interval is 5,000 hours since new with subsequent inspections every 3,000 operating hours. Engine operating time between overhauls and hot section inspection frequency are also outlined in Service Bulletin (SB) PT6A-72-1303, originally issued on April 19, 1977, revision 14 issued on October 20, 2020. According to the FAA Form 8130-3 following the engine HSI (discussed in the maintenance section of this report and shown in **Photo 1**), the CT blades on the incident engine were inspected in accordance with SB PT6A-72-1303 in December 2018. The incident engine had accumulated approximately 1,204.8 hours since the inspection.

⁸ Service bulletin compliance category 5 was applicable to a small subset of engine serial numbers. A majority of PT6-34AG engines, including the incident engine, had a recommended compliance category 6: "P&WC recommends to do this service bulletin when the subassembly (i.e. module, accessories, components, or build groups) is disassembled and access is available to the necessary part. Do all spare subassemblies."

C.	Compressor Turbine Blade	For Pre-SB1767 CT blade configuration:	
		(1) Send a sample of two CT blades for metallurgical analysis. (Ref. 72-50-02)	Ref NOTES 1 to 3
		NOTE: 1. For PT6A-34 in SKYDIVE OPERATION	Every 2000 hours
		NOTE: 2. For PT6A-34/34B/34AG/36 SINGLE ENGINE applications (Not SKYDIVE).	Initial interval: Every 5000 hours for compressor turbine disk with full set of new blades installed at last shop visit Subsequent interval: Every 3000 hours since last inspection for compressor turbine disk with full or partial set of previously operated compressor turbine blades.
		NOTE: 3. For Post-SB1767 or TWIN ENGINE non SKYDIVE application	Not required

Figure 3- Excerpt from Engine Maintenance Manual (72-00-00, Table 601, 2B/C)

Submitted by:

Robert Hunsberger
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