

Accident / Incident Report

P&WC 8114 (11-98)

**Pratt & Whitney Canada**

Une société de United Technologies / A United Technologies Company

Report No.:18SIE00239

Pentastar Aviation Charter Inc (Owner: Bennett Aviation LLC)
EC135P1 & Registration # N312SA
Chicago, Illinois
July7, 2018
PW206B
S/N BB0049 and BB0045

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I ANALYSIS

1.0 ACCIDENT SYNOPSIS

On July 7, 2018 an Airbus Helicopter EC135P1 helicopter with tail number N312SA, impacted the ground while carrying out a medical transfer flight in Chicago, Illinois. The helicopter was owned by Bennett Aviation, LLC, in Elmhurst, Illinois, and operated by Pentastar Aviation Charter Inc under the provision of being an air ambulance flight. The pilot and paramedic sustained minor injuries, the flight nurse sustained more serious injuries and the patient was unharmed.

The Electronic Engine Control's (EEC) and Data Collection Unit's (DCU), followed by the engines were shipped to the Service Investigation department at the plant 5 facility of Pratt and Whitney Canada (P&WC) in St. Hubert, Quebec, Canada where the units and engines were investigated further.

2.0 SUMMARY OF FINDINGS

BB0049 (#1 position)

The Power Turbine (PT) blades were all fractured at $\frac{1}{3}$ span by tensile overload, consistent with a fracture in overspeed. The release of these blades caused an imbalance of the PT disc allowing it to contact the retaining ring, which in turn worked its way out of the carbon seal housing. This condition allowed the No. 5 bearing carbon seal to become displaced and move forward.

The imbalance of the PT disc assembly and movement of the carbon seal caused the PT shaft to bow while it was rotating. This caused scoring marks on one side of the shaft in multiple locations.

During the overspeed event the blade growth caused the blade tips to machine through the PT shroud. When the PT blades released, the PT stator shroud was completely destroyed separating the PT stator mounting flange from the PT stator vanes section. This allowed one blade to puncture through the exhaust case. The trailing-edge damage on the PT stator vanes was a result of the PT stator moving aft into the PT disc assembly. The contact marks observed were not evenly distributed, likely a result of the combination of the PT stator moving aft-ward at an angle in conjunction with the PT shaft bowing while rotating and the PT disc being off-balanced.

The damages observed on the compressor spools are secondary to the PT blades fracturing as a result of an overspeed.

There were no findings with any of the accessories that would have prevented normal operation.

BB0045 (#2 position)

All of the PT blades were fractured at $\frac{1}{3}$ span by tensile overload consistent with a fracture due to overspeed. The blade release caused an imbalance and movement of the PT disc which caused the retaining ring to completely disengage. Once disengaged, the retaining ring was dragged due to contact friction on the disc, resulting in scoring on the disc and causing the retaining ring to break into multiple pieces.

As the blades oversped, they elongated and machined into the PT Stator shroud. As the blades released, they cut through the PT stator retaining flange, which allowed the PT stator vanes section to move aft and rub into the PT blade/disc assembly. The PT blade release with the PT stator shroud damaged enabled a blade to exit through the exhaust case.

With the retaining ring gone, the No. 5 bearing carbon seal housing moved forward and came into contact with the backside of the PT disc. This contact caused the carbon seal to disintegrate and break into pieces. As the seal moved forward the disintegrated seal allowed oil to leak across it due to improper sealing. Due to the temperature increase in the No. 5 bearing cavity, the oil leaking across the seal into the gas path likely caught fire. The oil continued to be pumped to the No. 5 bearing cavity thus sustaining the fire until the engine was shutdown.

As the No. 5 bearing area was exposed to elevated temperatures from the oil fire, the PT shaft would have softened and expanded due to the heat. This combination would have resulted in an increase of bowing on the shaft. With the rotating shaft imbalance, the shaft eventually fractured due to tensile overload at the PT disk location. The PT disk continued to rotate over of the PT shaft attachment area as is evident by the damages observed due to the shaft contact with the PT disc bore. The smaller portion of the broken PT shaft likely moved aft, resulting in the PT shaft no longer being supported at that end.

The Compressor Turbine (CT) blade tips rubbed against the CT shroud as a result of the overspeed and engine unbalance. Similarly the centrifugal impeller also rubbed its shroud as a consequence of the event.

There were no findings with any of the accessories that would have prevented normal operation.



DCU Data Review

A DCU download was carried out in the presence of the Transportation Safety Board (TSB) of Canada, however the only data present in the DCU is trims and component cycles (there are no faults or exceedances recorded). Both engines DCU's were successfully downloaded and contained their respective trims and cycles.

The DCU download can be seen in Appendix A

EEC Data Review

The EEC's were downloaded in the presence of the TSB of Canada, in order to observe any faults. Due to the basic nature of the fault recording in the EEC, we cannot make conclusions from this data as to a sequence of events, but can say which faults were seen on the last flight. There is no time stamp, so it is not possible to tell the order in which they occurred. The following sensors are recorded in the faults detected by the EEC.

Torque (Q) sensor: provides the primary torque signal (QA) and power turbine speed (NPT) signal to the EEC.

NPT sensor: provides the backup torque signal (QB) and backup NPT signal to the EEC. It provides the primary NPT signal to the cockpit.

NG (gas generator speed): Provides NG speed to the cockpit and the EEC.

The engine BB0049 detected an "NF (Power turbine speed) out of range fault" on both its Q and NPT sensors, both with NG values above 96%. This fault is triggered when the NPT speed exceeds 127%. The fact that a fault was present on both sensors indicates that both sensors detected the NPT speed exceeding 127%.

The engine BB0045 also detected an "NF out of range fault" on both its Q and NPT sensors, both with NG values above 97%. The fact that a fault was present on both sensors indicates that both sensors detected the NPT speed exceeding 127%.

The complete analysis can be seen in Appendix B

National Transportation Safety Board Data Review

The flight data recorded during this final flight was provided by the National Transportation Safety Board (NTSB) to P&WC for analysis. The data from the last flight was plotted with a focus on the following specific engine parameters: Filtered Torque 1 (%); Filtered torque 2 (%); Ground Speed (knots); Radio Height (ft); Time and Collective Angle 1 (%).

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The flight conditions were such that the main rotor speed (NR) should have been governing at 100% during the entire flight and thus it is deduced that the power turbine speeds should also have been governing at 100%.

It is believed, based on the data, that following a Collective (CLP) input at time 14:29:5 the number 1 engine (BB0049) entered manual mode and remained in manual mode for the remainder of the flight. This was deduced because the engine no longer responded to CLP inputs and appeared to increase in torque while the CLP was being lowered, which would indicate that it had another source of input to the power setting, which can be explained by an input/rotation on the twist grip.

The number 2 engine (BB0045) was believed to be running in automatic mode up to time 23:17:1 at which point the torque increases with a steady-state CLP (in Automatic mode the torque should have stayed constant with a constant CLP). The data shows that from this point on the engine remained in manual mode.

The following Plot 6 (For the full data analysis see Appendix C) shows the final 40s until both engines' torques were at 0.



The orange line at 24min and 1s represents an audible gong from the cockpit (information provided by the NTSB) indicating that the main rotor has reached or exceeded 106% NR. The red line at 23min 26s represents the beginning of the continuous audible high tone from the cockpit (information provided by the NTSB). This tone comes on when NR is greater or equal to 112%, and will stay on until the NR comes back below this range (information on when the tone came off was not provided and thus is not identified on the graph).



As the torque is increased with the CLP decreasing, the engines' NPT speeds would increase thus driving the rotor speed higher.

Both engines show a flat line in the data down to the forth decimal as indicated by items VII and VIII. This can be explained because the NPT and Q are both picked up from the same probe and as NP increase above its range (127%) two faults are flagged and the Q will no longer be calculated but instead will hold the last good value (LGV), thus flat-lining. Once the NPT comes back within range the Q was again calculated and can be seen decreasing towards 0% within approximately 1s.

The overspeed is consistent with the two faults per engine found in the EEC's as explained above. The NPT has a maximum range of 127% thus to attain a fault, the true NPT value must have exceeded 127%, however the maximum value attained cannot be determined. The PT blades are designed to shed at approximately 150% NPT. Based on the Engine 2's frozen data indicated by VII (at 43.2344) it can be concluded that the NPT was above 127% for almost 2s until either the blades were released or the pilot commanded the engine to 0% torque (there is insufficient parameters in the data to determine the Q loss, however the physical engine evidence show that the PT blades released due to overspeed). The loss of torque from Engine 2 would have reduced the total torque on the rotor system and then effectively reduced the total NR.

The engine 1 torque is stable and unchanging, at 51.5078% as indicated by point VIII, for approximately 23 seconds. As explained in point VII this shows that the NPT of this engine was above 127% for approximately 23s though the peak cannot be determined. As the CLP continues to descend to 0, and with a fixed fuel flow to the engine, the number 1 engine would continue to over-speed (there are no speeds available in the data to show this). The sudden decrease in torque is concluded to be due to the overspeed event and the loss of PT blades based on the physical evidence of the engine.

At the time 24min and 1s (not shown on this graph) there is an audible gong sound from the cockpit (information provided by the NTSB) indicating that the main rotor speed returned below 106%. Approximately 15s following this was the sound of impact (not shown on this graph).

For the complete analysis of the data please refer to Appendix C.



3.0 CONCLUSIONS

The damages observed on both engines are characteristics of blade release due to a power turbine rotor overspeed condition. The physical evidence of the overspeed is consistent with what was found from the flight data, which showed that prior to impact the engines were in manual mode and the torque was increased using the twist grip, with the collective decreasing. The high rotor alarms at 106% and 112% NR were activated, after which the engine torque was further increased until the NPT signal went above 127% at which point the data held the last good value until the speed came back below 127% NPT. The faults recovered in the EEC show that both Q and NPT sensors recorded the NPT exceeding 127%.



II FACTUAL INFORMATION

1.0 INVESTIGATION PARTICIPANTS

The powerplant investigation was performed from September 17 to 21 at the Pratt & Whitney Canada (P&WC) Service Investigation Facilities at St. Hubert, Quebec, Canada. The following individuals participated in the investigation as representatives of their respective organisations:

Merryn Spielman	Investigator Pratt & Whitney Canada
David Barnard	Accessories Investigator Pratt & Whitney Canada
Claude Beaudry	Investigator Pratt & Whitney Canada
Marc Hamilton	Senior technical Analyst Transportation Safety Board of Canada
Aaron M. Sauer	Senior Air safety Investigator National Transportation Safety Board
Harald Reichel	Senior Powerplant Investigator National Transportation Safety Board
Robert Farinas	Continuing Airworthiness Transport Canada
Tim Hilditch	Manager Helicopter Maintenance Operations Pentastar Aviation
Eric West	Air Safety Investigator Federal Aviation Administration (FAA)
Patrick D. Lusch	Air Safety Investigator FAA
Christian Bernhardt	Accident Investigator Airbus Helicopters
Steven A. Krugler	Senior Engineer Woodward



2.0 LEFT HAND ENGINE HISTORY

PW206B S/N BB0049

Hours Since New: 6223.7 hr

Cycles Since New: N/A

Time (hours) Since Overhaul (TSO): 142 hr

Cycles Since Overhaul: N/A

According to the maintenance records the engine was installed in the helicopter on Nov 1, 2016 after Foreign Object Damage (FOD) repairs, and at the time of the accident had accumulated 142 hours TSO.

The engine box was received and opened, with no visible damage to the engine due to shipping. Prior to shipping the oil had been drained from the tank, however an oil sample was shipped with the engine. There were no fluid leaks observed.

3. ENGINE EXAMINATION

All positional references are in relation to view from aft looking forward. Upstream and downstream references are in relation to gas path flow from the compressor inlet to exhaust. There was evidence of an internal fire in the exhaust area. There were no fluid leaks observed.

3.1 External Condition

The engine as received can be seen in the following Photo's 1 and 2.

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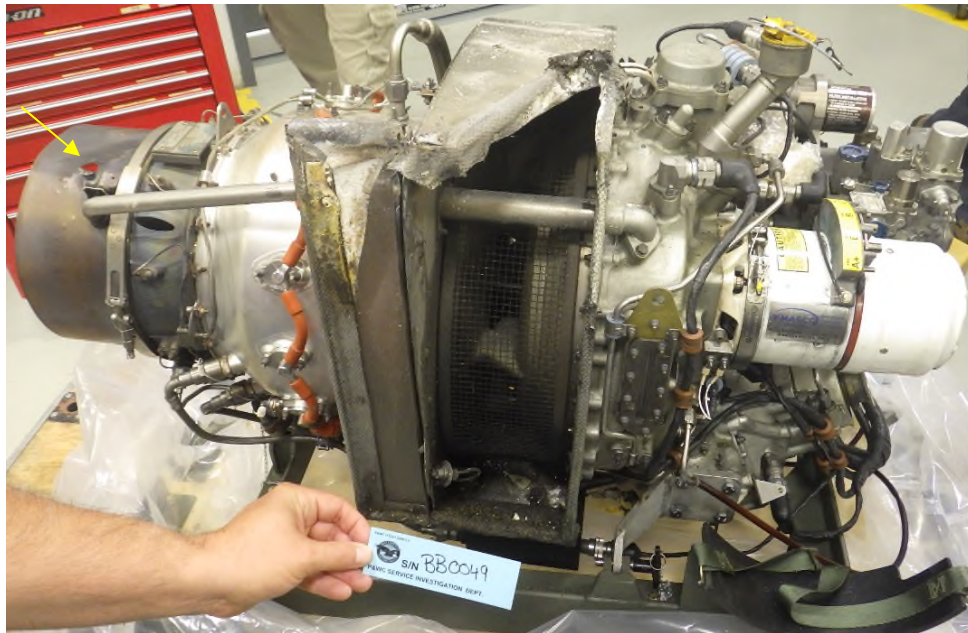


Photo No. 1: BB0049 Right hand side



Photo No. 2: BB0049 Left hand side



3.1.1 External Cases

Reduction Gearbox:

There was no visible damage to the reduction gear box (RGB) as seen in Photo No. 3.



Photo No. 3: RGB

Exhaust Duct:

There was partially separated and dislodged sheet metal from the turbine exhaust cone, which was deformed and partially covering the air flow path of the exhaust duct (see red arrows on Photo No. 4). The exhaust exhibited multiple pock marks consistent with high speed impact from small internal parts (yellow arrows on Photo No. 4). There was one perforation hole noticed at approximately the 1 O'clock location (yellow arrow on Photo No. 1), which exhibited petalling consistent with an inside to outside perforation direction.

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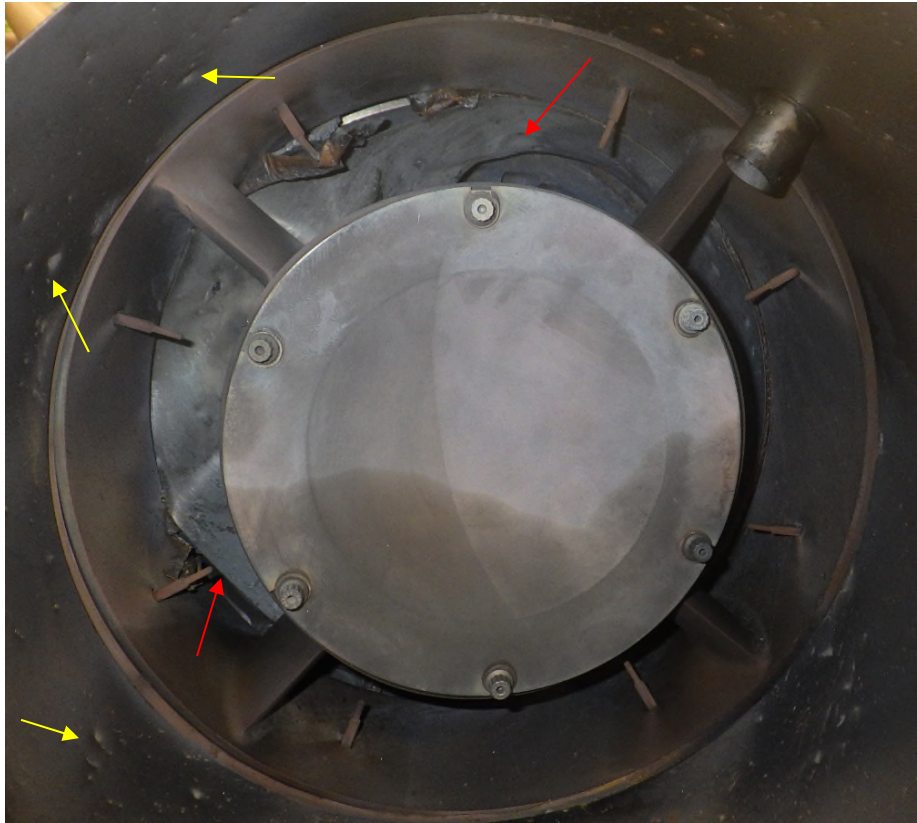


Photo No. 4: Exhaust

When viewing the PT blades through the exhaust it was observed that they were all fractured at the same height from the platform (Photo No. 5).



Photo No. 5: PT blades all fractured at $\frac{1}{3}$ span

Gas Generator Case:

The air inlet was clear, however flakes consistent with burned ash were found in the plenum.

3.1.2 Pneumatic Lines

Compressor Discharge Air (P3):

There was no visible damage to the P3 air boss.

3.1.3 Chip Detectors and Filters

Chip Detector:

The chip detector was clean (Photo No. 6).

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Photo No. 6: chip detector

Oil Filter:

The oil filter was clean (Photo No. 7).



Photo No. 7: Oil Filter

Fuel Filter:

The fuel filter was not received with the engine.



3.2 Disassembly Observations

3.2.1 Compressor Section

The compressor spool could be turned with the application of normal hand effort by rotating the starter shaft. There was no damage observed to the inlet screen, however there was a light grey-black deposit present which is consistent with fire residue.

Centrifugal Impeller:

The impeller showed minimal damage, however there were some minor nicks on the blades leading edges (red arrows on Photo No. 8).



Photo No. 8: Centrifugal impeller leading edge

The blade-tips were undamaged although there was some evidence of rubbing as seen on Photo No. 9 (red arrows).



Photo No. 9: Centrifugal impeller rubbing

Centrifugal Impeller Shroud:

The shroud was intact but showed rotational scoring near the impeller inlet between the 12 and 6 o'clock positions as seen in Photo's No. 10 and 11. The deepest scoring marks were between the 3 and 5 o'clock position which is in the region of the red arrows on Photo No. 11.

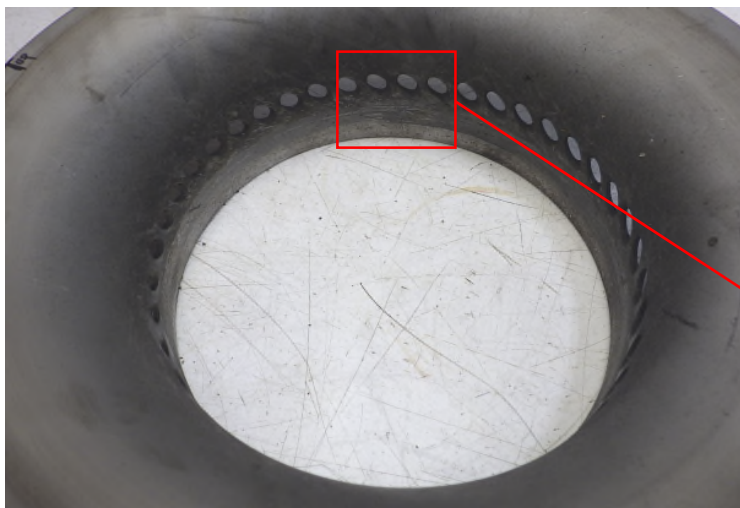


Photo No. 10: Centrifugal impeller shroud rubbing

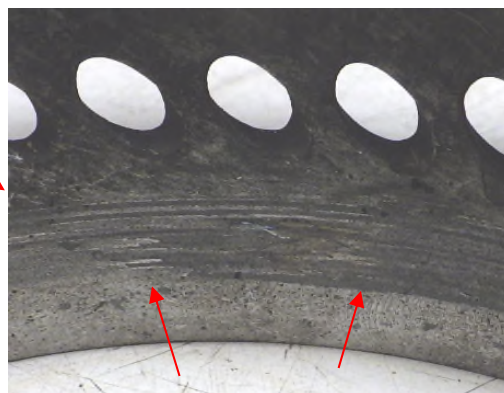


Photo No. 11: Rubbed shroud

Diffuser pipes:

The diffuser pipes were intact and undamaged and showing no sign of internal engine fire (Photo No. 12). There was some corrosion present on the diffuser pipes exterior as seen on Photo No. 13.



Photo No. 12: Diffuser pipes



Photo No. 13: Diffuser pipes

No. 3 and No. 4 Bearings:

The No. 3 and 4 bearings were inspected and found to be intact and undamaged. There were some contact marks in the bore (indicated by red arrows on Photo No. 14) due to impact with the PT shaft.

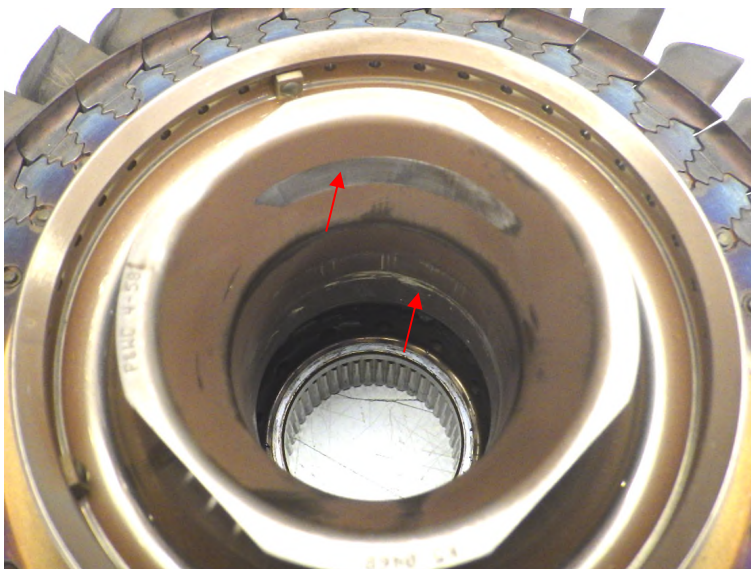


Photo No. 14: CT disc bore

3.2.2 Combustion Section

Combustion Chamber Liner:

The outer and inner combustor liners were intact and undamaged. Approximately 10% of the coating of the inner duct exit lip was cracked and missing as seen in Photo No. 15. This would have had no impact on the engine operation.



Photo No. 15: Coating loss on the inner liner exit lip

Outer Liner:

There was no damage noted to the outer liner as seen in Photo's 16 and 17. There were some minor black carbon (see red arrows) deposits near the fuel nozzle bores which aligned with the direction of the fuel nozzles as seen in Photo No. 17.

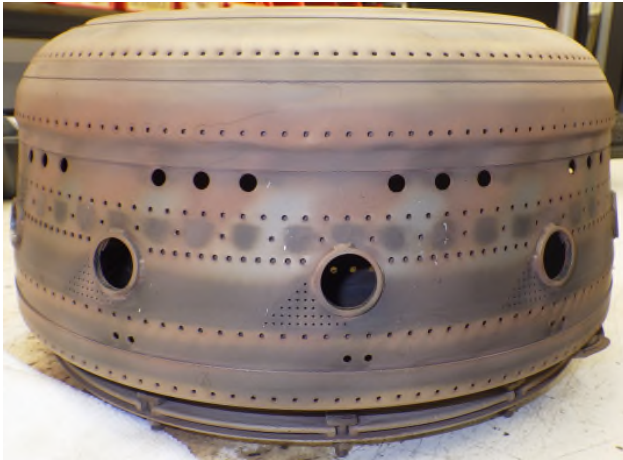


Photo No. 16: Exterior of outer liner

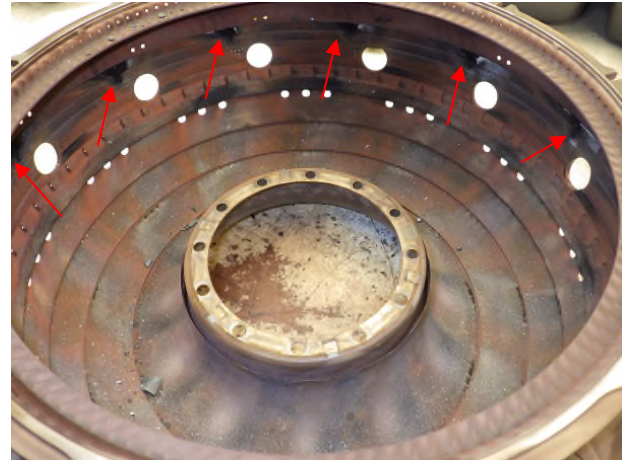


Photo No. 17: Interior with carbon deposit

Inner Liner:

The inner liner was intact (Photo's No. 18 and 19) and did not show any damage with the exception of some coating loss, as shown on Photo No. 19 indicated by red arrows.



Photo No. 18: Inner liner

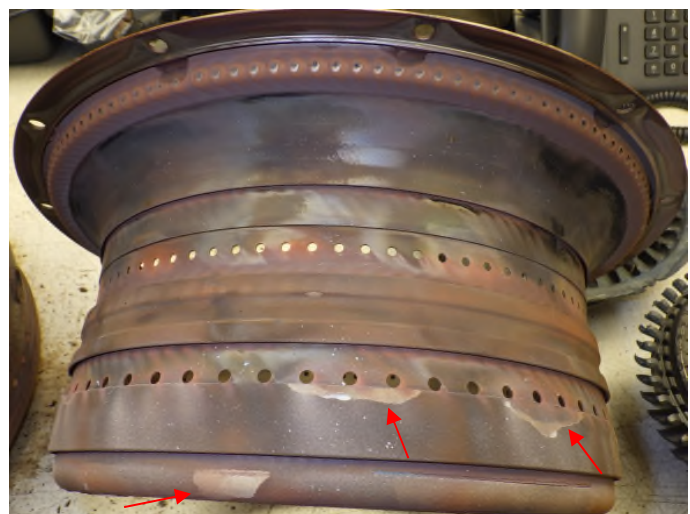


Photo No. 19: Inner liner



3.2.3 Turbine Section

The power turbine could not be turned by hand.

Compressor Turbine Stator:

The CT stator was undamaged. It had some bright, shiny metallic particles (see red arrows) that were adhered to the aft, suction side of the vanes (Photo No. 20). This is consistent with metal spray from the impeller shroud coating which was a result of the impeller vane tip rubbing.



Photo No. 20: Metal spray on backside of CT stator

Compressor Turbine Shroud:

The CT blade shrouds showed rubbing and material transfer due to contact with the CT blades tips as seen on Photo No. 21.



Photo No. 21: CT shroud rubbing



Compressor Turbine:

The CT disc and blade assembly was intact and undamaged as seen in Photo No. 22. The CT blade tips showed evidence of rotational scoring as indicated by the red arrows in Photo No. 23. The disc was de-bladed and the blade growth was measured to be an average of 0.0017 inches, which is within the CIR manual (Cleaning, Inspection, and Repair) limit.



Photo No. 22: CT disc and blades

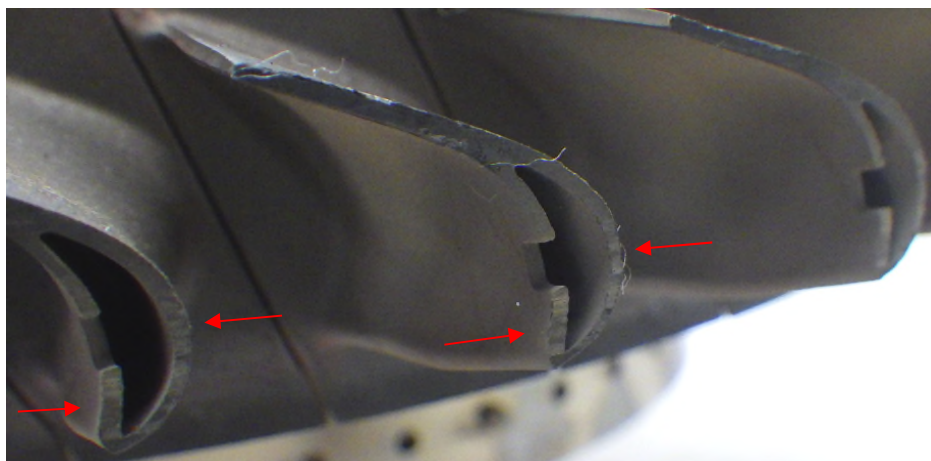


Photo No. 23: CT blade tip rubbing



ITT Probes, Busbar, and Harness:

Two of the T6 probes in the turbine exhaust nozzle were bent due to impact damage (red arrows on Photo No. 24). The harness and busbar appeared undamaged.



Photo No. 24: Damaged T6 probes

Power Turbine Housing:

Power Turbine Stator (Vane Ring):

The power turbine stator outer mounting flange was fractured, dented and deformed. This allowed the vane section to become loose and offset in the core, allowing it to move aft and contact with the PT disk assembly blades and platform. During disassembly the PT stator vane section and PT disc assembly had seized together and had to be removed at the same time (Photo No. 25).



Photo No. 25: PT stator vane ring and PT disc assembly removed together

After the PT blades had fractured, the PT blades contacted the inner third span of approximately half of the trailing edges of the stators (Photo No. 26). This machined a groove, the deepest of which was approximately $\frac{1}{2}$ inch, into the stators. The blue discolouration seen on the PT stator and blades is due to high temperature exposure in that area. The high temperature exposure was the result of contact friction between the PT blades and the stator. Damage to the PT stator baffle and honeycomb seal was revealed once the stator vane section was separated from the PT blade assembly.

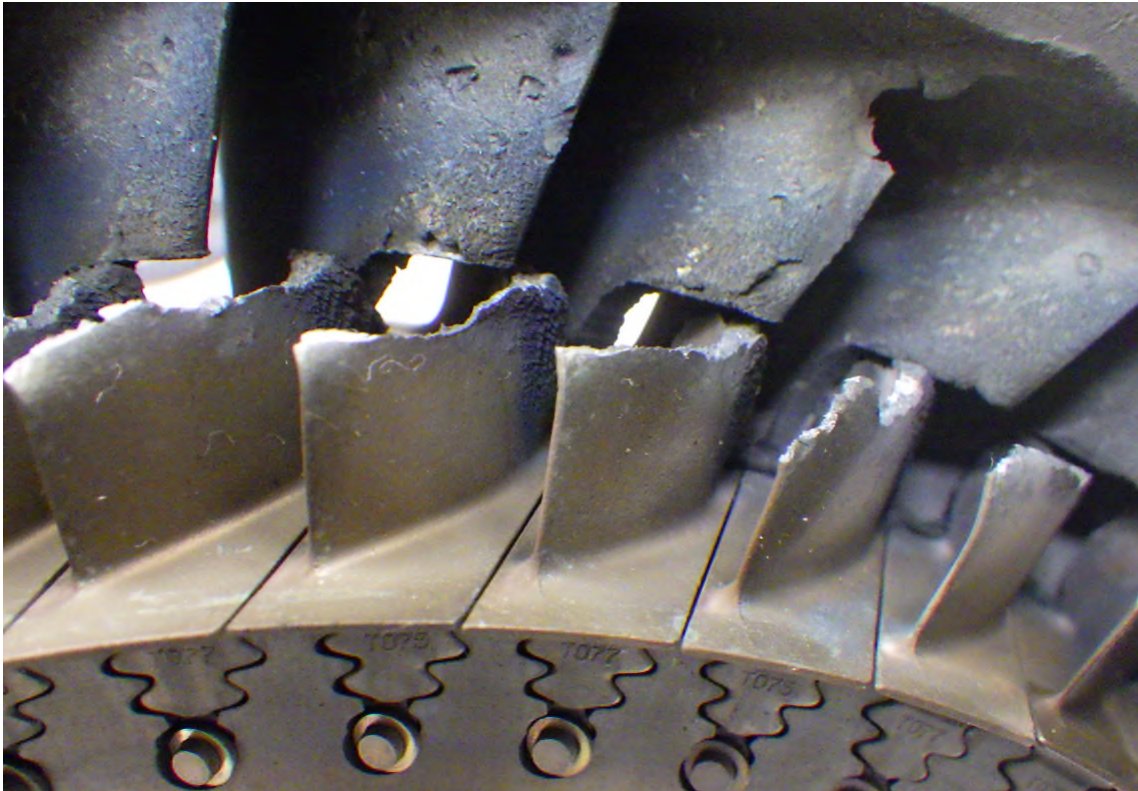


Photo No. 26: PT blades contacting the PT stator trailing edge

The leading edge of the PT stator vanes were intact and undamaged as seen in Photo No. 27.



Photo No. 27: Leading edge of PT stator vanes

**Power Turbine exhaust cone:**

The exhaust was removed at Flange “F” revealing the dislodged turbine exhaust cone deformed sheet metal as seen in Photo 28. This sheet metal is brazed onto the turbine exhaust cone but due to the PT blades release, the sheet metal had torn and dislodged from its original position.

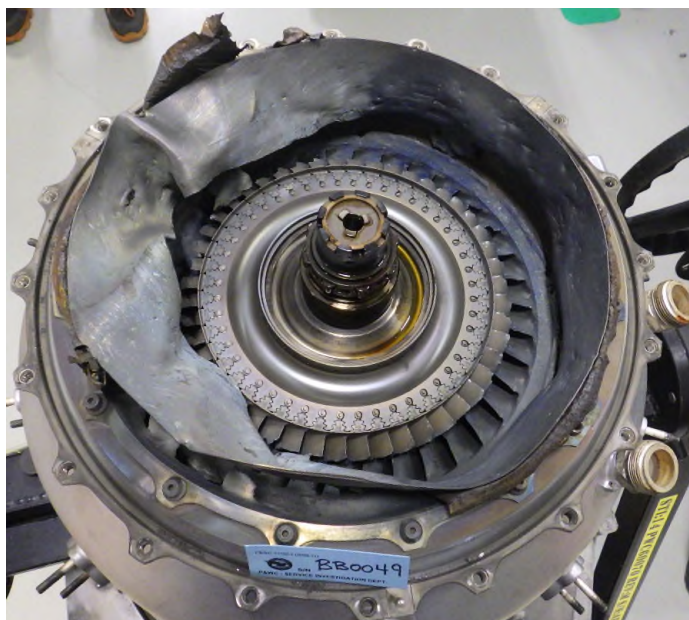


Photo No. 28: PT exhaust cone deformation

Power Turbine:

The power turbine blades were all fractured at the dimples (at $\frac{1}{3}$ span from the platforms) as seen in photo's No. 29 and 30. This is representative of a loss of blades due to an overspeed. PT blades are designed to release at the dimpled area (circled in red on Photo No. 29) at a speed of approximately 150% NPT in order to preserve the integrity of the PT disc. All of the PT blades' fracture surfaces showed signs of tensile overload (no signs of fatigue could be found). The disc was de-bladed and was measured for disc growth. The disk grew to 0.0057 inches over the factory limit which is characteristic of an overspeed condition.

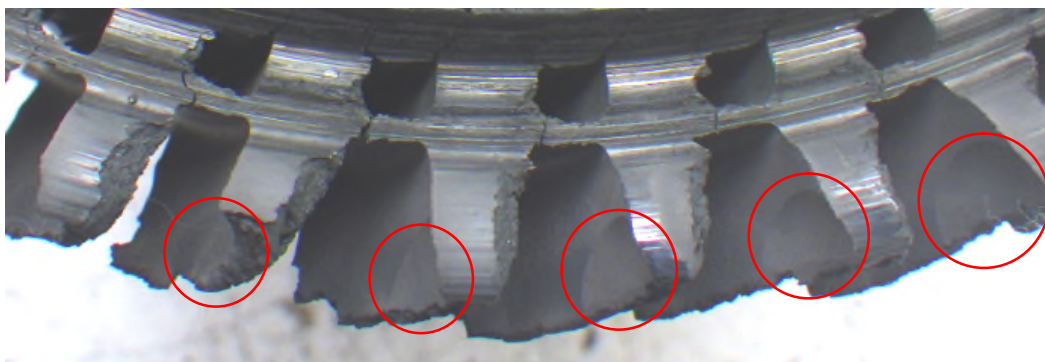


Photo No. 29: Blade fracture at dimples



Photo No. 30: PT blades all missing at 1/3 span

The fractured blades along with a new blade overlaid can be seen in Photo No. 31. The purpose of this is to visually demonstrate the remaining portion of PT blades in comparison to the original length.



Photo No. 31: Broken PT blades and a new PT blade

Power Turbine Shaft and Shaft Housing:

The PT shaft had three sets of rotational contact marks along its length, which is consistent with a temporary elastic bending of the shaft (Photo No. 32).



Photo No. 32: PT shaft

No. 5 Bearing and No. 5 bearing seals:

The No. 5 roller bearing was not damaged (Photo No. 33). The No. 5 bearing carbon seal retaining ring had become dislodged from its seat and was found in the downstream side of the balancing rim of the PT disk (Photo No. 33). The No. 5 bearing carbon seal had moved forwards from its seated location by approximately 0.1 inch (Photo No. 34). The seal runner was rotationally scored, which is consistent with an uneven contact against the No. 5 bearing carbon element (Photo No. 33).

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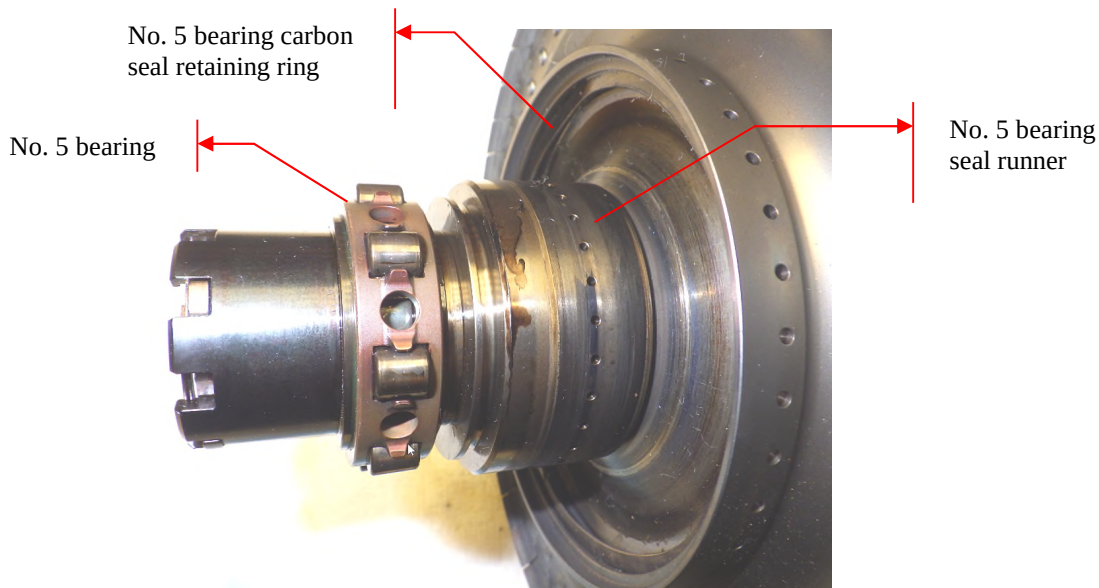


Photo No. 33: No. 5 bearing and No. 5 bearing seal runner

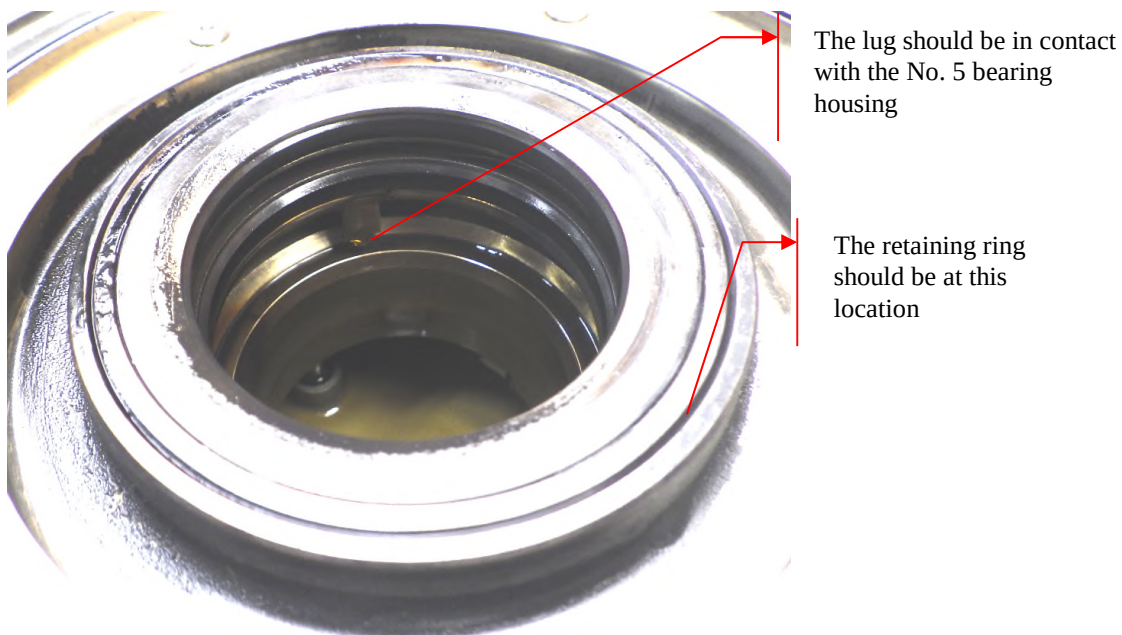


Photo No. 34: No. 5 carbon seal

There was minor impact damage found on the struts as can be seen in Photo No. 35.



Photo No. 35: Impact damage to exhaust strut

3.2.4 Reduction Gearbox

With the removal of the PT stator and PT disk which were seized together, all shafts in the RGB were free to rotate, confirming the internal integrity of the RGB. The RGB was split at Flange “A” (Photo No. 36 and 37), showing that all internal components were oil wetted. The No. 1 roller and No. 2 ball bearings were intact and undamaged, as was the input shaft, 1st stage reduction gear, 2nd stage reduction gear, accessory gears, and output shaft. Based on this the gearbox was not disassembled further.

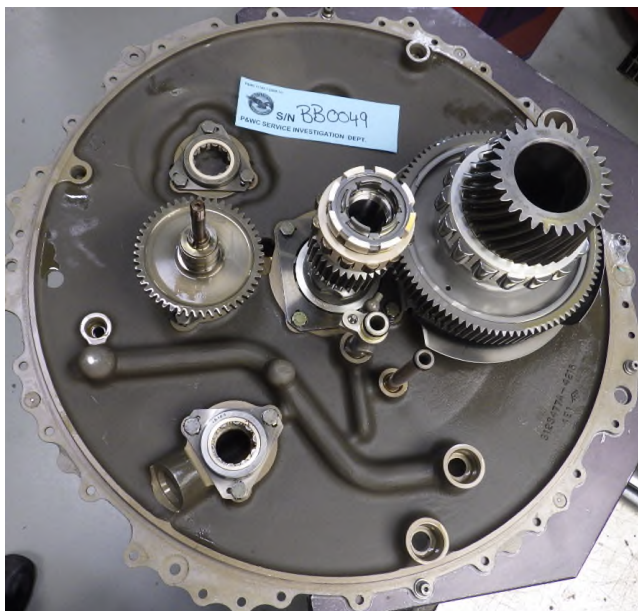


Photo No. 36: RGB diaphragm and gears

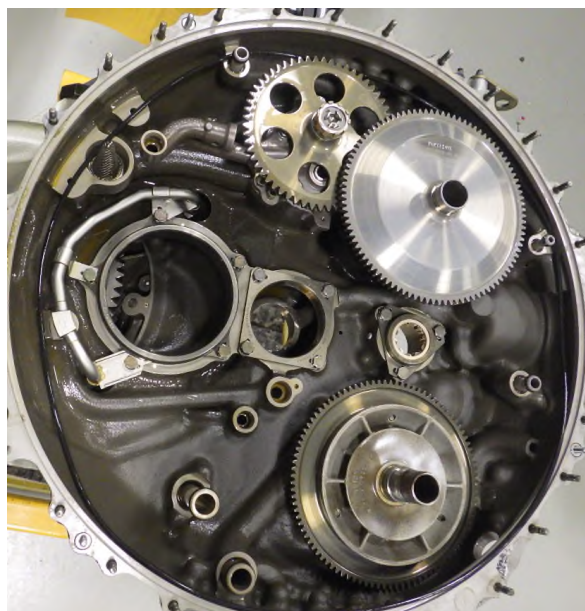


Photo No. 37: RGB housing and gears



3.3 Accessories Condition

DCU:

The DCU (Photo No. 38) had been shipped back to P&WC for a download and assessment. The DCU records the engine trim information as well as cycle counting information, but does not record engine faults. The DCU communication was established without problem and the trims and cycles downloaded successfully.

SYMBOL	ENG UNIT	VALUE	NEW VALUE	BLOCK	OFFSET
MGT_BIAS	N/A	105.0000		0	12
TORQUE_BIAS	N/A	-5.5000		0	8
TORQUE_GAIN	N/A	0.0000		0	10
GEAR_BOX #	N/A	1000049		0	114
TURBO_MACH #	N/A	1000049		0	108
AIR_FRAME #	N/A	0.0000		0	106
IMP_CYC_COARSE	Cycles	594.0000		5	0
IMP_CYC_FINE	Cycles	0.0943		5	2
CT_CYC_COARSE	Cycles	5548.0000		5	4
CT_CYC_FINE	Cycles	0.0972		5	6
PT_CYC_COARSE	Cycles	6536.0000		5	8
PT_CYC_FINE	Cycles	0.4905		5	10
ENG_RUN_COARSE	Hours	6254.0000		5	12
ENG_RUN_FINE	Hours	0.1920		5	14
LCHCREEP	Lchcreep				0

*A18 F0148
DCU From
ENG # 1 (LEFT)*

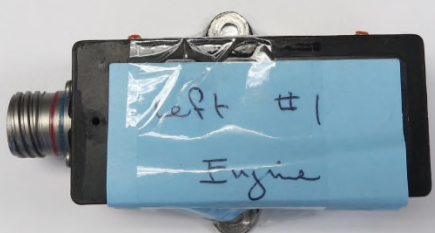


Photo No. 38: DCU

EEC:

The EEC (Photo No. 39) had previously been shipped back to P&WC for a download and analysis. What was found to be related to this event was a fault on two separate sensors which both showed that the NPT signal exceeded its max range of 127%.

An analysis (18-089 EEC download_SUPP 1) is included in Appendix A.



Photo No. 39: EEC

FMM:

The FMM (Photo No. 40) was inspected externally and was found to have all lockwires intact, with no noticeable damage except for some soil. The Power lever moved freely over the full range and the alignment with the rig-pin was obtainable at the detent. The driveshaft could not be moved by hand, which is normal. The FMM was tested in accordance with the Woodward CM 73-20-14 Rev. 5 and there were minor deviations noted, however nothing that would have effected normal operation. The FMM manual/automatic switch was tested and found to be fully functional.

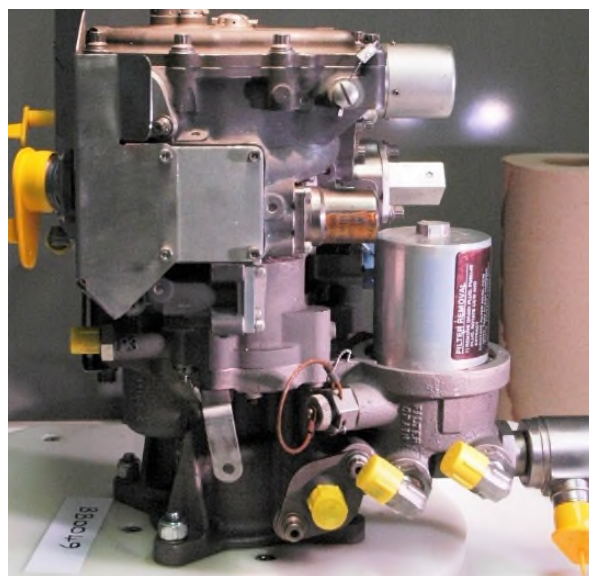


Photo No. 40: FMM

**Fuel Nozzles:**

Carbon deposits were present on each nozzle tip, which caused some streaking or voids (as shown on nozzle seen in Photo No. 41) and an uneven flow pattern on one nozzle. The other nozzles were satisfactory.



Photo No 41: Fuel nozzle

Flow divider valve:

The engine flow divider (Photo No. 42) was tested and the results were satisfactory. There were no findings that would have prevented normal operation.



Photo No. 42: Flow Divider Valve

**Speed sensors:**

Torque sensor: The torque sensor (Photo No. 43) was visually inspected and was found to be in an acceptable condition for further testing. The connector was undamaged, clean and the magnet was not protruding from the sensor body. There was some gold plating material loss which resulted in some black deposits. The sensor was tested, including temperature cycling and dynamic functions, and all tests were satisfactory.

Ng Speed Sensor: The Ng sensor (Photo No. 44) was visually inspected and found to be in an acceptable condition for further testing. The inside of the connector was undamaged, clean and the magnet was not protruding from the sensor body, however there was some black deposits on some of the pins. There was some burnishing on the tip of the sensor which may have occurred during impact. The sensor was tested and the results were satisfactory.

NPT Speed Sensor: The NPT sensor (Photo No. 45) exterior was generally clean and the magnet was not protruding from the sensor body. The electrical connector shell was undamaged however slightly stained, and some gold plating was missing and in its place some black deposit had formed. The sensor was tested and the results were satisfactory.



Photo No. 43: Q sensor

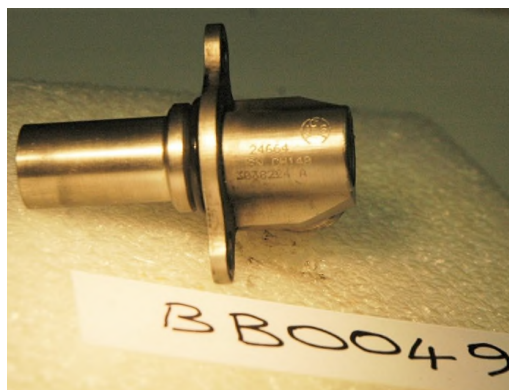


Photo No. 44: Ng sensor



Photo No. 45: NPT sensor

Harnesses:

The harness P/N 3121134-01 was visually inspected and generally clean, however had two tines missing from the connector P3. It is believed they went missing during the removal because these missing tines resulted in a test exceedance, which had they been missing during operation would have caused an indication to the cockpit. Additionally there was some barrel coating peeling on the external side of connector P1.



The harness P/N 3121138-01 was visually inspected and generally clean, however had two fire-detector connecting terminals bent and some insulation frayed. The harness was tested and found to have no deviations related to the main oil pressure, however had these observations been present during flight an indication would have been present in the cockpit, so it is believed that these observations were a consequence of the event.

4. RIGHT HAND ENGINE HISTORY

PW206B S/N: BB0045

Hours Since New: 6024.1

Cycles Since New: N/A

Time (hours) Since Overhaul (TSO): 142 hr

Cycles Since Overhaul: N/A

According to the maintenance records the engine was installed in the helicopter on Nov 1, 2016 after FOD repairs and at the time of the accident had accumulated 142 hours TSO.

The engine box was received and opened, with no visible damage to the engine due to shipping. Prior to shipping the oil had been drained from the tank, however an oil sample was shipped with the engine.

5. RIGHT HAND ENGINE EXAMINATION

All positional references are in relation to a view from aft looking forward. Upstream and downstream references are in relation to gas path flow from the compressor inlet to exhaust. As seen in Photo No. 46 the external surfaces had evidence of more soot, and oil residue, likely due to a nacelle fire, than observed on the left hand engine (BB0049). There was evidence of an internal fire in the exhaust area, but no obvious fluid leakage was observed.



Photo No. 46: Soot residue on BB0045

5.1 External Condition

The engine as received can be seen in the following Photo's 47 and 48.

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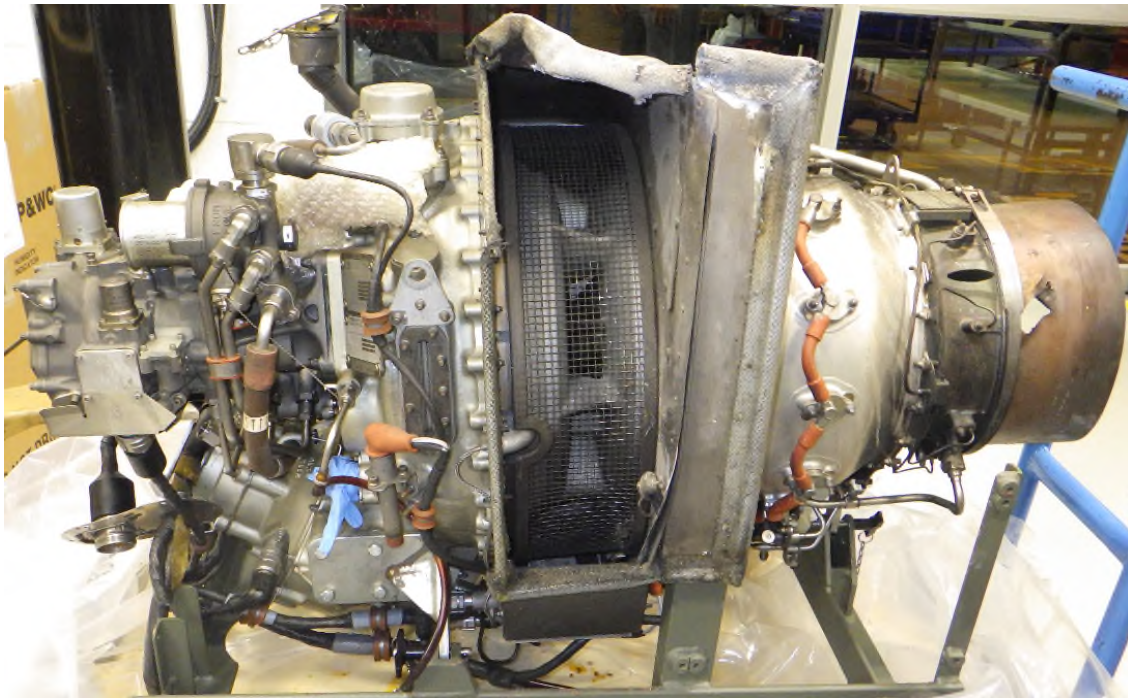


Photo No. 47: BB0045 left hand side

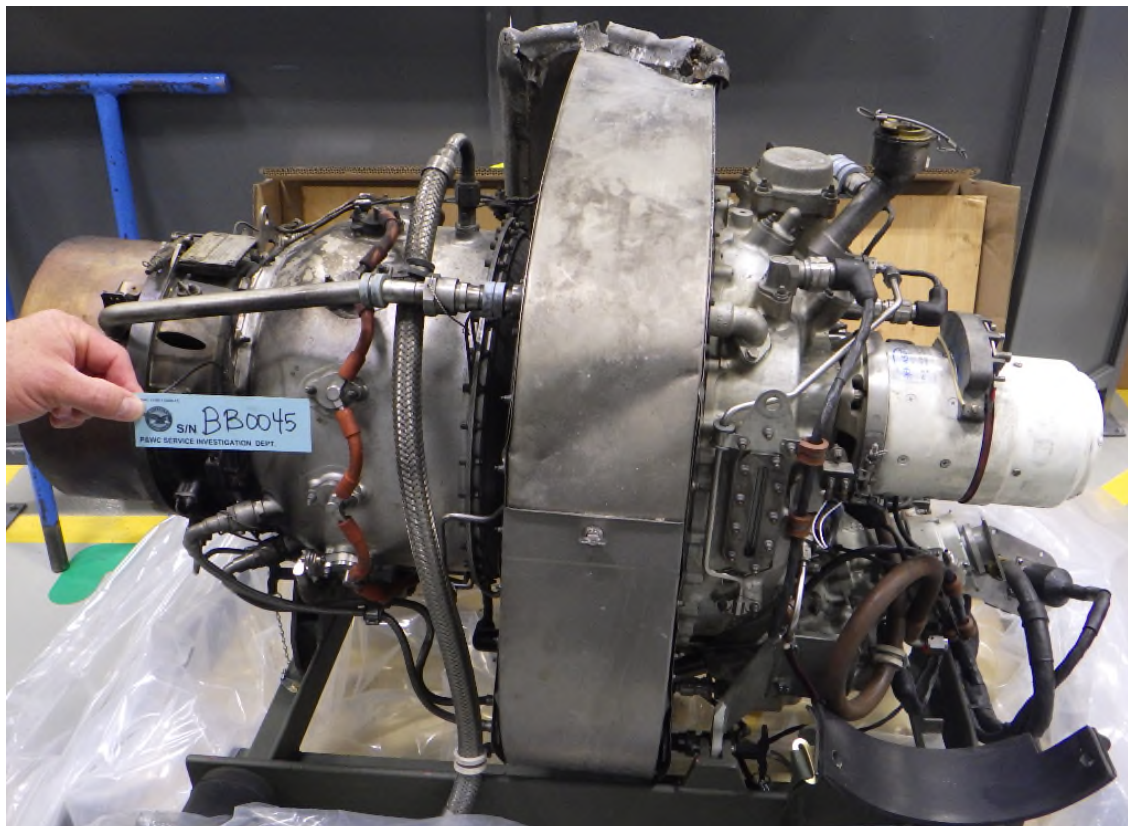


Photo No. 48: BB0045 right hand side

This document is subject to the restriction contained in the cover page.



5.1.1 External Cases

Reduction Gearbox:

There was no visible damage to the RGB as seen in Photo No. 49.



Photo No. 49: RGB

Exhaust Duct:

There was partially separated and dislodged sheet metal from the exhaust cone, which was deformed and covering the air flow path in the exhaust duct. Viewing the PT blades through the exhaust revealed that they were all fractured at the same height from the platform. The exhaust exhibited multiple pock marks consistent with high speed impact from small internal released material. There was one hole (red arrow on Photo No. 50) at approximately the 10 O'clock location exhibiting petalling which is consistent with an inside to outside perforation direction as seen on Photo No. 50. The size of the puncture hole was approximately 1.5 in x 1 in.

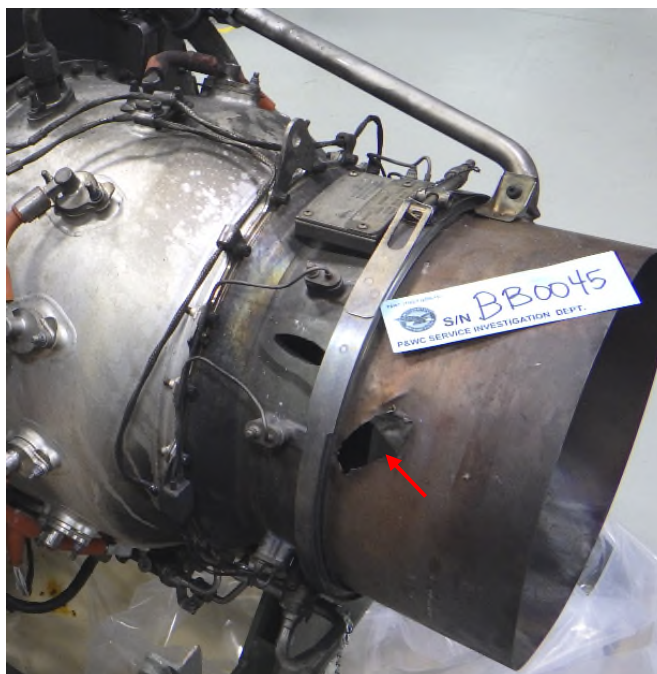


Photo No. 50: BB0045 soot and exhaust puncture

When examining the rear flange of the No. 5 bearing support housing, it was found that it was no longer circular and did not match the round aft cover plate. The red arrows on photo No. 51 show two locations where the support housing has deformed and is no longer circular. A red box was added to Photo No. 52 to show the direction in which the bearing support housing had been stretched to create a more rectangular shape.

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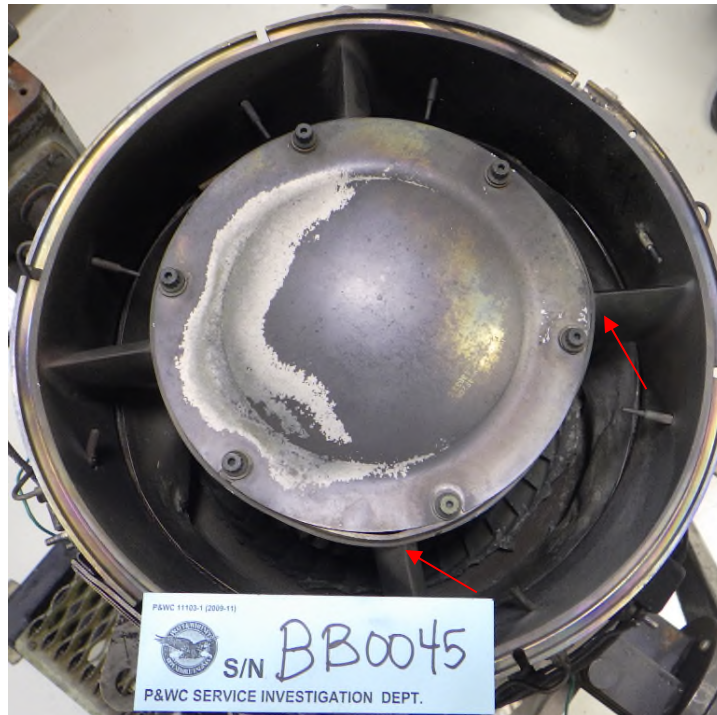


Photo No. 51: No. 5 bearing support deformation



Photo No. 52: BB0045 No. 5 bearing support



Gas Generator Case:

The air inlet was clear, however flakes consistent with burned ash were found in the plenum as seen in the following Photo No. 53.



Photo No. 53: Debris and soot in the inlet

5.1.2 Pneumatic Lines

Compressor Discharge Air (P3):

There was no visible damage to the P3 air boss.

5.1.3 Chip Detectors and Filters

Chip Detector:

The chip detector revealed small magnetic flakes as seen in Photo No. 54.

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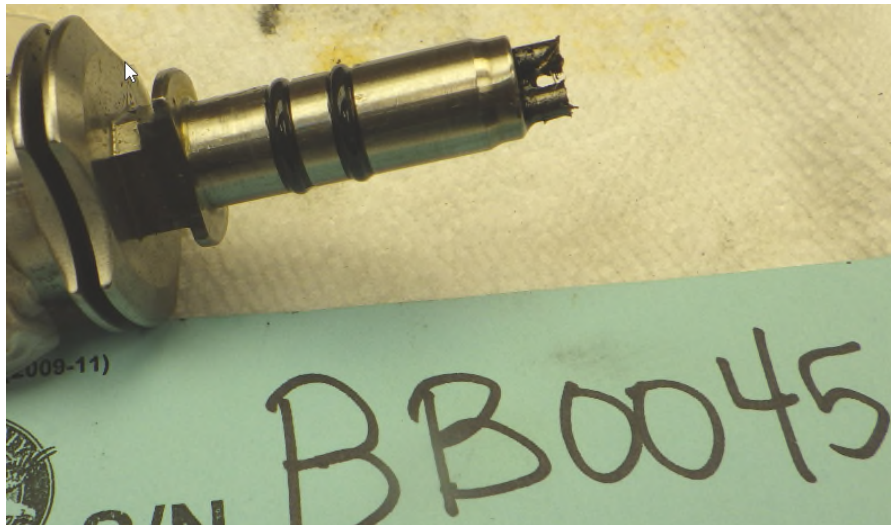


Photo No. 54: Chip detector with debris

Oil Filter:

The oil filter was clean, as seen in Photo No. 55.



Photo No. 55: Oil filter

Fuel Filter:

The fuel filter was not received with the engine.

This document is subject to the restriction contained in the cover page.



5.2 Disassembly Observations

5.2.1 Compressor Section

The compressor spool could be turned via the starter shaft with a normal hand effort, however as it turned a light metallic sound could be heard coming from the engine core. There was no damage observed on the inlet screen however there was a light grey-black deposit present which is consistent with fire residue. The deposits observed on this engine were more significant than that observed on the sister engine (BB0049).

Centrifugal Impeller:

The inlet case was intact and undamaged. The impeller showed minimal damage to the leading edges, however there was evidence of a previous blend repair (yellow arrow) and some minor nicks (red arrows) as seen on Photo's No. 56 and 57. The vanes tips were undamaged although there is some evidence of rubbing due to contact with the impeller shroud. This can be seen in Photo No. 58, where the red arrows point to a few locations where the shiny material represents the location that the impeller vanes tips contacted the impeller shroud.



Photo No. 56: As installed impeller

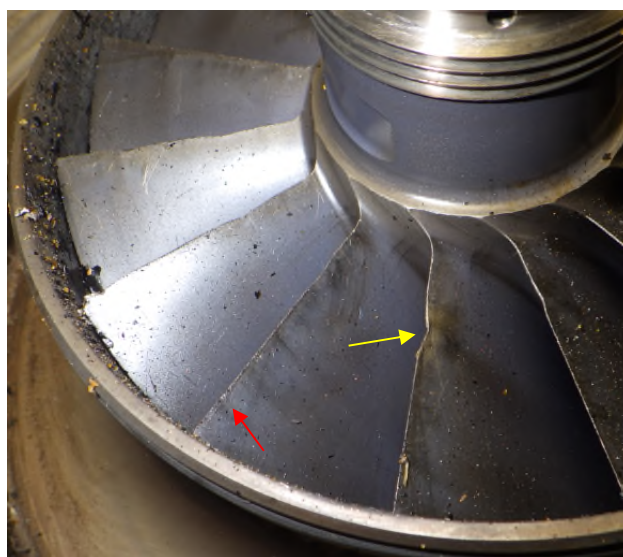


Photo No. 57: Close up of leading edges



Photo No. 58: Impeller with rub marks

Centrifugal Impeller Shroud:

The shroud was intact but showed rotational scoring near the impeller inlet across the entire 360 degrees as seen in Photo's No. 59 and 60.



Photo No. 59: Impeller shroud



Photo No. 60: Close up of scoring

Diffuser pipes:

The diffuser entrance openings were unobstructed and undamaged. The diffuser case and diffuser pipes were intact and undamaged, however there was a coating of black sooty material around the 12 O'clock position, consistent with an oxygen-starved fuel fire (red arrow on Photo No. 61). The concentration of black soot was higher at the 12 O'clock position, which is consistent with a post-event fire that occurred after engine shut down.



Photo No. 61: Soot build up on the diffuser tubes at the 12 O'clock position

The inner surface of the gas generator case showed evidence of a streaky, sooty deposit which is consistent with an internal oxygen-starved fire occurring post engine shut down. Photo No. 62 shows the soot with a high concentration around the 12 O'clock position as indicated by the red arrow.

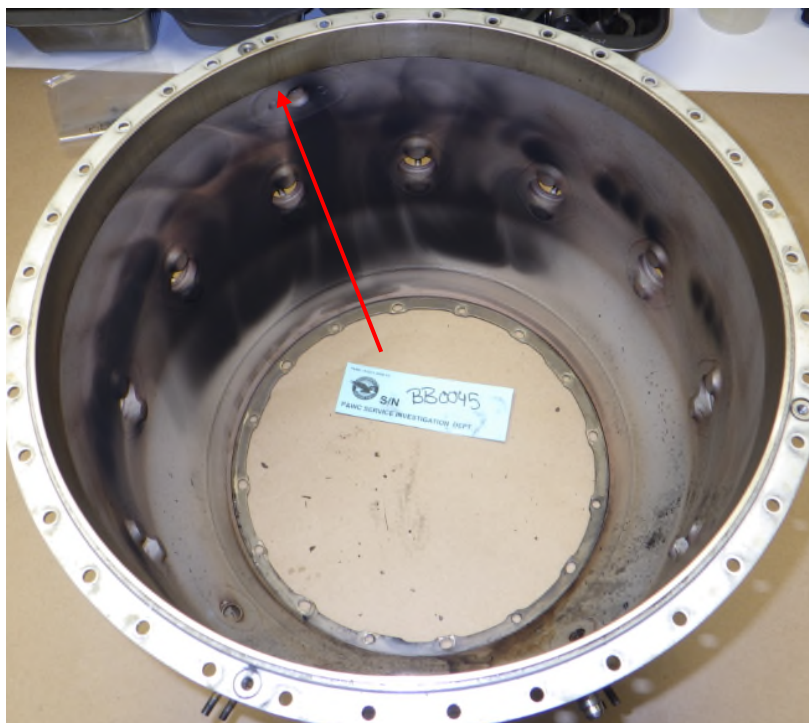


Photo No. 62: Gas Gen case with soot around 12 O'clock

No. 3 and No. 4 Bearings:

These bearings were inspected and found to be intact and undamaged.

3.2.2 Combustion Section

Combustion Chamber Liner:

The inner and outer combustor liners were intact and undamaged as seen on Photo No. 63.



Photo No. 63: Combustion chamber

Outer Liner:

The outer liner was examined and found undamaged however, had a high concentration of soot deposit as a result of an oxygen-starved fire that occurred post shutdown as seen in the following Photo No. 64. The ceramic coating was in good condition.



Photo No. 64: Outer liner



Inner Liner:

The inner liner also showed an accumulation of soot. The red arrow on Photo No. 65 points to the 12 O'clock position, where it can be seen that there is more apparent soot around this location than the 6 O'clock location. The side view of the inner liner shows further evidence of soot accumulation (Photo No. 66). The ceramic coating was in good condition.

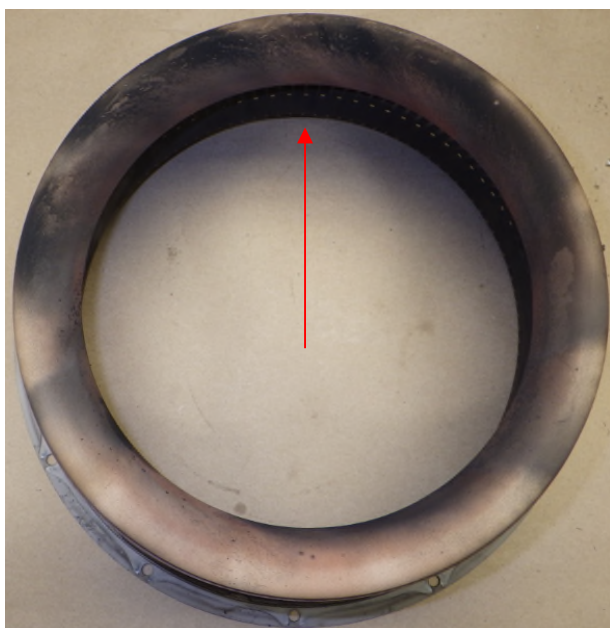


Photo No. 65: Inner liner exit lip



Photo No. 66: Inner liner soot build up

3.2.3 Turbine Section

The power turbine could be turned by hand, however with a high hand effort. As it was turned light metallic noises could be heard from the engine core.

Compressor Turbine stator:

The CT stator vanes were intact and undamaged on both the trailing and leading edges (Photo's No. 67 and 68), however on the aft sections of the vanes there was a slight colour change (bluish colour seen in Photo No. 69) which is consistent with a rapid over-heating event. The compressor turbine vane ring had some bright, shiny metallic particles (some of which are indicated with yellow arrows on Photo No. 70) which had adhered to the aft, suction side of the vanes. This is consistent with metal spray from the impeller shroud coating which was removed by the impeller vane tip rubbing.

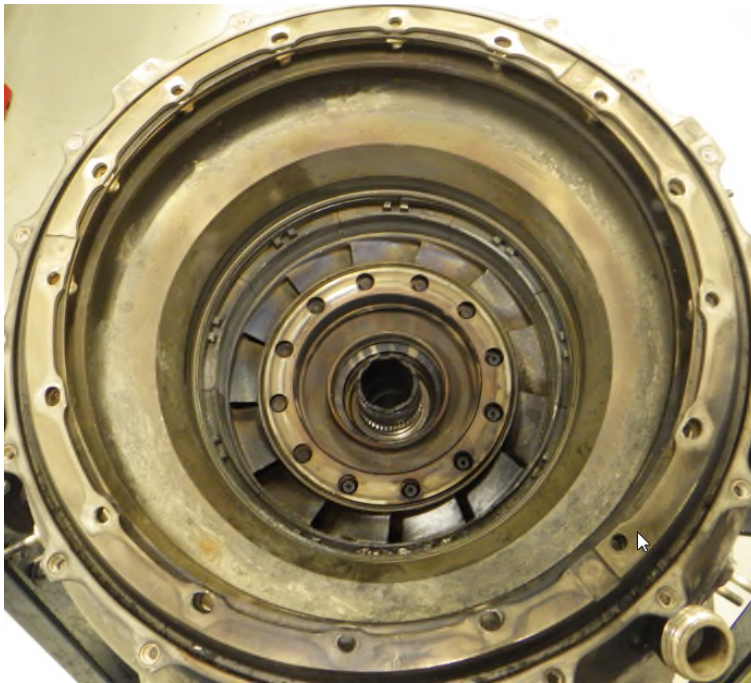


Photo No. 67: CT stator trailing edges as installed.



Photo No. 68: CT stator leading edges

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Photo No. 69: CT stator trailing edge



Photo No. 70: Silver specks

Compressor Turbine Shroud:

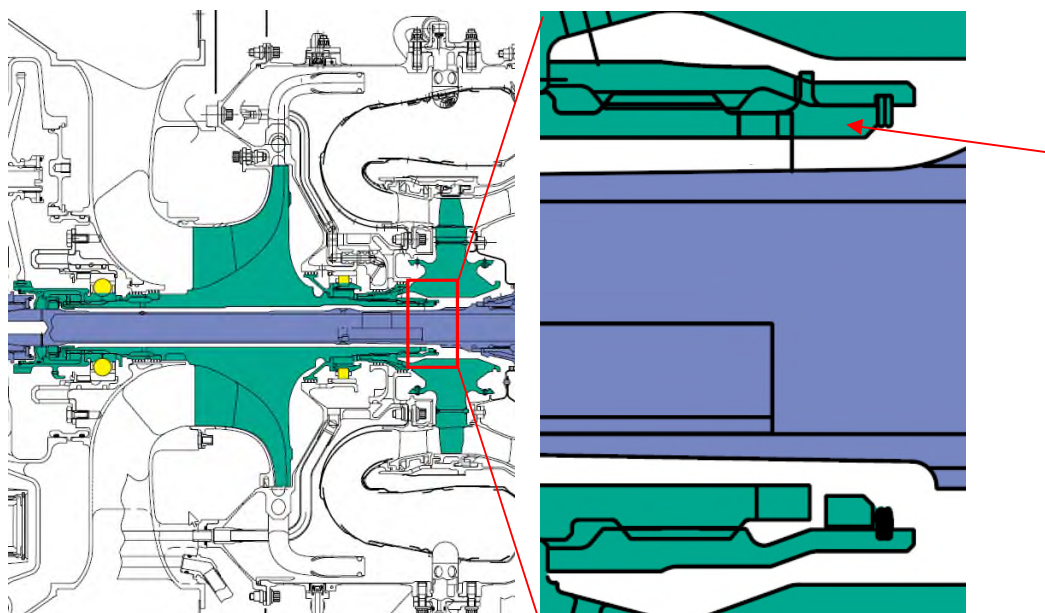
The CT blade shrouds showed significant rubbing and material transfer due to contact with the CT blades tips. The yellow arrows indicate the rub marks on all shroud segments which are shown on Photo No. 71.



Photo No. 71: CT shroud with rubbing marks

**Compressor Turbine:**

The compressor spool assembly is shown in sketch No. 1. The rear section comprised of the compressor impeller, a front No. 4 bearing air seal, the No. 4 bearing, the aft No. 4 bearing air seal and the compressor turbine assembly. These components are all rigidly retained in the axial direction with a retaining nut (red arrow) and key lock washer on the compressor impeller shaft.



Sketch No. 1

Upon inspection it was found that the retaining nut and key lock washer were correctly installed, however the assembly was no longer rigidly retained and the compressor turbine could be moved when loaded radially. The retaining nut's outer diameter was measured and it was found to be 0.11 inches larger than the factory dimension. The expansion of the nut is consistent with the release of the clamping load on the turbine spool assembly. The retaining nut had been exposed to elevated temperatures which caused the nut to grow.

The CT disc was intact and undamaged. The CT blades tips were all fractured by overload due to heavy contact with the CT shroud. The extensive blade tip damage, as seen in Photo No. 72, made it impossible to measure the blade growth.

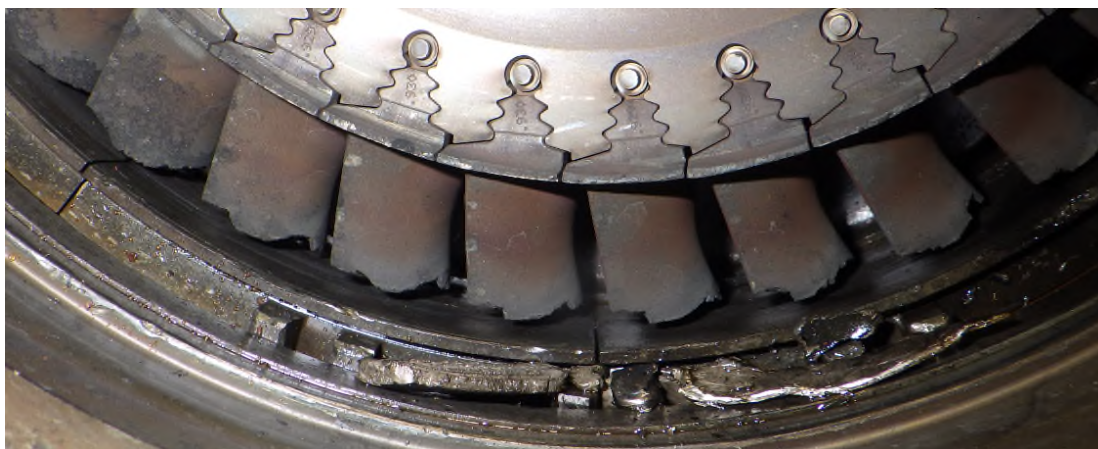


Photo No. 72: CT blade tip damage

The blade tip damage was due to contact caused by non-concentric rotation as a result of the loss of the compressor spool clamping load. The leading edges of the CT blades, as seen on Photo No. 73, were heavily covered in soot.



Photo No. 73: CT blades leading edges



ITT Probes, Busbar, and Harness:

Four of the T6 probes in the exhaust, which are identified with red arrows in Photo No. 74, were bent due to impact damage. The harness and busbar appeared undamaged.



Photo No. 74: Exhaust with damaged T6 probes.

Power Turbine exhaust

The exhaust was removed at Flange “F”, revealing the dislodged turbine exhaust cone deformed sheet metal as seen in Photo 75. This sheet metal is brazed onto the turbine exhaust cone but due to the PT blades release, the sheet metal had torn and dislodged from its original position.



Photo No. 75: PT exhaust cone deformation

Power Turbine stator:

The power turbine stator outer mounting flange was fractured, dented and deformed (Photo No. 77). Consequently, this allowed the vane section to become loose and offset from the core, permitting it to move aft into the PT blade/disk assembly and platforms. After the PT blade fracture, the PT blades contacted and machined a groove into the inner third span of approximately half of the trailing edge of the vane (Photo No. 76). The deepest groove was approximately $\frac{1}{4}$ inch. The No. 4 bearing front seal was grooved and fractured due to the PT disc assembly unbalance (Photo No. 78).



Photo No. 76: Grooved TE of PT stator vanes

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Photo No. 77: PT stator trailing edges

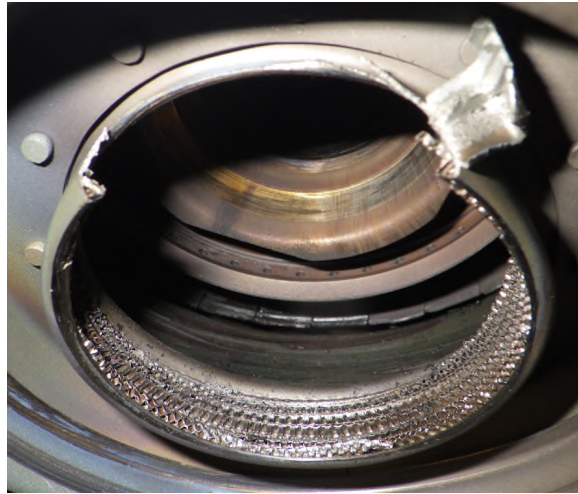


Photo No. 78: Damage due to PT shaft movement

The leading edges of the PT stator vanes were all intact and undamaged (Photo No. 79).



Photo No. 79: PT stator leading edges

**Power Turbine:**

The power turbine blades were all fractured in the dimpled area at approximately 1/3 the airfoil height above the platform as seen in Photo No. 80. This is representative of blade-loss due to an overspeed. PT blades are designed to release in the dimpled area at a speed of approximately 150% NPT in order to preserve the integrity of the PT disc. All fracture surfaces showed signs of tensile overload (no signs of fatigue could be found). The disc was de-bladed and measured for disc growth. The disk grew to 0.0026 inches over the factory limit which is characteristic of an overspeed condition.



Photo No. 80: PT blades fractured

The PT disk aft side had heat discoloration and severe rotational scoring (Photo No. 81). The aft crenelated flange was fractured from the disk and the fracture surface was smeared (red arrow on Photo No. 82). The yellow arrow on Photo No. 82 shows the rotational scoring due to the damaged PT shaft misalignment.

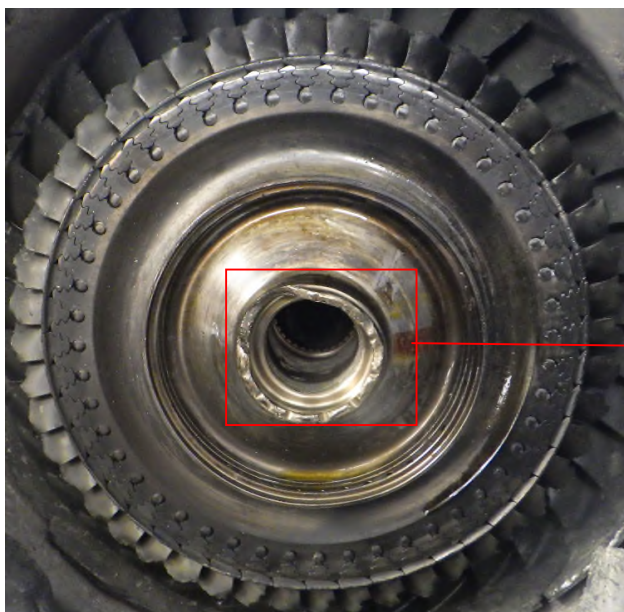


Photo No. 81: Rear PT disc with scoring

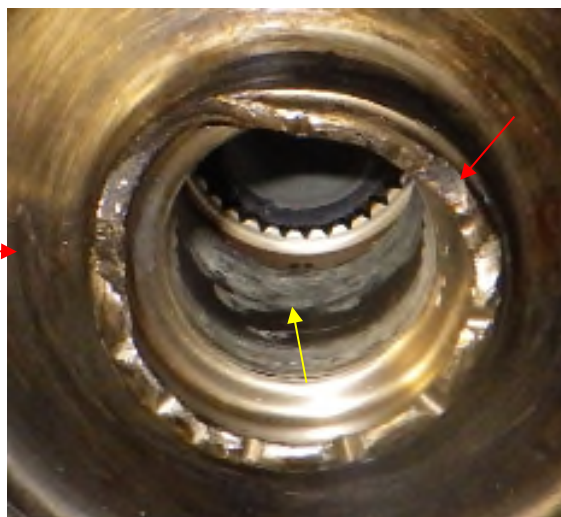


Photo No. 82: PT disc flange fractured

Power Turbine Shaft and Shaft Housing:

Examination of the engine as received revealed that the PT shaft was misaligned at an angle, as seen in Photo No. 83.



Photo No. 83: PT shaft off-center

The PT shaft was fractured at approximately 4 inches from the aft end as seen in Photo No. 84. The 45 degree shear lip on the fracture surface along with the twisting path of the fracture, is characteristic of torsional tensile overload (blue arrow). Severe rubbing marks were found in the fractured area (red arrow, Photo No. 84) which corresponded to the rubbing marks observed on the PT disc bore (yellow arrow, Photo No. 82).



Photo No. 84: Sheared section of PT shaft

The forward fractured PT shaft section had four sets of rotational contact marks along its length (see photo No. 85), which is consistent with a temporary elastic bending having occurred on the shaft.



Photo No. 85: Power Turbine Shaft

No. 5 Bearing and No. 5 bearing seals:

The No. 5 bearing seal runner was rotationally scored and partially fractured which is consistent with an uneven contact against the No. 5 bearing carbon seal (Photo No. 87).

The No. 5 bearing rollers showed flattened surfaces and the No. 5 bearing carbon seal was completely disintegrated (Photo No. 86). The No. 5 bearing seal runner was severely machined resulting in a through-crack (Photo No. 87). The No. 5 bearing housing was intact, however the rear bearing housing cylinder was distorted (Photo No. 88). The aft cover plate appeared to be offset from the housing because the housing had deformed as shown by the yellow arrows on Photo No 89. The forward cavity of the No. 5 bearing surface was coated in oily soot which is consistent with an oil fire.

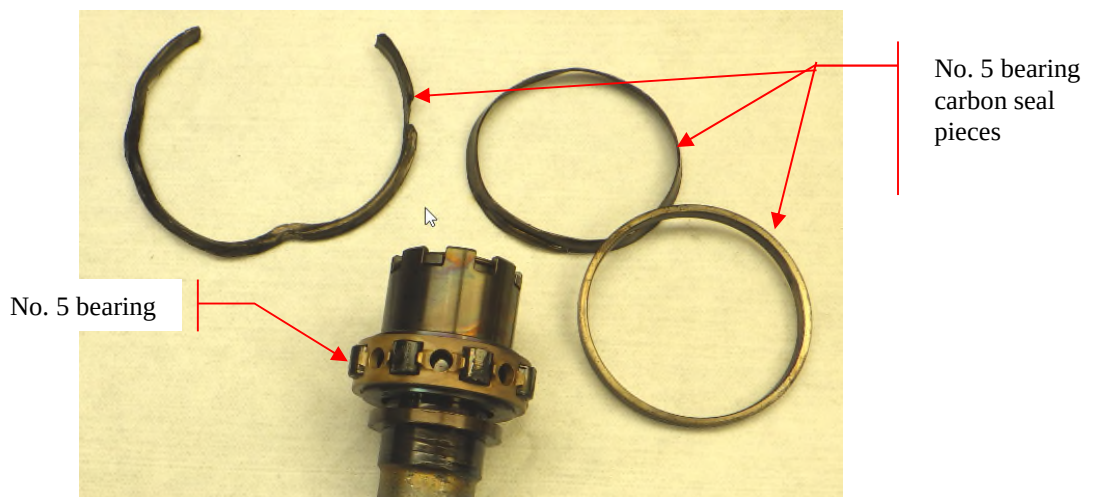


Photo No. 86: No. 5 bearing and No. 5 bearing carbon seal

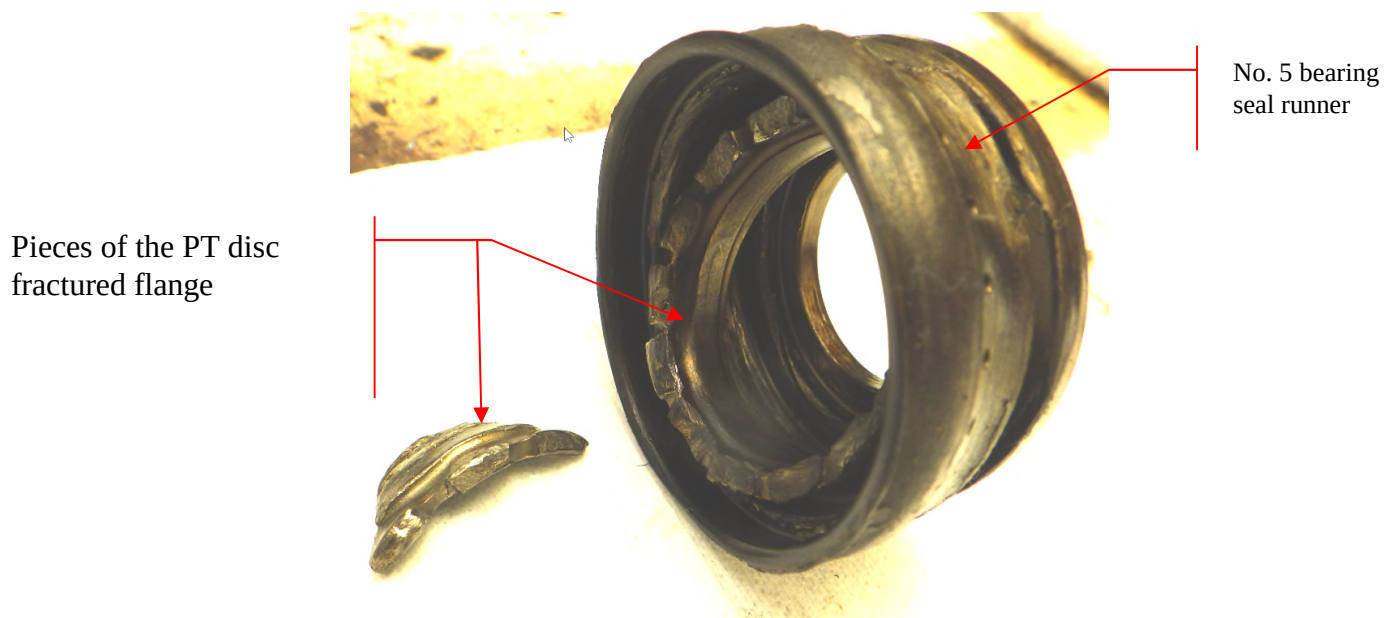


Photo No 87: No. 5 bearing seal runner

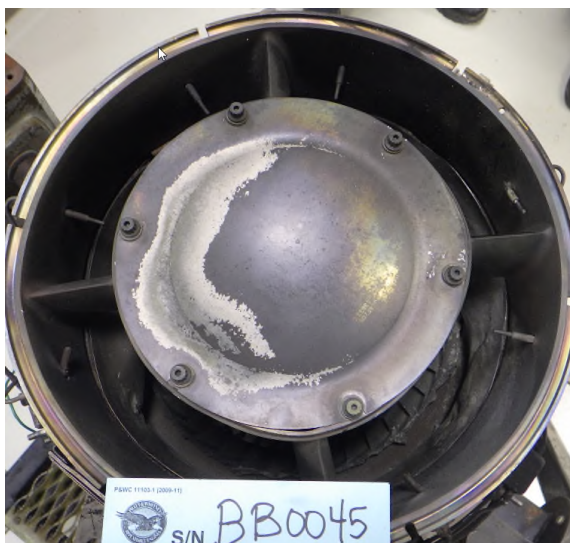


Photo No. 88: Aft cover plate



Photo No. 89: Exhaust

3.2.4 Reduction Gearbox

All of the shafts in the RGB were free to rotate, confirming the internal integrity of the RGB. The RGB was split at Flange “A”, showing that all internal components were oil wetted (Photo’s No. 90 and 91). The No. 1 and No. 2 bearings were intact and undamaged, as was the input shaft, 1st stage reduction gear, 2nd stage reduction gear, accessory gears, and output shaft. Based on this the gearbox was not disassembled further.



Photo No. 90: RGB diaphragm and gears



Photo No. 91: RGB housing



3.3 Accessories Condition

DCU:

The DCU (Photo No. 92) had been shipped back to P&WC for a download and analysis. The DCU's record the engine trim information as well as some cycle counting information, but does not record engine faults. The DCU communication was established without problem and the trims and cycles were downloaded successfully.

SYMBOL	ENG UNIT	VALUE	NEW VALUE	BLOCK	OFFSET
MGT BIAS	N/A	103.0000		0	12
TORQUE BIAS	N/A	-1.8984		0	8
TORQUE GAIN	N/A	0.9780		0	10
GEAR BOX #	N/A	BB0045		0	114
TURBO MACH #	N/A	BB0045		0	108
AIR FRAME #	N/A	0.0000		0	106
IMP_CYC_COARSE	Counts	646.0000		5	0
IMP_CYC_FINE	Counts	0.8035		5	2
CT_CYC_COARSE	Counts	5727.0000		5	4
CT_CYC_FINE	Counts	0.1921		5	6
PT_CYC_COARSE	Counts	6223.0000		5	8
PT_CYC_FINE	Counts	0.4539		5	10
ENG_RUN_COARSE	Hours	6054.0000		5	12
ENG_RUN_FINE	Hours	0.7631		5	14
LFCREEP	Lfcrcr				0

Handwritten notes on the table:
 A18F0148
 DCU from
 Eng #2 (Right)

Photo No. 92: DCU

EEC:

The EEC (Photo No. 93) had previously been shipped back to P&WC for a download and analysis. What was found to be related to this event was a fault on two separate sensors which both showed that the NPT signal had exceeded its max range of 127%.

An analysis (18-089 EEC download_SUPP 1) is included in Appendix A.



Photo No. 93: EEC

FMM:

When the unit S/N 11522498 (SB016), as seen in Photo No. 94, was removed from the engine fuel was present and exited the ports. The exterior of this unit was slightly soiled, however all lockwire was present. The power lever moved freely over its full range and the alignment with the rig-pin location was obtained at the detent. The driveshaft could not be turned by hand, which is normal. The FMM was tested in accordance with the Woodward CMM 73-20-14 Rev 5 and there were minor deviations noted, however nothing that would have effected normal operation. The FMM was able to transition between auto and manual mode without problem.

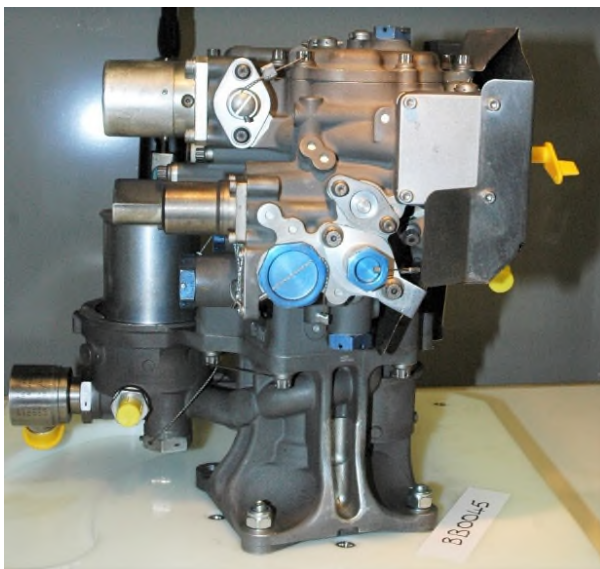


Photo No. 94: FMM



Fuel Nozzles:

The 12 fuel nozzles were removed from the gas generator case and found undamaged but with heavy sooting/carbon. It was decided not to test the nozzles due to the carbon present on the nozzles, which may have affected the flow test results. Three nozzles are shown in Photo's No. 95 through 97.

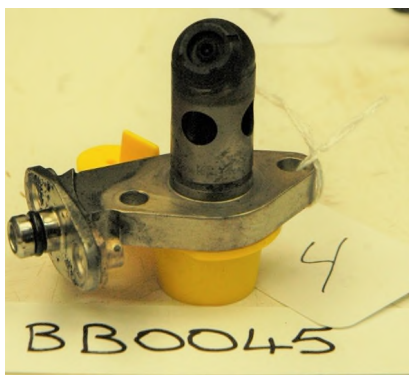


Photo No. 95: Nozzle 4



Photo No. 96: Nozzle 9

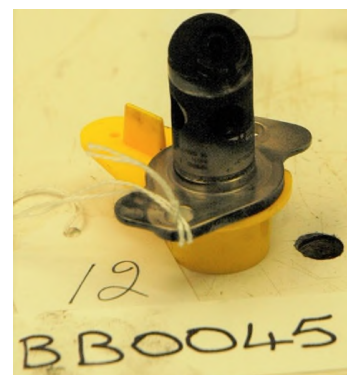


Photo No. 97: Nozzle 12

Flow divider valve:

The exterior was inspected (Photo No. 98) and the unit was generally clean and had the sealing compound present at the end-caps. Based on the visual results and condition of the engine, the investigation team agreed not to carry out further testing on this unit.



Photo No. 98: Flow divider valve

**Speed sensors:**

Torque sensor: The torque sensor (Photo No. 99) was visually inspected and was found to be in an acceptable condition for further testing. The connector had fluid present inside it, as well as black deposits on the contacts. The sensor was tested, including temperature cycling and dynamic functions and results satisfactory, with only minor deviations that would not have affect the sensor functionality during operation.

Ng Speed Sensor: The Ng sensor (Photo No. 100) was visually inspected and found to be in acceptable condition for further testing. The inside of the connector was undamaged and clean but had a few black deposits and the magnet was very slightly recessed into the sensor body. The sensor was tested and the results were satisfactory, thus confirming the recessing of the magnet had no operational effect.

NPT Speed Sensor: The exterior of the NPT sensor (Photo No. 101) was generally clean and the magnet was not protruding from the sensor body. The electrical connector shell was undamaged, however, it was slightly stained with some fluid inside. The gold plating was slightly worn at the base of contact F. The sensor was tested and the results satisfactory.

Note: It is possible that the fluid found on the connectors of multiple sensors may have been a result of extinguishing the reported fire on this engine, and this may have also influenced the test results.



Photo No. 99: Q sensor



Photo No. 100: Ng sensor



Photo No. 101: NPT sensor

Harness:

The harness P/N 3121134-05 could not be tested because the P23 connector had to be cut off during engine removal. The wire exterior was generally clean though there was some fluid residue inside connectors P10 and P11. Additionally inside connector P11 an inconsequential piece of packing was found.

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The harness P/N 3121138-01 was visually inspected and generally clean though there was some fluid residue present inside the shell of connector P16 and P22 and some black deposits present on connector J14. The harness was tested, with a few results found to be outside of the test point limits. Had these observations been present during flight an indication would have been present in the cockpit, therefore it is believed that these observations were a consequence of the event.

Note: It is possible that the fluid found on multiple connectors may have been a result of extinguishing the reported fire on this engine, and this may have also influenced the test results.



6.0 REFERENCE LISTING

- (A) DCU Download
- (B) EEC data review
- (C) NTSB data review
- (D) P&WC Accessories Incident Factual Notes.

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REFERENCE “A”

SYMBOL	ENG UNIT	VALUE	NEW VALUE	BLOCK	OFFSET
MGT BIAS	N/A	105.0000		0	12
TORQUE BIAS	N/A	-5.5000		0	8
TORQUE GAIN	N/A	0.9690		0	10
GEAR BOX #	N/A	BB0049		0	114
TURBO MACH #	N/A	BB0049		0	108
AIR FRAME #	N/A	0.0000		0	106
IMP_CYC_COARSE	Counts	594.0000		5	0
IMP_CYC_FINE	Counts	0.0945		5	2
CT_CYC_COARSE	Counts	5548.0000		5	4
CT_CYC_FINE	Counts	0.0972		5	6
PT_CYC_COARSE	Counts	6536.0000		5	8
PT_CYC_FINE	Counts	0.4905		5	10
ENG_RUN_COARSE	Hours	6254.0000		5	12
ENG_RUN_FINE	Hours	0.1920		5	14
LCFCREEP	Lcfcreep				0

A18 F0148
DCU From
ENG # 1 (LEFT)

SYMBOL	ENG UNIT	VALUE	NEW VALUE	BLOCK	OFFSET
MGT BIAS	N/A	103.0000		0	12
TORQUE BIAS	N/A	-1.8984		0	8
TORQUE GAIN	N/A	0.9780		0	10
GEAR BOX #	N/A	BB0045		0	114
TURBO MACH #	N/A	BB0045		0	108
AIR FRAME #	N/A	0.0000		0	106
IMP_CYC_COARSE	Counts	646.0000		5	0
IMP_CYC_FINE	Counts	0.8035		5	2
CT_CYC_COARSE	Counts	5727.0000		5	4
CT_CYC_FINE	Counts	0.1921		5	6
PT_CYC_COARSE	Counts	6223.0000		5	8
PT_CYC_FINE	Counts	0.4539		5	10
ENG_RUN_COARSE	Hours	6054.0000		5	12
ENG_RUN_FINE	Hours	0.7631		5	14
LCTCREEP	Lcfcrcrp				0

A18F0148
DCU From
ENG #2 (Right)

Service Investigation

Accident / Incident Report

P&WC 8114 (11-98)



Pratt & Whitney Canada

Une société de United Technologies / A United Technologies Company

REFERENCE “B”



November 1, 2018

Pratt and Whitney Canada EEC data review

Subject: Red File 18-089

Tail: N312SA

This supplement was written to add some additional information to the letter issued August 15, 2018. The changes or additions are highlighted with a black line in the left had column.

Summary:

The data was downloaded with the TSB of Canada present. The data was exported to excel and then decoded. In order to confirm the validity of the data conversion method, the temperature trim of both engines was exported, and decoded. The resulting value was then compared to the engine trim.

The EEPROM recording will hold up to 61 faults.

The same faults are always written to the same addresses.

On an engine start up the EEPROM will set the Interface Fault (IF) and NG (gas generator speed) to 0, and begin to re-write over the faults from the previous flight (if new faults occur). So we can distinguish a fault from the previous flight by an entry with a fault code, IF and NG.

The data is exported in the following format:

BLOCK 11	Parameter	Octal	OCT2BIN	DEC	Scaling	Value	
11/1150	NFQAIF	33					
11/1151	NFQAIF	1	00000001				bit 8 - NF Range ←
11/1152	NGLSB	343	11100011	24803	128	96.8867	←
11/1153	NGMSB	140	01100000				

The Block 11 is the address which the fault (parameter) is written to, in Octal.

The first output will always be the fault word.

The second output (red arrow) is what triggered the fault.

Export Control Classification			
			(x) if Applicable
Contains no Technical Data			()
Not Subject to the EAR pursuant to 15 CFR 734.7(a)(1) or Not Subject to the ITAR pursuant to 22 CFR 120.11 (NSR)			()
Jurisdiction and Classification based on Physical Location of the Item.	Location		Regulations
			EAR
			ITAR
	Outside US*		NSR
	U.S.		9E991
			NSR
* Additionally, refer to the classification under the local export regime where the item is located, as provided in the grid.			EIPA (ECL)
			DPA (CG)
	Canada		NSR
		No	

ISSUED: 11/01/2018

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The last two are the NG speed. NGLSB (NG Least Significant Bits), NGMSB (NG Most Significant Bits). The Ng is then converted to binary and then to decimal with the scaling applied (purple arrow).

So in the above example from BB0049 we determine that there was an NFQ fault which triggered because of NF range (out of range) at NG of 96.89%. We cannot determine if this was pre/during/post impact.

Due to the basic nature of the fault recording in the EEC we cannot make conclusions from this data, but can only say what faults could have been seen on the last flight. There is no time stamp so it is not possible to tell the order in which they occurred.

The data has been highlighted using the following color coding:

Red – no data or a previous flight

Yellow – shows an unsuccessful data transfer

Blue – Data source cannot be confirmed at this time however may be from the last flight but with an Ng at 0 (either prior to the engines starting or after shutdown), a previous flight, or due to the nature of a crash event there is sometimes not a complete data transfer which can affect data logging.

Green – shows data which is confirmed to be logged in the last flight while the engine was running and shows an NG.

The PW206B engine is equipped with the following sensors:

Torque sensor: provides the primary torque signal (QA) and NPT signal to the EEC.

NPT sensor: provides the backup torque signal (QB) and backup NPT signal to the EEC. It provides the primary NPT signal to the cockpit.

NG: Provides NG speed to the cockpit and the EEC.

Faults from the last flight with the engines running are as follows:

Engine 1: BB0049

EEC P/N: 816877-3-004

Cust No (PWC): not available

S/N: C95110010

NFQA fault at NG=96.88% due to out of NF range as detected by probe A

NFQB fault at NG=97.62% due to out of NF range as detected by probe B

ARI fault at NG=15.06% which was an ARINC Input interface failure word due to synchronization and loss of ARINC data

LCF fault at NG=98.67% due to a latched interface

Special fault word containing last NFQ word set at NG=100.06% (NF range fault/mark time range fault/space time range)

The fact that the engine BB0049 had an NFQA and NFQB fault indicates that both torque and NPT sensors detected the NF out of range fault. This fault is triggered when the NPT speed exceeds 127%.

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ISSUED: 11/01/2018

Page 2 of 3

PRATT & WHITNEY CANADA

Engine 2: BB0045
EEC P/N: 816877-5-004
Cust No (PWC): 01R3121671-06
S/N: 97064729

ALAF fault at NG=11.4% due to the alternator/airframe power checks
NFQA fault at NG=94.13% due to out of NF range as well as TS range as detected by probe A
NFQB fault at NG=95.13% due to out of NF range as well as TS range as detected by probe B
LCF fault at NG=96.4% due to a latched interface
Special fault word containing last NFQ word set at NG=73.57% (NF range fault/mark time range fault/space time range)

Note: ALAFIF is defined as Alternator/Airframe Power Interface status word. It is set when the NG Speed >40% and the PMA voltage is low.

Note: Special fault word SPECIF is a copy of NPQAIF so it has exactly the same information.

The fact that the engine BB0045 had an NFQA and NFQB fault indicates that both torque and NPT sensors detected the NF out of range fault. This fault is triggered when the NPT speed exceeds 127%.

Service Investigation

Accident / Incident Report

P&WC 8114 (11-98)



Pratt & Whitney Canada

Une société de United Technologies / A United Technologies Company

REFERENCE “C”

Subject: Red File 18-089

7 September 2018

National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC
20594

Attn: Aaron Sauer
Senior Air safety Investigator, Office of Aviation Safety

Reference: Operator: Pentastar Aviation Charter Inc (Owner: Bennett Aviation LLC)
EC135P1, registration N312SA
Chicago, IL, 07 Jul, 18
TSB File A18F0148
P&WC File 18-089

Dear Sir,

P&WC has received flight data including data from the PW206B engine's BB0045 and BB0049.

The analysed data was obtained from the following file:
AllParams_SecondExport_5hz_ForCider1.csv

The annotation used throughout this letter will be as follows:

Q1 = Filtered Torque 1
Q2 = Filtered torque 2
CLP = Collective Angle 1
NG = Gas generator speed
NPT (NF) = Power turbine speed
NR = Main rotor speed
PT = Power turbine

Export Control Classification			
			(x) if Applicable
Contains no Technical Data			()
Not Subject to the EAR pursuant to 15 CFR 734.7(a)(1) or Not Subject to the ITAR pursuant to 22 CFR 120.11 (NSR)			()
Jurisdiction and Classification based on Physical Location of the Item. * Additionally, refer to the classification under the local export regime where the item is located, as provided in the grid.	Location	Regulations	
		EAR	ITAR
	Outside US*	NSR	NSR
	U.S.	9E991	NSR
		EIPA (ECL)	DPA (CG)
	Canada	NSR	No

ISSUED: 10/31/2018

Page 1 of 14

Background information:

PW206B Normal Operation:

The EEC controls the torque motor, which rotates the fuel metering valve.

Manual mode operation:

The PLA twist grip movement sets the rotational position of the 3D cam of the NG (N1) speed governor.

The PW206B engine will govern at 100% or 104% in auto mode depending on the altitude. In flight the control system will provide power to maintain a governing speed of 100%NPT at a pressure altitude up to 5000ft. Between a pressure altitude of 5000ft and 10000ft the NPT speed will automatically adjust between 100% and 104%.

In auto mode the twist grip should remain in the normal (NORM) detent which is 55+/-5 deg, outside of which the EEC will switch to manual mode.

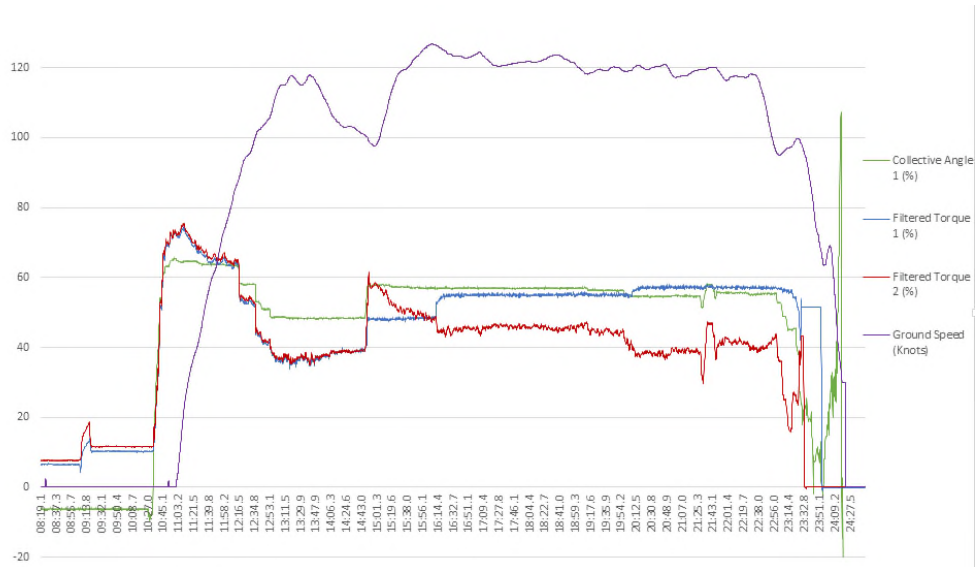
Summary of analysis:

The excel file with recorded flight data was provided by the NTSB. The data from the last flight was plotted with a focus on specific parameters: Filtered Torque 1 (%); Filtered torque 2 (%); Ground Speed (knots); Radio Height (ft); Time and Collective Angle 1 (%). Note that when plotted the collective angles 1 and 2 were similar so for the purposes of simplicity only collective angle 1 is being used.

In order to have a general view of the entire flight two plots were generated; first at a higher level and then re-plotted and examined in more detail. The first plot (Plot 1) includes the two engine torques, CLP and ground speed. In this graph the engine start can be seen, followed by the takeoff, flight and then subsequent impact. From plot 1 we can determine that the engines were running for approximately 15min.



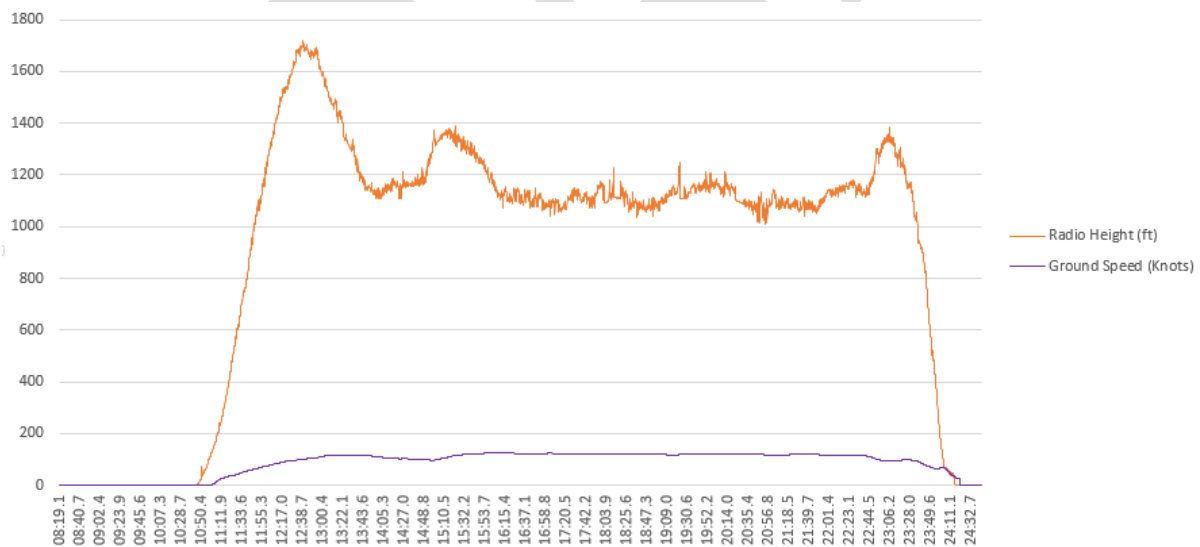
PLOT 1



Q1, Q2, CLP, Ground Speed

A second plot (Plot 2) was generated with the ground speed and radio height (ft). Based on this plot the pilot never exceeded 1800ft thus should have been governing with an NR at 100% at all times during this flight.

PLOT 2



Altitude and Groundspeed

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In order to more clearly understand the governing of the two engines, and their reactions to the collective movement the two filtered torques and the CLP have been re-plotted with a range of 20% to 75%, on plot 3. The engine 2 torque (shown in red) is reacting to the CLP inputs until the time 23:17.0. At time 14:29:5 the #1 engine (blue) is believed to have been switched into manual mode and from this point on reacts to twist grip inputs which explains why it is not following the CLP inputs.

PLOT 3

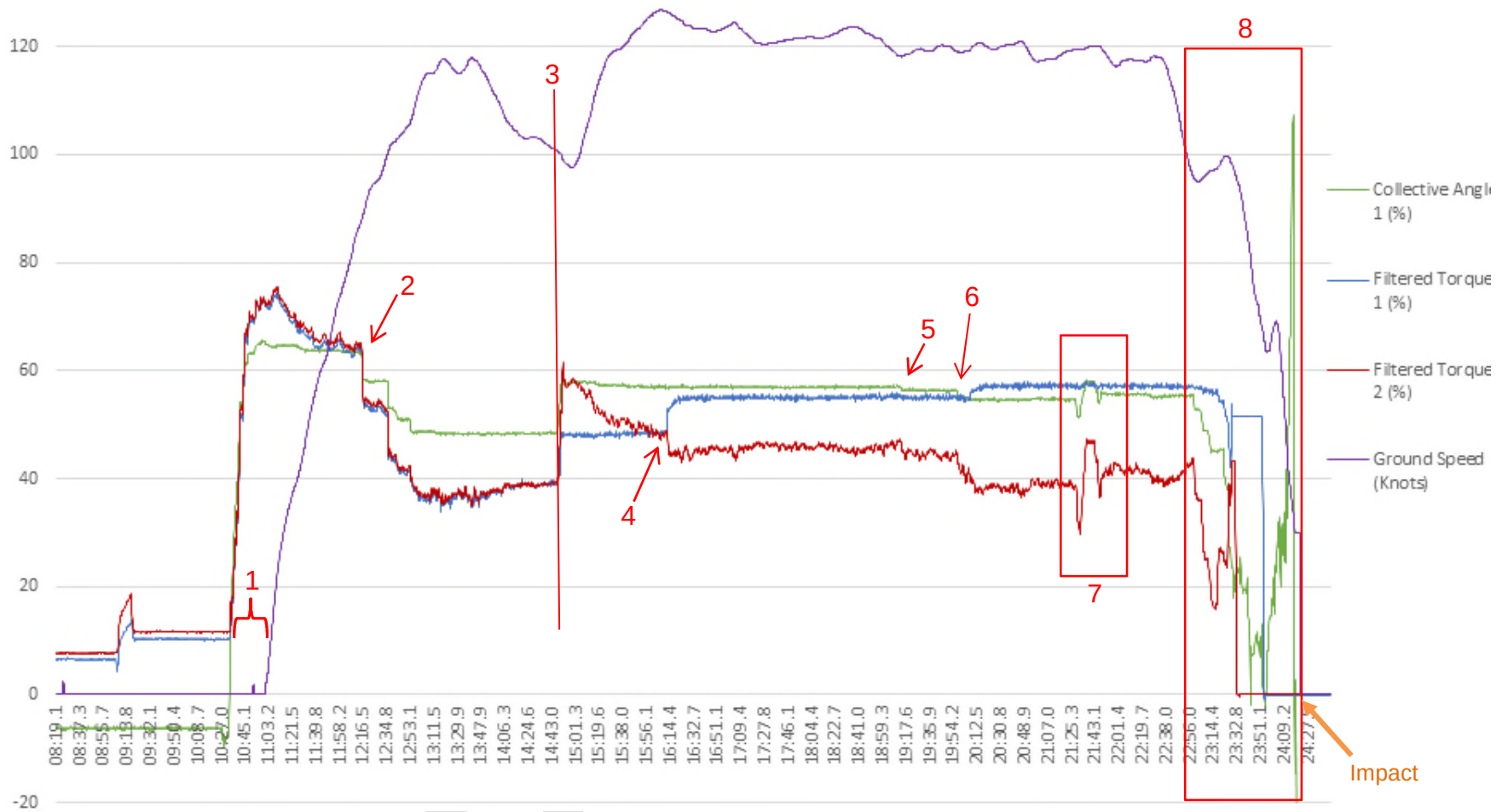


CLP, Engine 1&2 Torques

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PLOT 4



Plot 1 marked up

1 – The red bracket highlights the time while the engines have responded to the CLP demand and the aircraft moves into a hover, prior to gaining airspeed and continuing in the take-off regime. Both engines are responding to the CLP inputs.

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2 – At this point the CLP is reduced in 4 steps, following which the torques of both engines are reducing. At this point both engines are responding to the CLP inputs and thus running in auto mode.

3 – The reduced torque resulted in a reduction in airspeed (and altitude when referencing the same time on plot 2). At this point a CLP increase was carried out resulting in a torque increase and consequently an increase in airspeed. The torque of engine 2 increased following the CLP, while the torque on engine 1 increased partially and then holds its torque value. It is a very stable value, typical of manual mode governing.

3-4 – The airspeed and altitude increased (following the pilot inputs) and then decrease thus reducing the load on the system (see plot 2) and the CLP is very slightly decreased which in conjunction with the engine governing results in a slow decrease on the torque of engine 2. The engine 2 is still governing in auto mode, thus the control system will adjust the torque as necessary in order to maintain NPT. The torque on engine 1 is unchanged which could be representative of governing in manual mode.

4 – At this point the CLP is stable, however there is an apparent input through the twist grip to engine 1 causing an NG increase (due to an increase of fuel flow) and thus the torque to increase. This increase would have increased the NPT and thus the main rotor speed on this engine. The engine 2 is running in auto mode so will try to control the NR and try to maintain the setting, and this results in a slight decrease in the engine 2 torque in order to maintain the NPT speed (and thus main rotor speed) at the flight setting.

5 – At this point there is a CLP reduction. The engine 2 torque reduces as a consequence while the engine 1 torque does not respond to this request and remains unchanged. Even though the engine 1 torque is in manual mode there is a very slight movement to the signal. This can be explained because the two engines are coupled to the main rotor, so as the engine 2 reacts and changes settings in order to maintain NR, the engine 1 will experience slight fluctuations due to the output shafts being coupled.

6 – There is a further CLP reduction followed by an apparent twist grip manipulation to the engine 1 causing the torque of engine 1 to increase and the torque of engine 2 to further decrease. Following the torques stabilization of these inputs there would have been an apparent difference in the engine torques of approximately 18-20% in the cockpit (between points 6 and 7 on the graph).

7 – The area enclosed in the red square shows a CLP input starting at 54%, down to 51%, up to 58% and then settling at 55%. The engine 2 responds to this input and consequently drops torque to 29%, increases to 47% and then settles once

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the CLP inputs are removed. The engine 1 torque does not react to this input and holds its value; further confirming that this engine is running in manual mode thus the FMM is governing on inputs from the twist grip and not on the Collective.

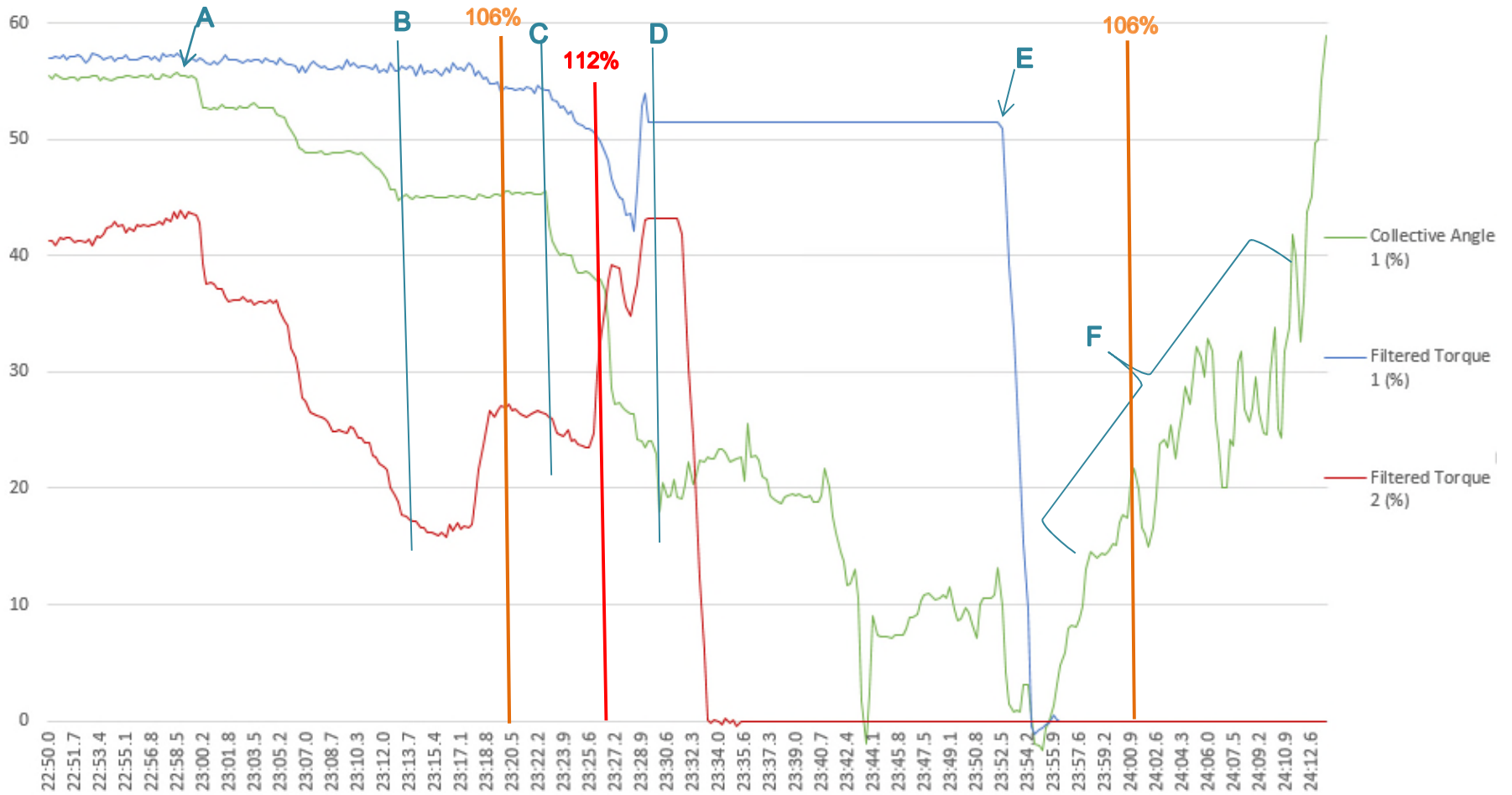
8 – The area in this box will be further expanded in plot 4 starting at time 22:25:00 and finishing at 24:19:00 with a zoom on the y-axis from 0 to 60.

The orange arrow point to the time of impact at 24min and 16s based on the audible sound from the cockpit (information provided by the NTSB).

DRAFT



PLOT 5



CLP and Q from time 22:50:00 to time 24:12:60

A – Up to this point the CLP has very little movement and the torques of both engines are constant.

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A to B – Between point A and B there were 3 CLP reductions, all of which followed by the torque of engine 2 dropping it to a value of 16%. The torque of engine 1 did not follow this input and remained relatively constant.

B to C – Between lines B and C the collective is constant but there is an increase in torque on the number 2 engine, which we deduce to be due to an input from the twist grip. There is a resulting slight reduction on the torque of engine 1 by approximately 2.5% that can be explained by either a main rotor speed increase or twist grip reduction.

The orange line at 23min and 26s represents an audible gong from the cockpit (information provided by the NTSB) indicating that the main rotor has reached or exceeded 106%

C to D – Between lines C and D the CLP is reduced by 25%, so it would be expected that the torques of both engines should also drop if they were in auto mode, however this did not occur – the torque of the number 1 engine is initially decreasing somewhat but this can be explained by an increase in NR speed caused by the reduction of CLP. The increase in torque from engine number 2 when CLP is concurrently being reduced can only be explained by an increase in twist grip position. Prior to line D both engine torques are increasing while CLP is decreasing. The engine reactions are examined further on plot 6.

The red line at 23min 26s represents when the audible sound from the cockpit (information provided by the NTSB) for the start of the continuous high tone. This tone comes on when NR is greater or equal to 112%, and will stay on until the NR comes back below this range.

D – Prior to line D there had been an increase in the torque on both engines, following which they were both held constant. It is deduced that the pilot used the twist grips to manually increase the power on both. With the collective around 20% and with the engine 1 and 2 torques at 51.5 and 43% respectively, this would cause the rotor and NPT speeds to increase (with a collective position around 20% in automatic governing mode the torques of the engines should have been at very low torque value, moving towards 0%). Based on the high torque values and low CLP, the conclusion is that both engines were in manual mode.

D to E – The CLP is still being decreased, until it reaches 0. The filtered torque of the number 2 engine drops to 0 (see description of plot 6 for further information).

E – At this point the engine 1 torque dropped suddenly to 0 (see description of plot 6 for further information).

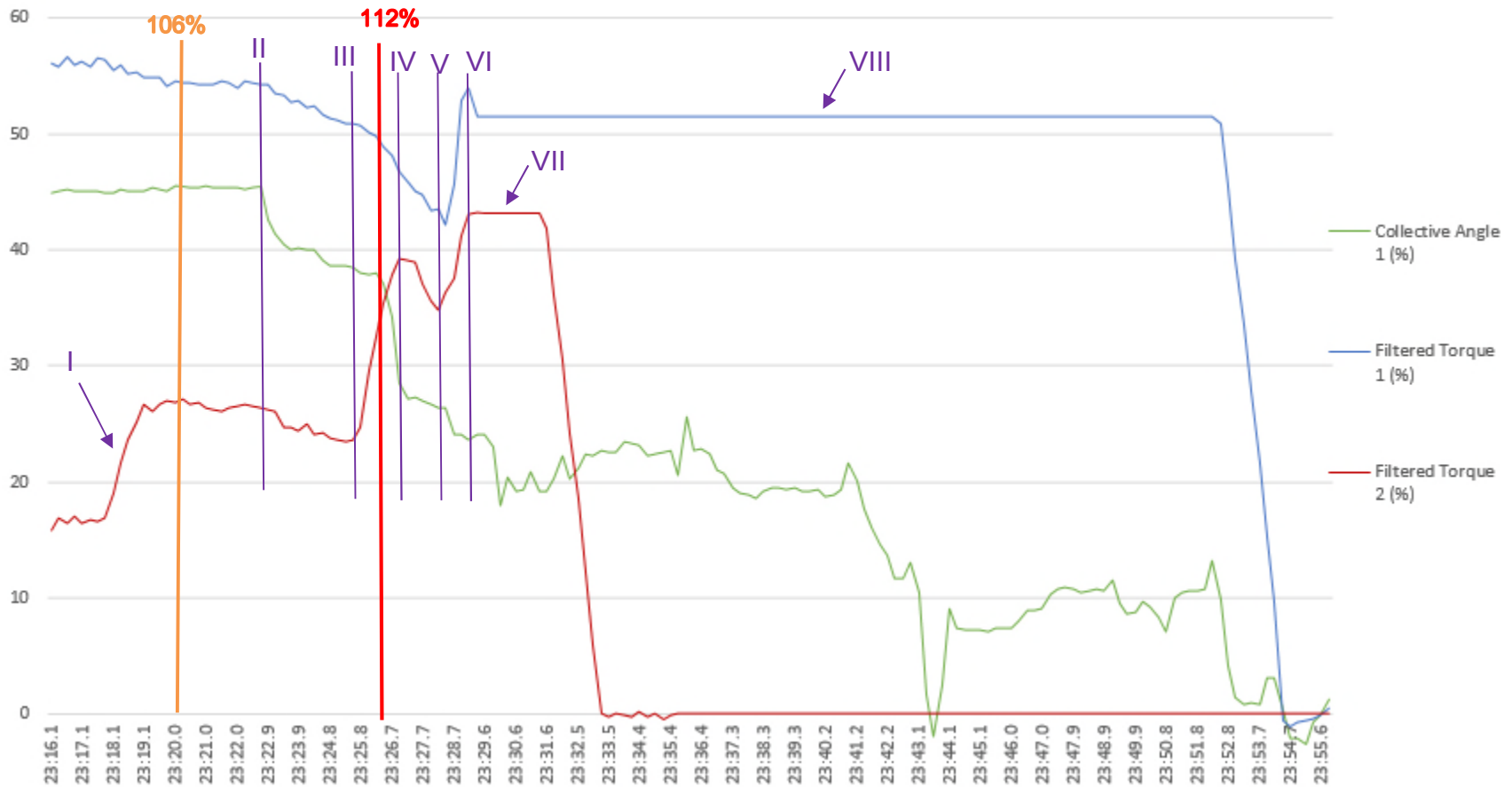
F – Past point F both engines were at 0% torque and believed to be declutched from the rotor. The movement of CLP has no apparent effect on the engines, which remained at 0% torque.

The orange line at 24min and 1s represents an audible gong from the cockpit (information provided by the NTSB) indicating that the main rotor has decreased below 106%. As previously mentioned, though not shown on this graph the time of impact is at 24min and 16s based on the audible sound from the cockpit (information provided by the NTSB).

DRAFT



PLOT 6



CLP and Q's from times 23:16:1 to 23:55:6

I – The filtered torque on the number 2 engine was increased, which is suspected be a result of the engine twist grip because there was no apparent CLP input at that time. It is thus possible that from this point forwards the pilot had both engines in manual mode.

I – II – The orange line at 23min and 26s represents an audible gong from the cockpit (information provided by the NTSB) indicating that the main rotor has reached or exceeded 106%

II – III – There is a CLP decrease. There is a decrease in the torques on the two engines which may be due to a twist grip manipulation to both engines or due to the result of a main rotor speed increase (with no twist grip input). This main rotor speed increase would be a result of both engines having fixed fuel flow while the collective was lowered.

III – IV – During this period the CLP continues to decrease (down to 27%), as does the torque of the number 1 engine which could be caused from a main rotor speed increase. The torque of the number 2 engine increases quickly by over 10% which we conclude to be due to the pilot manipulating the twist grip of this engine to get more power (with a CLP decreasing the only way to get a torque increase is with an increase fuel flow using the twist grip). As the CLP is decreasing towards 20% the torques should be dropping towards 0% while at point IV engine 1 had a torque of approximately 46% while engine 2 had a torque of approximately 39%. With the torques at these values and the CLP dropping both engines would still be clutched and the power turbines and main rotor would be increasing in speed, likely in an overspeed condition.

The red line at 23min 26s represents when the audible sound from the cockpit (information provided by the NTSB) for the start of the continuous high tone. This tone comes on when NR is greater or equal to 112%, and will stay on until the NR comes back below this range.

IV – V – In this period the collective continues to decrease, as do the torques of engines 1 and 2. The two possibilities to explain this torque decrease are either that the pilot decided to manually manipulate the twist grips or that the main rotor speed was permitted to increase (without a twist grip input).

V – VI – The CLP continues to decrease which should result in a reduction of torque, however both engine torques are increasing by over 8% in approximately one second. This input is believed to have been done using the engines twist grips commanding the engines running in manual mode to a higher fuel flow thus resulting in an NG increase and Q increase. This behavior supports the scenario that both engines are in manual mode (based on the data). With the high torque values, with respect this low collective, the NPT and main rotor would have continued to be high or have increased further.

VII – The engine 2 torque is stable at 43.2344% for approximately 2 seconds. The value of the torque on this engine is unchanging down to the 4th decimal as seen below.

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23:29.6	43.2344
23:29.9	43.2344
23:30.1	43.2344
23:30.4	43.2344
23:30.6	43.2344
23:30.8	43.2344
23:31.1	43.2344
23:31.3	43.2344

Engine 2 Last Good Value: Torque & Time

The recorded data is the ARINC 429 (which is the cross-talk between the two engines). The NPT and Q are both picked up from the same probe and as NP increase above its range (127%) two faults are flagged and the Q will no longer be calculated but instead will hold the last good value (LGV), thus flat-lining. Once the NPT comes back within range the Q was again calculated and can be seen decreasing towards 0% within approximately 1s.

Both engines EEC downloads showed NFQ out of range faults, with NG above 94%. The NPT has a maximum range of 127% thus to attain a fault, the true NPT value must have exceeded 127%, however the maximum value attained cannot be determined. The PT blades are designed to shed at approximately 150% NPT. Based on the frozen data at 43.2344 it can be concluded that the NPT was above 127% for almost 2s until either the blades were released or the pilot used the twist grip to command the engine down to 0% torque.

VIII – The engine 1 torque is stable and unchanging, at 51.5078% for approximately 23 seconds. As explained in point 7 this shows that the NPT of this engine was above 127% for approximately 23s though the peak cannot be determined. As the CLP continues to descend to 0, and with a fixed fuel flow to the engine, the number 1 engine would continue to over-speed (there are no speeds available in the data to show this). The sudden decrease in torque appears to be the same as previously described for the number 2 engine.

At the time 24min and 1s (not shown on this graph) there is an audible gong sound from the cockpit (information provided by the NTSB) indicating that the main rotor speed returned below 106%. 15s following this was the sound of impact (not shown on this graph).

Conclusion:

Based on the limited data provided, P&WC believes that the engines were able to maintain power and were responding to inputs provided to them until the point where the torques dropped to 0.



Merryn Spielman

Service Investigator

Pratt & Whitney Canada

Service Investigation

Phone: (450) 468-2555 x53178



C.C.: Richard Benoit, P&WC Service Investigation Manager

Marc Hamilton, TSB of Canada Accredited Representative/Air Investigations Branch

Service Investigation

Accident / Incident Report

P&WC 8114 (11-98)



Pratt & Whitney Canada

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REFERENCE “D”

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Customer: Superior Ambulance

Engine Model: PW206B

Engine S/N: BB0049 (No. 1 left), BB0045 (No. 2 right)

This report is to support the engine review regarding an accident that occurred on 07 July 2018.

1.0 Event:

The aircraft impacted terrain nearby an inter-state highway on the south east side of Chicago at about 21h30 local time July 7, 2018.

2.0 Summary of findings:

Investigation of the accessories comprised testing of the torque and speed sensors from each engine, testing of the No. 1 engine flow divider valve (FDV), testing of both wiring harnesses from the No. 1 engine and one harness from the No. 2 engine, testing of the fuel management modules (FMM) from each engine and testing of the fuel nozzles from the No. 1 engine. Testing of the torque and speed sensors from the No. 1 engine and the speed sensors from the No. 2 engine confirmed that the sensors were satisfactory. Slightly low voltages were recorded during dynamic testing of the No. 2 engine torque sensor. This would not have had a detrimental effect on the function of the torque sensor when installed in the aircraft and may be a consequence of the event. Testing confirmed that the No. 1 engine FDV was satisfactory. Continued...

Export Control Classification		
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	Canadian ECL(s)*	NSR
	ECCN(s)*	9E991
	P-ECCN(s)**	NRS
	USML(ITAR)*	
	P-USML**	
Date: 1/29/2019 Badge: E-28042		

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ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

No. 1 engine wiring harness P/N 3121134-01 exhibited high resistance that was caused by missing tines in connector P3 socket C and D. It is possible that the tines were dislodged and lost when the wiring harness was disconnected from the PMA. Connector P3 provides power from the PMA to the EEC. If an intermittent connection existed prior to the event it would have caused the EEC to raise a fault code (possibly Figure 105, NCFUR 2=5). No. 1 and 2 wiring harnesses P/N 3121138-01 resistances were out of limits. These wiring harness test observations may be a consequence of the event. Had these issues been present during operation it may have resulted in an out of normal range indication for the oil pressure. It was not possible to test the No. 2 engine wiring harness P/N 3121134-05 because connector P23 was missing. Minor and inconsequential observations were recorded during testing of both FMM's. Minor observations were recorded during testing of two of the fuel nozzles from the No. 1 engine. It was agreed by the investigation team that testing of the fuel nozzles from the No. 2 engine was not required.

3.0 Conclusion:

There were no defects or damage evident that would have prevented normal operation prior to the event.

4.0 Investigation:

Conducted at: Pratt & Whitney Canada

Initiated on: 19 September 2018

In attendance: Dave Barnard P&WC

List of Accessories:

Engine S/N BB0049 No. 1 left:

Accessory	P&WC P/N	Manufacturer	Supplier P/N	S/N
Torque sensor	3038223	Weston Aerospace	843-1-12	CH2089
Compressor turbine speed sensor	3038224	Weston Aerospace	841-1-12	CH148
Power turbine speed sensor	3038225	Weston Aerospace	842-1-12	CH551
Flow divider assembly (FDV)	None	Woodward	8063-141	11610155
Wiring harness	3121134-05	Atlas	AA5219	AA8250
Wiring harness	3121138-01	Atlas	AA4983	AA8154
Fuel management module (FMM)	None	Woodward	8063-865	11501897
No. 1 fuel nozzle	3039265	P&WC/UTAS		1TK05420
No. 2 fuel nozzle	3039265	P&WC/UTAS		1TK04348
No. 3 fuel nozzle	3039265	P&WC/UTAS		1YL07024
No. 4 fuel nozzle	3039260	P&WC/UTAS		1TL06288
No. 4 fuel nozzle	3039260	P&WC/UTAS		1RK02918
No. 6 fuel nozzle	3039265	P&WC/UTAS		1SL06438
No. 7 fuel nozzle	3039265	P&WC/UTAS		1SL06454
No. 8 fuel nozzle	3039265	P&WC/UTAS		1SM05674
No. 9 fuel nozzle	3039265	P&WC/UTAS		1SM05689
No. 10 fuel nozzle	3039265	P&WC/UTAS		1VM03763
No. 11 fuel nozzle	3039265	P&WC/UTAS		1YK05087
No. 12 fuel nozzle	3039265	P&WC/UTAS		1ZL06288

Engine S/N BB0045 No. 2 right

Accessory	P&WC P/N	Manufacturer	Supplier P/N	S/N
Torque sensor	3038223	Weston Aerospace	843-1-12	CH316
Compressor turbine speed sensor	3038224	Weston Aerospace	841-1-12	CH385

P&WC 10760(2012-12)

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ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Power turbine speed sensor	3077760-01	Weston Aerospace	842-1-15	CH1136
Flow divider assembly (FDV)	None	Woodward	8063-141	12150056
Wiring harness	3121134-05	Atlas	AA5219	AA8249
Wiring harness	3121138-01	Atlas	AA4983	AA8148
Fuel management module (FMM)	None	Woodward	8063-865	11522498

Accessory: No. 1 engine torque sensor

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the torque sensor was generally clean. The end of the magnet was not protruding from the sensor body. There was a darkened ring around the tip of the magnet. The inside of the electrical connector was clean. Gold plating was peeling and black deposits were present on some of the contacts.

The torque sensor was tested in accordance with P&WC ACMM 3045330 Rev. 05. The tests, including temperature cycling and dynamic functions was satisfactory.



Figure 1
No. 1 engine torque sensor as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine compressor turbine speed sensor

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the compressor turbine speed sensor was generally clean. The end of the magnet was not protruding from the sensor body. There was burnishing at the tip of the sensor. The inside of the electrical connector was clean. Black deposits were observed on some of the contacts.

The compressor speed sensor was tested in accordance with P&WC ACMM 3043640 Rev. 04. The test was satisfactory.

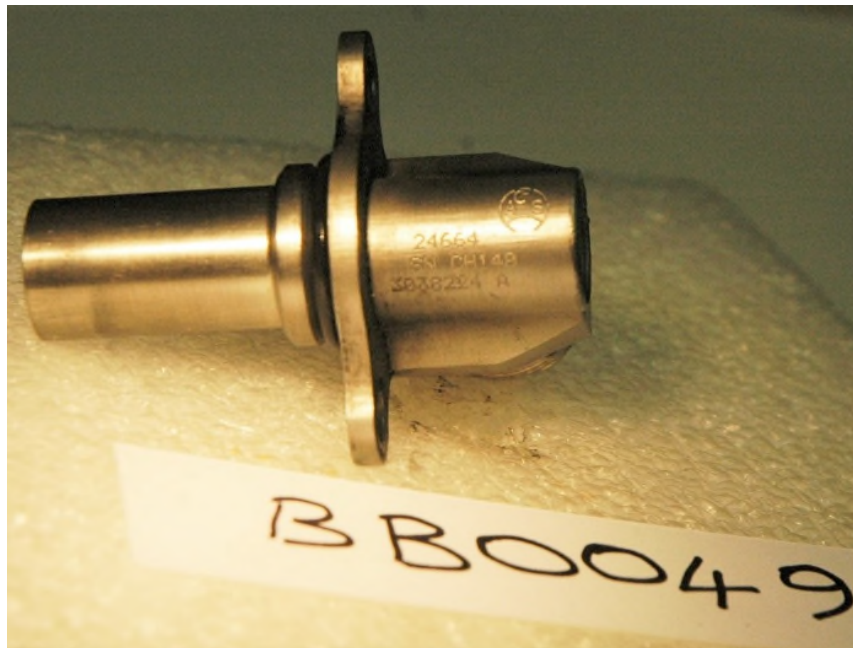


Figure 2
No. 1 engine compressor turbine speed sensor as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine power turbine speed sensor

Note: This hardware was on the engine at initial engine delivery.

Investigation Results:

The exterior of the power turbine speed sensor was generally clean. The end of the magnet was not protruding from the sensor body. The inside of the electrical connector shell was stained. Gold plating was missing and black deposits were present on some of the contacts.

The power turbine speed sensor was tested in accordance with P&WC ACMM 3043640 Rev. 04. The test was satisfactory.



Figure 3
No. 1 engine power turbine speed sensor as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine flow divider valve (FDV)

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the flow divider valve (FDV) was generally clean. Sealing compound was present at the end-cap. The FDV was partially tested in accordance with Woodward CMM 73-20-27.

The following observation was recorded:

Test step C Reset flow and accuracy: the primary fuel flow was below the test point minimum limit. However this was a consequence of the test set-up and not an indication of the performance of the FDV. All other test recordings were satisfactory.

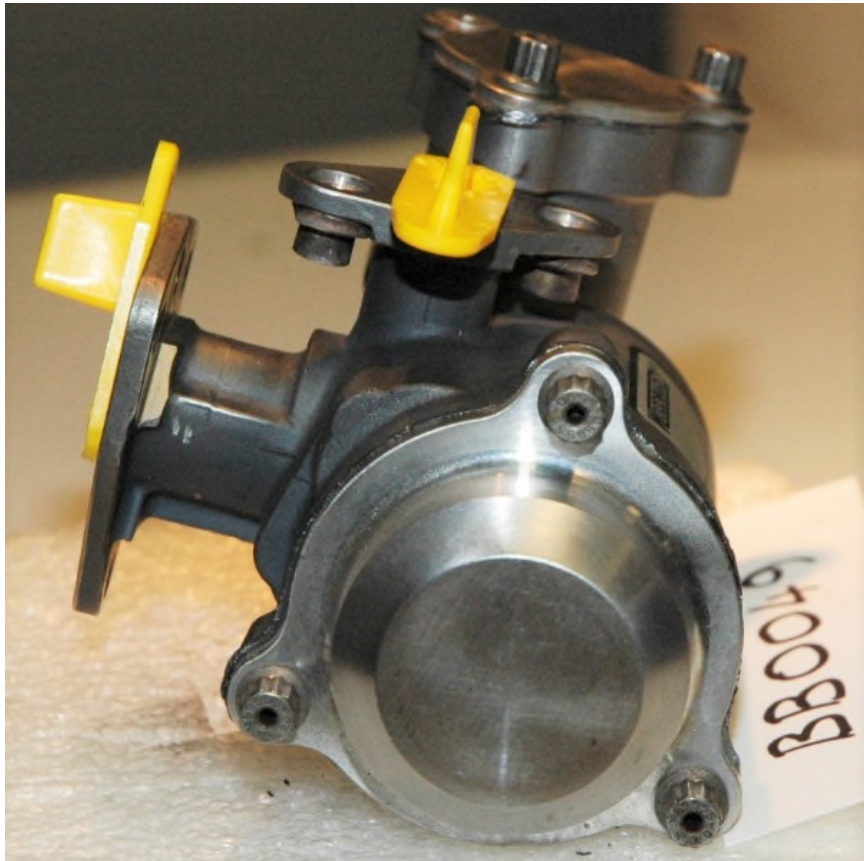


Figure 4
No. 1 engine flow divider valve as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine wiring harness P/N 3121134-01

Note: This hardware was on the engine at initial engine delivery.

Investigation Results:

The exterior of the wiring harness was generally clean. Some of the identification sleeves had faded. The mount flange was present and securely attached. The two tines were missing from connector P3 sockets C and D. The barrel coating was peeling on connector P1.

The wiring harness was tested in accordance with P&WC CMM 3041335 Rev. 4. The following observations were recorded:

Connector P1T to P3C (PMA connector) the resistance was above the CMM maximum limit.

Connector P1S to P3D (PMA connector) the resistance was above the CMM maximum limit.

The high resistance was caused by missing tines in connector P3 socket C and D.

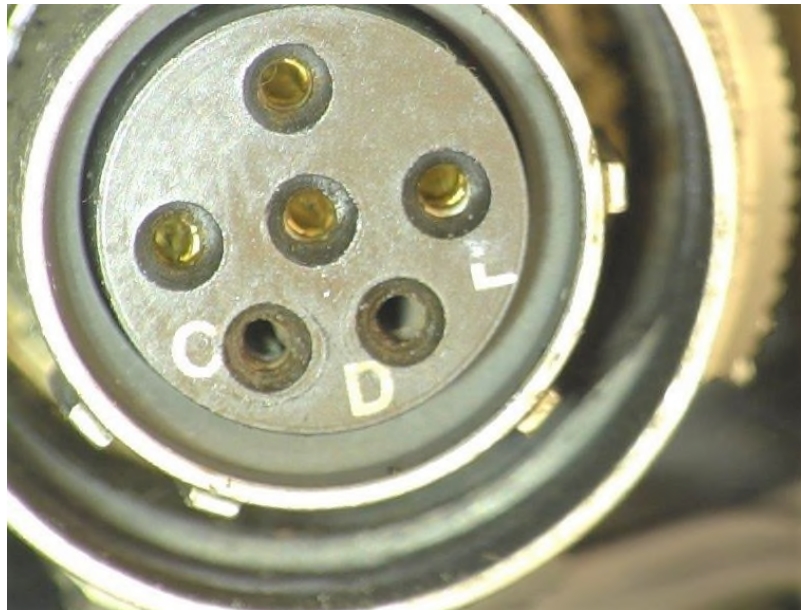


Figure 5
P3 connector socket C and D missing tines

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine wiring harness P/N 3121138-01

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the wiring harness was generally clean. Some of the identification sleeves had faded. The mounting flange was present and securely attached. The fire-detector connecting terminals were bent and the insulation was frayed on the rear terminal. The connector ratchet was weak on connector P18, P21 and P24.

The wiring harness was tested in accordance with P&WC CMM 3041335 Rev. 4. The following observations were recorded:

The resistance between connector J14 shield to P21 socket ZZ (main oil pressure sensor) was open.
The resistance between connector J14 pin 54 to P21 socket ZZ (main oil pressure sensor) was above the test point maximum limit.

The isolation resistance between connector J14 pin 55 and 23 was below the test point limit.

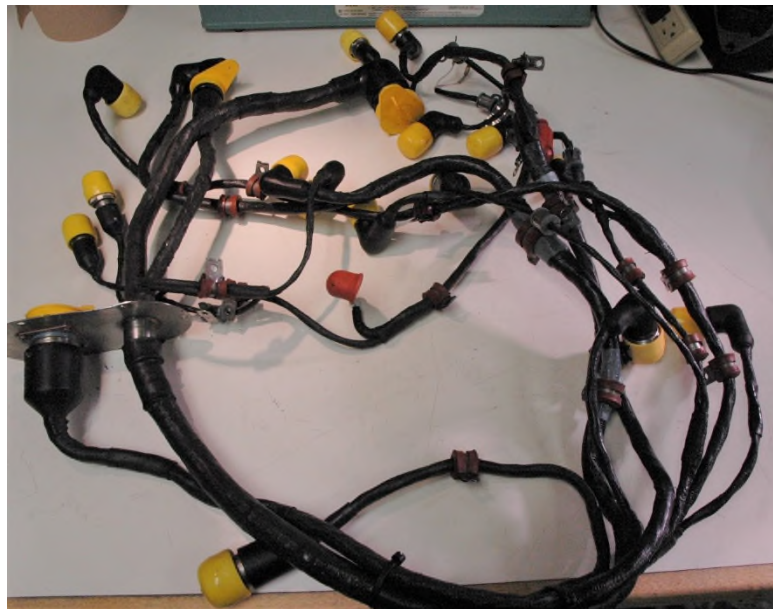


Figure 6
No 1 engine wiring harnesses as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine fuel management module (FMM)

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the fuel management module (FMM) was lightly soiled. The power lever moved freely over the full range. Alignment with the rig-pin location was obtainable at the detent. The driveshaft could not be turned by hand (this is normal). Lockwire was present at all locations. The lockwire seals were marked PWC AB (Pratt & Whitney Canada Accessories Business).

The FMM was tested in accordance with Woodward CMM 73-20-14 Rev. 5. The following observations were recorded:

Test point N acceleration cam schedule check (cold day): the fuel outlet flow was 4pph and 3pph above the test point maximum limits.

Test point AD auto-mode minimum flow check: the fuel outlet flow was 1pph below the test point minimum limit.

Test point AN power lever shut-off: outlet flow shut-off occurred 0.5 degrees above the test point maximum limit.

Test point AU high speed governor gain check: the fuel outlet flow was 8 and 13pph below the test point minimum limits.

Test point AW neutral switch check: the power lever angle was 1 degree and 0.2 degrees above the test point maximum limits.

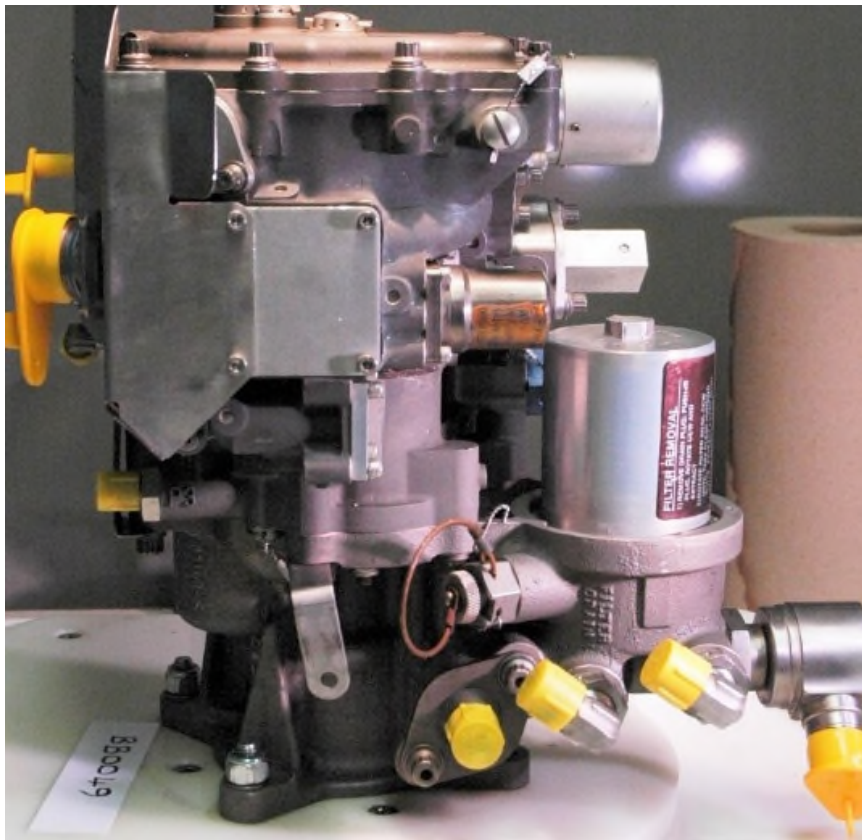


Figure 7
No. 1 engine fuel management module as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 1 engine fuel nozzles

Note: It was not possible to determine if this hardware was on the engine at initial engine delivery.

Investigation Results:

Carbon deposits were present at each nozzle tip. The carbon accumulation was heavier on the No. 5 nozzle tip.

Nozzle position	Observation
4	The secondary spray pattern was not optimal. Streaks and voids were present in the primary flow.
5	The secondary spray pattern was not optimal. The primary spray was uneven.



Figure 8
No. 1 engine No. 4 (top) and 5 (bottom) fuel nozzles as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine torque sensor

Note: This hardware was on the engine at initial engine delivery.

Investigation Results:

The exterior of the torque sensor was generally clean. The end of the magnet was protruding slightly from the sensor body. Fluid was present inside of the electrical connector. Black deposits were present on the contacts.

The torque sensor was tested in accordance with P&WC ACMM 3045330 Rev. 05. The static and temperature cycling tests were satisfactory. However the voltage recorded during the dynamic testing was 0.037volts below the minimum limit at 1200RPM and 0.648 volts below the minimum limit at 7200RPM.



Figure 9
No. 2 engine torque sensor as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine compressor speed sensor

Note: This hardware was on the engine at initial engine delivery.

Investigation Results:

The exterior of the compressor turbine speed sensor was generally clean. The end of the magnet was recessed slightly into the sensor body. The inside of the electrical connector was clean. Black deposits were present on some of the contacts.

The compressor speed sensor was tested in accordance with P&WC ACMM 3043640 Rev. 04. The test was satisfactory.



Figure 10
No. 2 engine compressor speed sensor as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine power turbine speed sensor

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the speed sensor was generally clean. The end of the magnet was not protruding from the sensor body. The inside of the electrical connector shell was stained and fluid was present inside the shell. Gold plating was worn at the base of contact F.

The power turbine speed sensor was tested in accordance with P&WC ACMM 3043640 Rev. 04. The test was satisfactory.



Figure 11
No. 2 engine power turbine speed sensor as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine flow divider valve (FDV)

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the flow divider valve was generally clean. Sealing compound was present at the end-cap. It was agreed by the investigation team that testing of the No. 2 engine FDV was not required.

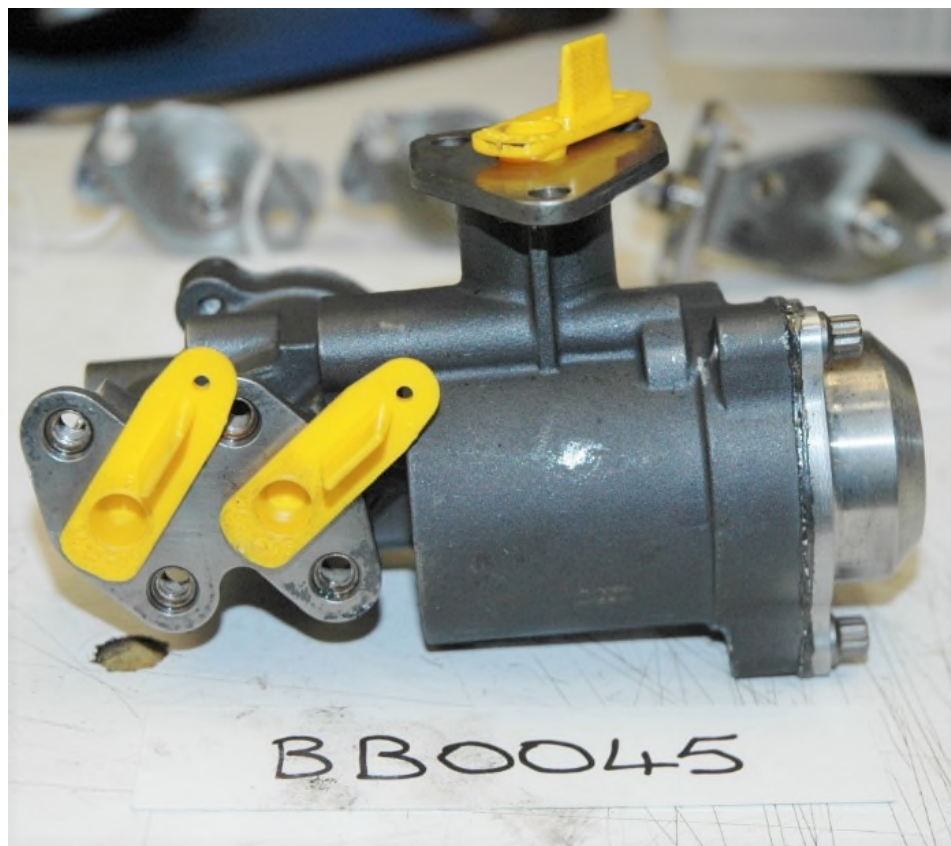


Figure 12
No. 2 engine flow divider valve as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine wiring harness P/N 3121134-05

Note: This hardware was on the engine at initial engine delivery.

Investigation Results:

The exterior of the wiring harness was generally clean. Some of the identification sleeves had faded. The mount flange was present and securely attached. Connector P23 was not present (the harness had been cut to facilitate removal of the engine from the airframe). Fluid residue was present inside of connector P10 and P11. A piece of a packing was present inside connector P11. It was not possible to test this harness because connector P23 was missing.

Accessory: No. 2 engine wiring harness P/N 3121138-01

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the wiring harness was generally clean. Some of the identification sleeves had faded. The mounting flange was present and securely attached. Fluid residue was present inside the shell of connector P16 and P22. Black deposits were present on the pins of connector J14.

The wiring harness was tested in accordance with P&WC CMM 3041335 Rev. 4. The following observations were recorded:

The resistance between connector J14 pin 15 and connector P21 sockets A and B (main oil temperature sensor) were above the test point maximum limit.

The isolation resistance between connector J14 pin 55 and 23 was below the test point limit.

The isolation resistance between connector J14 pin 32 and 25 was below the test point limit.

Arcing was present between connector J14 pin 33 and 26 was below the test point limit.

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29



Figure 13
No. 2 engine wiring harnesses as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine fuel management module

Note: This hardware was not on the engine at initial engine delivery.

Investigation Results:

The exterior of the fuel management module (FMM) was lightly soiled. The power lever moved freely over the full range. Alignment with the rig-pin location was obtainable at the detent. The driveshaft could not be turned by hand (this is normal). There was a Pratt & Whitney Canada Accessories Business service label on the cover. Lockwire was present at all locations. The lockwire seals were marked WW (Woodward).

The FMM was tested in accordance with Woodward CMM 73-20-14 Rev. 5. The following observations were recorded:

Test point J Manual mode minimum flow check: the fuel outlet flow was 5pph above the test point maximum limit.

Test point L deceleration cam schedule check: the fuel outlet flow was 2pph below the test point minimum limit.

Test point AU2 high speed governor gain: the fuel outlet flow was 5pph above the test point maximum limit.

Test point AU4 high speed governor gain: the fuel outlet flow was 8pph and 9pph below the test point minimum limit.

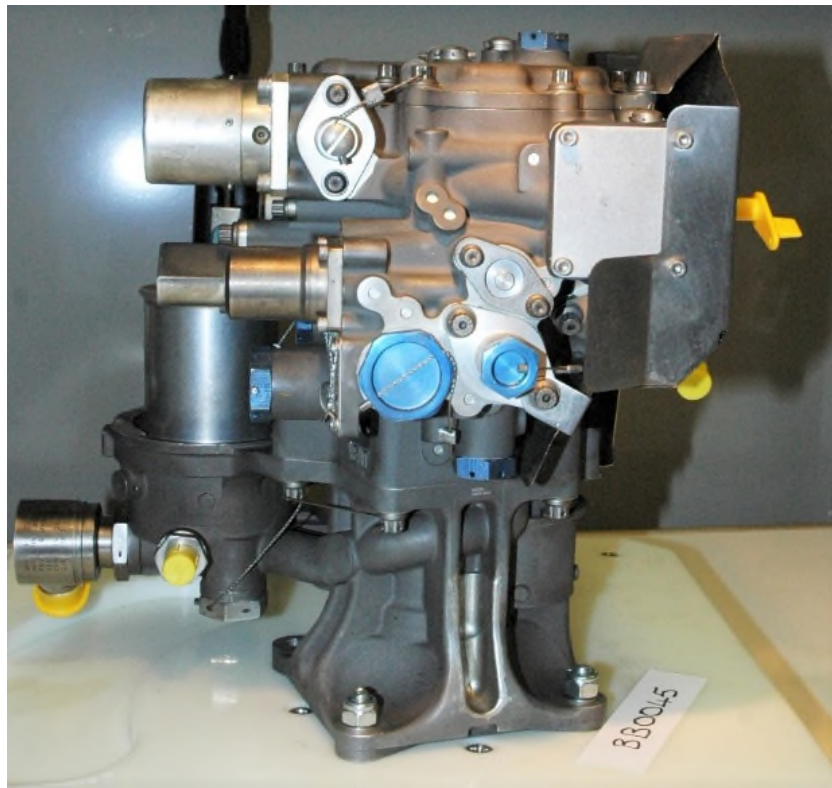


Figure 14
No. 2 engine fuel management module as received

ACCESSORIES ACCIDENT REPORT

Date issued: 2019-01-29

Accessory: No. 2 engine fuel nozzles

Note: It was not possible to determine if this hardware was on the engine at initial engine delivery.

Investigation Results:

Carbon deposits were present at each nozzle tip. It was agreed by the investigation team that testing of the fuel nozzles was not required.

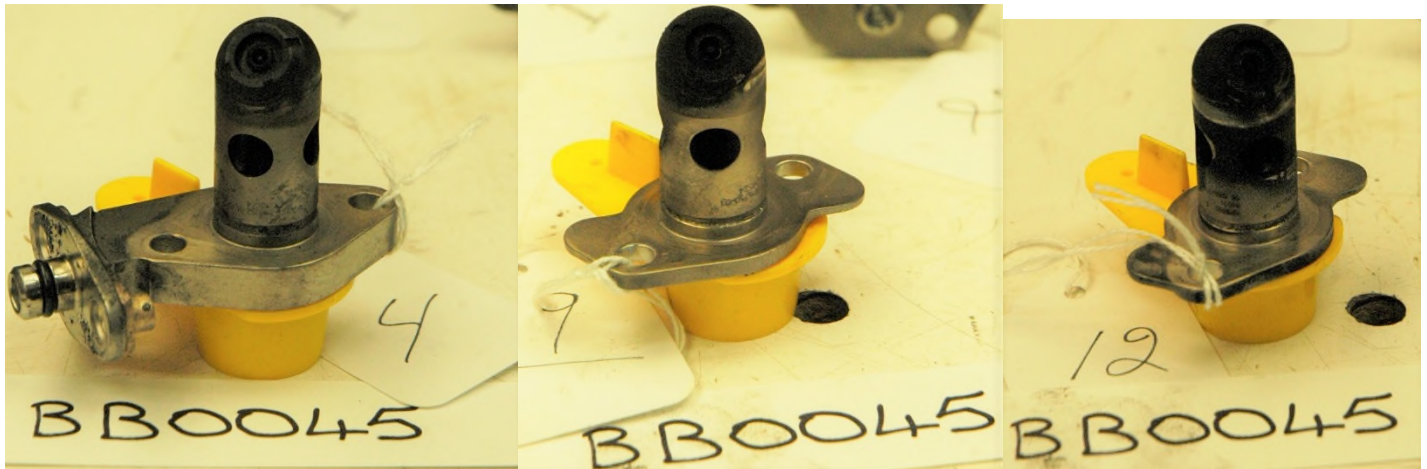


Figure 15
No. 2 engine fuel nozzle examples as received

5.0 Closing Statement

The data contained in this report, collected at the time of the review may be altered or corrected on the basis of further information.

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