



Service Investigation

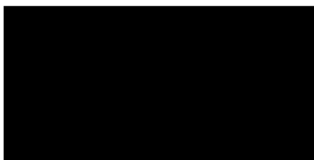
Accident / Incident Report

P&WC 8114 (2021-02)

Report No.: 23-093

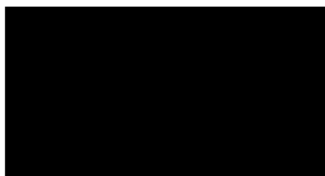
Roma Air
Air Tractor AT-802A, N3069S
Wellington, Florida, USA
20 June 2023
PT6A-65AG, PN0077

Written By:



Service Investigation Department

Approved By:

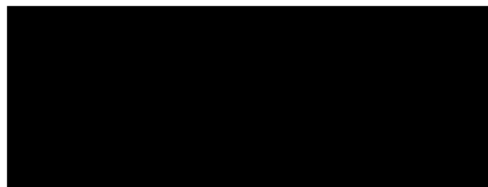
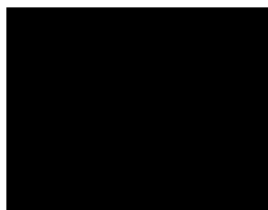


Manager, Service Investigation Department

Date of Issue:

14 May 2025

Distribution:

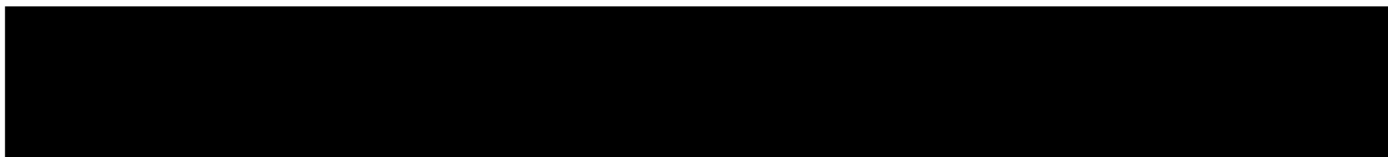


NTSB Identification: .. ERA23LA272

TSB Identification: A23F0197

Red File No.: 23-093

RFA No.: 23SIE00169



EXPORT CONTROL CLASSIFICATION		LOCATION		U.S. REGULATION	
		U.S.		EAR	ITAR
		OUTSIDE U.S.		P-ECCN 9E991	P-USML NSR
				ECCN NSR	USML NSR
				LOCAL REGULATION	
		CANADA		EIPA (ECL)	DPA (CG)
Date of marking				NSR	NO



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I ANALYSIS

1.0 ACCIDENT SYNOPSIS

- 1.1 On June 20th, 2023, an Air Tractor AT-802A with registration N3069S, was ferrying back from an aerial application to the landing strip with an empty hopper and two hours of fuel, at 500ft above ground level (AGL). The pilot felt a faint engine surge, scanned his gauges, and saw the needle of the torque gauge dropping quickly. He felt that the engine power reduced, and the nose of the aircraft began to drop. The pilot managed to land the aircraft in marshland without injuries. The aircraft sustained minimal damage in the front of the aircraft (cockpit to propeller) but heavy damage aft the cockpit fuselage and empennage. The engine was removed and sent to Pratt & Whitney Canada (P&WC) for investigation.

2.0 SUMMARY OF FINDINGS AND DISCUSSION

- 2.1 The engine was evaluated at the P&WC overhaul shop and was cleared for a safe test as received. The engine successfully started only after the FCU, and fuel pump were replaced with test cell slave units.
- 2.2 Closer observation of the removed FCU drive shaft and fuel pump interface found worn external and internal mating splines coated with a brownish iron oxide residue. As a result, the significant wear on the splined connection contributed to the disengagement of the Ng input to the FCU which, resulted in a commanded minimum fuel flow condition.
- 2.3 Metallurgical analysis by the [REDACTED] material laboratory confirmed that the FCU drive shaft splines were in conformance with, the material composition, hardness and case hardening thickness requirements of the drawing specification.
- 2.4 The presence of iron oxide on the FCU fuel inlet strainer suggests a possible contamination of the fuel, which consequently, may have reduced the fuel lubricity and caused the observed corrosion, wear and cavitation on the fuel pump internal components. In addition, it is probable that this lower fuel lubricity may have introduced vibrations in the drive gear which, induced the wear observed on the FCU and fuel pump splines.



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3.0 CONCLUSION

- 3.1 The reported loss of power was determined to be due to the decoupling that occurred between the worn FCU drive shaft splines and the worn fuel pump drive gear splines. The decoupling between the FCU and fuel pump resulted in the FCU to command minimum fuel flow and prevent normal engine operation. The wear mechanism of the splines in the absence of any original material anomaly could not be determined conclusively.

II FACTUAL INFORMATION

1.0 INVESTIGATION PARTICIPANTS

The powerplant investigation was performed on the 7th to 9th of November 2023 at the Pratt & Whitney Canada (P&WC) Service Investigation Facility at Saint-Hubert, Quebec, Canada. The following individuals participated in the investigation as representatives of their respective organisations:

[REDACTED]

Senior Technical Analyst
Transportation Safety Board of Canada, TSB

[REDACTED]

Air Safety Investigator
Engine Controls and Accessories Technical Support, P&WC

[REDACTED]

Air Safety Investigator
Service Investigation, P&WC

2.0 ENGINE HISTORY

Engine Model: PT6A-65AG, **Serial No.:** PN0077

Logbook Available: *Yes

**Electronic copies of the engine logbook pages were provided by the NTSB.*

**The engine logbooks were not available at the time of the investigation.*

Time Since New (TSN): 8,893.5

Cycles Since New (CSN): Unknown

Time Since Overhaul (TSO): Unknown

Cycles Since Overhaul (CSO): Unknown

[REDACTED]



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3.0 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 engine inlet to exhaust.

3.1 External Condition

The as received engine shipping container showed no external signs of any damage, Photo No. 1. Opening of the container showed that the engine was mounted on a standard P&WC engine shipping cradle with the rear side covered in a black plastic bag, Photo No. 2. A cardboard box, in which the engine exciter was shipped in, was found to the left side of the reduction gear box, red arrows, Photo No. 2 & 3. The engine data plate, Photo No. 4, confirmed the engine model to be a PT6A-65AG with serial no.: PN0077.



Photo No. 1, Shipping Box as Received



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Photo No. 2, Engine Side Views

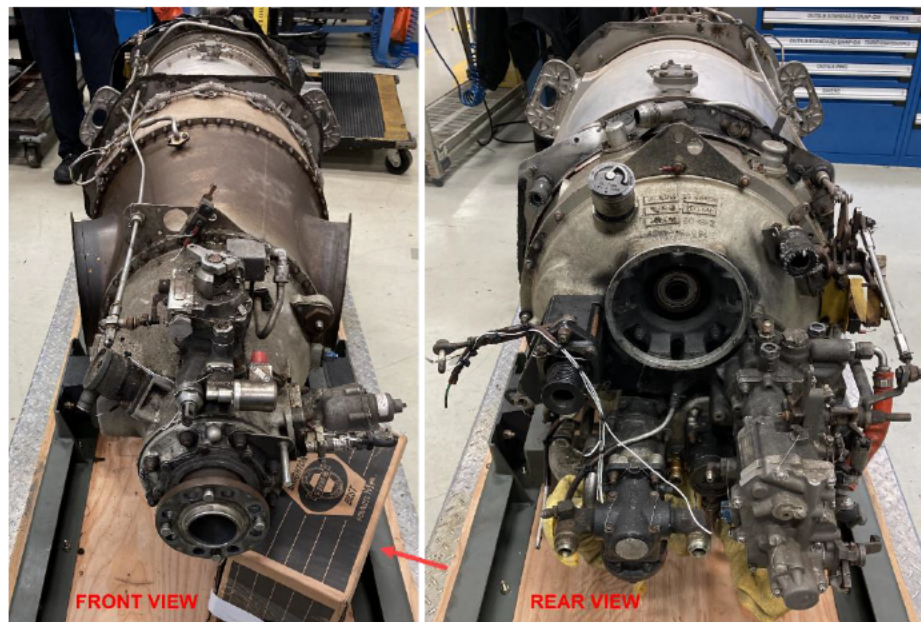


Photo No. 3, Engine Front and Rear Views



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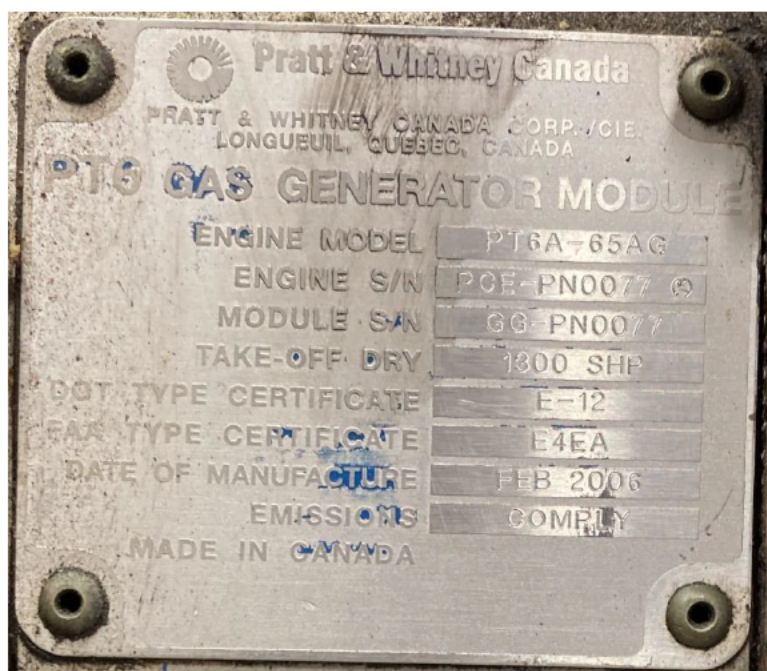


Photo No. 4, Engine Data Plate

3.1.1 External Cases

Reduction Gearbox (RGB): Visual examination of the RGB housing and attached accessories exhibited a normal in-service condition, Photo No. 5. The propeller shaft rotated freely by hand with no abnormal sound or feel.

Exhaust Duct: The exhaust duct external surfaces exhibited a normal in-service condition, Photo No. 6. Visual examination through the exhaust ports showed dark and oil wetted surfaces including the power turbine (PT) blades, Photo No. 7.

Gas Generator Case (GGC): The external surfaces of the GGC visually exhibited a normal in-service condition, Photo No. 8.

Accessory Gearbox (AGB) and Inlet Case: The AGB external surfaces visually exhibited a normal in-service condition, Photo No. 9.



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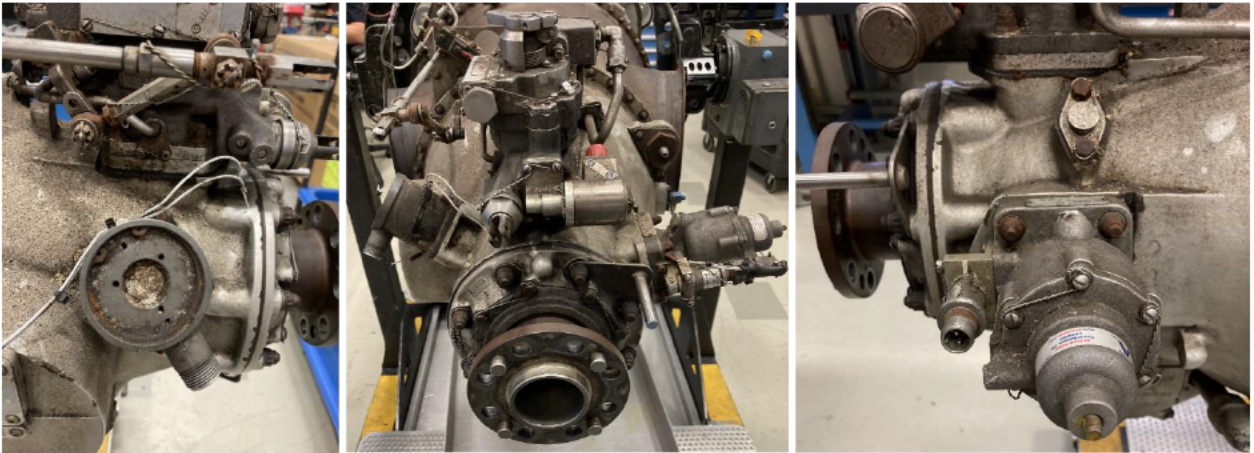


Photo No. 5, Reduction Gear Box

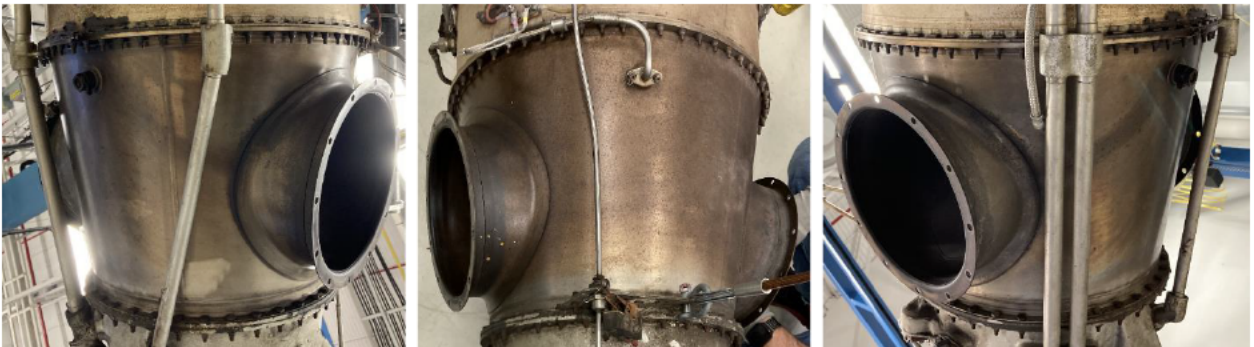


Photo No. 6, Exhaust Duct

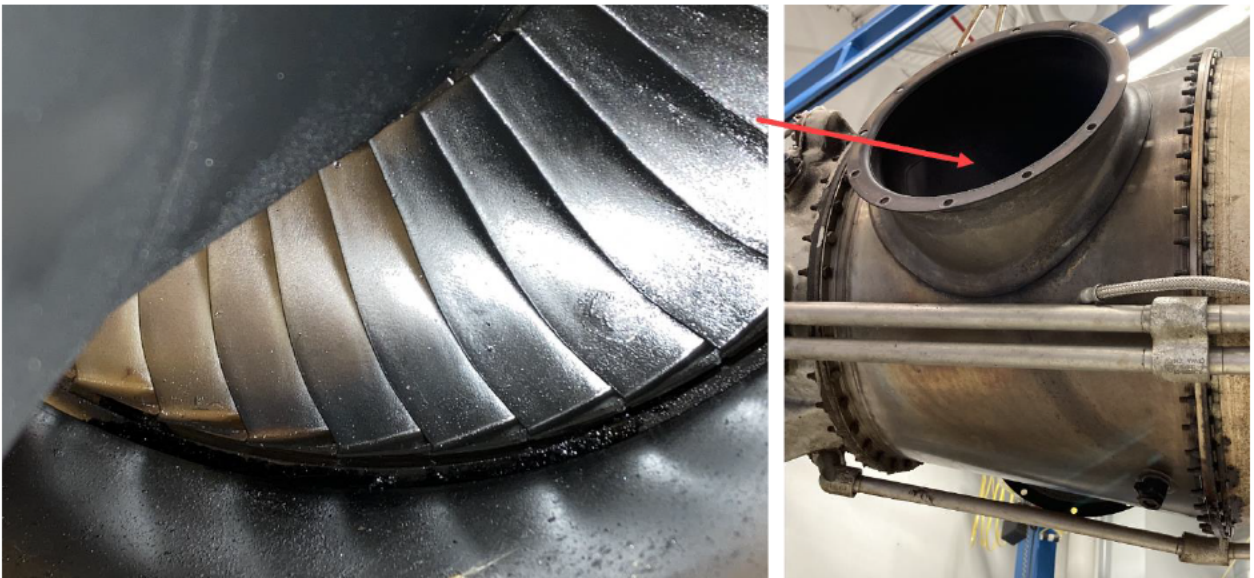


Photo No. 7, Turbine Rotor Blades



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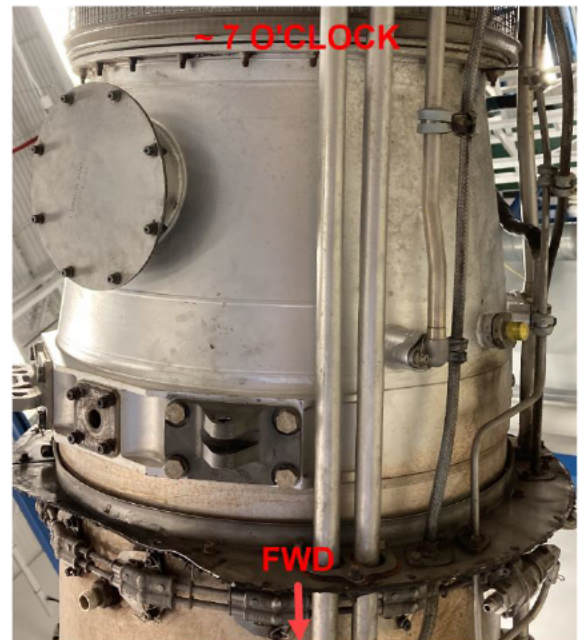
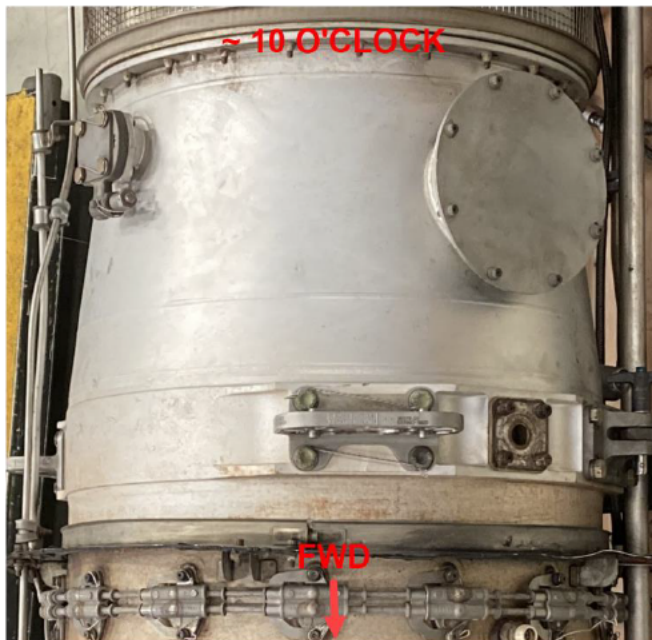
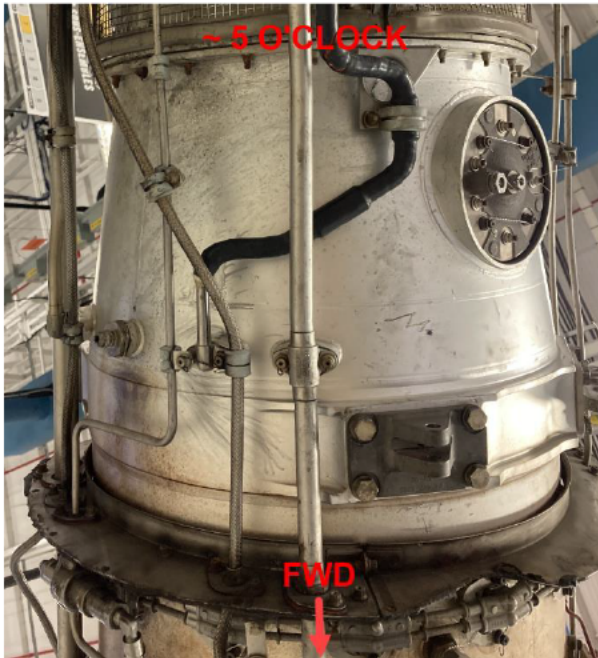


Photo No. 8, Gas Generator Case



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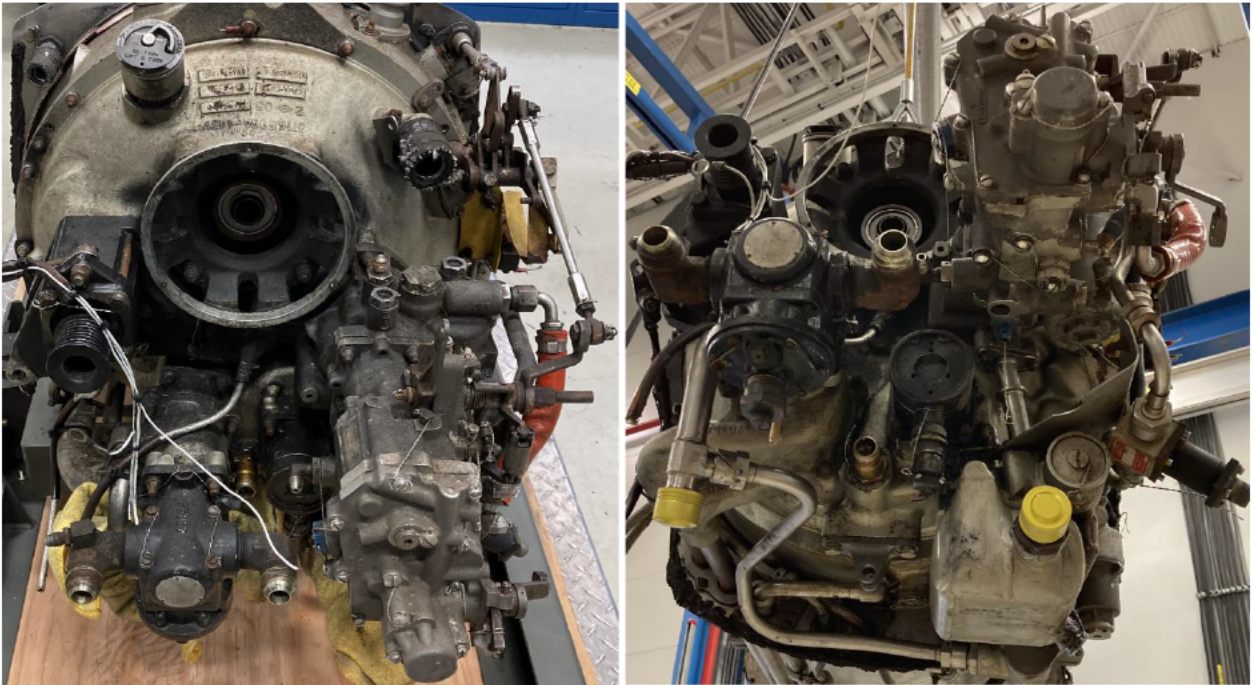


Photo No. 9, Accessory Gear Box

3.1.2 Power Control Linkage and Reversing Linkage

The FCU power control and reversing linkages were covered in environmental debris but visually did not show any damage. Continuity check of the linkages and connecting rod confirmed a continuous movement through the entire range of travel, red arrow, Photo No. 10.

The CAM box linkages and propeller governor were also covered in environmental debris and exhibited no damage, red arrow, Photo No. 11. The linkages exhibited a continuous movement through the entire range of travel. As the Beta valve lever was not received, movement of the Beta valve was verified to be unimpeded by hand, which showed a normal in-service condition, green arrow, Photo No. 12. The Beta pin was straight with no visual damage, red arrow, Photo No. 12.



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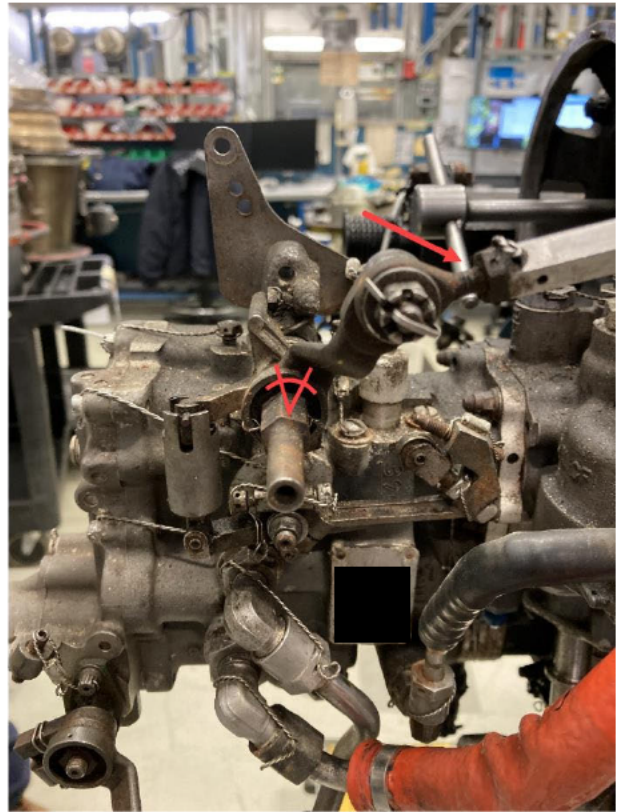
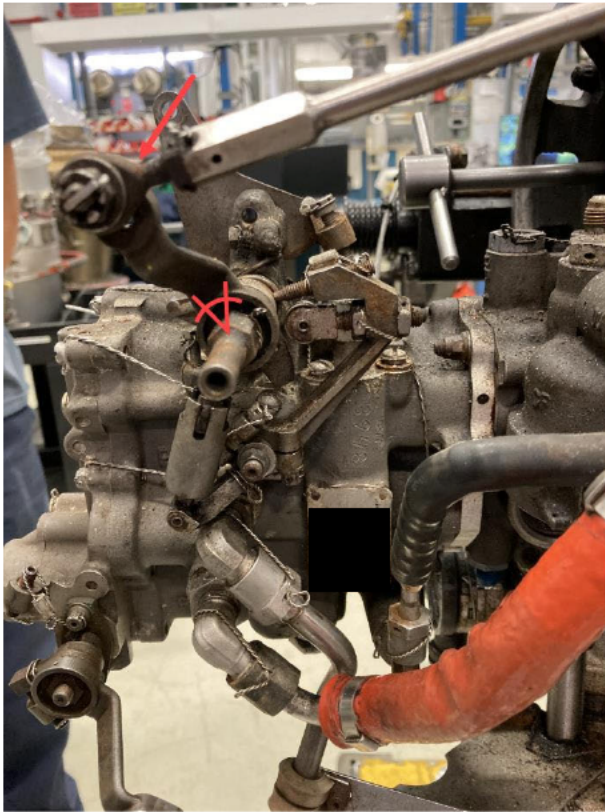


Photo No. 10, Power Control and Reversing Linkages

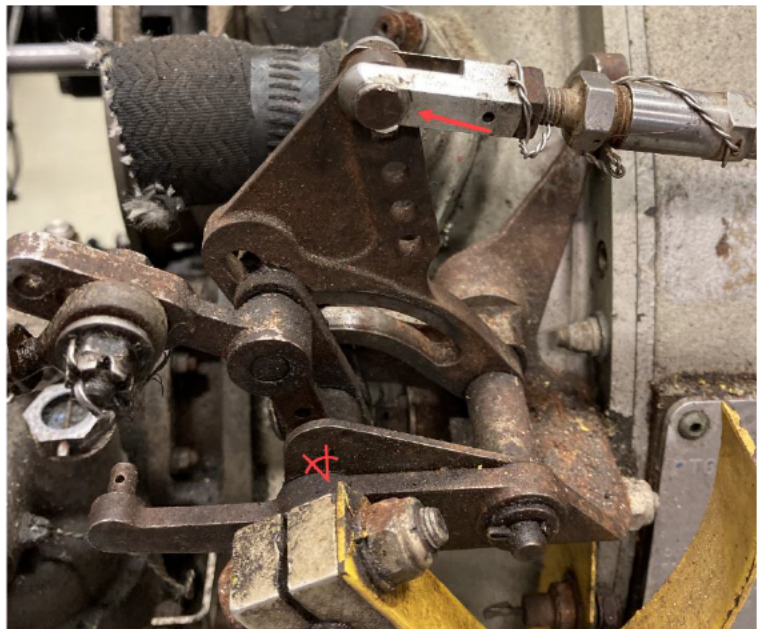


Photo No. 11, CAM Box Linkages





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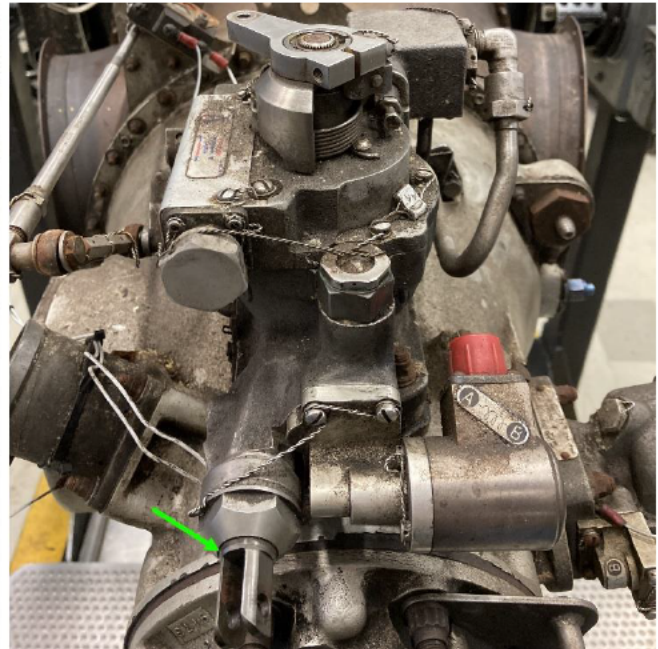
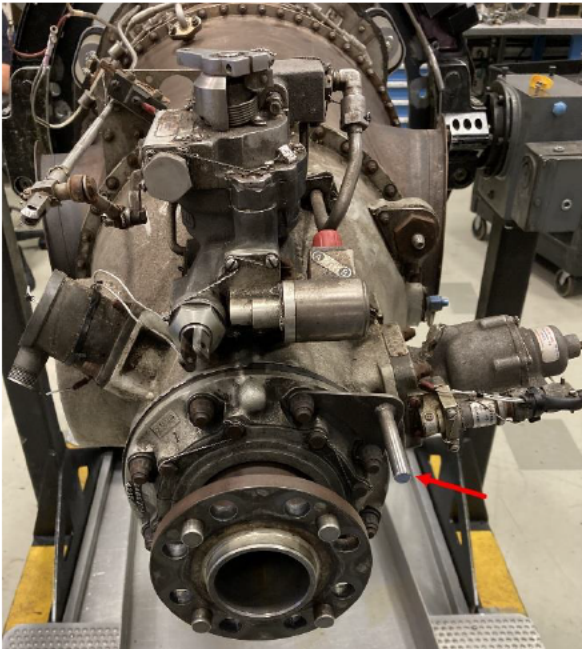


Photo No. 12, Propeller Governor, Beta Valve and Beta Pin

3.1.3 Pneumatic Lines

Compressor Discharge Air (P3) and P3 Filter: It was observed that the P3 filter bowl safety lockwire was cut, yellow arrows, Photo No. 13. The bottom of the filter bowl exhibited dark staining, right view, Photo No. 13. The air filter was clean with no visible debris, Photo No. 14. The filter bowl interface top surface exhibited a black sticky powder like substance, bottom view, Photo No. 15. The B-nuts on the P3 line between the GGC and the FCU were tight and secured with lockwire. A leak test of the P3 line was not performed.

Power Turbine Control (Py): The P&WC rigid Py line had been replaced with a flexible line by the OEM on this aircraft model. The P3 OEM flexible line was not received.



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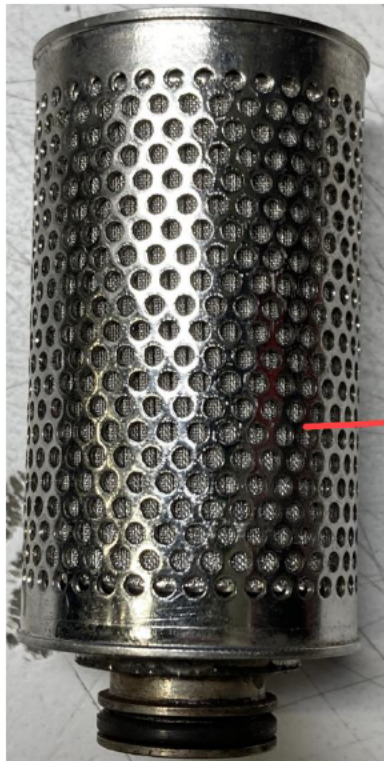
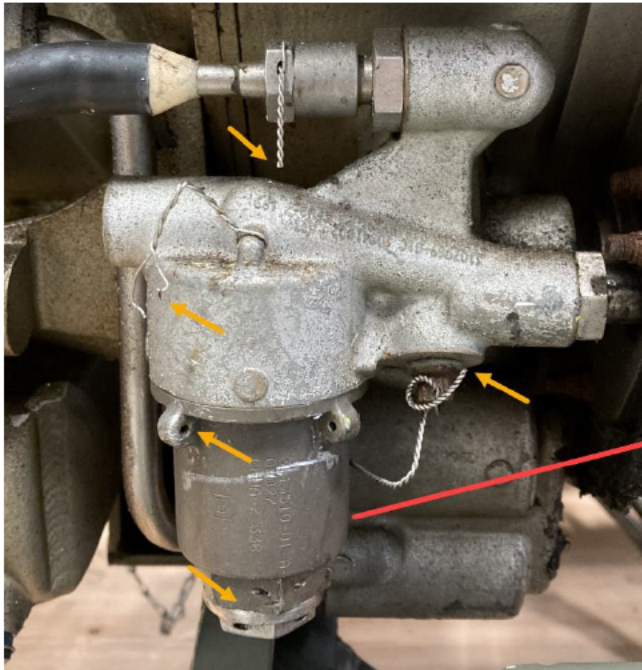
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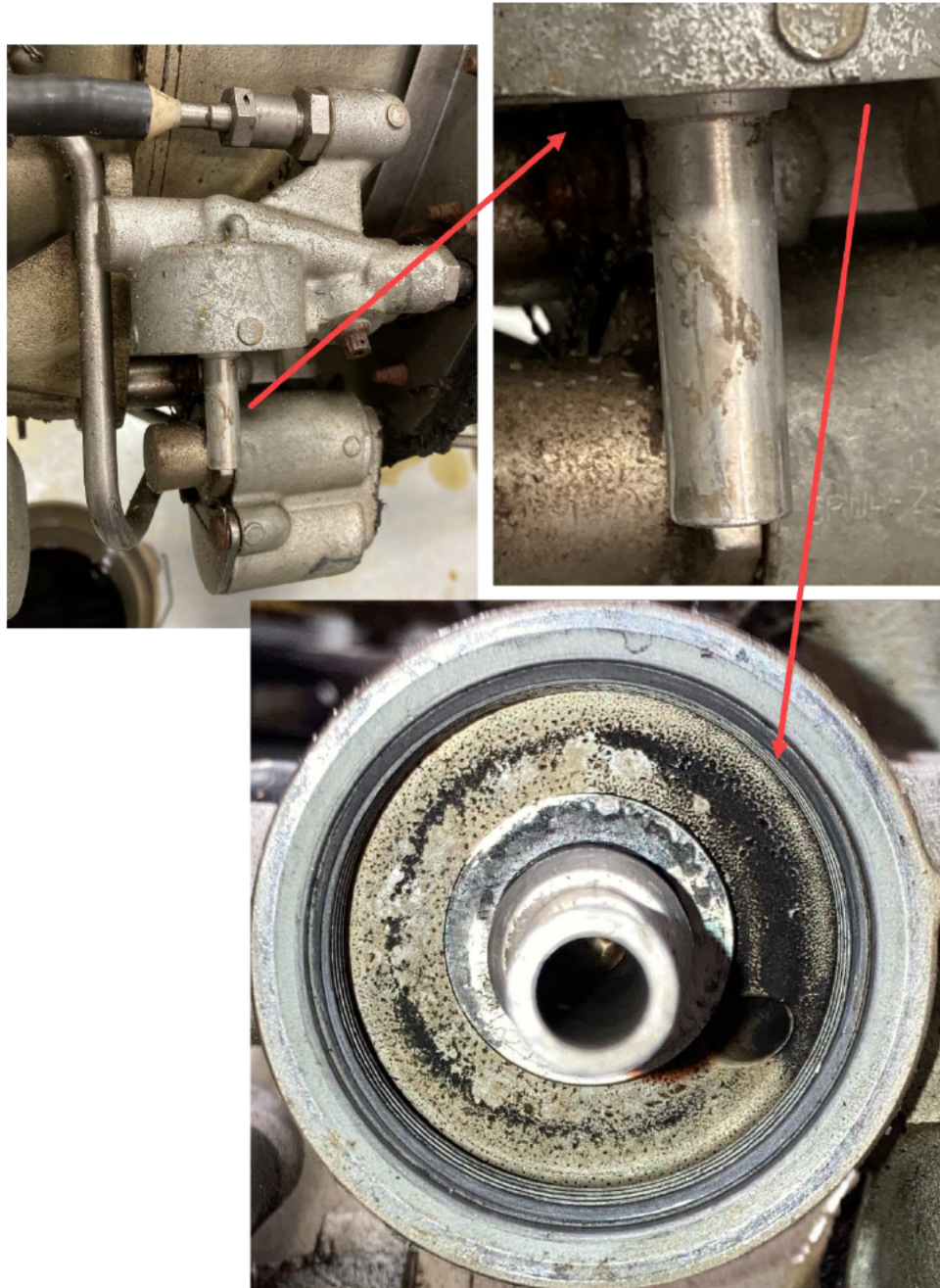


Photo No. 15, P3 Filter Bowl Interface



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3.1.4 Chip Detectors and Filters

Chip Detectors: The AGB and RGB magnetic chip detectors (MCD) exhibited a normal in-service condition, Photo No. 16.

Oil Filter: The oil filter housing and filter were wet with oil and visually free of debris, Photo No. 17.

Fuel Filter: The fuel filter element and filter bowl were wet with fuel and visually free of debris, Photo No. 18. The fuel filter screen was clean and free of debris, Photo No. 19.



Photo No. 16, RGB & AGB Magnetic Chip Detectors



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Photo No. 17, Oil Filter & Housing



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Photo No. 18, Fuel Filter and Bowl

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Photo No. 19, Fuel Pump Screen Filter

3.2 Borescope Inspection Observations

Borescope inspection (BSI) of the compressor turbine blades showed a slight erosion on the pressure side blade tips but no indications of any anomalies that would affect normal engine operation, Photo No. 20.



Photo No. 20, Compressor Turbine Borescope Inspection



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3.3 Test Cell Engine Testing

3.3.1 Decision to Test Engine

Initial engine examination, which included a borescope inspection of the gas path, did not reveal any anomalies that would prevent safe operation of the engine, as a result the decision was taken to perform an engine test in the “as received” condition.

3.3.2 Engine Preparation for Test Cell

In preparation for the engine test, the following hardware listed below was removed:

- AGB, Photo No. 21
 - A/C compressor drive
 - Operator drive pump mating with scavenge pump drive
 - Starter Generator quad pad
 - Tachometer\Speed probe
- Cam Box, Photo No. 22
 - Aircraft cam lever with follower
 - Adjacent electronic switch
- RGB, Photo No. 23
 - Tachometer\Speed probe

Additionally, the engine was fitted with the standard P&WC test cell hardware, original engine excitor box and a slave Py line.





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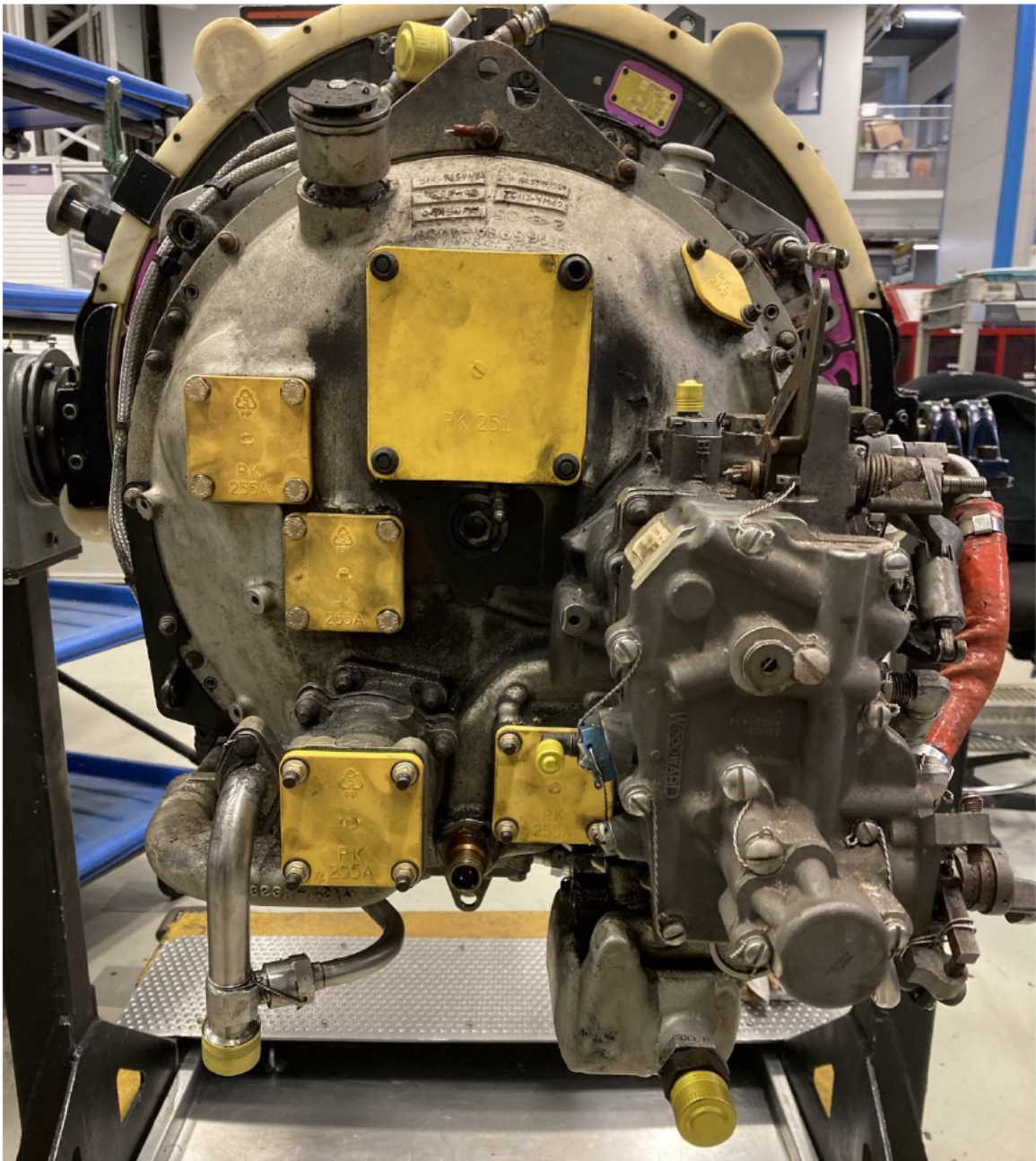


Photo No. 21, AGB Airframe Hardware Removed



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Photo No. 22, CAM Box Assembly Removed

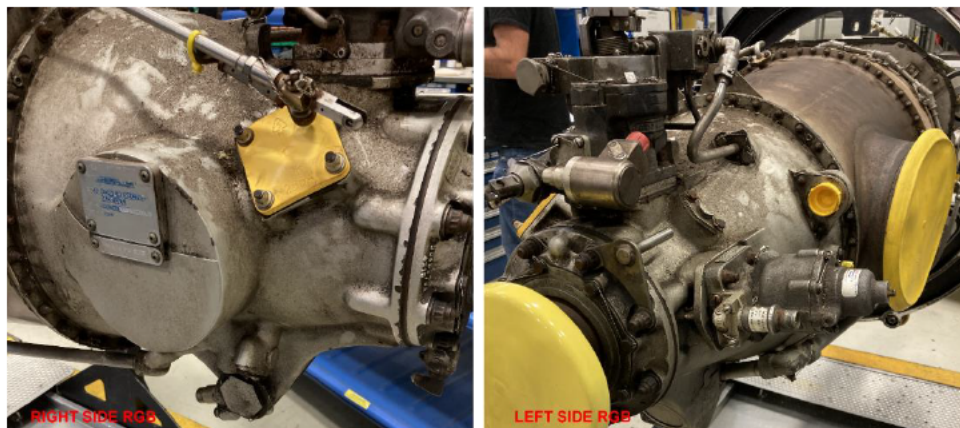


Photo No. 23, RGB Hardware Removed

3.3.3 Engine Test Results

The engine was tested per the procedure defined in the overhaul manual P/N 3032843.

Wet motoring cycles were performed to purge all fluid systems followed by dry motoring to dry the engine primary pathway. For the first four start attempts the engine achieved ignition but due to the engine failing to reach ground idle speed the start attempt was aborted. The following troubleshooting iterations were performed on the engine after each aborted engine start:

- 1) The Py line was capped at the Fuel Control Unit (FCU) side.
- 2) The Py line was reconnected and the engine P3 line was bypassed.
- 3) The P3 line was reconnected as per original installation and the Flow Divider Valve (FDV) was replaced with a slave unit.
- 4) The original FDV was reinstalled and the FCU and Fuel Pump were replaced with test cell slave units.

With the installation of the slave FCU and Fuel Pump, the 5th engine start was successful. The engine maintained ground idle speed and slowly was increased to maintain a 500 SHP output for a few minutes and then shut down.

3.4 Test Observations

During the 4th troubleshooting iteration it was observed upon removal of the original FCU that the drive shaft splines were worn, red arrow, Photo No. 24. The mating internal splines of the fuel pump were wet with a brown residue and exhibited wear as observed on the drive shaft splines, Photo No. 25. Removal of the fuel pump from the AGB revealed a similar brown residue on the AGB interface and drive shaft, Photo No. 26. The FCU and fuel pump were packed in separate boxes and submitted to the P&WC Engine Controls Accessories Technical Support (ECATS) for investigation.



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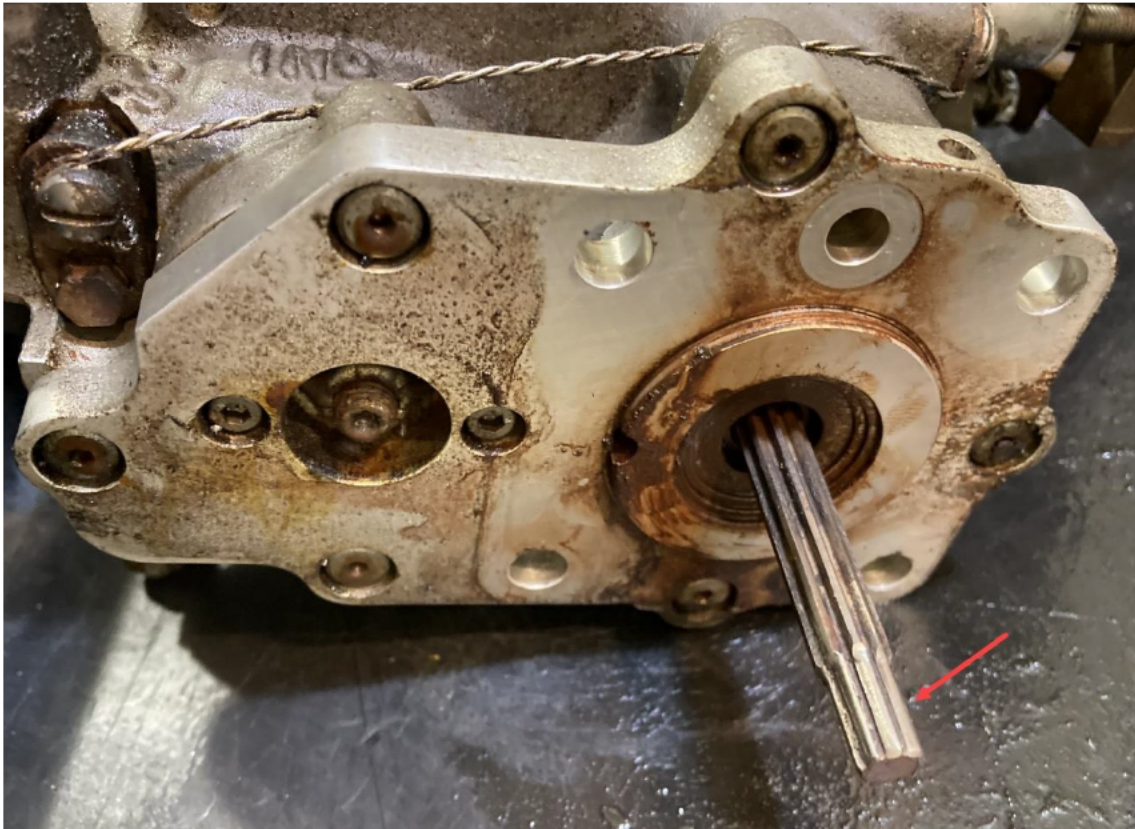


Photo No. 24, FCU Drive Shaft Wear

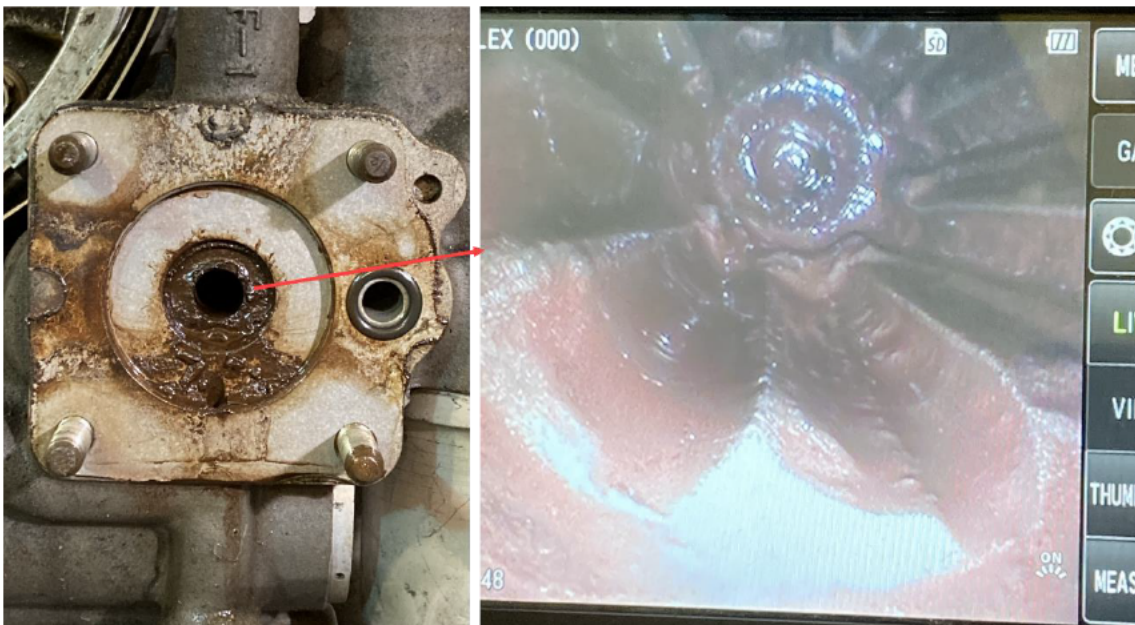


Photo No. 25, Fuel Pump Internal Spline Wear



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3.5 Controls and Accessories

3.5.1 Fuel System

Fuel Pump [PN:3040760 SN:007646]: Rotational resistance of the drive shaft was noted to be normal, Photo No. 27. The fuel pump was tested to the Component Maintenance Manual (CMM) criteria, and the fuel flows were below the minimum limits, most likely caused by worn pump gears. The wear of the pump gears could be associated with low fuel lubricity. These fuel flow deviations would not have been contributory to the event, as the fuel pump delivers more fuel than required by the engine. The fuel pump investigation is detailed in the P&WC ECATS Accessories Investigation Report (Reference A)

Fuel Control Unit [PN:8063-014 SN:14587842]: The FCU drive shaft running torque was 2–3 inch pounds, which was only slightly higher than typical units returned from service and was not found excessive. The FCU plate was removed to examine the tach valve and governor components for signs of possible shaft rotation restrictions. There were no visual anomalies observed. The FCU data plate did not show the PWC part number. This indicates that maintenance was performed on the unit at some point in the life of the FCU, where the ID plate was changed, Photo No. 28.

Testing by P&WC ECATS using a slave drive shaft was installed in lieu of the damaged one and the FCU was tested to the CMM criteria. The FCU test results showed that the FCU operation was acceptable. Further testing at the supplier supported the findings at P&WC. Additional testing at the supplier was capable of simulating the loss of RPM input in the FCU conditions, which confirmed a 34% decrease in output fuel flow that would have resulted in some level of power loss. The FCU investigation is detailed in the P&WC ECATS Accessories Investigation Report (Reference A)



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Photo No. 27, Fuel Pump Data Plate and Drive Shaft

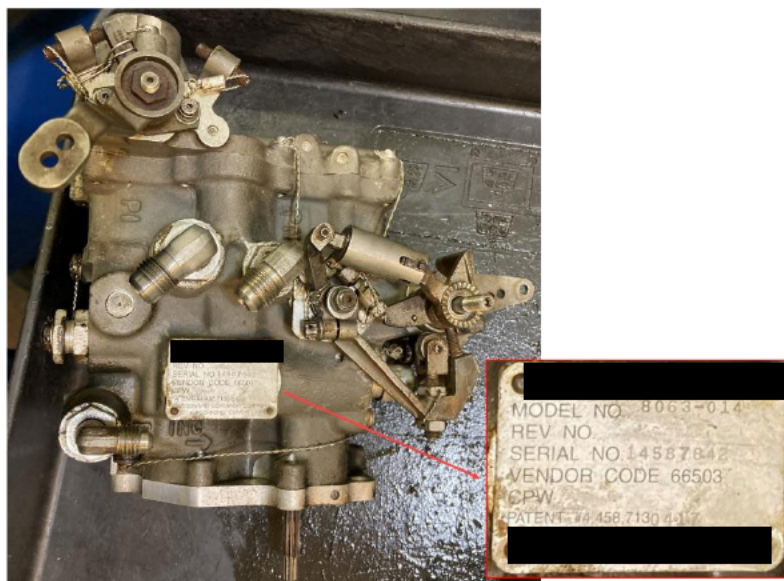


Photo No. 28, Fuel Control Unit Data Plate

4.0 REFERENCE LISTING

- (A) P&WC Accessories Accident Report 23ECN00135.

REFERENCE “A”



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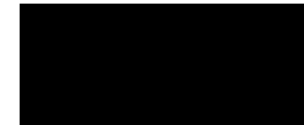
Roma Air
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Written By:



Air Safety Investigator, Engine Controls Accessories Technical Support

Approved By:



Manager, Service Investigation Department

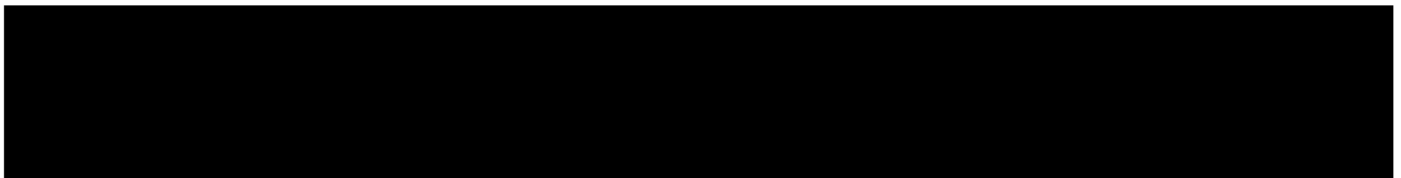
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This report is in support to the engine review.



EXPORT CONTROL CLASSIFICATION		LOCATION		U.S. REGULATION	
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		U.S.		P-ECCN 9E991	P-USML NSR
		OUTSIDE U.S.		ECCN NSR	USML NSR
				LOCAL REGULATION	
		CANADA		EIPA (ECL)	DPA (CG)
Date of marking	27 September 2024			NSR	No



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Engine Controls Accessories Technical Support Accessories Investigation

1. Accident synopsis:

An Air Tractor AT-802A, registration N3069S, was substantially damaged when it was involved in an accident near Wellington, Florida. The pilot was not injured. The flight was operated as a Title 14 Code of Federal Regulations Part 137 aerial application flight. The pilot had been applying fertilizer to several fields, during which he noted no engine performance anomalies. After finishing the last application, he was returning to the landing strip at about 500 ft above ground level when the engine was reported to have stopped producing power.

2. Summary of findings and discussion:

The investigation encompassed the visual examination, testing and disassembly of the fuel control unit (FCU) and of the fuel pump at P&WC. The FCU and fuel pump were then sent to their respective manufacturers [REDACTED] respectively) for further analysis.

The FCU receives the engine gas generator rotational speed (N_g) signal via the drive shaft of the fuel pump (Figure 1). This allows fuel modulation in relation to the engine gas generator RPM (N_g), among other inputs.

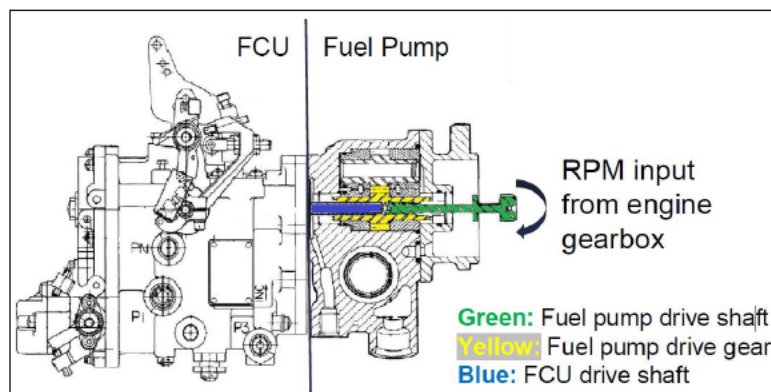


Figure 1

Visual examination showed that the FCU drive shaft splines and the corresponding fuel pump drive gear splines were sufficiently worn to allow disengagement of the FCU drive shaft from the fuel pump. The surfaces in the vicinity of the FCU to the fuel pump interface were wet, with a presence of reddish-brown debris similar to iron oxide.

Prior to testing, the FCU was partially disassembled to examine the rotating components. No evidence of resistance to the rotating components that would have contributed to wear of the drive shaft was observed. The FCU fuel inlet strainer surfaces showed presence of a red-brownish contaminant, which was confirmed at the chemical laboratory to be iron oxide. Testing of the FCU with a spare drive shaft showed typical deviations related to permissible field adjustments.

Engine Controls Accessories Technical Support

Accessories Investigation

Testing of the fuel pump showed some leakage at the FCU side carbon seal, supporting the wetness observed on the surfaces. The fuel flow capacity of the fuel pump was below the CMM minimum limits. These fuel flow deviations would not have been contributory to the event, as the fuel pump delivers more fuel than required by the engine (most of the fuel is by-passed by the FCU and returned to the fuel pump inlet).

Disassembly of the fuel pump showed pitting on the fixed bearing dams and on the housing gear bore inlet surfaces, both evidence of exposure to prolonged cavitation. The drive gear journals exhibited surface corrosion. The drive and driven gear teeth showed a high level of wear on the working flanks of the teeth.

The FCU and the fuel pump were sent to the suppliers ([REDACTED] respectively) for further analysis.

The bench test installation at [REDACTED] allowed to simulate a loss of speed input condition. With the FCU set to a condition simulating high power, the input RPM was changed from approximately 6500 RPM to 0 RPM. This RPM change resulted in approximately a 34% output fuel flow decrease, decreasing from 632 pounds per hour (PPH) to 416 PPH. With the corresponding P3 air pressure of 140 psig, this represents a fuel to air ratio unit (RU) decrease from 4.5 to 2.97. Metallurgical analysis of the FCU drive by the material laboratory at [REDACTED] showed the part was conforming to the drawing specifications.

The analysis performed at [REDACTED] supported the findings observed at P&WC. The fuel pump gear teeth advanced wear condition may have originated from an overloaded condition such as too much speed and/or pressure. This is unlikely as the installation is protected against overspeed and over pressurization. Insufficient lubrication from the fuel could also have been a contributor, reducing the fluid film as fuel temperature rises.

The presence of iron oxide in the FCU fuel inlet strainer as well as corrosion, wear and cavitation observed on the fuel pump components, suggests contamination may have been present in the fuel.

This possible contamination of the fuel may have altered the fuel lubricity, inducing the wear observed on the working flanks of the fuel pump gears teeth. A probable wear mechanism is that this wear may have led to vibrations in the drive gear, inducing wear to the FCU and fuel pump splines. However, this theory could not be confirmed.

The failure modes effect analysis (FMEA) for similar model FCU's suggests a decoupling of the FCU drive shaft from the fuel pump would result in a built-in fail-safe fuel schedule of a specific RU sufficient to maintain power. Discussions with and testing by the FCU manufacturer ([REDACTED]) suggested that design limitations in the metering valve and minimum flow orifice may create a condition where the fuel flow would tend towards minimum flow in an event of drive decoupling, contrary to the FMEA.

3. Conclusion:

The decoupling of the FCU to the fuel pump drive contributed to the event. The wear mechanism leading to the decoupling could not be confirmed.

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4. Investigation results:

Conducted at: Pratt & Whitney Canada

Initiated on: 9 November 2023

In attendance:

Name	Representing	Title
██████████	Transportation Safety Board (TSB) of Canada	Senior Technical Analyst
██████████	Pratt & Whitney Canada	Air Safety Investigator
██████████	Pratt & Whitney Canada	Air Safety Investigator

Hardware investigated:

Accessory	P&WC P/N	Manufacturer P/N	Manufacturer	S/N	Times/cycles
Fuel control unit	N/A	8063-014	██████████	14587842	Unknown
Fuel pump	3040760	825601-5	██████████	007646	Unknown

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Accessory name: Fuel control unit

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

External condition and attachments:

The external surfaces of the FCU were soiled. The condition lever and the power levers were rotating freely by hand on their entire range. The manual override (MOR) lever was lockwired to the cover, preventing movement. There was an [REDACTED] decal on the housing. The FCU plate showed dark brownish debris on the fuel pump locating diameter and brownish deposits on the fuel pump mounting surface of the plate (Figure 2). The drive shaft splines were worn on the area mating to the fuel pump (Figure 3). The FCU drive shaft worn splines axial length was measured to approximately 0.450". The drive shaft was rotating freely by hand with a resistance slightly higher than typical. The running torque of the drive shaft was measured to 2-3 inch-pounds using a dial torque wrench. The P3 inlet port fitting showed presence of a white powder on the threads. All lockwire and lockwire seals were present at the correct locations and in good condition.

Disassembly:

Prior to testing, to ensure no further damage was induced to the FCU, the FCU plate was removed to examine the governor and tachometer valve components for indications of drive shaft rotation restrictions. The ballhead assembly, cup, tachometer cam sleeve, bearings, carbon seal and carbon seal running face were unremarkable (Figure 4 to Figure 8). The bearings were turning smoothly by hand and the FCU cavity was generally clean. The inlet port and tachometer filters were removed, showing a red-brownish coloration, with no observable particulates (Figure 11, Figure 12). Using a borescope, the tachometer valve metering ports and the tach valve pilot orifice were examined and appeared free of obstructions.



Figure 2



Figure 3



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Figure 4



Figure 5



Figure 6



Figure 7

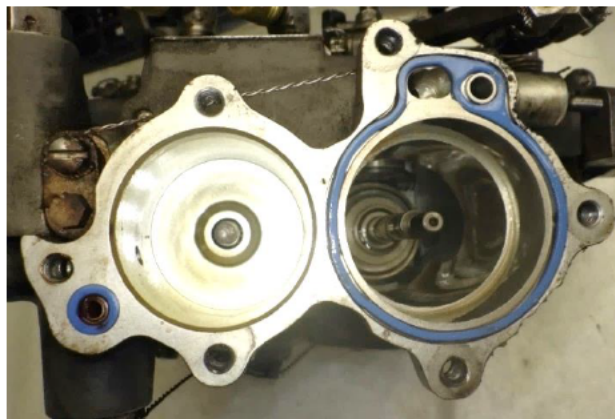


Figure 8

Test results:

A spare drive shaft was installed and the FCU was tested in accordance with the [REDACTED] component maintenance manual (CMM) 73-20-11. The following deviations were observed.

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The condition lever and shut down test, test point (TP) 3.1, was 19 PPH above the CMM maximum limit. The TP 3.2 was 27 PPH above the CMM maximum limit. This is a permissible field adjustment. The power lever test TP 4.1 was 10 PPH above the CMM maximum limit and the TP 4.2 was 36 PPH below the CMM minimum limit. The TP 4.6 dead band was 2.5 degrees above the maximum limit and the TP 4.7 maximum forward angle was 1 degree below the CMM minimum limit. This is a permissible field adjustment. The CDP (P3) schedule TP 6.4 was 7 PPH above the CMM maximum limit and the TP 6.5 was 15 PPH above the CMM maximum limit. The deceleration schedule TP 8.4 minimum fuel flow was 1 PPH below the CMM minimum limit. The start and acceleration test TP 9.1 at high idle was 15 PPH above the CMM maximum limit and the power lever (P/L) at -5 degrees was 1 PPH above the CMM maximum limit. The TP 9.2 at high idle, P/L at -5 degrees and P/L at maximum were respectively 12 PPH, 5 PPH and 1 PPH above the CMM maximum limit. The TP 9.3 at high idle, P/L at -5 degrees and P/L at maximum were respectively 13 PPH, 4 PPH and 4 PPH above the CMM maximum limit. The TP 9.4 at high idle, P/L at -5 degrees and P/L at maximum were respectively 8 PPH, 7 PPH and 3 PPH above the CMM maximum limit. The TP 9.5 at high idle, P/L at -5 degrees and P/L at maximum were respectively 5 PPH, 4 PPH and 4 PPH above the CMM maximum limit. The TP 9.6 at high idle, P/L at -5 degrees and P/L at maximum were respectively 4 PPH, 4 PPH and 4 PPH above the CMM maximum limit. The TP 9.7 was 2 PPH above the CMM maximum limit. The TP 9.8 was 4 PPH above the CMM maximum limit. The TP 9.11 was 4 PPH above the CMM maximum limit. The TP 9.12 was 1 PPH above the CMM maximum limit. The TP 9.13 was 11 PPH above the CMM maximum limit. The TP 9.14 was 16 PPH above the CMM maximum limit. The maximum flow test TP 10.1 was 10 PPH above the CMM maximum limit.

The FCU was sent to the manufacturer (██████████) for further analysis and testing. The following is an extract from the manufacturer's report:

“Testing at ██████████ was limited to simulating conditions of a loss of speed input to the FCU at max forward conditions. A slave inlet filter and drive coupling were installed, and the unit was mounted on the test stand. The max forward stop was found to be set at 6483 RPM [...] with a delta pressure of 46.7 psid [with an output fuel flow of 632 PPH]. The Control Drive Speed (N) was dropped to 0 rpm and the output fuel flow was recorded at 416 pph.

Chemical laboratory findings:

The FCU drive shaft, the debris observed on the flange face and both fuel strainers were sent to the chemical laboratory to determine the nature of the observed debris.

The samples were first visually observed under an optical microscope. The residues and surface debris were analyzed by scanning electron microscopy (SEM-EDX), and/or Fourier transform infrared spectroscopy (FTIR). The fuel inlet strainer and the tachometer valve strainers were ultrasonically cleaned with prefiltered heptane followed by filtration on a 1.2µm filter patch. The residue was then evaluated by automatic particle analysis (APA) which excludes organic, carbon rich, and fluorinated particles.

A visual observation of the drive shaft displayed a brown residue along the surface of the piece and concentrated within the grooves (Figure 9, Figure 10). The base material of the drive shaft was similar to



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a series 300 stainless steel (SST). The dark residue was composed of iron, oxygen, some chromium, and traces of sulfur, suggesting an iron-oxide material.

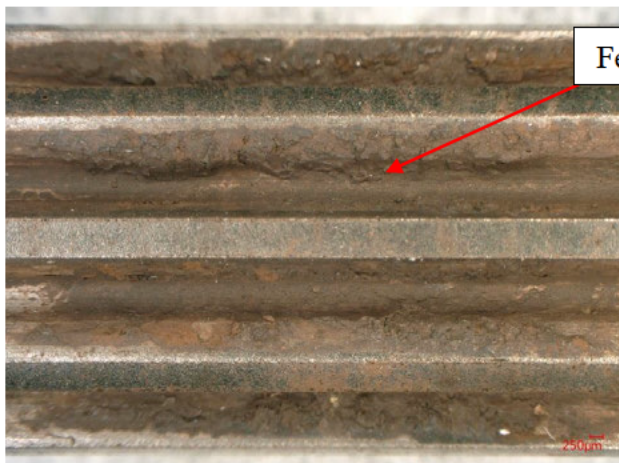


Figure 9

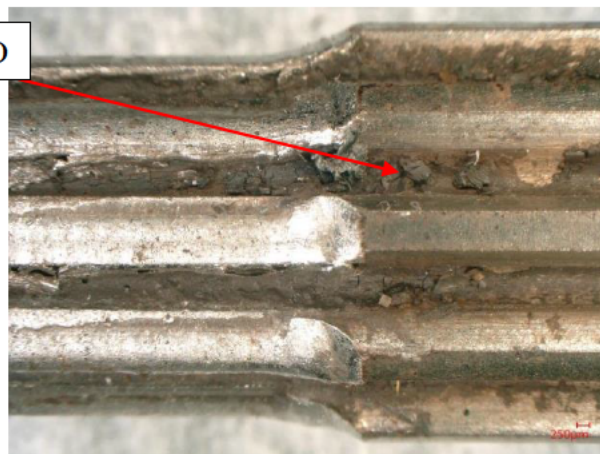


Figure 10

The fuel inlet strainer (Figure 11) and the tachometer valve strainer (Figure 12) showed a brownish-red deposit. The deposit was identified as a mixture of iron-sodium-sulfur-zinc rich particles as well as silicon rich particles (Figure 13).



Figure 11

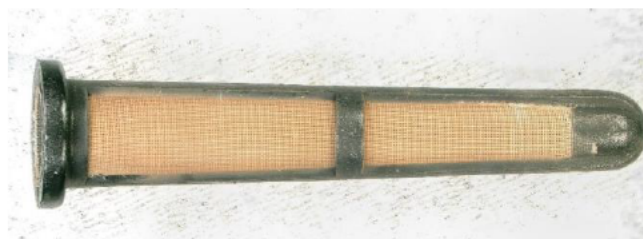


Figure 12



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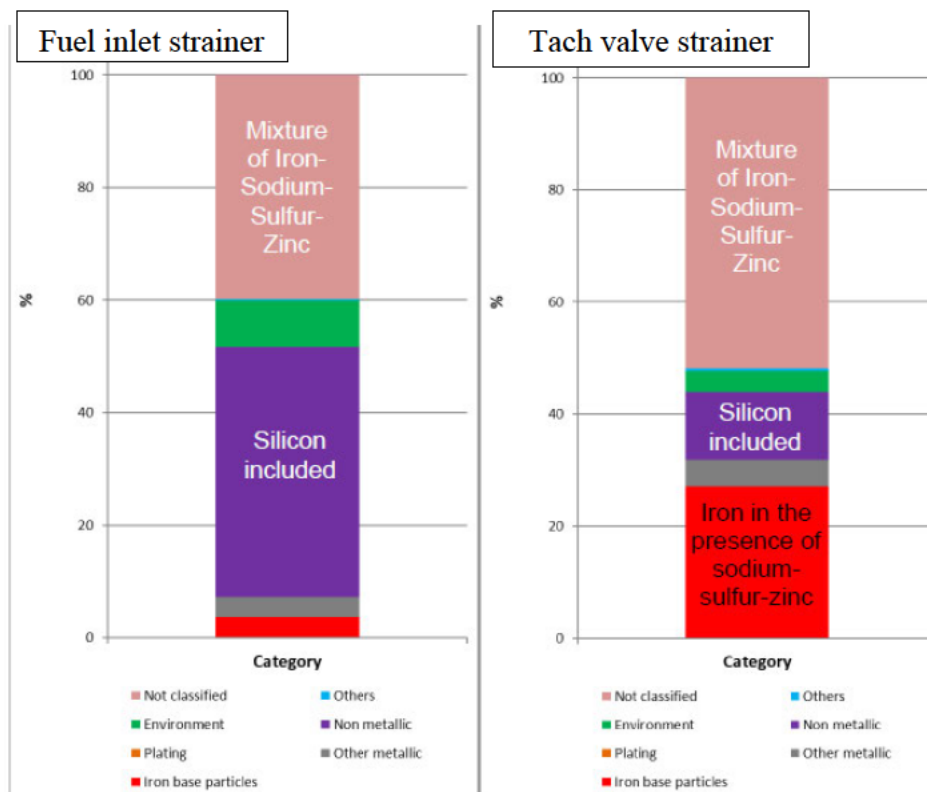


Figure 13

The debris observed on the FCU mounting flange face was mainly composed of iron, oxygen, and some chromium suggesting an iron-oxide material.

Material analysis:

The FCU drive shaft metallurgy was analyzed by the manufacturer (██████████). The following is an extract from the manufacturer's report:

“The raw material of the drive coupling was inspected using an energy-dispersive spectroscopy (EDS), where the core chemistry was consistent with expected values for 410 stainless steel (SST). The microhardness was verified using 5 Vickers indentations at 500-gram load. The hardness was recorded at 277 HV (29HRC), within ██████████ tolerance [...] for 410 SST. Nitride case depth was verified by a calibrated microscope, etched via Marble's Reagent. Nitride case depth was measured within tolerance at 0.00115" - 0.00144" [...]. The wear surface was evaluated via a combination of stereoscopy and scanning electron microscope (SEM) analysis. Wear surface evaluation did not find any features of note, as the level of deformation damage obscured any potential features. EDS did not identify any imbedded foreign material present on the wear surface. Stereoscopy of the damaged shaft end showed evidence of the wear direction being the clockwise radial direction (relative to the [installation] interface end of the component).”

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Accessory name: Fuel pump

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

External condition and attachments:

The external surfaces of the fuel pump were soiled. The FCU mounting flange face of the fuel pump showed brownish deposits and the drain area had presence of wet brownish debris (Figure 14). The brownish deposits were observed in the vicinity of the drain cavity on the engine accessory gearbox (AGB) side of the fuel pump. The surface between the AGB side carbon seal and the drain cavity was slightly wet (Figure 15). The drain port showed a brownish deposit with a wet appearance. The outlet filter was removed and found unremarkable. The inlet strainer was removed, and some debris was observed in the bottom of the strainer. The debris was collected and sent to the chemical laboratory for analysis. The fuel pump drive shaft was turning freely with the typical resistance and the running torque was measured at approximately 7 inch-pounds using a dial torque wrench. With the fuel pump drive shaft removed, the drive gear splines on the fuel pump drive shaft side were found in good condition, with presence of dark brownish debris (Figure 16). The drive shaft splines end face showed chipping, on the fuel pump side (Figure 17). Examination of the drive gear internal splines with a borescope showed wear on the FCU side (Figure 18 and Figure 19). The lockwire between the BF-1 and BF-2 fittings was loose. The lockwire on the outlet filter bowl was missing. All other lockwire and safety cable were present in the correct locations and in good condition.

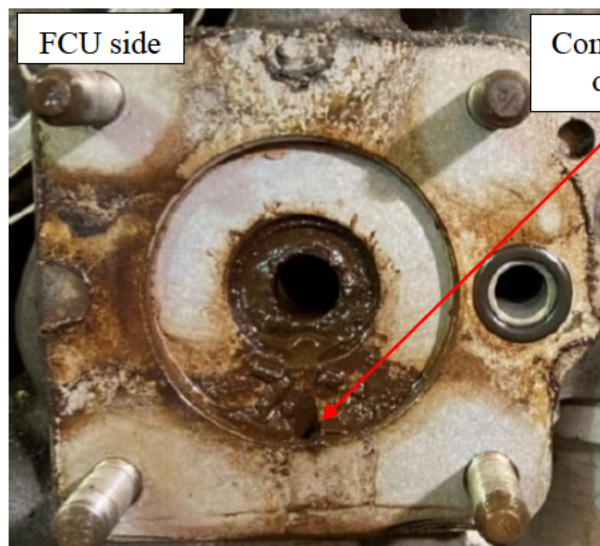


Figure 14

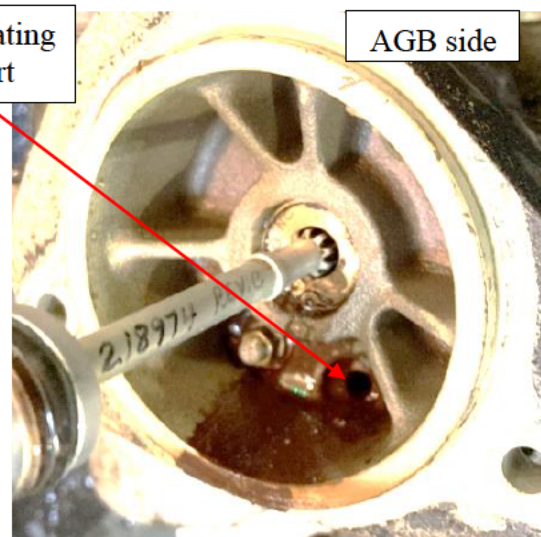


Figure 15



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Figure 16

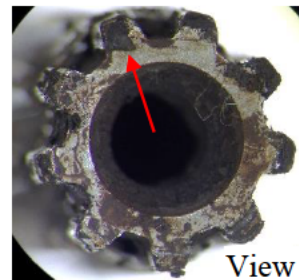


Figure 17

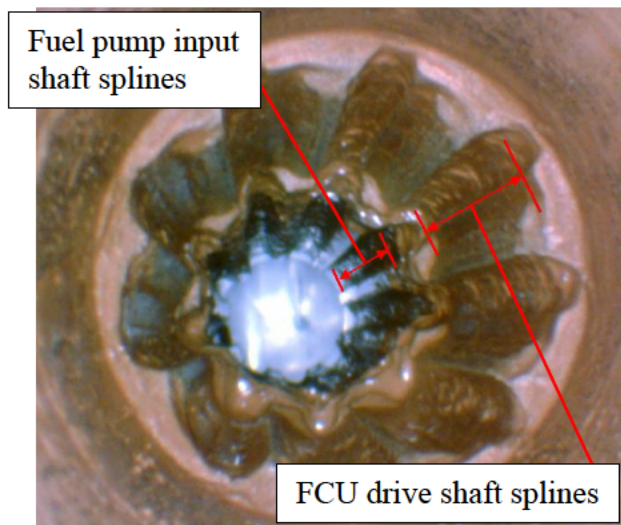


Figure 18



Figure 19

Test results:

The fuel pump was tested in accordance with the [REDACTED] CMM 73-10-12 and the following deviations were observed.

The pump calibration TP 2 at low RPM and pressure was 37 PPH below the CMM minimum limit. The TP 2 at high RPM and pressure was 131 PPH below the CMM minimum limit. The FCU side carbon seal showed a pooling of fuel throughout the test while the AGB side carbon seal showed some dampness.

Disassembly:

The fuel pump cover, with the AGB side carbon seal, and the fixed bearings were removed and found unremarkable. The drain cavity in the housing had a brownish coloration. A step wear on both gears face mating to the pressurized bearings could be felt with a scribe. The two floating bearing packings had displaced rubber and the base material of the bushing above the packing was scored (Figure 20 and Figure 21). The fixed bearings had pitting on the dams (Figure 22). There was one small debris on the face of the FCU side carbon seal, with corresponding scoring of the drive gear sealing face (Figure 23). The gearset showed wear on the teeth face working flank (Figure 24, Figure 25) as well as corrosion on the gear journal



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(Figure 26). The housing gear pockets showed some cavitation pitting (Figure 27, Figure 28) and the gear wipe was typical of an in-service fuel pump.

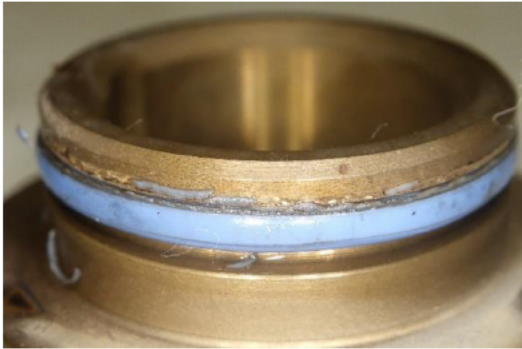


Figure 20



Figure 21

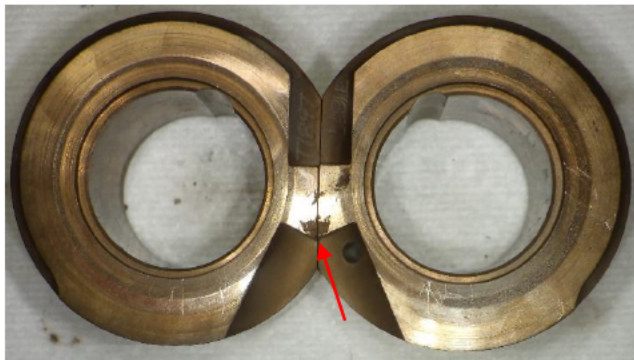


Figure 22



Figure 23



Figure 24

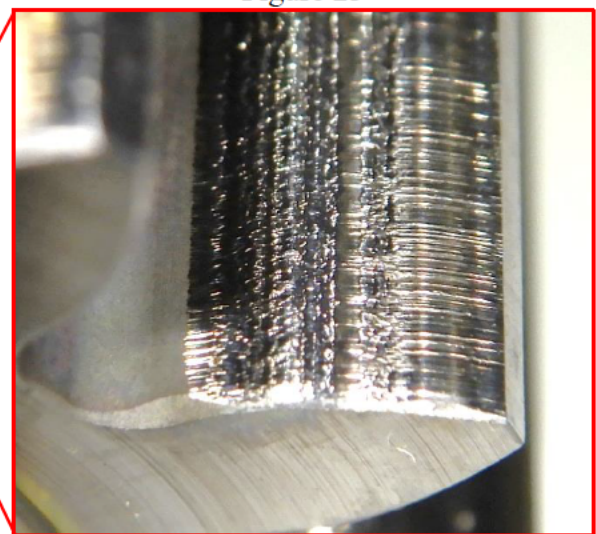


Figure 25



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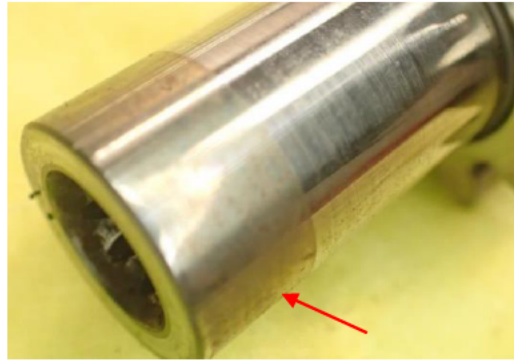


Figure 26

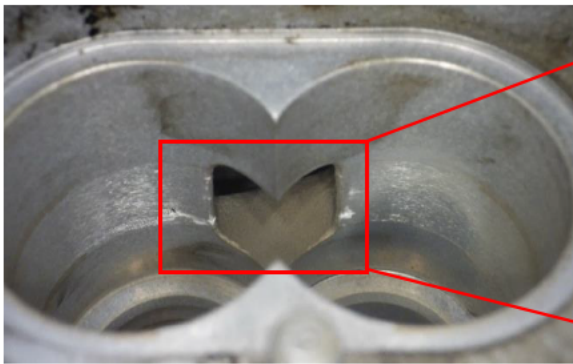


Figure 27

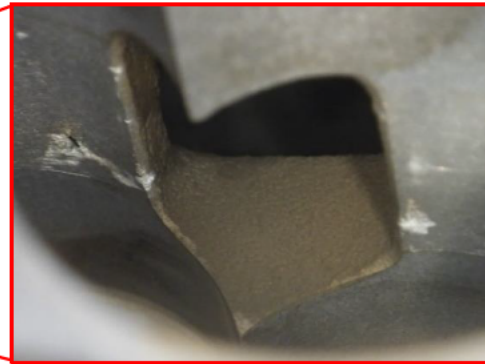


Figure 28

Chemical laboratory findings:

The fuel pump drive shaft, the drive gear, the debris observed on both mating flanges (FCU and AGB side) and the debris found in the inlet strainer were sent to the chemical laboratory to determine their nature. The samples were first visually observed under an optical microscope. The residues and surface debris were analyzed by scanning electron microscopy (SEM-EDX), and/or Fourier transform infrared spectroscopy (FTIR).

The fuel pump drive shaft showed dark brown residues on both splined ends (Figure 29). SEM-EDX analysis of the residue from the fuel pump drive splines (Figure 30) displayed iron, fluorine, oxygen, some carbon, and traces of chromium, aluminum, and sodium. FTIR displayed an organic material suggesting a perfluorinated grease. The residue was possibly a mixture of an iron-oxide material with a grease.



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Figure 29

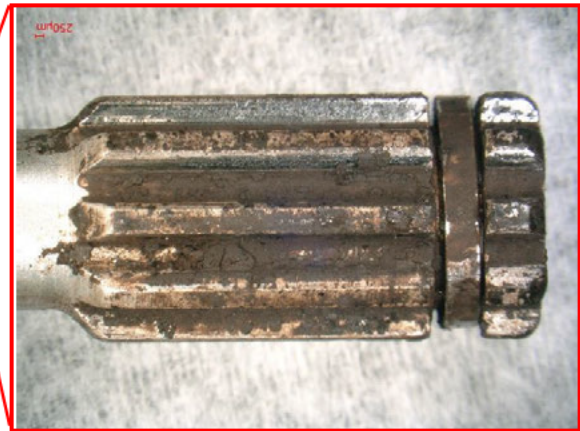


Figure 30

SEM-EDX analysis of the residue from the AGB side of the fuel pump drive gear (Figure 31, Figure 32) displayed iron, fluorine, oxygen, some carbon, and traces of chromium, aluminum, and sodium. FTIR displayed an organic material suggesting a perfluorinated grease. The residue is possibly a mixture of an iron-oxide material with a grease. The residue present in the FCU drive side (Figure 31, Figure 33) was rich in iron, oxygen, and traces of chromium suggesting an iron-oxide material.



Figure 31

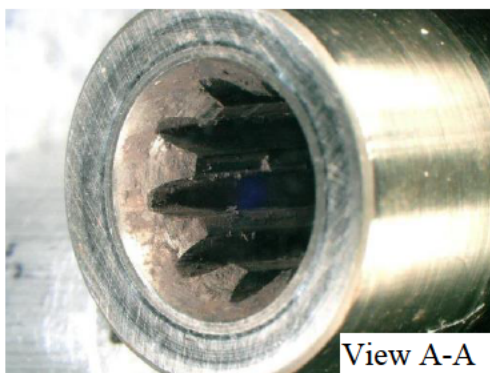


Figure 32



Figure 33

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The debris observed on the AGB mounting face of the fuel pump was composed of a viscous fluid and of a flaky material (Figure 34)



Figure 34

The flaky material contained two distinctive surfaces. One side of the surface was composed of magnesium with some oxygen and traces of zinc and aluminum. The other side was composed of carbon, some oxygen, magnesium, and traces of chromium, phosphorus, sodium, sulfur, and aluminum. FTIR displayed a hydroxide compound as well as an enamel compound. This may have suggested a magnesium hydroxide compound in the presence of an enamel coating.

The viscous material was similar in composition to a perfluorinated grease.

The red-brownish material on the FCU and the AGB side mounting faces were composed mainly of iron, oxygen, and some chromium, suggesting an iron-oxide material.

The debris found in the fuel inlet strainer (Figure 35) contained various particles. A flat brown coloured particle suggested wood fibers (circled in red). A fluorine rich particle with some carbon suggested a fluorocarbon material. A leaded bronze (circled in yellow) material was observed. Particles rich in calcium, sulfur, and oxygen suggested a calcium sulfate material. Calcium rich particles with traces of silicon suggested environmental particles. Aluminum-based particles and fibrous particles composed of carbon, some sulfur and oxygen were detected. A particle suggesting an acrylic compound (circled in blue) was detected.



Figure 35