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

May 29, 2013

POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB ID: ENG11IA021

A. INCIDENT:

Location: Pittsburgh, Pennsylvania

Date: March 17, 2011

Time: 1640 coordinated universal time (UTC)

Aircraft: Bombardier DeHavilland DHC-8, Reg. No. N339NG, Colgan Air flight 3212

B. POWERPLANTS GROUP:

Group Chairman: Carol Horgan
National Transportation Safety Board
Washington, DC

Member: Jim Lawrence
Federal Aviation Administration
Burlington, MA

Member: Michael Crook
Colgan Air
Memphis, TN

Technical Advisors to the Accredited Representative, Canada:

Richard Berg
Transport Canada
Ottawa, Ontario

Marc Hemmings
Pratt & Whitney Canada
Longueuil, Quebec

Albert G. Whitty
Pratt & Whitney Canada
Mississauga, Ontario

Jean-Francois Houle
Pratt & Whitney Canada
Longueuil, Quebec

Ricardo Pereira
Pratt & Whitney Canada
Longueuil, Quebec

AK Durrani
Transport Canada
Ottawa, Ontario

Glenn Hansen
Bombardier
Toronto, Ontario

C. SUMMARY

On March 17, 2011, about 1640 UTC, a Colgan Air DeHavilland DHC-8-400Q, N339NG, experienced a left engine undercowl fire while en route from Cleveland Hopkins International Airport, Cleveland, Ohio to Baltimore-Washington International Airport, Baltimore, Maryland. The flight crew reported that while in cruise flight at FL230 the left engine oil pressure master warning illuminated and the digital oil pressure gauge displayed dashes without a readout. The left engine oil temperature was observed to rise rapidly. A left engine fire warning indicated and the engine began to lose power. The engine was shut down and both fire suppression bottles were discharged. The flight declared an emergency and diverted to Pittsburgh International Airport, where it landed without incident. The engine fire warning remained active after airport firefighting personnel determined that the fire was extinguished. The airplane was operating on an instrument flight rules flight plan under the provisions of 14 CFR Part 121. There were no injuries to the two flight crew, two cabin crew, and 36 passengers. Post-flight inspection of the left engine, a Pratt & Whitney Canada (PWC) PW150A, found a hole in the casing between the high pressure (HP) impeller and the combustor and thermal damage to engine components in the area of the hole. There was minor scorching damage to the airplane nacelle.

An engine analytical teardown was performed at PWC in St-Hubert, Quebec, March 28 through April 1 2011. Debris recovered from the engine chip detectors and the No. 1 bearing were retained for analysis by a PWC materials laboratory. The engine oil pump was examined at Hamilton Sundstrand in Windsor Locks, Connecticut, on May 2-3, 2011. The two nacelle fire/overheat detector assemblies were examined at Kidde Aerospace & Defense (KAD) on May 9, 2011.

D. DETAILS OF THE INVESTIGATION

1.0 Engine information

1.1 Engine data

The incident engine was a PW150A, serial number (S/N) FA0737. At the time of the incident, it had accumulated 551 hours since new (TSN) and 551 cycles since new (CSN).

1.2 Engine description

The PW150A is a three-spool free turbine turboprop engine incorporating a low pressure (LP) 3-stage axial compressor and a HP centrifugal compressor driven by independent axial turbines, a reverse flow[1] annular combustor, and a two-stage power turbine (PT) that drives a reduction gearbox (RGB). The LP spool is supported by two roller bearings (Nos. 2.5 and 6) and an aft ball bearing (No. 3), which accepts forward thrust loads. The HP spool is supported by a front ball bearing (No. 4) that accepts forward thrust loads, and a roller bearing (No. 5). The PT spool is supported by a front ball bearing (No. 1) that accepts rearward thrust loads and by the Nos. 2, 6.5, and 7 roller bearings. The engine fuel flow is controlled by a full authority digital electronic control (FADEC) with input from a propeller electronic control (PEC). The PW150A has a maximum sea level takeoff rating of 5,071 shaft horsepower.

[1] All directional references are as viewed from the rear of the engine looking forward unless otherwise noted. Upstream (leading edge) and downstream (trailing edge) references indicate the direction of the gas flow during operation.

1.3 Engine service history

The engine was manufactured in July 2010 and was installed on the incident airplane, N339NG, on September 17, 2010. N339NG was placed in service by Colgan Air on December 13, 2010. A review of Colgan Air maintenance records for the incident engine found no maintenance discrepancies.

1.3.1 Engine monitoring unit (EMU) data

The PW150A is equipped with an engine monitoring unit (EMU) that observes FADEC and PEC operational data and records parameter exceedances, trend condition data, and fault codes. A review of the EMU data from October 2010 through March 14, 2011 found no unusual fault history. A RGB chip detector fault, which is a Class 2 maintenance[2] fault, was recorded on March 15, 2011. The next EMU fault download was scheduled for the evening of March 17, 2011.

A digital flight data recorder plot of the event with an overlay of the EMU fault code data was created. See Figure 1.

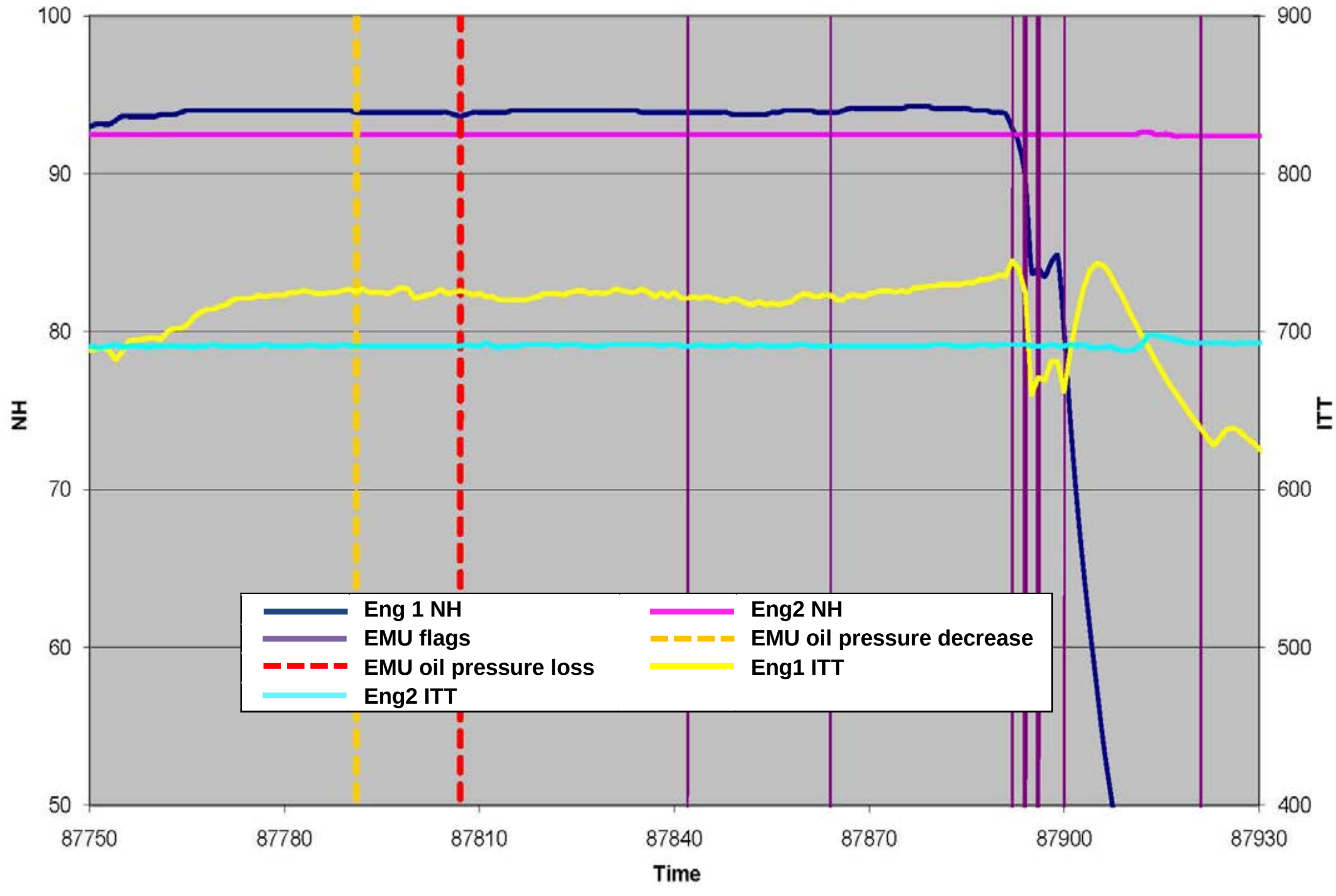

Figure 1. N339NG March 17, 2011 EMU data with DFDR overlay

[2] Class 2 faults indicate conditions that do not prevent continued system function. They are read with maintenance interrogation, which is performed on an opportunity basis.

2.0 Engine investigation

The as-received condition of the engine is shown in Figures 2 through 5.

Figure 2. ESN FA0737, right side view

Figure 3. ESN FA0737, left side view

Figure 4. ESN FA0737, inlet

Figure 5. ESN FA0737, exhaust

There was an approximately 4.5-inch circumferential by 3.5-inch axial hole through the gas generator case (GGC) and insulation blanket between 6 and 7 o'clock[3] and roughly in line with the diffuser pipe exit ports. The edges of the hole were irregular and charred, with deposits of molten

[3] O'clock refers to approximate circumferential locations in a clockwise direction, viewed from the rear of the engine looking forward.

metallic material characteristic of an internal engine fire burning through the side of the engine case from the inside out (burn-through). See Figure 6.

Figure 6. GGC viewed from bottom LH side

A borescope probe was inserted through the 4, 7, and 10 o'clock combustion positioning pin bores to inspect the fuel nozzles before their removal and to further document the damaged area. Partially consumed sections of combustion outer liner, diffuser duct, and HP impeller were observed through the hole. A bag of metallic debris received with the engine included fragments of burnt diffuser duct material. See Figure 7.

Figure 7. Burnt diffuser duct and other debris received with the engine

An engine inlet inspection found no evidence of foreign object damage. The front intake case (FIC) inner surface, the exterior of the P2.7 bleed valve, and the bottom of the LPC case were oily. The inside surface of the bleed valves was dry. No metal contamination was found at the drains collector.

The LP spool rotated freely. The HP spool was seized. There was continuity from the PT to the propeller drive but there was some resistance to rotation.

The left ignition cable braid showed some thermal damage and molten metal deposits in the area of the burn-through. Also in this area, the plastic sleeve covering the identification band on the right fuel manifold was partially melted, and the exhaust gas temperature harness insulating material showed thermal distress (shiny, hardened).

No other damage to external engine components was noted.

2.1 Disassembly observations

2.1.1 Oil system sensors, filters, valves

Both the RGB and turbomachinery (TM) magnetic chip detectors were covered with ferrous particles and chips. The main engine oil and RGB scavenge oil filters, which were removed and bagged in Pittsburgh, were contaminated with non-ferrous and ferrous particles. The RGB oil scavenge sump strainer contained a large amount of metal debris, including an O-ring segment, a key washer, one bolt (distorted and gouged), and material later identified as No.1 bearing cage and No. 1 bearing cavity lug fragments. The strainer also contained a large amount of small, dark, ferrous chips. See Figures 8 and 9.

Figure 8. RGB oil scavenge sump strainer

Figure 9. Some of the debris found in RGB oil scavenge sump strainer

Inspection of the engine oil system scavenge relief valves found that the ball inside the relief valve serving the Nos. 6 and 6.5 bearing scavenge passage was free; the ball inside the relief valve serving the Nos. 3 and 4 bearing passage was stuck in the bypass position; the ball inside the relief valve serving the No. 5 bearing passage was stuck in the bypass position and was heat discolored; and the ball inside the relief valve serving the Nos. 2 and 2.5 (2/2.5) bearing passage was stuck in the non-bypass position. Fine metal contamination was found in all of the valve cavities and the No. 5 cavity was more heavily contaminated with sludge-like deposits.

2.1.2 Main engine oil pump

When the engine accessories were removed, the coupling shaft of the main engine oil pump was found fractured at its shear neck. See Figure 10. The oil pump was seized.

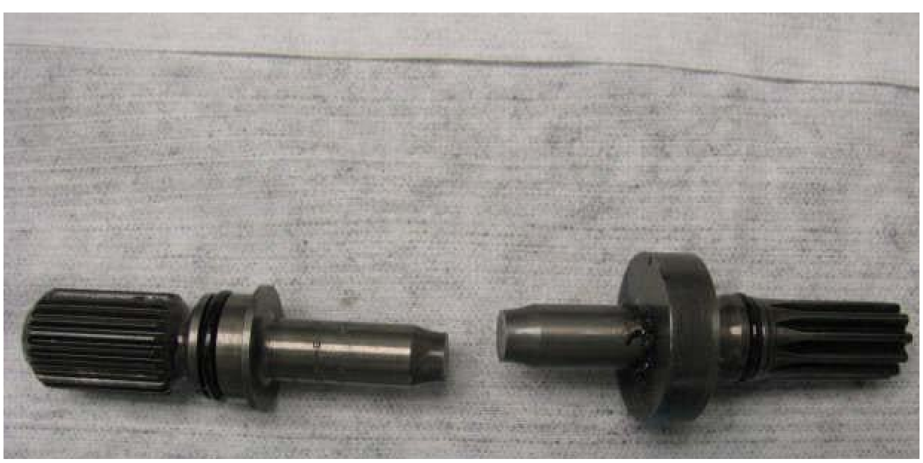

Figure 10. Oil pump coupling shaft separation

Metallic paste deposits were noted at the scavenge inlet ports, and a pump vane visible at the Nos. 2 and 2.5 (2/2.5) bearing scavenge oil entry port appeared damaged and out of alignment. See Figure 11.

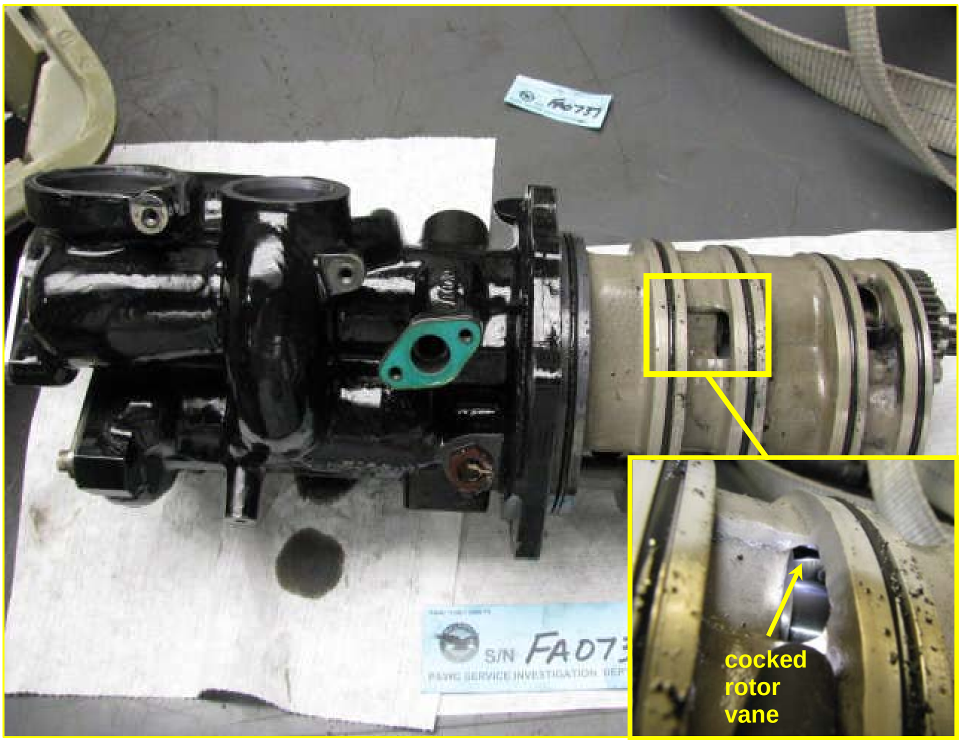

Figure 11. Oil pump, with 2/2.5 bearing scavenge oil entry port noted

2.1.3 Turbine section

2.1.3.1 Power turbine

The forward face of the turbine exhaust duct (TED) assembly was rubbed 360° and its baffle section was detached. See Figure 12. The No. 7 oil delivery nozzles were damaged, with metal smearing at the orifices.

Figure 12. TED assembly, showing detached baffle

The second stage power turbine (PT2) disk assembly was intact. The No. 7 bearing was dry and heat discolored, but intact. The No. 7 bearing inner race, carbon seal and runner, and retention nut exhibited rotational damage. See Figure 13.

Figure 13. PT2 disk assembly, showing No. 7 bearing, seal, and retaining nut

The PT2 vane ring assembly airfoil leading edges (LEs) were rubbed. See Figure 14.

Figure 14. PT2 vane ring assembly, showing contact damage

The first stage power turbine (PT1) disk assembly blade trailing edges (TEs) showed 360° scoring. See Figure 15.

Figure 15. PT1 disk assembly airfoil trailing edges

The 6.5 bearing and carbon seal runner were intact but dry. See Figure 16.

Figure 16. Forward side of PT1 disk assembly, showing 6.5 bearing and carbon seal runner

The inter-stage turbine vane ring was intact. See Figure 17.

Figure 17. Inter-stage turbine vane ring

2.1.3.2 Low pressure turbine (LPT)

The LPT disk assembly showed no mechanical damage. There was metal splatter on the blade airfoils and shroud segments. The vane segments were coated with metal splatter but the vane ring assembly installation was in otherwise good condition. The No. 6 bearing was intact but dry.

2.1.3.3 High pressure turbine (HPT)

All of the HPT disk assembly blade tips were rubbed at the TEs and the LEs were heat discolored and thermally eroded, with exposure of the airfoil air passages. See Figure 18. There was a thin coating of metallic splatter over the airfoils and a heavy coating of metal deposits on the shrouds. The front stub splines were in normal condition. There were no indications of axial contact/rub. The bore was coated with metal splatter and oxidation material.

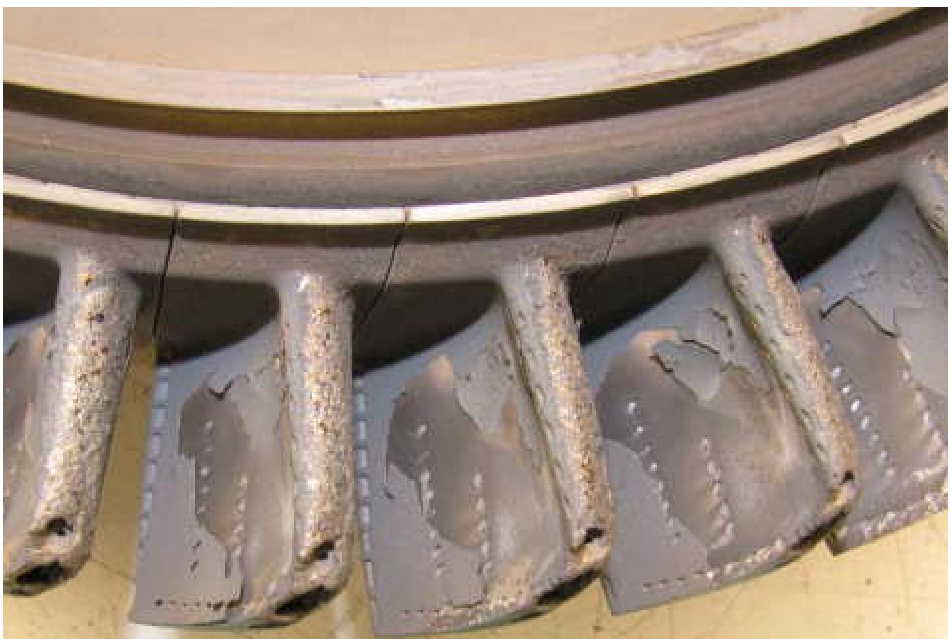

Figure 18. HPT blades

The HPT vane ring assembly showed no mechanical damage. There was a bluish discoloration on the vane trailing edges between 7 and 12 o'clock; the remaining TEs were metal splattered. See Figures 19 and 21. Chunks of re-solidified metallic debris adhered to the airfoil LE surfaces between 6 and 12 o'clock. See Figure 20. The HPT front cover was oxidized consistent with heat distress. The HPT rear cover showed deposits of reddish dust-like material.

Figure 19. HPT vanes showing metal deposits and thermal discoloration

Figure 20. LE side of HPT vanes showing deposits of re-solidified metal; small exit duct showing metallic deposits

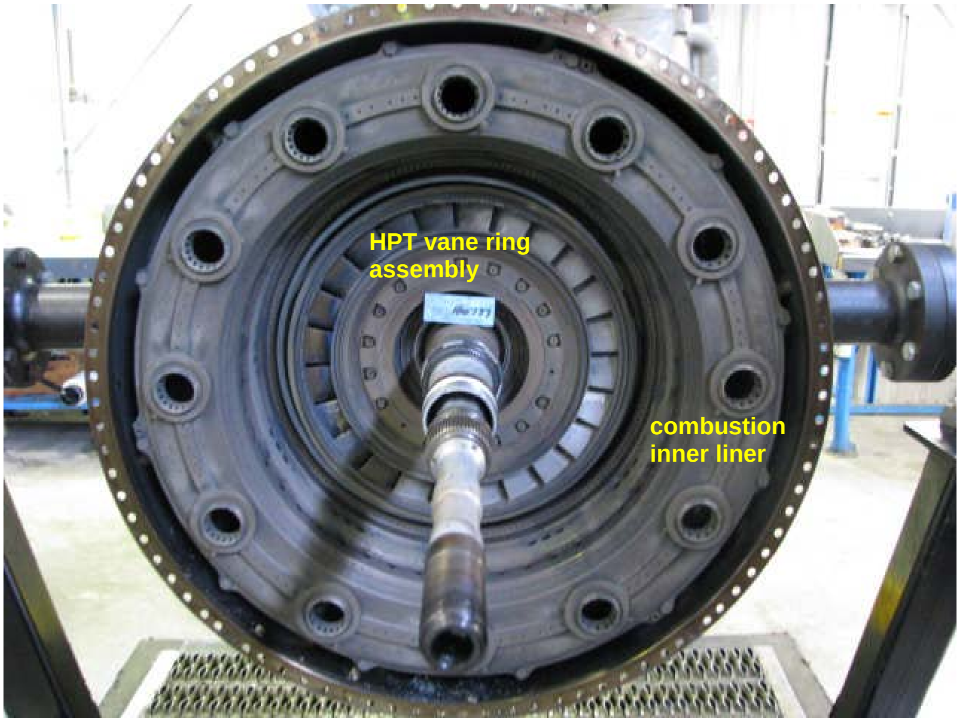

Figure 21. TE side of HPT vane ring assembly

2.1.4 Combustion section

Several of the fuel nozzles had metal debris lodged in a few of the air atomization holes. The small exit duct (SED) exhibited metal splatter between 6 and 12 o'clock but was in otherwise good condition. See Figure 20. The combustor inner liner was intact, with some minor metallic splatter. See Figures 21 and 22.

Figure 22. Combustion inner liner

The large exit support duct (LESD) section of the combustion outer liner was in an advanced state of thermal deterioration with material missing between 7 and 12 o'clock and cracked and bulging inward between 12 and 3 o'clock. See Figure 23(a). Much of the LESD outer wall was thermally consumed and the remaining LESD outer wall was splattered with fused, re-solidified metal. See Figure 23(b).

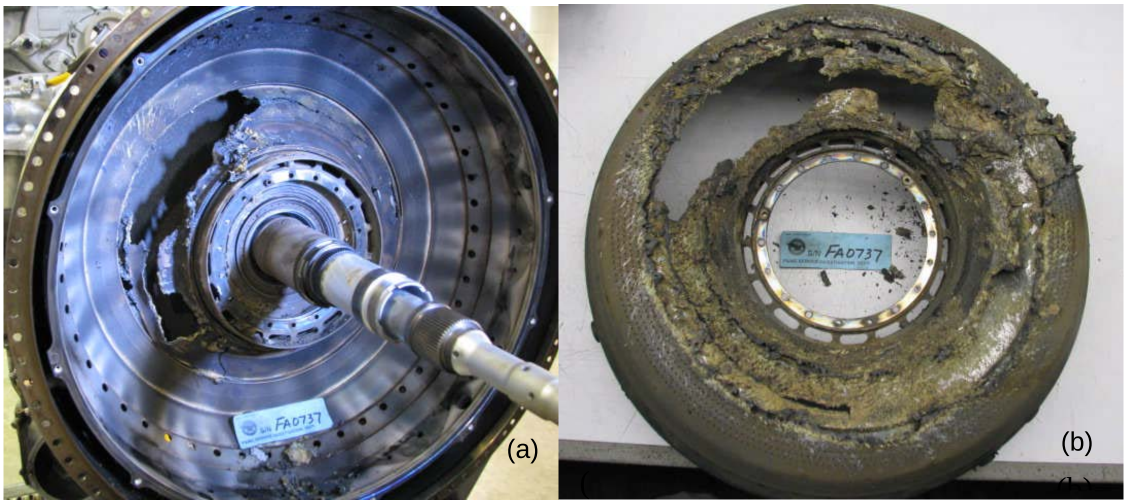

Figure 23. Upstream (a) and downstream (b) views of the combustion outer liner

Much of the ring and diaphragm section of the diffuser, which is Ti-6-2-4-2, was missing/consumed, exposing the back face of the HP impeller. Three consecutive diffuser exit ducts located in the area of the GGC burn-through were partially or totally consumed. See Figure 24.

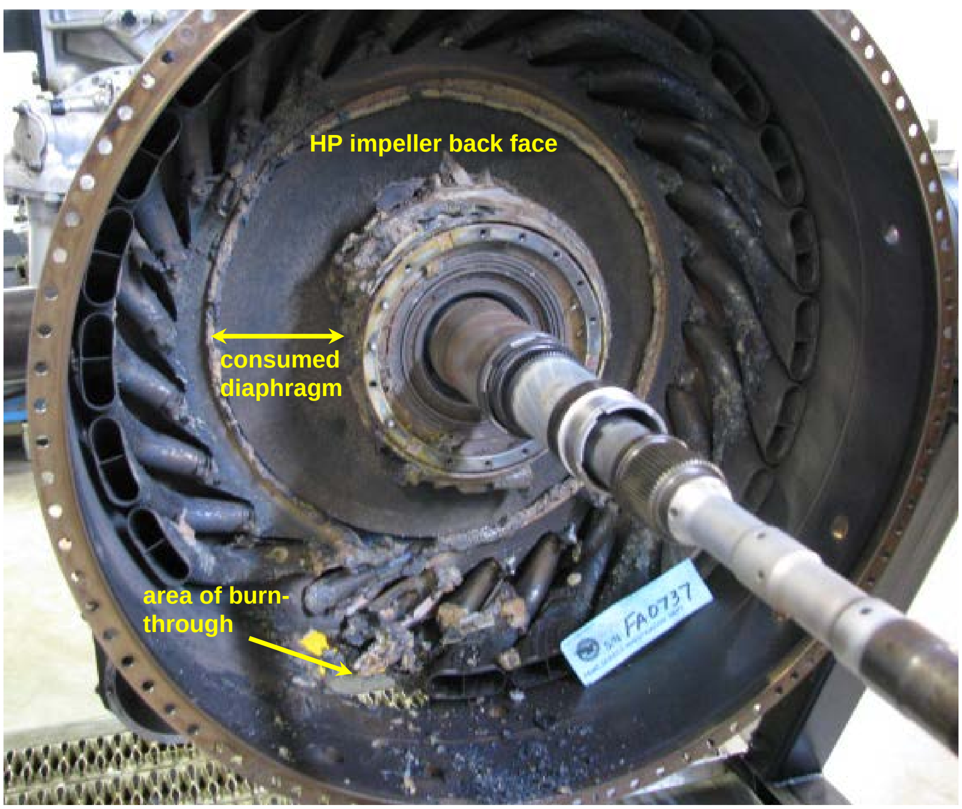

Figure 24. GGC with combustion outer liner removed

The external surfaces of the remaining diffuser and GG diffuser exit ducts were splattered with fused metal. No significant debris was noted inside the exit ducts, with the exception of the concave side at the turn radius, where small accumulations were observed. Several of the intact ducts adjacent to the burn-through area had small burn holes consistent with melting that originated on the external surface. The No. 5 bearing pressure and scavenge tubes were consumed. The integral pressure tube support bracket remained intact and bolted to the diffuser duct.

The remaining No. 5 bearing support housing was significantly heat-eroded, perforated and oxidized. The No. 5 bearing front cover, flexible support housing, which is Ti 6-2-4-2, and front carbon seal were melted or partially consumed and were not recognizable. The No. 5 bearing oil nozzle housing, rear carbon seal assembly, housing outer cover, and outer race were recognizable but showed severe thermal distress and were splattered with metal. The oil delivery nozzles were intact but showed rotational scoring. See Figure 25.

Figure 25. No. 5 bearing support housing

The No. 5 bearing was dry and oxidized. The cage and races were severely discolored, but intact. The raceways were smeared with metal. No races were fractured. The bearing rollers were disintegrated; two small spherical balls, approximately 1/8-inch in diameter, were recovered from the bearing cage. The inner race was found loose on the impeller rear shaft. The oil slinger was intact. The No. 5 bearing front air seal runner was scorched and partially missing. See Figure 26.

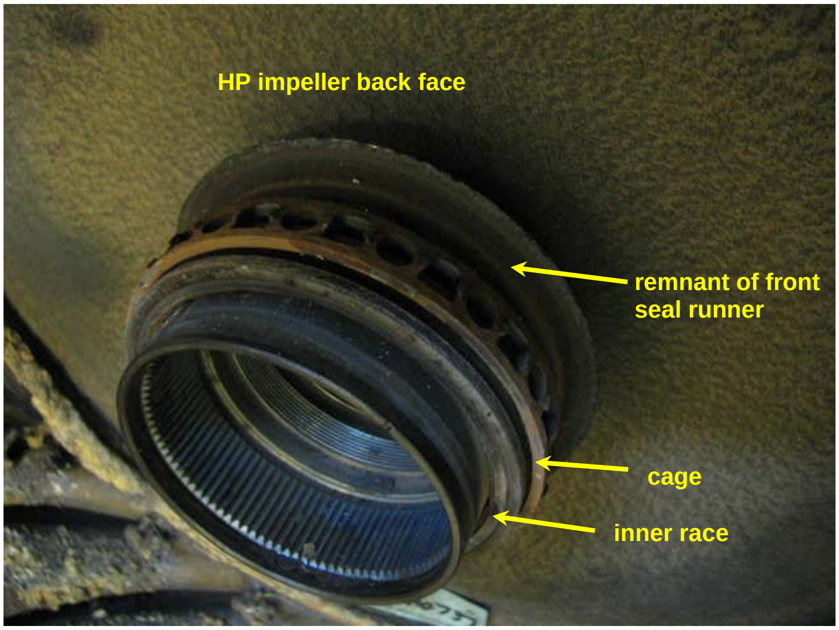

Figure 26. No. 5 bearing and seal components

The gas generator case (GGC) was damaged at 7 o'clock characteristic of having burnt from the inside out.

2.1.5 HP compressor

The back surface of the HP impeller was rough and eroded consistent with scorching. The impeller shroud housing profile, including the $P_{2.8}$ plenum/cavity, was machined into the impeller vanes, and there was localized rub damage (thermal distress) on the exducer tips. See Figure 27.

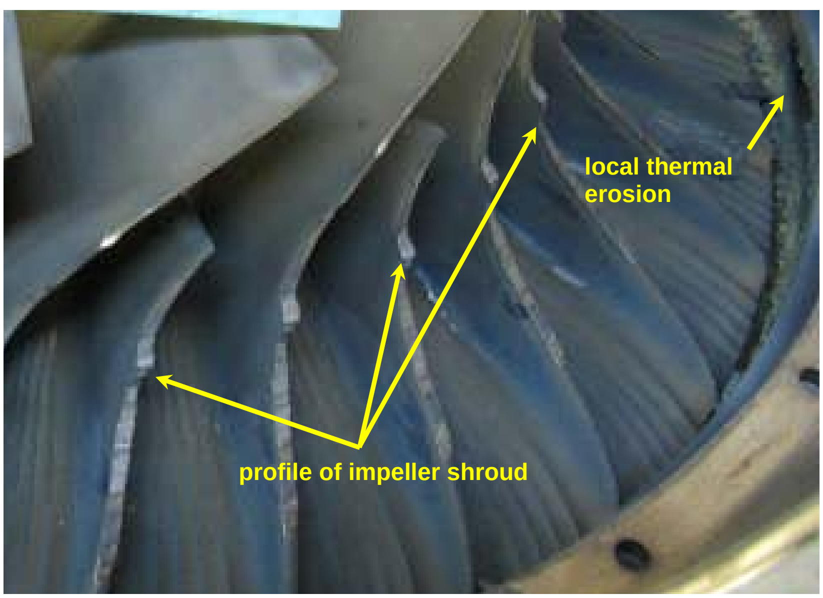

Figure 27. HP impeller vane damage

The No. 4 bearing was dry. All of the balls were worn and discolored. The non-thrust inner raceway was rubbed. The thrust-side inner race was broken into three segments that were partially disintegrated. The cage and outer race showed metal splatter and thermal discoloration. See Figure 28.

Figure 28. No. 4 bearing

The No. 3 bearing was dry but intact.

2.1.6 Reduction gearbox flanged coupling shaft and rear diaphragm

The RGB flanged coupling shaft and diaphragm assembly was intact; however the flange and exposed threaded portion of the rear diaphragm flange attachment bolts were gouged and deformed. The damaged bolts were difficult to remove. The rear face of the diaphragm was scored and gouged. The PT coupling shaft retaining nut was intact and tight.

The No. 1 bearing was dry and severely distressed. The (flanged) outer race was fractured in place; the bolts retaining it were loose and the key washers were missing from under two of the bolts. The bearing balls were worn and stacked. See Figure 29. The missing key washers were recovered from the RGB oil scavenge sump strainer and were fretted and battered. Severely battered cage pieces were also recovered at the RGB oil scavenge sump strainer. In addition, a fragment identified as No. 1 bearing cage material and an approximately 2.5-inch piece of No. 1 bearing outer race were found lying at the bottom of the front inlet case oil compartment. The No. 1 bearing was submitted for metallurgical analysis. See Paragraph 3.1.

The No. 1 bearing jet pump scavenge line was severed. The left retention bolt of the No. 1 bearing jet pump ferrule tube assembly bracket was missing and the bracket was deeply scored and bent. See Figure 30. The missing retention bolt was recovered at the RGB oil scavenge sump screen. The recovered bolt was scored and bent, and the bracket boltholes were elongated. The ferrule-bracket FIC mating face, the underside of the bolt heads, and the key washers all showed fretting damage.

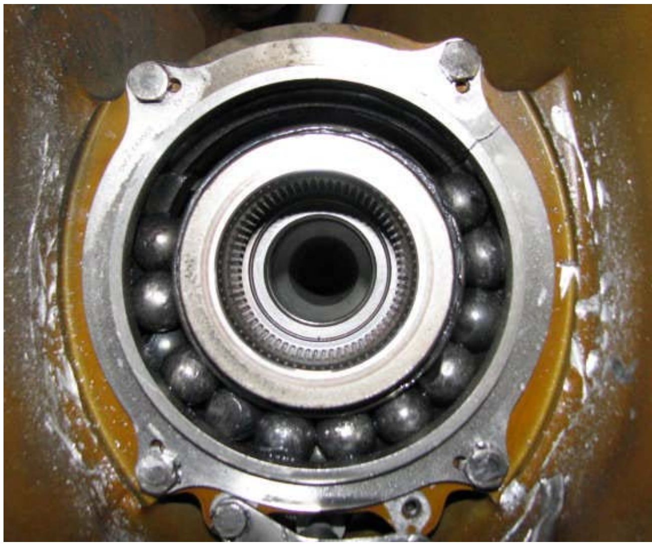

Figure 29. No. 1 bearing

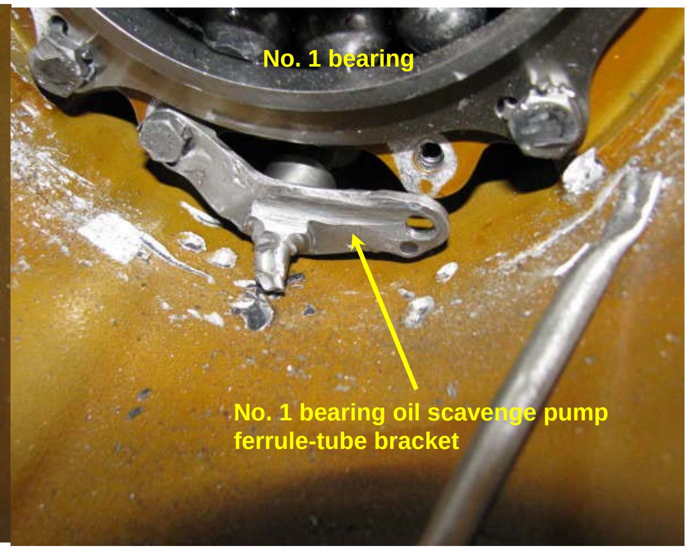

Figure 30. Damaged and detached oil scavenge pump ferrule-tube bracket

Underneath the No. 1 bearing outer race, the FIC surface was deeply fretted and gouged. See Figure 31. A 40° arc of the scavenge jet pump transfer tube O-ring was missing and the O-ring fragment recovered from the RGB oil scavenge sump screen matched the missing section. See Figure 32.

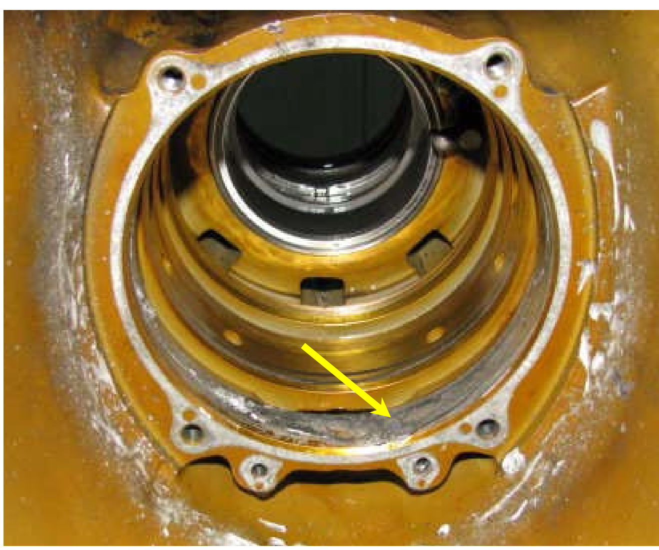

Figure 31. FIC, showing heavy fretting/gouging at No. 1 bearing fit area

Figure 32. No. 1 bearing oil scavenge pump assembly, with severed O-ring and recovered segment

The LP and HP torque sensor magnetic tips were coated with fine ferrous particles.

Figure 33. No. 1 bearing split inner race and oil nozzle housing retaining ring

The ring that retains the No. 1 bearing oil nozzle housing to the bearing inner race was present but was fractured, and several retaining ring lugs and small pieces of the housing were fractured off. See Figure 33. Some of this material was recovered from the debris in the RGB oil scavenge sump strainer. The No. 1 bearing oil delivery nozzles were circumferentially scored. The scoring was approximately 3/8-inch deep and exposed the internal oil passages. See Figure 34. The No. 1 and No. 2 oil strainers were clean.

Figure 34. No. 1 bearing oil nozzle housing, showing circumferential scoring

The No. 2 bearing was intact but dry. The bearing retaining nut, key washer, and retaining ring were torn and partially disintegrated. See Figure 35. The outer diameter of the PT shaft was not rubbed.

Figure 35. PT shaft and No. 2 bearing nut, key washer, and retaining ring, showing rotational damage

2.1.7 Low pressure compressor (LPC)

The No. 2.5 bearing was dry but intact. The front end of the phonic ring was flared. The LPC assembly was in otherwise good condition. See Figure 36.

Figure 36. LPC, showing phonic ring rub damage

2.1.8 Reduction gearbox

The RGB turned smoothly. A visual inspection of the main gears and bearings showed no obvious distress; however, the first stage of gear reduction was contaminated with metallic particles and the compartment walls showed scuffs and scratches characteristic of the damage that can occur with debris circulation.

3.0 Materials investigation

The materials analysis of the No. 1 bearing and the chemical analysis of chip detector debris is described in PWC Report No. 11GI00158A.

3.1 No. 1 bearing

The No. 1 bearing cage was fractured circumferentially at the cross bars, and these sections were axially fractured into multiple fragments. See Figure 37. The split inner race was severely worn. The balls were heat discolored consistent with having rubbed against the split inner race. Five of the thirteen balls showed a circumferential band of spalling; the remaining balls were too damaged to confirm the presence of the band.

Figure 37. No. 1 bearing components

Several outer race fracture surfaces displayed fatigue features. A reconstruction of the outer race showed a fatigue crack initiating at the inner radius of a lug on the non-flanged side of the bearing and propagating axially to the middle of the rolling path, then circumferentially in both directions. See Figures 38 and 39.

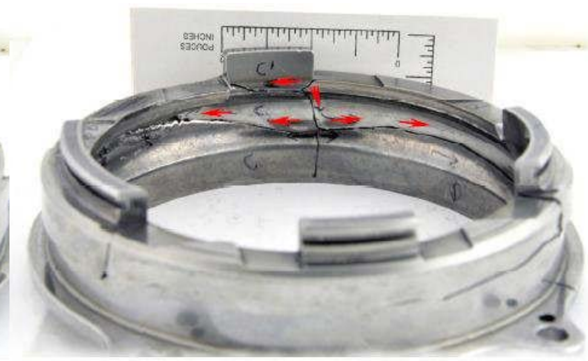

Figure 38. Reconstruction of the bearing outer race. showing origin and direction of fatigue crack propagation (red arrows)

Figure 39. Bearing outer race rotated 180° clockwise

The fractured outer race showed spalled areas on either side of the main axial fracture. See Figure 40.

Figure 40. Regions of spalling on both sides of the axial crack

Microscopic examination of the origin area showed the fatigue crack propagating from the upper section of the radius at the intersection of the large lug and the end face of the outer race. See Figure 41.

A radius measurement performed at the origin of the fatigue crack between the edge of the large lug and the end face of the outer race was within drawing requirements. No metallurgical anomalies were observed in the base material of the outer race. The outer race microstructure and the hardness met drawing requirements.

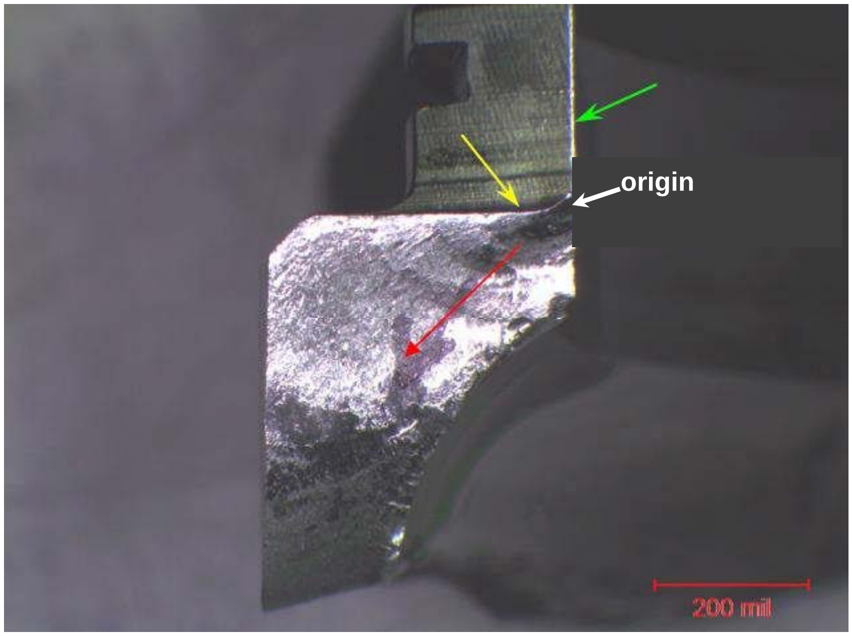

Figure 41. Magnified view of origin area showing the fatigue crack propagating from the upper section of the radius at the intersection of the large lug (green arrow) and the end face of the outer race (yellow arrow). Red arrow denotes the direction of fatigue growth

PWC determined that fatigue cracks initiated in the outer race at the inner radius of one of the large lugs due to a radial pressure on the loaded side of the outer race. The source of the radial pressure is unknown. However, the radial pressure may have been created by particle accumulation on the rolling surface of the outer race that was generated by the ball degradation.

3.1 Debris analysis

Chemical analysis of the debris collected from the TM chip detector found particles similar to M50 bearing material, stainless steel 410 alloy, and undefined low-alloy steel, along with iron-based material with various levels of carbon and oxygen.

Chemical analysis of the metallic particles collected from the RGB chip detector found particles similar to M50 bearing material and a low-alloy steel suggesting cage material; one particle showed silver coating on a low-alloy steel-based material.

4.0 Oil pump investigation

4.1 Pump data

The P/N 766859 Hamilton Standard lube and scavenge pump, S/N 0881, had accumulated 551 TSN.

4.2 Pump description

The Hamilton Standard P/N 766859 is a vane-type, positive displacement oil pump with pressure and scavenge pump elements and a pressure relief valve in a machined magnesium alloy housing. Each pump element is a separate pumping mechanism that includes a slotted rotor that turns inside an eccentric sleeve. The rotor includes vanes that slide in and out of slots. The chamber created by the eccentric sleeve provides a swept volume that increases with rotation at the inlet. The increasing volume creates a partial vacuum that draws the oil in. As the pump rotation continues, the chamber's volume decreases at the outlet and forces the oil out of the chamber under pressure.

4.3 Disassembly observations

The pump external surfaces were heavily contaminated. See Figure 42.

Figure 42. Main oil pump external contamination - spur gears

Contamination was also found between the element sleeves and the main housing bores and inside of the scavenge pump elements, making disassembly difficult. A fractured sleeve was found at the discharge window of the 2/2.5 element. See Figure 43.

Figure 43. 2/2.5 bearing element, showing fractured sleeve

The vane 180° from the fractured sleeve damaged and was jammed inside its slot and the rotor exhibited localized metal smearing, adhesion and heat discoloration on either side of the slot. See Figure 44.

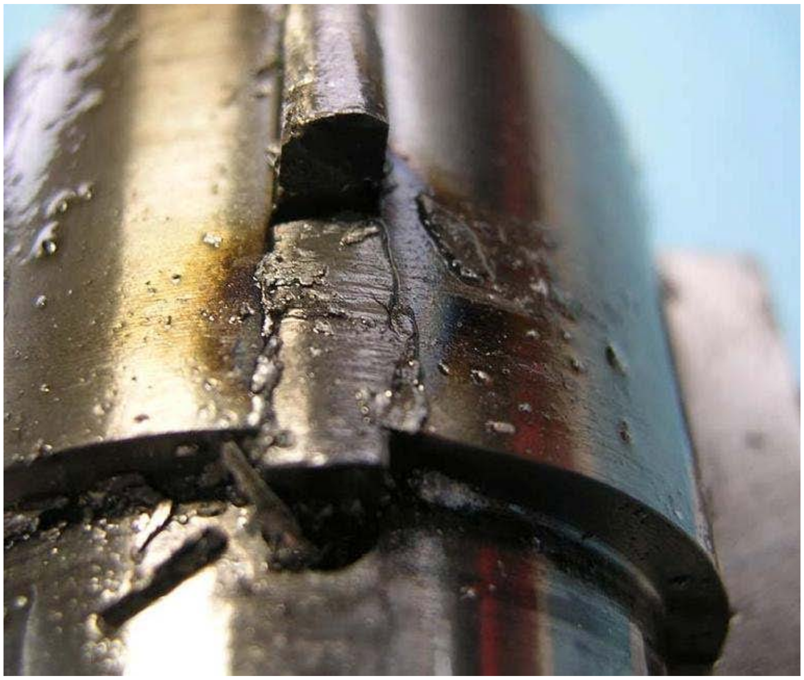

Figure 44. Vane seized in rotor, showing metal smearing and vane heat discoloration

Disassembly of the 2/2.5 element found that it was heavily contamination and confirmed that the heat-discolored vane had seized inside its slot.

Chemical analysis of the particles collected from the 2/2.5 pump scavenge element and elsewhere in the pump identified M50 material consistent with engine bearing material. The pump does not contain any parts made of M50 material.

5.0 Wiring harness and sensor testing

PWC performed functional checks of the engine electrical wiring harness, the main oil filter impending bypass switch, the scavenge oil filter impending bypass switch, the low oil pressure switch, and the main oil pressure sensor. The functional tests found no evidence of a pre-existing condition that would have prevented normal operation. The actuating pressure of the main oil filter impending bypass switch was set 2 pounds per square inch above the normal range.

Functional checks of the RGB and TM chip detectors found that they were both in serviceable condition.

6.0 Fire protection system evaluation

The cockpit left engine fire warning light is triggered if a left engine overheat/fire or a detector loop circuit malfunction is sensed.

One of the two left engine nacelle pneumatic fire/overheat detection elements, “advance pneumatic detectors” (APDs) remained in the alarm state during as-received testing at KAD. Further examination found that the APD was unable to return to its non-alarm state because of the detector switch diaphragm was permanently deformed.

The investigation found that KAD APDs have failed to reset after activation during other fire events on DHC-8 Series 400 airplanes. Bombardier issued service bulletin (SB) 84-26-08, Revision (Rev) A, dated May 12, 2011; SB 84-26-09, Rev A, dated May 12, 2011; and SB 84-26-12, Rev B, dated October 12, 2012, recommending replacement of three APD P/Ns, including the two engine nacelle detector assemblies, with new design detector assemblies that are not susceptible to permanent diaphragm deformation when exposed to fire. Transport Canada determined that the abnormal condition of a continued engine fire indication in the cockpit after the fire is extinguished is misleading and could influence the pilot's decision to conduct a potentially hazardous off-airport landing, and issued airworthiness directive (AD) CF-2012-07 in February 2012 to mandate the incorporation of the Bombardier SBs on affected airplanes. The FAA published notice of proposed rulemaking (NPRM) 2012–NM–064–AD on April 9, 2013 (which extended the comment period of a previous October 2, 2012 NPRM, due to a revised compliance) indicating its intention to publish an AD consistent with Canada’s AD CF-2012-07.

5.0 No. 1 engine timeline

The FDR and EMU data were used to create a timeline of No. 1 engine parameters and fault codes around the time of the event. See Table 1.

TIME (EDT)	NO. 1 ENGINE OCCURRENCE	CODE
12:18:34	Torque fluctuation fault recorded	1504
12:22:28	Turbomachinery chip fault recorded	938
12:26:50	Oil pressure drops 15 pounds per square inch differential (psid)	
12:27:15	Oil pressure indication turns **AMBER** (< 52 psid) and value is replaced by dash lines	
	Oil pressure exceedance fault recorded	1707
12:27:32	Oil pressure indication turns **RED** (0-50 psid), **RED Flashing Light, Master Warning ON** Oil pressure exceedance warning activates (remains activated remainder of flight)	
	Oil pressure exceedance fault recorded	1707
12:27:41	Master Warning deactivated	
	PEC speed track error fault recorded	158
	Oil temperature exceedance fault recorded	1708
12:28:21	Torque increased slightly to 71% Torque fluctuates between 71 and 73.5% for the next 5 seconds	
	Flameout fault recorded	907
	Surge fault recorded	801
	Power lever angle (PLA) adjusted to 77.96° and rotor speeds began to decay	
12:28:58	Torque = 58%	
	Oil pressure exceedance fault recorded	1707
12:29:00	PLA = 77.43°	
12:29:08	Torque = 0% PLA = 70.14° (fuel flow: 1,312 pph; Nh 61; Nl 39)	
12:29:10	**RED Flashing Master Warning ON** **Fire Warning ON**	
12:29:18	**Master Caution ON**	
12:29:19	PLA = 67.68°	
12:29:21	PLA = 35.33°	
12:29:25	Condition lever angle = 34.8° and decreasing	
12:29:27	Fuel flow = 0 pph	
	In-flight shut down fault recorded	1500
12:59:52	Master Caution OFF	
	RGB impending bypass fault recorded	932

Table 1. No. 1 engine event time line