NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, DC 20594

January 27, 2005

POWERPLANTS GROUP FACTUAL REPORT

NTSB ID No. DCA05MA003

A. INCIDENT

Location:	Jefferson City, Missouri
Date:	October 14, 2004
Time:	10:13 pm CDT
Aircraft:	Bombadier CRJ-200, Reg. No. N8396A, Northwest Airlines #3701 Operated by Pinnacle (REXA)

B. POWERPLANTS GROUP

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C. SUMMARY

On October 14, 2004, at about 2215 central daylight time, N8396A, a Bombardier CL-600-2B19 operating as Pinnacle Airlines flight 3701 (d.b.a. Northwest *Airlink*) crashed in a residential area in Jefferson City, Missouri, about 2.5 miles south of the Jefferson City, Missouri, airport (JEF). The airplane was destroyed by the impact forces and a post crash fire. The two crew members were fatally injured. The flight was a repositioning flight from Little Rock, Arkansas (LIT) to Minneapolis-St. Paul, Minnesota (MSP). There were no passengers on board. There were no injuries on the ground.

The aircraft was equipped with two General Electric Company (GE) Model CF34-3B1 turbofan engines and one Garrett GTCP 36-150RJ auxiliary power unit (APU).[1] A Powerplants Group was formed at Jefferson City on October 15, 2004, and powerplant evidence was documented on site October 15 through October 17, 2004. The engines were removed to Jefferson City Flight Services, a secure hangar at JEF, on October 17. Further documentation and preparation for shipment took place October 17 through October 19, 2004. The engines were then shipped by flatbed truck to the GE manufacturing facility at Lynn, Massachusetts. On October 26 2004, members of the Powerplants Group reconvened at Lynn for disassembly inspection of the engines.

This report describes the on-site observations and engine teardown inspections. Subsequent Powerplant Group activities will be described in Addendums to this report.

D. DETAILS OF THE INVESTIGATION

1. Engine information

[1] **The APU was part of the NTSB Systems Group investigation.**

1.1 Engine description

The CF34-3B1 is a high bypass turbofan engine that features a single-stage fan; a 14-stage axial, variable geometry compressor; an annular combustion chamber; a two-stage high pressure turbine (HPT); and a four-stage low pressure turbine (LPT). Two independent rotor systems are supported by seven bearings, which are housed in three oil sump cavities (A-, B-, and C-sumps). The CF34-3B1 has a takeoff thrust of 8,729 pounds, flat-rated to 86°F.[2]

1.2 Engine service history

According to the Maintenance Records Factual Report, the No. 1 (left) engine, serial number (S/N) 872746, was installed on the accident airplane April 6 2004, and had accumulated 8,856 hours and 8,480 cycles at the time of the accident.[3] The No. 2 (right) engine, S/N 873514, was installed new on the accident airplane on October 23, 2003, and had accumulated 2,303.9 hours and 1,971 cycles at the time of the accident (see Table 1). Both engines were removed and reinstalled during scheduled maintenance in February – March 2004, to accommodate compliance with Bombardier SB 601R53-059, *Engine Beam Rework.* No other pertinent maintenance entries were noted.[4]

component	*serial no.*	*TSN*	*TSO*	*CSN*	*CSO*
No. 1 engine	872746	8,856	new	8,480	new
No. 2 engine	873514	2,303.9	new	1,971	new

Table 1. Engine data

1.2.1 Recent maintenance

The last flight prior to the accident flight was a rejected takeoff at Little Rock, Arkansas, due to a No. 2 engine 14th stage bleed air sensing loop EICAS indication ("R 14th DUCT"). Inspection found chaffing damage and the loop was replaced. This maintenance did not involve opening of the engine cowling.

2. No. 1 engine

2.1 On-site observations

The No. 1 engine was found lying on its right side[5] on the east side of Hutton Lane, a residential street, approximately 25 yards from the airframe rear fuselage/tail section. (See Figure

[2] Flat-rated to a specific temperature indicates the engine will be capable of attaining the rated thrust level up to the specified inlet temperature.

[3] Time Since New (TSN), expressed in operational hours, is the industry standard for referring to a component's total hours in service. Cycle counts are the industry standard for expressing the total low cycle fatigue cycles that critical components in turbine engines experience.

[4] See the NTSB Maintenance Records Group Chairman's Factual Report for details.

[5] All references to engine position are aft looking forward unless otherwise noted.

1.)[6] The engine was lying on top of fencing material that had broken away from a property line fence. An 18 inch long, 8 inch deep ground scar (divot) was observed about 10 feet from the forward end of the engine, on the east side of the fence line. Clay was found in the fan inlet, packed between the fan blades.[7] There were no indications of engine uncontainment or fire damage. A visual inspection of the LPT through the tailpipe found no anomalies.

(a)

(b)

Figure 1. (a) Position of No. 1 engine relative to rear fuselage; (b) right side of No. 1 engine

The engine's nacelle inlet cowl was missing just forward of its attachment flange, which was distorted. Nacelle inlet material was found along the wreckage path, north of the main wreckage and about 150 feet from the engine. Additional nacelle components, sections of thrust reverser, and two fan outlet guide vanes were found in the vicinity of the main wreckage.

The integrated drive generator (IDG) oil cooler mount assembly, thrust reverser tracks and thrust reverser linkage, and the cooler unit and its surrounding structure were missing from the bifurcation unit (firewall). The airframe pylon attachment lines had separated with the engine. The aft end of the exhaust duct was crushed. Large pieces were missing from the tailpipe fairing. The exhaust centerbody was intact. The aft thrust mount fitting retaining bolts were sheared. The (cable actuated) fuel control throttle setting was in the fuel shutoff position. The (fuel pressure driven) variable guide vane feedback setting was in the fuel shutoff position.

The system A ignition box was crushed. The 10th stage bleed pipe was separated at the check valve, and its retaining clamp was missing. The 14th stage bleed pipe was crushed and cracked at the aft side of its attachment flange. A fuel manifold-to-injector tube was separated at the injector, just aft of the B-nut (injector nearest the 10th stage check valve). The fuel filter bypass indicator button was not popped. The IDG was fully serviced; its bypass pin was not popped. An undetermined amount of oil was lost from the oil tank at the scavenge tube when the engine was repositioned. A limited

[6] The empennage and the rear section of the fuselage from the wing center section aft, was found lying inverted about 55 feet west of the main wreckage. See the Structures Group Chairman's Factual Report for a diagram of the wreckage distribution.

[7] The clay included grass roots and blades, and was consistent with the disturbed lawn material found at the ground scars.

borescope inspection was made through the igniter hole, with no unusual findings. A fuel sample was taken at the fuel filter.

2.2 Engine disassembly inspection

An engine disassembly inspection was conducted October 26 through 29 2004, at GE's manufacturing facility in Lynn, Massachusetts.

Prior to engine disassembly, the accessory drive train was rotated at the starter pad. Rotation required 310 inch-pounds of applied torque, and was smooth, with no grinding or unusual sounds noted.

The drive train was rotated again following LPT removal, and gear train-to-engine core mechanical continuity was confirmed. Rotation required 320 inch-pounds of applied torque.

2.2.1 Fan module

2.2.1.1 Fan blade containment case

The fan containment case was ovalized and had displaced aftward between 10 and 12 o'clock; the aft fan case was separated aft of its forward flange in this area.[8] There were deep airfoil-shaped gouges on the flow path surface of the fan blade containment casing between 2 o'clock and 3 o'clock, about 5 inches forward of the normal blade tip running plane. These gouges were consistent with the contour of the fan blade tips. Four gouges of lesser depth were found along the same circumferential plane, between 3 o'clock and 4 o'clock. An 18 inch x 8 inch area of the containment case Kevlar material was damaged at 9 o'clock, with one ¾ inch-diameter penetration through the Kevlar layers, and tearing of the outer Kevlar layers in several other locations. A large amount of clay[9] was packed in the spaces between fan blades 13 to 21, and loosely packed in other areas of the module.[10]

2.2.1.2 Fan aft case

A section of the aft fan case was missing from 12 to 4 o'clock; this section included the 2 o'clock forward engine mount. The case was torn between 7 and 12 o'clock, and additional sections were separated, exposing stator vanes or empty stator vane slots. At least ten stator vanes were observed separated at their inner band (root) attachment; these vanes remained attached at their outer band. Stator vanes protruded from the case from just beneath the upper forward engine mount, from 11 to 7 o'clock, and the fan case was displaced outboard in this area. (See Figure 2.)

2.2.1.3 Fan rotor assembly

The spinner was severely damaged. The fan rotor was seized. An arc of eight blades (fan blades 10, 9, 8, 7, 6, 5, 4, and 3) was bent opposite to the direction of rotation, where the fan

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

[9] The clay included grass roots and other material consistent with residential lawns.

[10] The 28 fan blades are numbered clockwise with reference to a notch behind the aft spinner, which indicates the position of blade 1.

blade containment case was crushed inward between 2 o'clock and 4 o'clock. An arc of four blades (fan blades 19, 18, 17, 16) was bent in the direction of rotation where the fan blade containment case was crushed inward between 8 and 9 o'clock. The tips of fan blades 20 and 21 were embedded in the fan containment case, and fan blade 20 had a chordwise trailing edge (TE) tear at ¾ span. The outer 25 percent of the fan blade 22 airfoil was missing. . The tip of fan blade 23 exhibited leading edge (LE) hard body impact damage and a small TE tear at ¾ span.

Figure 2. No. 1 engine fan module damage

2.2.2 Compressor module

The compressor's variable geometry (VG) linkage was intact. A template check of the VG hardware found that all VG vane stage positions indicated fully closed.[11] The 2 o'clock VG actuator shaft was displaced forward approximately 5/16-inch, as evidenced by the positions of the bearings in their supports.[12] The 8 o'clock actuator shaft was not displaced from its supports. The VG feedback cable match marks were offset approximately 0.080-inch.[13]

2.2.2.1 Compressor front frame

Sections of the compressor front frame were broken away at 3 o'clock. There was a 4-inch x 1/8-inch circumferential fracture just forward of the 2 o'clock tie rod lug. The 4 o'clock tie rod attachment points were separated from the front frame, and the tie rods were missing at both 2 and 8 o'clock. The two tie rods at 10 o'clock were attached at their outboard ends and detached at their inboard ends and the front frame casting was fractured/separated inboard of the tie rods. The front frame assembly inner duct was fractured at least 180° around.

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[11] The templates are GE's standard visual guides for VG position verification.

[12] The VG system is controlled by two actuator shafts on opposite sides of the engine (2 and 8 o'clock.) Each actuator shaft is supported by three bearings, in three compressor-mounted brackets.

[13] The variable geometry match marks are references on the main fuel control used to adjust main fuel control rigging. With the vanes in the fully closed position, the fuel control rig mark should be lined up with the rig mark on the feedback lever where the feedback cable is attached.

2.2.2.2 Compressor stator

The upper compressor case half was removed and the compressor flowpath was visually inspected.[14] No vane damage or deformation was noted. There were no stator vane-to-rotor blade contact indications. Light casing rub was observed in stage 2 at 3 o'clock.

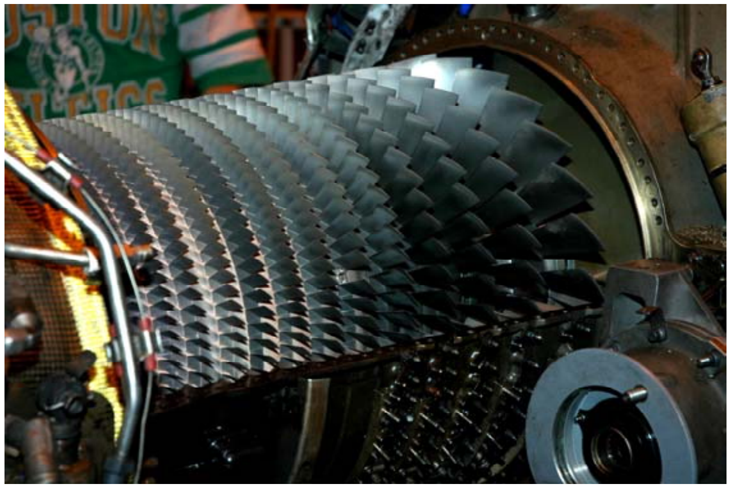

Figure 3. No. 1 engine compressor rotor

2.2.2.3 Compressor rotor

The compressor rotor was in good condition. (See Figure 3.) Very light (typical in-service) rotor blade tip rubs were noted on stages 2, 6, 8, 12, and 13. The stage 1 and stage 2 inner shroud seals were intact, with typical in-service seal wear-in grooves.[15] A small amount of leaves and dirt was found in the first three stages of the compressor gas path. A single fragment of outlet guide vane spacer was found just forward of the stage 1 vanes.

2.2.3 Combustion module

The combustion module was partially disassembled and inspected. Two minor dimples with associated cracks were found on the combustion liner outer panel. The injector and swirler alignment appeared normal, and all swirlers and ignitor bosses moved freely. The 2 o'clock fuel manifold-to-injector line (pigtail) was separated aft of the B-nut. There was no evidence of fuel leakage. The igniters were in typical in-service condition. The stage 1 nozzle was in typical in-service condition. There was no stage 1 rotor-to-nozzle contact either at the angel wing area of the stage 1 blade, or at the cooling plate-to-stage 1 nozzle flow discourager.[16]

2.2.3.1 B-sump

[14] A section of the forward fixed core cowl was destructively removed, and several VG actuation ring bridge sections on either side of the engine were deformed aftward.

[15] Typical in-service condition refers to a part assessed by general visual inspection and which appears to be in serviceable condition, with no dimensional inspections performed.

[16] Angel wings refer to the forward platform section of a turbine blade.

The No. 5 carbon seal was in typical in-service condition, with no notable coking and free movement at all segments. The No. 5 bearing was not disassembled; visual inspection found no anomalies.

2.2.3.2 High pressure turbine (HPT)

All of the HPT airfoils were in good condition. (See Figure 4.)

2.2.3.2.1 HPT stator

The HPT stage 1 shroud segments had light rubs at 11 o'clock and were heavily rubbed and gouged between 4 and 5 o'clock, and from 6 to 8 o'clock. There was surface corrosion on all of the segments, including areas with rub indications.

The stage 2 nozzle was generally in good condition; there was no evidence of blade-to-stator vane contact, including at the angel wing areas. There were light to moderate rub indications on the shroud between 9 and 12 o'clock, and light rub marks between 4 and 6 o'clock. Airfoil tip-shaped marks were found at 11 o'clock.

Interstage seal. According to GE, the interstage seal rub grooves were normal in both width and depths. There were shiny areas on both forward and aft sides of the rub grooves, at multiple locations. Some light rub/scuffing across the seal was noted in areas outside the rub groove; these marks were located at the same clock position as the airfoil-shaped impact marks found on the stage 2 shrouds.[17]

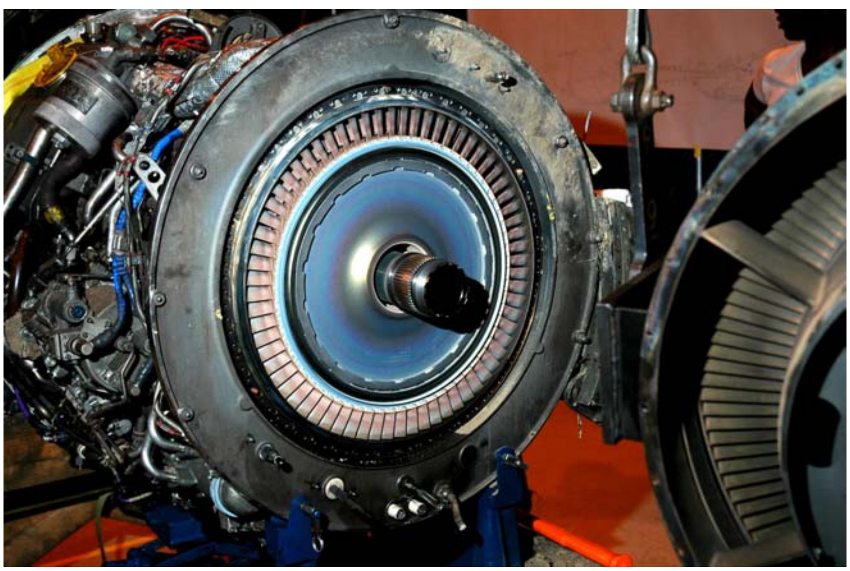

Figure 4. No. 1 engine turbine modules

Inner balance piston seal. The inner balance piston static seal rub grooves were approximately 0.05-inch away from the static seal steps. According to GE, their axial position

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[17] **The shiny areas noted on the seal surface could possibly have been caused when the stator from the rotating seal during disassembly, since the clearance is tight, and the stator is heavy and is removed by hand.**

indicated proper rotor-to-stator alignment, and both groove depth and groove width were indicative of normal operation. The rub grooves had a shiny appearance between 1 and 5 o'clock.

Outer balance piston seal. The outer balance piston static seal rub grooves were approximately 0.05-inch away from the static seal steps. According to GE, their axial position indicated proper rotor-to-stator alignment, and both groove depth and groove widths were indicative of normal operation. The rub grooves had a shiny appearance between 12 and 6 o'clock.

2.2.3.2.2 HPT rotor

Minor tip oxidation was present on the HPT stage 1 blade tips, and there was no evidence of heavy tip rub. The stage 2 blades were in typical in-service condition, with light rub indications at the blade tips. [18]

2.2.4 Low pressure turbine (LPT)

The LPT rotated freely after disengagement from the LPT shaft. The stage 3 and stage 6 nozzles and blades were in typical in-service condition, with no airfoil distress. The LPT was not disassembled further, and the 4th and 5th stages were not examined.

2.2.4.1 Exhaust frame

No distortion to the exhaust frame was noted. A small amount of coking was observed on the (C-sump) oil scavenge/feed fitting.[19] One of the two bolts securing this fitting was found loose; the lock wire was intact. The scavenge connection (C-sump) B-nut at this fitting was found with lower than expected disassembly torque.[20]

An oil sample was collected at the C-sump drain line.

2.2.4.2 C-sump

Visual inspection of the No. 7 bearing found no anomalies. There was minor coking on the No. 7 carbon seal; all carbon segments moved freely. The No. 7 carbon seal runner was in typical in-service condition. A normal amount of oil was present in the C-sump cover; the forward end of the C-sump cover exhibited coking 360° around its outer diameter (OD).[21] There was a moderate amount of coking noted at the 4 o'clock and 6 o'clock service tubes. About 40 percent of the center vent exit was blocked by soil. The overall condition of the C-sump was normal.

2.2.5 Accessory gearbox (AGB) drive train

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[18] These shroud and blade tip rub indications are consistent with blade-to-shroud contact during operation, and are considered normal wear patterns.

[19] Light oil seepage/coking typically occur at this location.

[20] Breakaway torque was not measured.

[21] Coking in this location is considered normal.

The main fuel control (MFC) was removed from the main fuel pump (MFP) and the MFP-to-MFC driveshaft was inspected and appeared in good condition. The accessory gearbox was rotated at the starter drive pad and drive train continuity was verified at the drive shaft and at the hydraulic pump, alternator, and lubrication pump drive pads, as well as at the compressor rotor.

2.2.6 Lubrication system

The magnetic chip detector and self-closing valve screen were inspected and found clean. Approximately 1 cup of oil was drained from the oil tank.[22]

3. No. 2 engine

3.1 On-site observations

The No. 2 engine was found still attached to the fuselage pylon. This section of the fuselage was inverted, and the engine's nose cowl, access cowl, thrust reverser and transition cowl were resting on the ground. (See Figure 5.)

The core cowls opened easily. Inspection of the core found no evidence of uncontainment or fire damage. There were numerous dents on the left side of the inlet cowl leading edge, between 5 and 9 o'clock. The inlet cowl was intact; there was a 5-inch puncture located 14 inches from the forward cowl end, at 8 o'clock. The aft portion of the access cowl had a puncture at 6 o'clock, where a 3-inch diameter tree limb had penetrated through thrust reverser cascade vane assembly.

Figure 5. Attitude of rear fuselage, with No. 2 engine attached at pylon

A large amount of tree branch material was trapped between the fan blades and stators. This

[22] A large amount of oil was lost from the (damaged) oil tank scavenge line when the engine was re-positioned at Jefferson City.

material included branches up to18 inches in length and ¾-inch in diameter was positioned radially behind the fan. Twigs and mud were caked on the aft lip of the fan case from 11 to 1 o'clock. The mud included grass leaves and root material. The transition cowl was crushed up against the core cowl at 12 o'clock. There was minor bending to the tailpipe and tailpipe fairing at 12 o'clock.

Overall, the core engine appeared in good condition. The pylon mounting structure was undamaged, and the engine-to-pylon connections were disconnected using standard tools. (See Figure 6.)

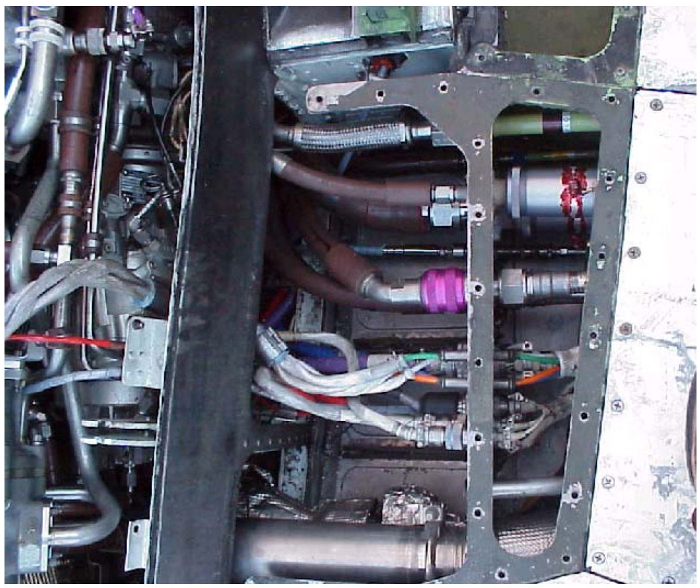

Figure 6. Condition of No. 2 engine pylon

The system A igniter was removed from the No. 2 engine. A limited borescope inspection through the ignitor port found no damage to the combustion liner, fuel nozzles, or stage 1 nozzle. Material was missing at the stage 1 nozzle blade tip TE's, the stage 2 stator vane TE's and the stage 1 blade tips.[23] A borescope inspection through the tailpipe found extensive airfoil damage, with uniform rotor blade tip damage, consistent with exposure to excessive temperatures during operation.

Fuel samples were taken at the fuel filter and at the main fuel line pylon connection.

3.2 Disassembly investigation

An engine disassembly inspection was conducted October 26 through 29 2004, at GE's manufacturing facility in Lynn, Massachusetts.

[23] Limited view of these components.

The engine remained in an inverted position, as shipped. The core was rotated at the starter pad and required 450 inch-pounds to turn. 'Crunching' sounds could be heard from the tailpipe during core rotation.[24]

The engine was repositioned to a vertical attitude with the forward end down, to facilitate removal of quick engine change (QEC) components, and the remaining nacelle components. Once the QEC and nacelle were removed, the engine was repositioned to its normal horizontal attitude, and mounted into an engine stand.

3.2.1 Fan module

3.2.1.1 Fan stator

The inner diameter (ID) of the fan stator was coated with soot. There was light circumferential scratching in the polyurethane paint 360° around the flow path surface, just forward of the fan containment case abradable material.

3.2.1.2 Fan rotor

The spinner assembly was in good condition, and blackened with soot. There was an approximately 0.25-inch deep nick located at 75 percent-span on the LE of one fan blade.

3.2.2 Compressor module

The No. 2 engine variable geometry (VG) guide vane system was intact. Using templates, all VG stages were verified to be in the full closed position. No anomalies or distress to the VG system components was noted. The VG feedback cable match marks were aligned.

3.2.2.1 Compressor front frame

The compressor front frame was in good condition.

3.2.2.2 Compressor stator

The lower compressor case half was removed, allowing a limited compressor stator inspection. No vane airfoil damage or deformation was noted. The stage 1 and stage 2 inner shroud seals were intact, with expected seal wear-in grooves. There were no stator vane-to-rotor blade contact indications. There were no indications of rub on the lower casing half vane tips or on the casing lands.

3.2.2.3 Compressor rotor

The compressor rotor was generally in good condition. (See Figure 7.) A small amount of wood, dirt, and leaves were found in the first four stages of the gas path when the lower compressor case half was removed. Very light (normal operational) rotor blade tip rubs were noted on the stage 11 and stage 13 blades. The rotor moved freely while in both vertical and horizontal positions.[25]

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[24] The core was rotated at the starter pad again, following LPT removal. This rotation also required 450 inch-pounds of applied torque.

[25] The HPT was removed prior to rotation.

Figure 7. Compressor rotor, No. 2 engine

3 Combustion module

Overall, the combustion module was in typical in-service condition. Injector and swirler alignment appeared normal, and all swirlers and ignitor bosses moved freely. The igniters were in typical in-service condition. The stage 1 nozzle was in typical in-service condition. No indications of stage 1 rotor-to-nozzle contact were found, either at the stage 1 blade angel wing area or at the cooling plate-to-stage 1 nozzle flow discourager.

3.2.3.1 B-sump

The No. 5 carbon seal was in typical in-service condition, with no notable coking, and free movement at all segments. The No. 5 bearing was not disassembled; visual inspection found no anomalies.

3.2.3.2 High pressure turbine (HPT)

3.2.3.2.1 HPT stator

There was metal splatter on the flow path surfaces of all stage 1 and stage 2 shrouds. All stage 2 nozzle vanes exhibited heat distress, with vane melting at mid-span towards the TE. There was no evidence of angel wing or other blade-to-vane contact between the stage 2 nozzle and either the stage 1 or the stage 2 blades.

Interstage seal. According to GE, the interstage seal rub grooves were normal in both width and depth. There were a number of light, shiny areas within the rub grooves. Some light rub/scuffing across the seal in areas outside the rub groove was noted. According to GE, it is possible that this condition was caused by the stator disassembly process.[26]

Inner balance piston static seal. The inner balance piston static seal rub grooves were approximately 0.075 inch away from the static seal steps. According to GE, their axial position indicated proper rotor-to-stator alignment, and both groove depth and groove widths were indicative of normal operation. The rub grooves had a shiny appearance between 12 and 6 o'clock.

Outer balance piston static seal. The outer balance piston static seal rub grooves were approximately 0.05 inch away from the static seal steps. According to GE, their axial position indicated proper rotor-to-stator alignment, and both groove depth and groove widths were indicative of normal operation. The rub grooves had a shiny appearance between 12 and 6 o'clock.

3.2.3.2.2 HPT rotor

The stage 1 blades exhibited heat distress, with missing material tapering back from the LE tips to the 5th cooling slot in the TE's, approximately midspan. The stage 2 blades showed heat distress. All airfoil material above 60 percent span was missing. A cursory metallurgical evaluation of the HPT blades identified lifting and spalling of the coating on the airfoils, indicative of incipient melting at the coating diffusion zone/base metal interface.[27] (See Figure 8.)

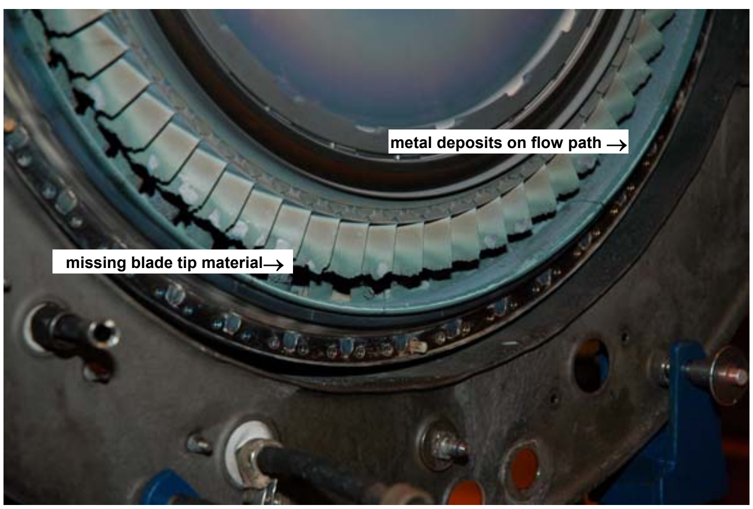

Figure 8. No. 2 engine HPT damage

3.2.3.3 Low pressure turbine (LPT)

There were metal deposits on the transition duct flow path surface, and on the thermocouple probes. All thermocouple probes were intact. All stage 3 nozzle vanes exhibited areas of bulging and waviness and the TE material of most of the vanes was missing at about 70 percent span.

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[26] An initial attempt was made to remove the HPT with the stage 2 shroud assembly already removed, which allowed the seals to contact when lifting the stator assembly off the rotating seal.

[27] A GE metallurgist visually inspected (up to 10x magnification) the blades.

Debris was lodged between the stage 3 nozzle and the stage 3 rotor at 3, 6, and 9 o'clock. A large amount of metallic debris, including pieces identifiable as blade and shroud fragments, had accumulated along the entire LPT flow path at 6 o'clock. The stage 4, 5, and 6 stator vanes were missing 80 to 90 percent of their airfoil length between 12 and 2 o'clock. The remaining portions of the vanes were heat distressed. Material appearing to be re-solidified metal was deposited on the stage 6 nozzle at 3 and 9 o'clock. The stage 6 shroud was heavily scored over 360° including areas of sufficient depth to be through the honeycomb and into the backing material of the shroud. All LPT blades exhibited uniform airfoil loss per the percentages listed in Table 3. With the exception of metal splatter found deposited on each of the struts, the exhaust frame appeared in typical in-service condition.

stage	estimated percentage of missing airfoil length
3	75
4	80
5	80
6	50

Table 3. Estimated percentage of missing airfoil length by stage

Metallurgical evaluation. One of the thermocouple probes was destructively removed from the harness to provide a sample for analysis of splatter deposits. The probe, a blade tip fragment found in the LPT flow path, and the two re-solidified pieces of material found in the LPT were submitted to GE's Materials Lab. X-ray energy dispersive analysis (XEDA) found that the deposits on the probe were consistent with HPT rotor blade material. A blade tip fragment was determined to be either a stage 5 or stage 6 LPT blade. XEDA identified the material found in the LPT as consistent with LPT airfoil material.

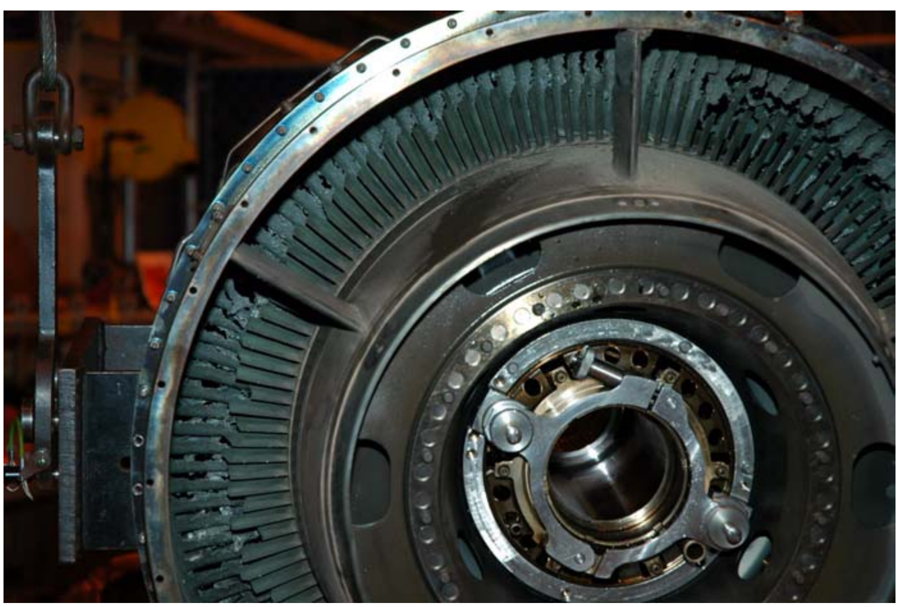

Figure 9. No. 2 engine LPT damage

3.2.3.4.1 Exhaust frame

A small amount of coking was noted on the exhaust frame (C-sump) oil scavenge/feed fitting.[28] An oil sample was collected at the C-sump drain line.

3.2.3.4.2 C-sump

Visual inspection of the No. 7 bearing found no anomalies. The No. 7 carbon seal and runner were in typical in-service condition; the carbon segments moved freely. The forward end of the C-sump cover exhibited coking 360° around its OD.[29] A normal amount of oil was present in the C-sump cover. There was a moderate amount of coking noted at the 4 and 6 o'clock service tubes. The overall condition of the sump was normal.

3.2.4 Accessory gearbox (AGB) drive train

The MFC was removed from the MFP. The MFP-to-MFC driveshaft was examined and appeared in good condition. The accessory gearbox was rotated at the starter drive and drive train continuity was verified at the hydraulic pump drive, the alternator drive, the main fuel pump MFP/MFC drive, the IDG drive, and the lubrication pump drive pads, as well as at the compressor rotor.[30]

3.2.5 Lubrication system

The magnetic chip detector and self-closing valve screen were inspected and found clean. Approximately 7.6 quarts of oil was drained from the oil tank.

4. Airframe installation hardware and accessories

The airframe components that had separated from the airplane with the No. 1 engine and the QEC components installed on the No. 2 engine were not removed from the engines prior to shipment. These components were removed and visually inspected during the teardowns. Air start system and other start-related components and were labeled and packaged.

4.1 No. 1 engine

4.1.1 Bleed air piping

[28] Light oil seepage/coking typically occur at this location.

[29] Coking in this location is considered normal.

[30] This test was performed with the gearbox removed from the engine.

Figure 10.   Damaged No. 1 engine stage 10 ducting

The No. 1 engine 10th stage bleed pipe was crushed and bent at the top elbow, and twisted and crushed at the Y-joint below the check valve. (See Figure 10.) The 10th stage bleed air check valve housing had separated, revealing the valve mechanism. (See Figure 11.) The exposed valve was moved within its housing, and opened and closed freely.[31] The mount supporting the 14th stage bleed pipe at 2 o'clock was flattened (spread open); the insulation was missing from the pipe at this location, but the pipe was not distorted; the pipe was crushed at its transition through the bifurcation unit.


Figure 11.   Stage 10 bleed air check valve

4.1.2 Starter

[31] The bleed air check valves are installed on the engine in the 10th-stage ducts. The check valve is a pneumatically-operated, spring-loaded-closed check valve. The valve lets bleed air flow into the 10th-stage manifold and prevents the flow in the reverse direction into the engine. If a valve fails to close, low pressure starting problems will occur.

The starter monopole connector was fractured. The fitting where the starter control valve-to-starter sense tube attaches to the starter was fractured along the weld, and had separated from the starter housing. The starter driveshaft was not sheared, and could be rotated freely in both directions. It was noisy compared to the starter removed from the No. 2 engine. The aft flange (connecting lip) of the starter was bent.

4.1.3 Starter control valve

Visual inspection of the start control valve found no anomalies.

4.2 No. 2 engine

4.2.1 Bleed air piping

The No. 2 engine 10th and 14th stage piping were in good condition. (See Figure 12.) Visual inspection found no apparent cracks or damage, with the exception of one small dent on the 10th stage pipe at 12 o'clock. All joints were intact, with no evidence of leakage. The bleed pipes from the starter to the pylon connection were intact.

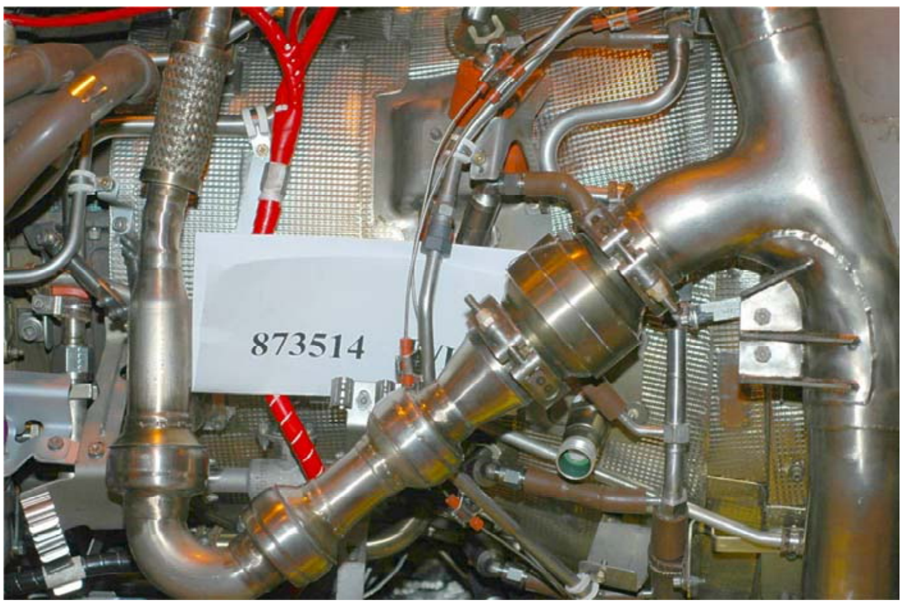

Figure 12. Intact No. 2 engine stage 10 ducting

4.2.2 Starter

The No. 2 engine starter was in good overall condition. All electrical connections were intact. Some small shavings of insulator material were found in the starter harness connector when the connector was removed from the starter monopole. There was no evidence of arcing or mechanical damage. The starter driveshaft had not sheared, and rotated freely in both directions.

4.2.3 Starter control valve

Visual inspection of the start control valve found no anomalies.

5. Other information

5.1 Fluid samples

The fuel samples taken from the engine fuel systems were given to the Kansas City FSDO for analysis. (See Attachment 1, Laboratory Analysis Report.) Test results found insignificant amounts of fuel system icing inhibitors (<0.01%). (See Attachment 1, Fuel Analysis Report.) Engine oil samples were not submitted for analysis.

E. ATTACHMENTS

1. Magellan MP, L.P. Jet Fuel Laboratory Analysis Report

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