

Accident / Incident Summary Report

P&WC 8114 (11-98)



Pratt & Whitney Canada

A United Technologies Company

Report No.: 14-081

**Croom Aviation
Gulfstream-Schweizer G-164B Reg. N425LS
Bonifay, Florida
25 July 2014
PT6A-27 Engine
S/N 40160**

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Table of Contents

	Page No.
I ANALYSIS	1.
1.0 ACCIDENT SYNOPSIS	1.
2.0 SUMMARY OF FINDINGS	1.
3.0 CONCLUSIONS	2.
II FACTUAL INFORMATION	3.
1.0 INVESTIGATION PARTICIPANTS	3.
2.0 ENGINE HISTORY	3.
3.0 ENGINE EXAMINATION	7.



I ANALYSIS

1.0 ACCIDENT SYNOPSIS

On 25 July 2014 a Schweizer G-164B Reg. N425LS, operated by Croom Aviation, was substantially damaged during a forced landing following loss of engine power near Bonifay, Florida. The pilot reported that on reducing power for landing approach, the engine lost thrust and produced a loud, high pitched report with material exiting the right hand exhaust stub. There was no engine response to power lever inputs. With insufficient altitude to reach the runway or field, the pilot manoeuvred the aircraft to a controlled impact in a wooded area. The pilot was not injured.

The agricultural application aircraft was conducting a repositioning flight from Donalsonville, GA to Bonifay, FL at the time of the event.

2.0 SUMMARY OF FINDINGS

The engine gas generator rotor roller bearing (No. 2 bearing) was disintegrated. 12 of the 16 rolling elements were recovered and displayed severe heat oxidation and mechanical damage. The cage was fractured into 5 sections and displayed severe heat oxidation, mechanical damage, and deformation. The bearing inner and outer races were coated with heat fused melted material. Scanning Electron Microscope - Energy Dispersive X-ray Spectroscopy (SEM-EDS) analysis determined the material fused to the bearing races to show a significant amount of rolling element material. Trace amounts of Cadmium were observed on the inner race. The origin of this element could not be identified. Micro structural analysis and SEM-EDS chemical analysis of the bearing races and cage showed the material to be consistent with drawing requirements. The hardness of the inner race and the cage was consistent with drawing requirements. The hardness of the outer race was compromised, likely by heat exposure. The rolling elements material and hardness could not be assessed for conformance to drawing requirements due to their severe heat exposure.

The bearing oil nozzle outer jet was found to be obstructed. SEM-EDS analysis determined the material blocking the jet to correspond to material used in the composition of the bearing races and rollers.

There was extensive resultant damage to the compressor rotor and the compressor housing. There were no other indications of pre-impact anomalies or operational dysfunction to any of the engine components examined.

The No. 2 bearing was replaced as part of a major repair conducted approximately 286 hours prior to the event. The facility conducting the repair is not recognised by Pratt & Whitney Canada.



II FACTUAL INFORMATION

1. INVESTIGATION PARTICIPANTS

The power plant investigation was performed on 18-19 November 2014 at the Pratt & Whitney Canada Service Investigation Facilities at St. Hubert, Quebec, Canada. The following individuals participated in the investigation as representatives of their respective organisations:

Earl Chapman	Senior Technical Analyst Operations Service Branch Transportation Safety Board Canada
Michel Allard	Engine Controls and Accessories Technical Services Pratt & Whitney Canada
Jennifer Thuss	Associate Analyst Materials Investigation and Test Pratt & Whitney Canada
Thomas Berthe	Service Investigation Pratt & Whitney Canada

2. ENGINE HISTORY

PT6A-27 S/N 40160

Hours Since New: 19,059

Cycles Since New: Not recorded.

Hours Since Overhaul: 10,424

Hours Since Last Repair: 286

Cycles Since Last Repair: Not recorded.

The above hours and cycles are as of the last recorded maintenance for the subject engine, a hot section inspection completed on 9 July 2014 by Gary W. Kilpatrick A&P No. [REDACTED]. The logbook entry stated that "all sighted components were found to be in acceptable condition" and that "the power section was sent to Tarheel Turbines for inspection". There was no record of this work performed at Tarheel Turbines work in the available engine records.

Accident / Incident Summary Report

At 18,855 total hours a hot section inspection, including replacement of the compressor turbine blades with overhauled P/N 3023401 units, was completed by Tarheel Turbines, Cert. No. [REDACTED]A, under W/O TT1328 dated 7 October 2013.

At 18,773 total hours the engine was repaired for vibration and unusual noise. The repair included replacement of the No. 2 bearing with a unit overhauled by Bearing Inspection, Inc. under W/O 739453. Bearings Nos. 1 through 5 were replaced with overhauled units. This work was completed by Don Morrison, A&P No. [REDACTED] on 7 March 2013. Please refer to photo No. 1.

At 18,045 total hours the engine was repaired for No. 1 bearing failure. The repair included replacement of the Nos. 1 and 2 bearings, and replacement of the compressor impeller and housing with serviceable units. This work was completed by Don Morrison, A&P No. [REDACTED] on 6 April 2012. Please refer to photo No. 2.

At 17,743 total hours the engine was repaired for compressor turbine blade failure. This repair included replacement of the compressor turbine blades with overhauled units and replacement of the power turbine blades with new PMA units. This work was completed by Don Morrison, A&P No. [REDACTED] on 14 July 2011. Please refer to photo No. 3.

At 17,593 total hours the engine was repaired for sudden stoppage. This work included replacement of the gas generator case, compressor balancing assembly, and the compressor turbine. This work was completed by Don Morrison, A&P No. [REDACTED] on 14 June 2010. Please refer to photo No. 4.

The last overhaul was recorded at 8,635 total hours.

Accident / Incident Summary Report

P&WC 8114 (11-98)

Report No.: 14-081
Page 5 of 51

DATE: 3/7/2013 ENG MODEL: PT6A-27 ENG S/N: PCE-40160 TT: 18,772.9 HOBBS: 3239.1

Engine received for vibration and unusual noise. Engine was disassembled, cleaned, inspected and repaired in accordance with Pratt & Whitney MM 3013242 Rev. 38, dated May 18, 2012. The following repairs were made:

1. The following Compressor Components were recoated by Action Plating Corp. on Invoice 323918: Hub P/N 3013111 S/N 6902, 2nd Stage Disk P/N 3013712 S/N 8583, 3rd Stage Disk P/N 3011713 S/N 7981, 3rd Stage Spacer P/N 3014679, Blade Retaining Ring P/N 3010607, 1st Stage Stator P/N 3013661, 2nd Stage Stator P/N 3013662, 3rd Stage Stator P/N 3013663, 2nd Stage Blades P/N 3013602 (32 ea.), and 3rd Stage Blades P/N 3013603 (32 ea.)
2. P/N 3013632 - 2nd Stage Spacer was recoated by Action Plating Corp. on Invoice 324324.
3. Replaced #1 Bearing with P/N 3033459 S/N 588561, overhauled by Bearing Inspection, Inc. on Work Order 714445.
4. Replaced #2 Bearing with P/N 3006146 S/N C757, Overhauled by Bearing Inspection, Inc. on Work Order 739453.
5. Compressor Assy. was balanced by Southwest Airmotive, Corp. on Work Order 7254.
6. Replaced #3 Bearing with P/N 3006146 S/N F992, Overhauled by Bearing Inspection, Inc. on Work Order 739454.
7. Replaced #4 Bearing with P/N 3028006 S/N 88963915, Overhauled by Bearing Inspection, Inc. on Work Order 691782.
8. PT Balance Assy. was balanced by Southwest Airmotive, Corp. on Work Order 7178.
9. Replaced #5 Bearing with P/N 3003476 S/N Q851, Overhauled by Bearing Inspection, Inc. on Work Order 738387.
10. Inspected #6 Bearing and found to be in serviceable condition.
11. Replaced (8) Accessory Drive Bearings, all Overhauled by Bearing Inspection, Inc. on various Work Orders as listed: P/N 3101636-01 S/N 47A550 on Work Order 20387, P/N 3028005 S/N 68561 on Work Order 170617, P/N 3010674 S/N J7729 on Work Order 650123, P/N 3010674 S/N P419 on Work Order 650125, P/N 3010674 S/N P6294 on Work Order 650129, P/N 3010674 S/N J7763 on Work Order 714451, P/N 3010674 S/N N6324 on Work Order 714452, P/N 3010674 S/N M6673 on Work Order 714453.
12. Replaced Carbon Seal with P/N 3011218, Repaired by Rexnord Seal Operation on Work Order 1017685.
13. Performed a touch-up grind to Hot Section to restore a minimum of .012" CT clearance.
14. Cleaned and Flow checked Fuel Nozzles - All good.
15. Reassembled Engine and motored for leak check - No leaks found.
16. Performed ground run for performance and found to be in satisfactory condition.
17. Sattled and prepared for shipping.

All work performed in accordance with manufacturer's maintenance manual and current FAA regulations.

Don Morrison
A&P

Photo No. 1

Logbook entry for repair at 18,772.9 total hours.

DATE: 4/06/12 ENG. MODEL: PT6A- PT6A-27 ENG. S/N: PCE-40160

HOBBS: **2511.5** ENG: 18,045.3

Received engine for repairs due to a #1 Bearing Failure.

1. Disassembled Engine to the extent necessary to effect repairs.
2. Removed Compressor for Rebuild. Disassembled inspected and repaired by replacing #1 Bearing P/N 3007194, S/N 2665 with new. Replaced #2 bearing with P/N 3028004, S/N BB0038433 overhauled by Bearing Inspection on W.O. 691762. Replaced Compressor Impeller P/N 3013176, S/N 9F218 having Total Cycles of 4420 and cycles remaining 14,580, in serviceable condition removed from PT6A-34AG, S/N PCE-PH0078 removed 01/3/11 TSN: 6882.6, STARTS: 2137, FLIGHT: 14542. Compressor Impeller housing P/N 3021182 replaced with serviceable. Compressor Rotor Assy. and compressor Turbine Disk was sent to Prime Turbines of Balance on W.O. X1846.
3. Gas Generator Section was reassembled.
4. Replaced Main Oil Filter with P/N 1761865 new.
5. Cleaned and Flow checked all fuel nozzles replaced (2) each nozzle tip P/N 3010035 overhauled condition.
6. Cleaned all oil wetted passages.
7. Power Section Inspected for metal for metal contamination OK.
8. Replaced Aircraft Oil Cooler with P/N 8536068, S/N HH-2781 overhauled by Pacific Oil Cooler Service on W.O. 84651.
9. Engine reassembled and performed ground run of engine for leaks and performance OK.

All work performed in accordance with manufacturer's maintenance manual and current FAA regulations.

Don Morrison
A&P

Alterations
(Number of entries)

Photo No. 2

Logbook entry for repair at 18,045.3 total hours.

Accident / Incident Summary Report

P&WC 8114 (11-98)


Pratt & Whitney Canada
 A United Technologies Company

Report No.: 14-081
Page 6 of 51

YEAR	TACH	FLIGHT	TIME IN	Description of inspections, tests, repairs and alterations
DATE: 7-14-2011	ENG. MODEL: PT6A-27	ENG. S/N: PCE-40160		
HOBBS: 1,865.4	ENG. TSN: 17,743.4			
This engine was received for repair due to Compressor Turbine blade failure. Following repairs were performed:				
1. Engine was disassembled to the extent necessary, cleaned, inspected and following parts were replaced. 2. Installed Exhaust Duct P/N 3111780-01, S/N 2C517 overhauled by Aviation Welding Technologies on W.O. 6077. 3. Performed a Hot Section Inspection in accordance with Pratt and Whitney Maintenance Manual. Compressor Turbine Disk P/N 3013411, S/N A0081 was rebled with P/N 3039901 (58) each overhaul C/T blades from Prime Turbines on W.O. X1490 and X1491, and was riveted, skim cut to 8.555 and balanced by Southwest Aeromotive on W.O. 6547. 4. Inner Exit Duct was rebuilt with overhauled C/T Guide Van Assy. P/N 3032651 Flow class 13.47 by Sifco Turbine component Services on W.O. 6409; Serviceable C/T Shroud housing P/N 3028768, New Shroud Segments P/N 3019438 and Ground to a clearance of 0.012." 5. Replaced Power Turbine Blades with New P/N E3013102 (41) each from Timken Alcor Aerospace Tech. on W.O. PT1 1233; in P/T Disk 3022412 S/n 0447, blades were riveted and assembly was balanced by Southwest Aeromotive on W.O. 6547. 6. Replaced Power Turbine Vane Ring with P/N 3024862, S/N 5CD99 overhauled by Sifco Turbine component on W.O. 5542. 7. Replaced Power Turbine Shroud with Serviceable P/N 3010231. 8. Replaced Stator Air Seals P/N 3011429 and 3028222 in Gas Generator Case. Replaced Stator Air Seal P/N 3031184 on #1 Bearing. Replaced Rotor Air Seals on Compressor P/N 3011425 and 3015527. 9. Replaced Rotor Air Seal P/N 3020035 and Stator Air Seal P/N 3011261 on Power Turbine Shaft. 10. Compressor Rotor Balanced assembly P/N 3028764 was check balanced by Southwest Aeromotive on W.O. 6547. 11. Installed overspeed Governor P/N A210507, S/N 2480217W overhauled by Rocky Mountain Propellers on W.O. 36897. 12. Engine was reassembled as necessary and prepared for shipping. 13. Engine must be functionally tested prior to return to service.				
All work performed in accordance with manufacturer's maintenance manual and current FAA regulations.				
Don Morrison A&P [REDACTED]				

Photo No. 3

Logbook entry for repair at 17,743.4 total hours.

YEAR	TACH	FLIGHT	TIME IN	Description of inspections, tests, repairs and alterations
DATE: 6/14/10	ENG. MODEL: PT6A-27	ENG. S/N: PCE-40160		
HOBBS: 1715.4	ENG. TT: 17593.4			
Received engine off-wing for a Sudden Stoppage. Disassembled engine to the extent necessary to determine damage. Performed a Hot Section Inspection. A (100HR) Periodic Inspection and found said engine to be in a serviceable condition with the following repairs performed:				
1. Installed P/N 3003999 S/N 6130 Prop Shaft, overhauled by Aero Component Repair, LLC on W.O. 05D013. 2. Installed P/N 3007147 S/N R3319 46 Bearing, overhauled by Bearing Inspection, Inc on W.O. 597862. 3. Installed Serviceable Condition P/N 3101073-02, S/N 7B082 Exhaust Duct. 4. Installed P/N 3027037, S/N A7062 Gas Generator Case, overhauled by Aero Component Repair, LLC on W.O. 07J021. 5. Installed P/N 3032651, S/N 70710 C/T Vane Ring, overhauled by Texoma Turbines, Inc. W.O. 1916. 6. Installed P/N 3022582, S/N 3434 Large Exit Duct, repaired by Aviation Welding Technologies, LLC on W.O. 5664. 7. Installed P/N 025323-101-03, S/N 15067 Fuel Pump, overhauled by Kansas Aviation of Independence, LLC. On W.O. 050255. 8. Installed P/N 8210-002-01, S/N 1201102 Constant Speed Governor, overhauled by International Governor Services, LLC on W.O. 66278. 9. Installed P/N A210507, S/N 2477243W Over Speed Governor, overhauled by Rocky Mountain Propellers, Inc. on W.O. 33877. 10. Installed P/N 3101525-01 Set #A219 1* Stage Planetary Gears with New P/N 3035031 Bearings, installed by RT Turbines, Inc. on W.O. 01550. 11. Installed P/N 3008041, S/N 4-37-9 1* Carrier Assy. Balanced by Prime Turbines on W.O. C1245. 12. Installed P/N 3022412, S/N 0417 P/T Disk and Shaft assy with (41) each P/N 3013102 P/T Blades, overhauled by MT Texas, LLC on W.O. R0116695, installed riveted, and balanced by Western Skyways Turbines on W.O. T001176. 13. Installed P/N 3028764 Compressor Rotor Balancing Assy. with P/N 3013411, S/N A0081 C/T Disk, Balanced by Prime Turbines on W.O. C1238. 14. Installed New P/N 3019438 CL 7 C/T Shroud Segments and ground to an average tip clearance of 0.012". 15. Cleaned and Flow Checked fuel nozzles and installed (1) each P/N 3010036 Nozzle Tip. 16. Motored engine for leak check- Good. 17. Safetied and prepared for shipping. Performances check to be accomplished upon installation.				
All work performed in accordance with manufacturer's maintenance manual and current FAA regulations.				
Don Morrison A&P [REDACTED]				

Photo No. 4

Logbook entry for repair at 17,593.4 total hours.

3. ENGINE EXAMINATION

All positional references are in relation to view from aft looking forward. Upstream and downstream references are in relation to gas path flow from the compressor inlet to exhaust.

3.1 External Condition

The engine was received in a standard shipping container with all quick engine change items removed with the exception of the starter generator. The power section and gas generator rotor could not be rotated.

3.1.1 External Cases

Reduction Gearbox: The housing was intact. The propeller governor, over speed governor, and the Np tachometer generator were in place and intact.

Exhaust Duct: Displayed moderate compressional deformation.

Gas Generator Case: The housing displayed no impact deformation. The compressor housing displayed outward punctures at the approximate 2:00 and 9:00 positions. The fuel manifold, compressor bleed valve, and the ITT harness were in place and intact.

Accessory Gearbox: Displayed no impact damage. The oil to fuel heater, start control, high pressure fuel pump, fuel control unit, ignition exciter and the Ng tachometer generator were in place and intact.

Please refer to photos No. 5 through 11.

Accident / Incident Summary Report

P&WC 8114 (11-98)

Report No.: 14-081
Page 8 of 51



Photo No. 5
Engine left hand forward view.



Photo No. 6
Engine left hand aft view.

Accident / Incident Summary Report

P&WC 8114 (11-98)

Report No.: 14-081
Page 9 of 51

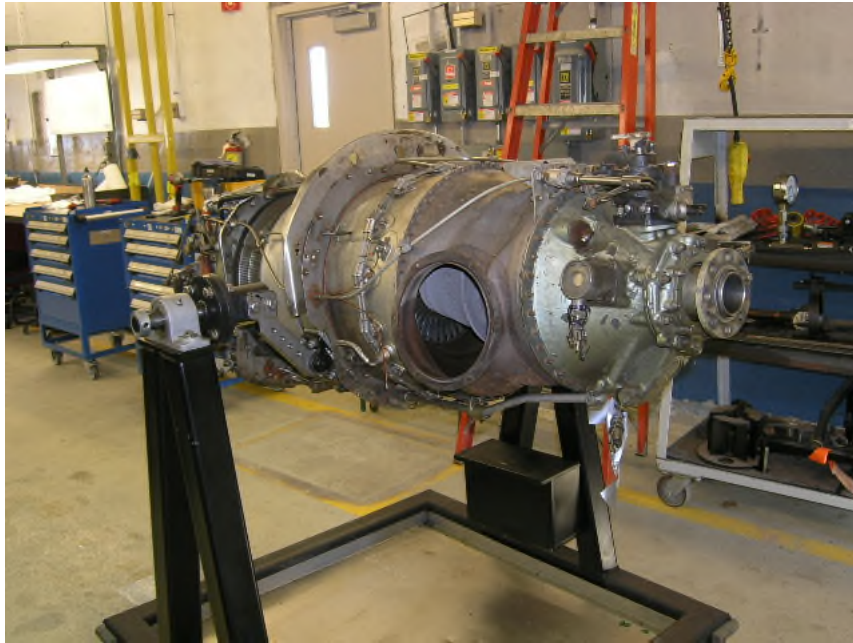


Photo No. 7
Engine right hand forward view.

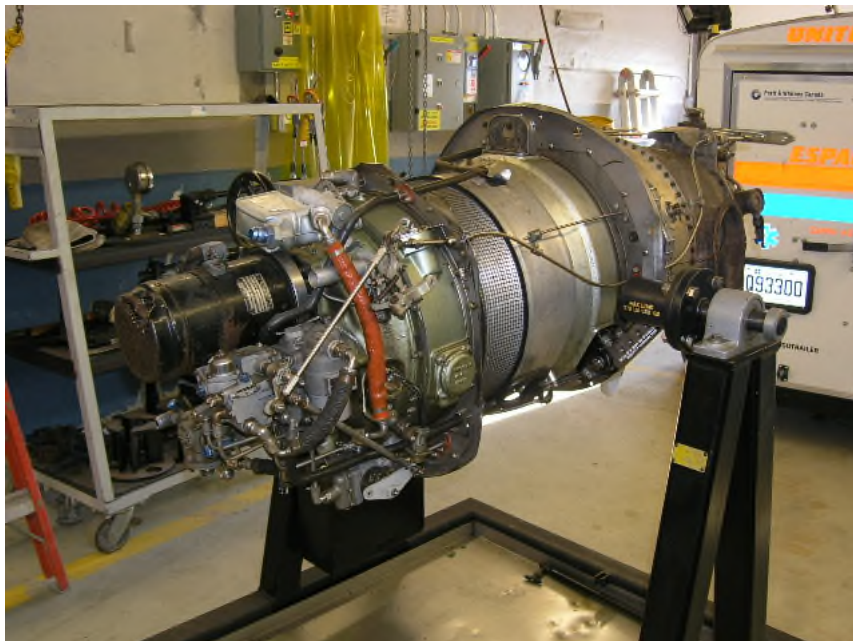


Photo No. 8
Engine right hand aft view.

Accident / Incident Summary Report

P&WC 8114 (11-98)

Report No.: 14-081
Page 10 of 51



Photo No. 9

Engine aft gas generator case and accessory section.



Photo No. 10

Gas generator case compressor housing and shroud, approximate 2:00 position.



Photo No. 11

Gas generator case compressor housing and shroud, 9:00 position.

3.1.2 Power Control and Reversing Linkage

The forward linkage was removed and not received. The linkage was otherwise continuous and intact to the controls cam box and fuel control unit. Please refer to photos No. 7, 8, and 9.

3.1.3 Pneumatic Lines

Compressor Discharge Air (P3): Intact and continuous from the gas generator case fitting to the fuel control fitting. All connections and lock wire were intact. No P3 filter system was fitted. Please refer to photo No. 9.

Power Turbine Control (Py): Intact and continuous from the propeller governor fitting to the fuel control unit fitting. All connections and lock wire were intact. Please refer to photos No. 5 and 9.

3.1.4 Chip Detectors and Filters

Reduction Gearbox Chip Detector: Clean. Please refer to photo No. 12.

Oil Filter: Clean. Please refer to photo No. 13.

Fuel Filter: Clean. Please refer to photo No. 14.

Accident / Incident Summary Report

P&WC 8114 (11-98)

Report No.: 14-081
Page 12 of 51



Photo No. 12
Reduction gearbox chip detector.



Photo No. 13
Oil filter



Photo No. 14
Fuel filter.

3.2 Disassembly Observations

3.2.1 Compressor Section

The gas generator case housing interior displayed an approximate 1 inch x 2 inch hole at the approximate 2:00 position, and an approximate 2 inch x 2-3/4 inch hole at the approximate 9:00 position. There were numerous outward dimples and pockmarks around the housing interior. Please refer to photos No. 15 through 17.

Accident / Incident Summary Report

P&WC 8114 (11-98)

Report No.: 14-081
Page 14 of 51



Photo No. 15

Gas generator case compressor housing interior, approximate 2:00 position.



Photo No. 16

Gas generator case compressor housing interior, approximate 9:00 position.



Photo No. 17

Gas generator case compressor housing interior, centered at the approximate 4:00 position.



Photo No. 18

Compressor assembly as removed, centered at 12:00 position.



Photo No. 19

Compressor assembly as removed, centered at 6:00 position.

Compressor 1st, 2nd, and 3rd Stage Discs and Blades: The 1st stage blades were intact, with circumferential rubbing at the blade tips due to contact with the shroud. The 2nd stage blades were intact, with circumferential rubbing at the blade tips and trailing edge roots, due to contact with the shroud and 2nd stage stator. The third stage blades displayed heavy rubbing and tearing due to contact with the shroud and adjacent stator. 9 blades and root sections were displaced axially from the disc and liberated due to the partial obliteration of the adjacent spacer. Two blades were not recovered. Please refer to photos Nos. 20 through 29.

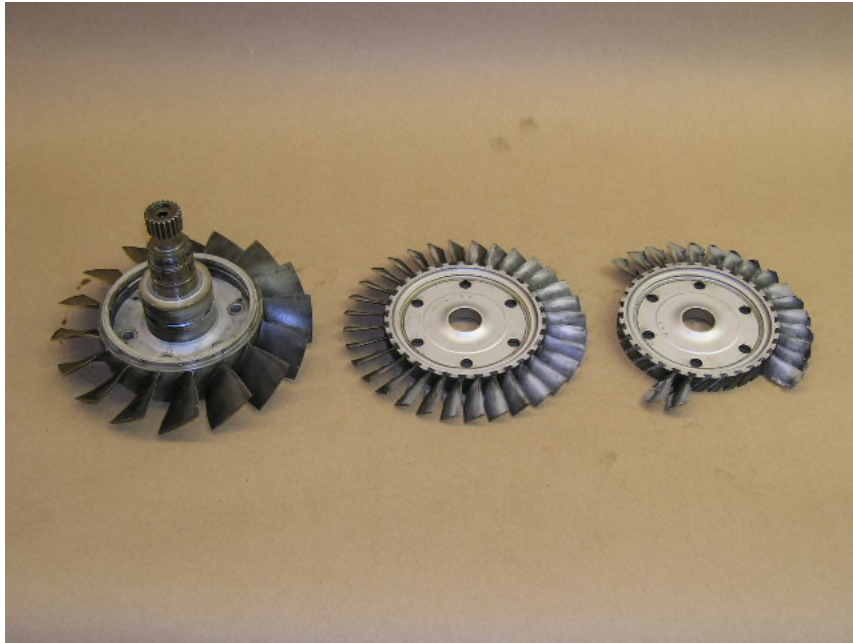


Photo No. 20
Compressor 1st, 2nd, and 3rd stage discs and blades.



Photo No. 21
Compressor 1st stage disc and blades, upstream side.



Photo No. 22

Compressor 1st stage blades and shroud, in-situ detail centered at the approximate 9:00 position.



Photo No. 23

Compressor 2nd stage disc and blades upstream side, in-situ.



Photo No. 24
Compressor 2nd stage disc and blades downstream side.



Photo No. 25
Compressor 3rd stage disc and blades upstream side, in-situ.



Photo No. 26
Compressor 3rd stage disc and blades, downstream side.



Photo No. 27
Compressor 3rd stage disc and blades, downstream side.

Accident / Incident Summary Report

P&WC 8114 (11-98)



Report No.: 14-081
Page 21 of 51



Photo No. 28
Recovered 3rd stage blade airfoils.



Photo No. 29
Recovered 3rd stage blade airfoils, alternate view.



Compressor 1st, 2nd, and 3rd Stage Stators and Shrouds: The 3rd stage stator housing displayed an approximate 3-½ inch x ¾ inch outward rupture centred at the approximate 2:00 position and an approximate 1 inch x 1 inch outward rupture at the approximate 7:00 position. The 1st and 2nd stage stators and shrouds displayed heavy rubbing and deformation due to radial contact with the compressor rotor. The 3rd stage stator vanes were completely obliterated and the shroud rubbed completely though due to radial contact with compressor rotor. Only 7 identifiable fragments of the 3rd stage stator vane were recovered. Please refer to photos No. 18 and 19, and 30 through 38.



Photo No. 30

Compressor 3rd stage stator housing, centered at the approximate 2:00 position. ¾ inch x 3 ½ inch



Photo No. 31

Compressor 3rd stage stator housing and impeller housing, centered at the approximate 7:00 position.



Photo No. 32

Compressor 1st, 2nd, and 3rd stage stator assemblies.



Photo No. 33

Compressor 1st stage stator and shroud upstream side, upper circumference.



Photo No. 34

Compressor 2nd stage stator and shroud upstream side, upper circumference.



Photo No. 35

Compressor impeller, 3rd stage stator housing, and 3rd stage spacer in-situ.



Photo No. 36

Compressor 3rd stage stator and shroud downstream side, upper circumference.



Photo No. 37

Compressor 3rd stage stator and shroud downstream side, lower circumference.



Photo No. 38

Recovered 3rd stage stator airfoil fragments.



Compressor 1st, 2nd, and 3rd Stage Spacers: For identification the spacer assembly was divided into quadrants “W, X, Y, and Z” with quadrant “X” centred at the “X” rotor balancing mark, clockwise viewed from aft looking forward. The 3rd stage spacer was completely rubbed obliterated across approximately $\frac{3}{4}$'s of its circumference to due rubbing and machining under radial contact with the 3rd stage stator vanes. The 1st and 2nd stage spacers displayed circumferential rubbing and machining completely through the spacer around the quadrant “Y” due to radial contact with their adjacent stator vanes. Please refer to photos No. 35 and 39 through 45.



Photo No. 39

1st, 2nd, and 3rd stage compressor spacers quadrant “W”.



Photo No. 40

1st, 2nd, and 3rd stage compressor spacers quadrant "X"



Photo No. 41

1st, 2nd, and 3rd stage compressor spacers quadrant "Y".



Photo No. 42
1st, 2nd, and 3rd stage compressor spacers quadrant "Z".



Photo No. 43
Compressor 3rd stage spacer upstream side, position "X" at 12:00.



Photo No. 44
Compressor 3rd stage spacer, centered at position “X”



Photo No. 45
Compressor 3rd stage spacer, centered at position “Z”



Centrifugal Impeller: The impeller vanes displayed heavy circumferential rubbing due to radial contact with impeller housing. The impeller inlet leading edges were gouged, torn, and deformed due to ingested compressor debris. Please refer to photos No. 46 and 47.



Photo No. 46
Centrifugal impeller.



Photo No. 47
Centrifugal impeller, detail.

Centrifugal Impeller Shroud: The shroud face showed severe rubbing, with heavy frictional heat discoloration and material smearing, due to radial contact with the impeller. The shroud face was rubbed completely through at the approximate 7:00 and 11:00 positions. Please refer to photos No. 18 and 19, 31, 48, and 49.



Photo No. 48
Centrifugal impeller shroud.



Photo No. 49

Centrifugal impeller shroud, centered at the approximate 7:00 position.

No. 1 Bearing and Air Seals: The No. 1 bearing displayed no indications of operational distress. The compressor bearing adapter housing forward face was displaced in clockwise torsion approximately 20 degrees in relation to the aft flange. Please refer to photos No. 50 through 52.



Photo No. 50

Compressor bearing adapter.



Photo No. 51

No. 1 bearing outer race, cage, and rolling elements.



Photo No. 52

No. 1 bearing inner races.

No. 2 Bearing and Air Seals: P/N 3006146, 3011426, S/N C757. The bearing rolling elements and cage were disintegrated. The compressor stub shaft could be moved radially by hand. The bearing air seal rotors displayed heavy circumferential scoring and machining due to radial contact with the air seal stator knife edges. 12 of the 16 rolling elements were recovered and displayed severe heat oxidation and mechanical damage. The cage was fractured into 5 sections and displayed severe heat oxidation, mechanical damage, and deformation. The bearing inner and outer races were coated with heat fused melted material. P&WC Materials Engineering analysis determined the material fused to the bearing races to show a significant amount of rolling element material under Scanning Electron Microscope - Energy Dispersive X-ray Spectroscopy (SEM-EDS) analysis. Trace amounts of Cadmium was observed on the inner race. The origin of this element could not be identified. Micro structural analysis and SEM-EDS chemical analysis of the bearing races and cage showed the material to be consistent with drawing requirements. The hardness of the inner race and the cage was consistent with drawing requirements. The hardness of the outer race appeared to be compromised by heat exposure. The material and hardness of the rolling elements could not be determined to meet drawing requirements due to their severe heat exposure. The primary mode of the bearing distress could not be determined due to the extent of mechanical and heat damage to all of the components.

The bearing oil nozzle was flow checked, and the outer nozzle jet was found to be obstructed. SEM-EDS analysis determined the material blocking the jet to correspond to material used in the composition of the bearing races and rollers.

Please refer to photos No. 53 through 69.



Photo No. 53

No. 2 bearing and air seals, in-situ.



Photo No. 54

No. 2 bearing inner race and air seal rotors, in-situ on compressor stub shaft.



Photo No. 55

No. 2 bearing inner race and air seal rotors, in-situ on compressor stub shaft, opposite view.

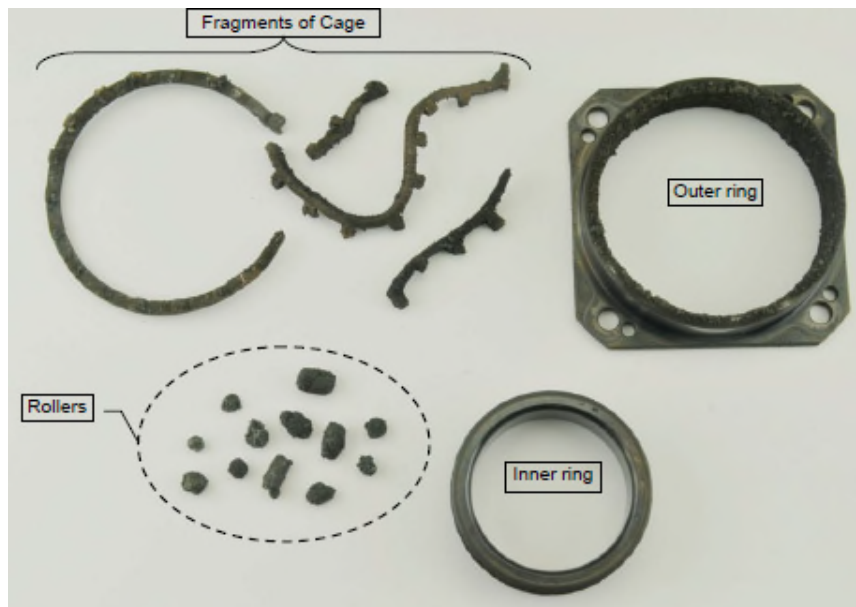


Photo No. 56

General view of No. 2 roller bearing components. The components were significantly oxidized and exhibited substantial amounts of deposited material. The cage had fractured into several pieces which were deformed and contained deposits of coked oil and molten material. Twelve out of the sixteen rollers were recovered.



Photo No. 57

No. 2 bearing outer race.

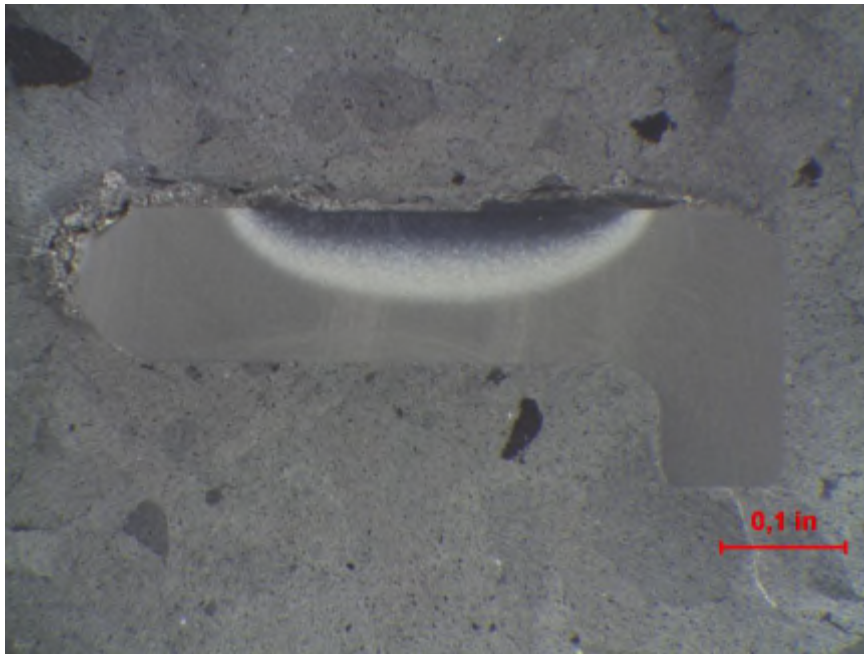


Photo No. 58

View of cross-section through the outer race, showing a significant heat affected region associated with a worn band at the inner surface of the race matching the area of contact with the rollers.

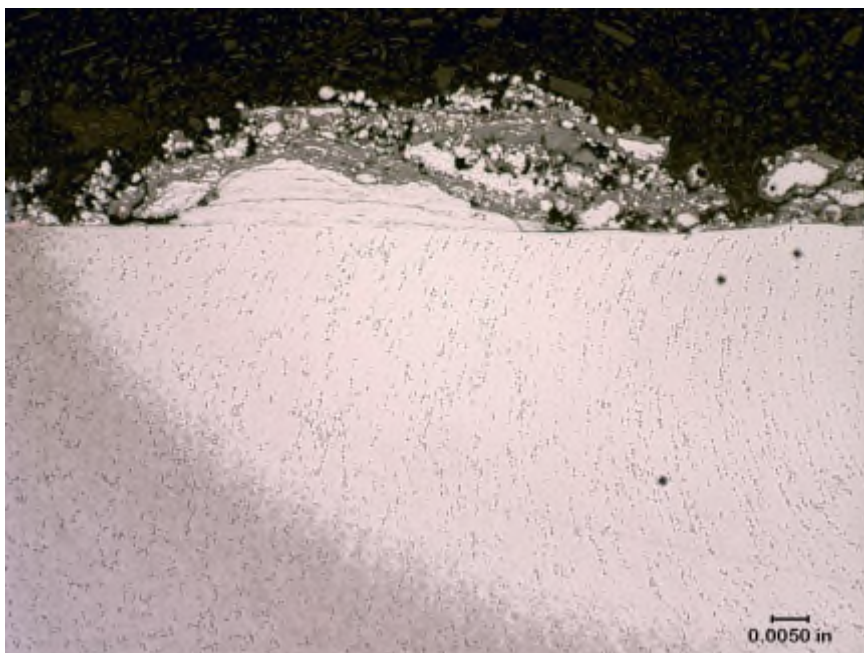


Photo No. 59

Heat fused material on the outer race. SEM-EDS analysis of this material showed material elements characteristic of rolling element and cage material, with phosphorous characteristic of coked engine oil.



Photo No. 60
No. 2 bearing inner race.



Photo No. 61

View of cross-section through the inner race, showing a significant heat affected region associated with a worn band at the inner surface of the race matching the area of contact with the rollers.



Photo No. 62

Heat fused material on the inner race. SEM-EDS analysis of this material showed material elements characteristic of rolling element and cage material, with Phosphorous characteristic of coked engine oil. Traces of cadmium were identified.



Photo No. 63

No. 2 bearing cage, as recovered.



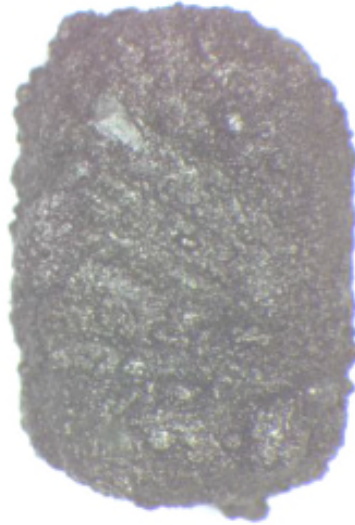
Photo No. 64

Magnified view of one of the fragments of the cage showing significant deformation and deposited material. SEM-EDS analysis of this material showed material elements characteristic of rolling element material, with Phosphorous characteristic of coked engine oil.



Photo No. 65

No. 2 bearing rollers, as recovered.



0,1 in

Photo No. 66

General view of one of the No. 2 bearing rollers showing significant deposited material and deterioration. SEM-EDS analysis of this material showed material elements characteristic of rolling element and cage material, with Phosphorous characteristic of coked engine oil.



Photo No. 67
No. 2 bearing oil nozzle.

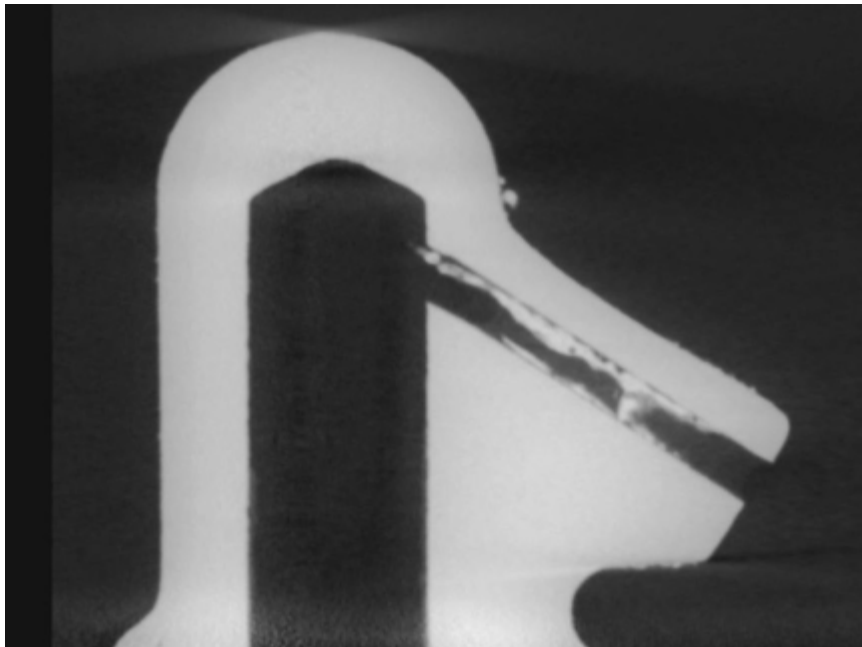


Photo No. 68

X-ray photograph of the No. 2 bearing oil nozzle showing material build up within the top nozzle jet.

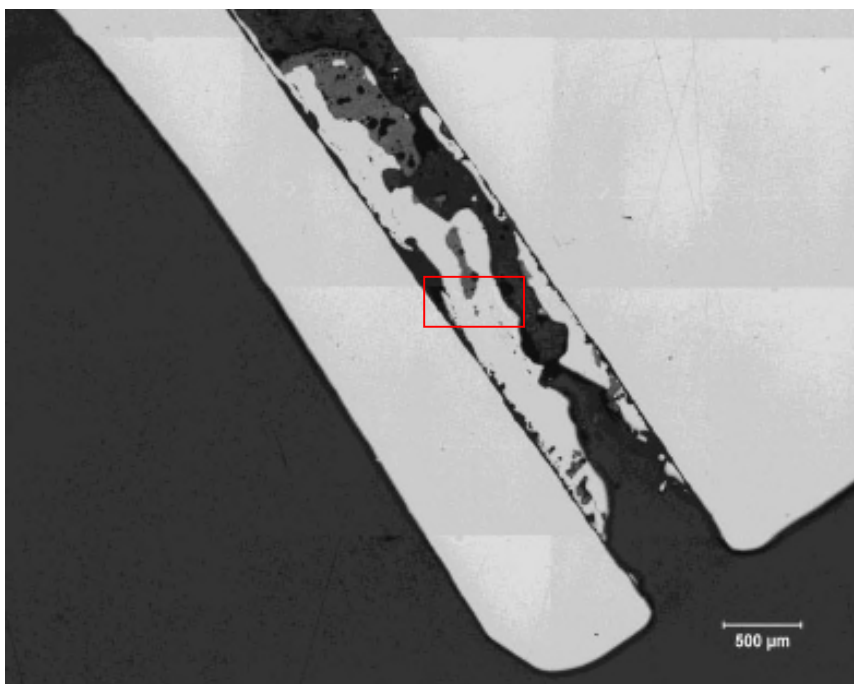


Photo No. 69

Metallographic cross-section through the top nozzle showing the material build-up. SEM-EDS analysis taken in the area marked in red box showed material elements characteristic of bearing race rolling element material.

3.2.2 Combustion Section

Combustion Chamber Liner: Displayed no indications of distress. Please refer to photo No. 70.

Large Exit Duct: Not accessed.

Small Exit Duct: Displayed no indications of distress. Please refer to photo No. 71.



Photo No. 70

Gas generator case interior, combustion chamber liner and compressor turbine, in-situ.

3.2.3 Turbine Section

Compressor Turbine Guide Vane Ring: The vane airfoil leading edges were intact. One vane airfoil at the approximate 8:00 position trailing was eroded, and the vane airfoil showed a bright silver metal deposit characteristic of melted compressor blade or vane material. Please refer to photos No. 71 through 73.



Photo No. 71

Compressor turbine guide vane ring and small exit duct, upstream side.

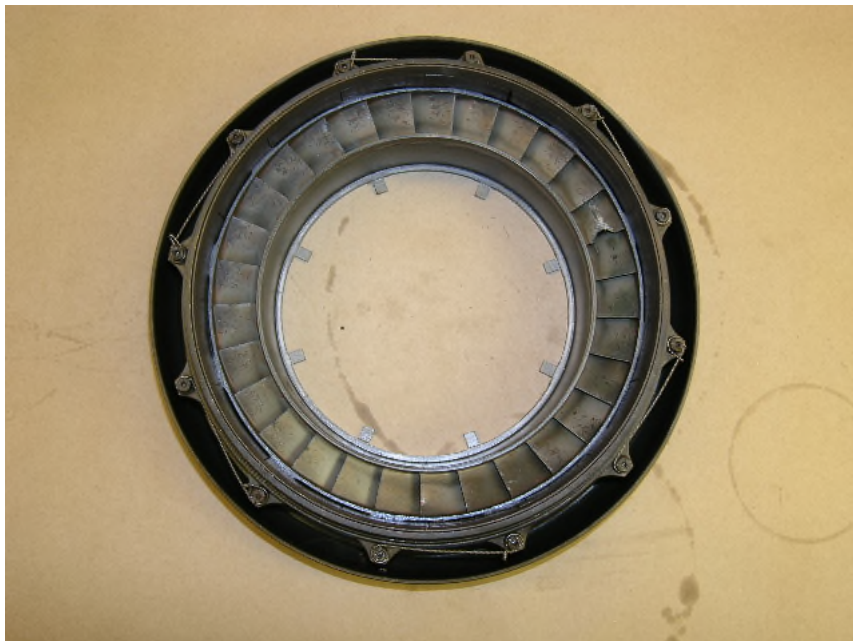


Photo No. 72

Compressor turbine guide vane ring downstream side.



Photo No. 73

Compressor turbine guide vane ring downstream side and shroud, centered at the approximate 8:00 position.

Compressor Turbine Shroud: Displayed circumferential rubbing, with frictional heat discoloration and material transfer, due to contact with the compressor turbine blades. Please refer to photo No. 73.

Compressor Turbine: The blade airfoils were lightly battered and gouged due to contact with upstream debris. The blade tips displayed circumferential rubbing due to contact with the shroud. Fine silver metal material was heat fused to the airfoil surfaces. The disc downstream side displayed circumferential rubbing due to contact with the power turbine guide vane ring. Please refer to photos No. 74 through 78.

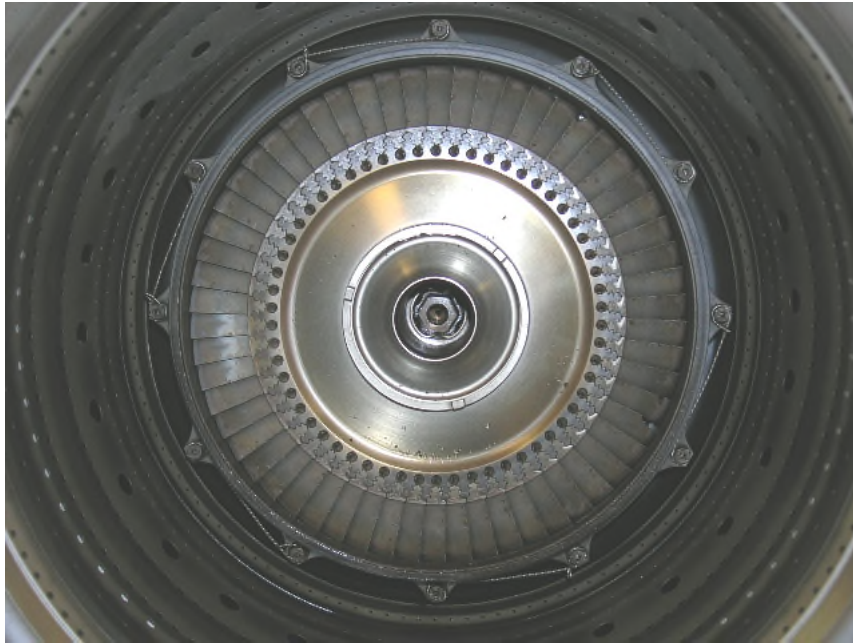


Photo No. 74
Compressor turbine, in-situ.

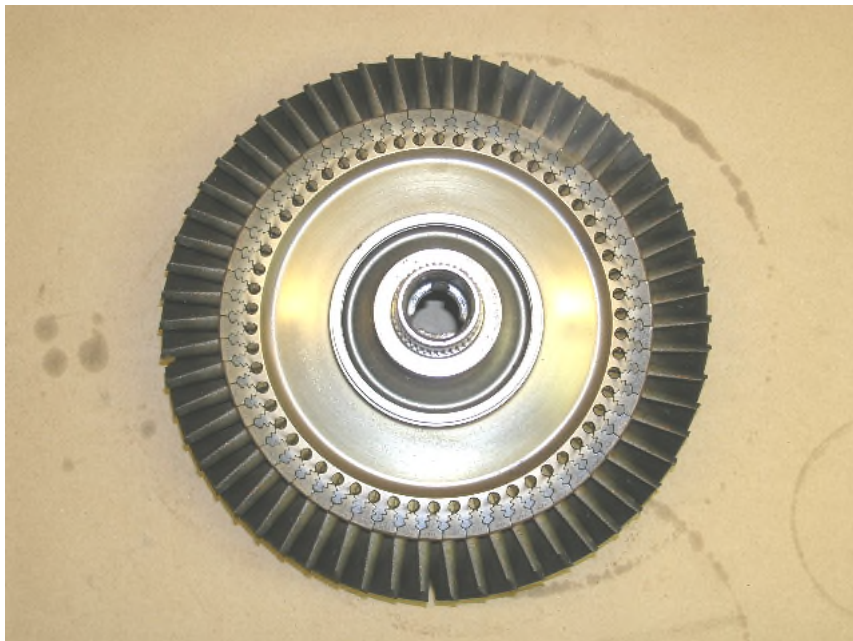


Photo No. 75
Compressor turbine, upstream side.



Photo No. 76
Compressor turbine upstream side, detail.



Photo No. 77
Compressor turbine downstream side, detail.



Photo No. 78

Compressor turbine downstream side, detail.

ITT Probes, Bus bar, and Harness: Displayed no distress. Please refer to photo No. 79.

Power Turbine Housing: Displayed no distress, please refer to photo No. 79.

Power Turbine Guide Vane Ring and Interstage Baffle: Observed in-situ, displayed no distress. Please refer to photo No. 79.



Photo No. 79

Power turbine guide vane ring and interstage baffle, in-situ.

Power Turbine Shroud: Observed in-situ, displayed no distress. Please refer to photo No. 80.

Power Turbine: Observed in-situ, displayed no distress. Please refer to photo No. 80.



Photo No. 80

Power turbine downstream side, in-situ.



3.2.4 Reduction Gearbox

Not disassembled.

3.2.5 Accessory Gearbox

Not disassembled.

3.3 Controls and Accessories Evaluation

The controls and accessories were not removed.