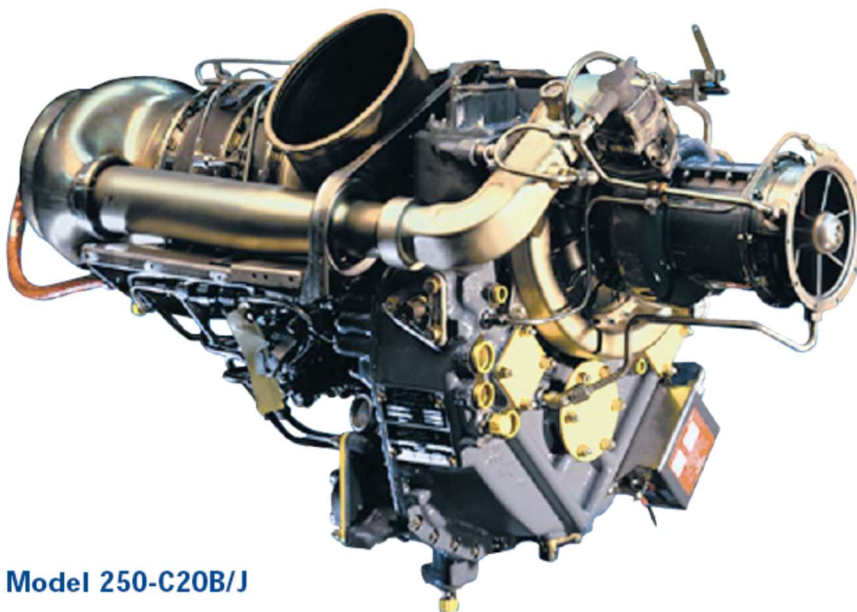




Rolls-Royce

Engine Investigation Report

**Rolls-Royce Corporation
Model 250-C20
Engine CAE-800953BA**



Model 250-C20B/J

**Nick Shepler
Air Safety Investigations**

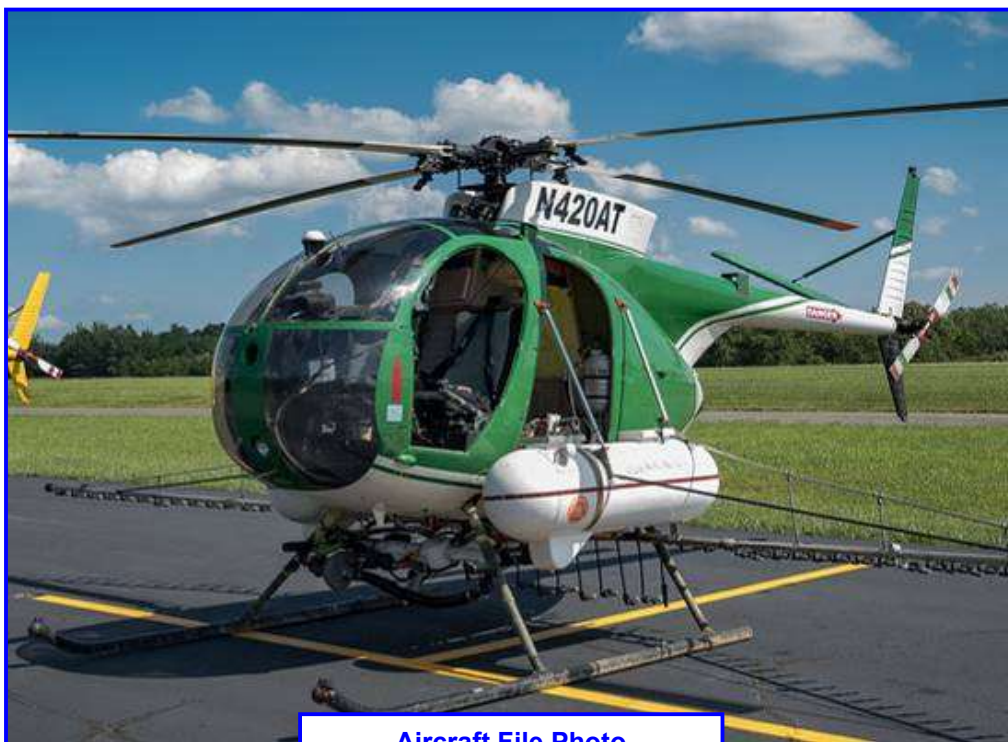
**DAT Aircraft LLC – MD-369HS
Ash, North Carolina**

**Accident date: 17 September 2021
Wreckage exam date: 16 November 2021
Engine exam date: 19 April 2022
Report date: 17 January 2023
NTSB Case: ERA21LA368**

Background

On September 17, 2021, at 1030 eastern daylight time, a Hughes 369HS helicopter, N420AT, was substantially damaged when it was involved in an accident in Ash, North Carolina. The pilot was not injured. The helicopter was operated as a Title 14 Code of Federal Regulations Part 137 aerial application flight.

The helicopter was substantially damaged however there was no post-crash fire and the ELT did not activate. The aircraft was recovered back to Atlanta Air Exchange in Griffin, GA for further examination.



Aircraft File Photo

This report presents the observations made during the investigation.

Accident Flight

NOTE: The author of this report did not attend the accident site examination but was provided details of the scene as well as the accident flight by the NTSB-IIC.

According to the pilot, he flew from his home base to the remote job site and landed on his flatbed support truck to load the chemical hopper. The helicopter had about 25 gallons of fuel on board when it arrived at the truck. After landing, the pilot reduced the throttle to flight idle while the ground crew loaded 60 gallons of chemical to the hoppers. Prior to liftoff, the pilot increased the throttle until the engine and rotor rpm needles were in the green range of the tachometer. He believed that the throttle was in the flight detent. As he started to lift the helicopter from the truck, he noticed one of the truck's doors was open, so he delayed liftoff until the ground crew could close the truck door. Subsequently, immediately after liftoff from the truck, the pilot heard the low-rotor rpm warning horn, and the helicopter began to descend. He attempted to pull more pitch; however, the helicopter did not respond. The helicopter descended, impacted a field, and rolled over on to its right side. The pilot shut down the engine after the helicopter came to rest.

Examination of the helicopter by a Federal Aviation Administration inspector revealed that the helicopter sustained substantial damage to the tail boom. The tail boom was fractured just forward of the horizontal stabilizer. The flight controls were continuous from the cockpit controls to the main and tail rotor. All main rotor blades were fragmented and fracture separated near their roots.



Aircraft Information

Model	MD-369HS
Serial Number	0648S
Registration Number	N420AT
Airframe Total Time	5,178.3 Hours (at time of accident)
Hobbs	2,165.9
Last Inspection (100/300/600 Hr)	100.2 Hours (4-April-2021)

Engine Information

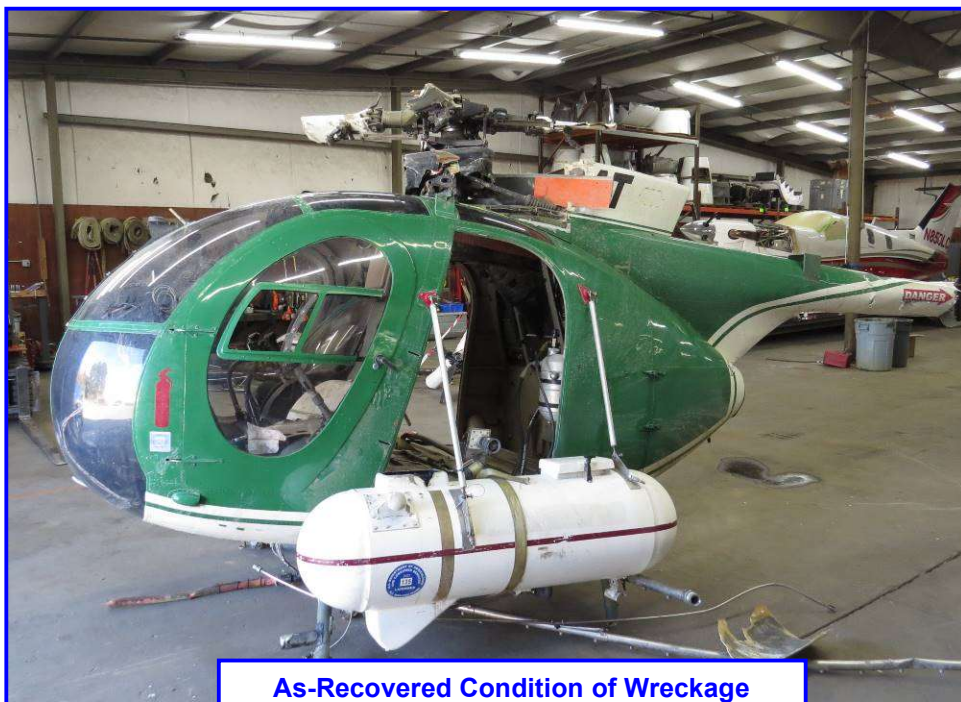
Engine Model	Rolls-Royce 250-C20
Rating:	400 HP
Serial Number	CAE-800953BA
Engine Total Hours/Cycles	8,253.4 Hours/12,950 Cycles (at time of accident)
Last Inspection (150/300/600 Hr)	100.2 Hours (4-April-2021)

Wreckage Examination Details

Recovery examination was conducted 16-November-2021 at Atlanta Air Exchange in Griffin, GA. The NTSB did not participate in the recovery examination due to a scheduling/communications oversight. However, the IIC opted to have periodic phone updates from the party members that included Rolls-Royce & MD Helicopters.

The aircraft sustained substantial damage upon impact fracturing the entire right hand skid and strut assembly. The left-hand landing gear struts were mechanical cut on site to facilitate recovery transportation & to allow the fuselage to sit level for the purposes of the wreckage examination.

The tail-boom and tail rotor driveshaft were severed approximately 18"-24" forward of the tail-rotor gearbox & aft stabilizer. The tail rotor drive shaft exhibited signs of rotational scoring & torsional fracture at the severed location. All 4 main rotor blades were fractured outside of the doublers adjacent to the main rotor attachments. One of the blades was wrapped around the base of the main rotor mast.



As-Recovered Condition of Wreckage

The engine remained within the engine compartment. All three mount struts were secure with no sign of bending, fracture, or lateral displacement. The engine exterior did not reveal any obvious signs of damage from impact forces, internal engine failure, or evidence of fire.

The output drive shaft coupling forward of the freewheeling unit was securely attached at the 4-bolt mount flange. The engine to main rotor transmission interconnect shaft was intact at its respective connection points and exhibited no visually noticeable damage.

Collective pitch continuity to the power turbine governor (PTG) was confirmed but was bound up due to extensive airframe damage limiting collective pitch lever travel. Full stop-to-stop travel of the control arm was confirmed at the PTG following disconnection of the input linkage.

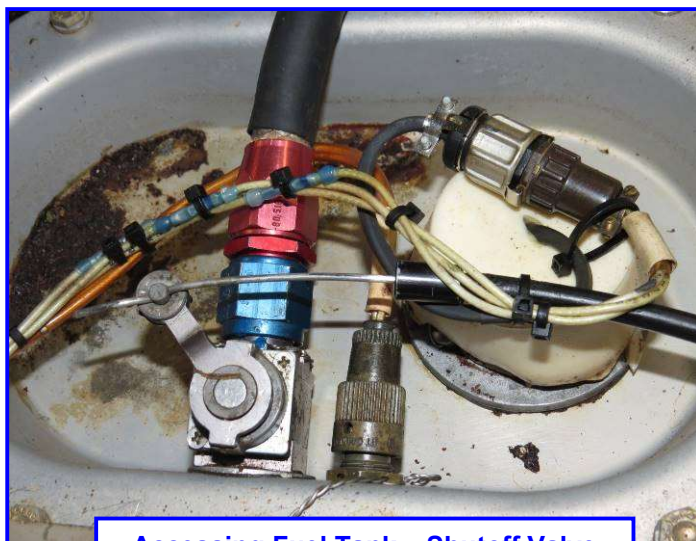


Engine Compartment – General Condition

Throttle continuity to the fuel control unit (FCU) was confirmed from the collective arm twist grip to the input linkage at the FCU pointer indicator. The pointer indicator was at the “0” mark on the scale; however, it is unknown if this had been moved prior to the wreckage recovery effort. The cockpit fuel cut-off knob was noted in the out position indicating the OFF position.

Prior to engine removal, a vacuum check of the airframe to engine fuel system was performed. In preparation for the test and per the test procedure, the fuel cut-off was actuated in the cockpit. The fuel supply system was checked for integrity by applying vacuum to the fuel filter bowl upper port. A hand vacuum pump was exercised to apply 10-in.Hg; the vacuum held for the required 2 minutes. The test was repeated at the same settings with no anomalies noted.

In conjunction with the airframe fuel system vacuum check, the airframe fuel tank was accessed to verify functionality of the fuel cut-off valve, condition of the fuel start boost pump, & presence/condition of fuel in the tank. The shut-off valve was reaching its full open/close travel positions via the cockpit push/pull knob control on the instrument panel. The start boost pump was removed & visually examined. No obvious anomalies were noted. The pump was not electrically tested. The tank was approximately $\frac{1}{2}$ full of clean, clear fuel with no obvious signs of debris. A fuel sample was not collected for further examination.



Accessing Fuel Tank – Shutoff Valve

The aircraft was not equipped with an airframe mounted fuel filter. It was fitted with an external engine oil filter adjacent to the lower right portion of the firewall. The bypass indicator on the filter housing was not extended. The filter housing was not opened for examination.

The aircraft was fitted with an inlet (last chance) coarse screen forward of the compressor inlet. A large amount of random vegetation debris was noted on the intake side, lower portion of the screen.

In preparation for further examination the engine was removed and secured within a temporary, padded crate. The engine was later installed in an appropriate shipping container to facilitate transportation to an authorized maintenance center.



As-Removed Condition of Engine

Both N1 and N2 rotors could be rotated freely by hand and were smooth and quiet. Continuity from the power turbine 4th-stage wheel to the power output shaft forward of the freewheeling unit was established. Continuity was also confirmed throughout the N1 rotor system from the impeller to the starter-generator cooling fan.

The 4th-stage turbine blades appeared undamaged when inspected as did the surrounding turbine sections and exhaust plenum. The compressor inlet was also undamaged and exhibited no indication of FOD ingestion.



Compressor Inlet



4th-Stage Power Turbine Blades

The engine B-nuts and fittings were checked by hand for proper torque. All were found to be at least hand tight and marked with a variety of torque paint colors.

The upper & lower magnetic chip detectors, engine fuel filter, engine oil pressure filter, and fuel spray nozzle were not altered to facilitate a more thorough engine examination prior to testing.

The bleed air valve was operated by hand. The poppet valve appeared clean and smoothly travelled its full stroke with no indication of radial movement or binding.

Per the direction of the NTSB-IIC, the engine was prepped for shipment by removing all airframe specific accessories and protecting various air, oil, & fuel connections as well as the intake & exhaust openings. Several days later the engine was placed into a Rolls-Royce supplied shipping container by Atlanta Air Exchange maintenance personnel & transported to Keystone Turbine Services in Coatesville, PA, which is a Rolls-Royce authorized maintenance center (AMC).

ENGINE EXAMINATION DETAILS

On 19 April 2022, the subject engine was removed from the shipping container & examined at Keystone Turbine Services with regulatory oversight provided by the NTSB. Prior to prepping the engine for test a number of additional investigative actions were performed.



As-Received Condition of Engine

A check of the Pc system was conducted using shop air at the inlet side of the Pc air filter at 80 psi. A soapy water solution was applied to the Pc system B-nuts and rigid tubing. Pressure was then reduced to 20 psi to check for leakage at the governor diaphragm. No leaks were detected anywhere throughout the system. Both magnetic chip plugs were removed with no findings.

Upon completion of standard test cell preparedness tasks by Keystone technicians, the engine was considered acceptable to run on the test cell. The engine was installed on a test cell and a 5-point performance test was attempted to new engine production standards (Model M250-C20B), in accordance with Rolls-Royce M250-C20 Series Overhaul Manual (Publication ref. 10W3) revision 16 dated 1-June-2020.



Engine in Test Cell Prior to Run

The engine successfully started but was unable to achieve 100% N2 speed even with no load applied and was going over temperature (above 1460°F) in the process. The burner drain valve was replaced due to an observed air leak. Replacing the valve had no impact on engine performance. Also of note was that the engine was not hitting an N1 speed where the bleed valve should have been closing. Further engine testing was terminated and follow-on troubleshooting performed.

The fuel spray nozzle was removed and visually examined. The external spray surface was uniformly black in color with no carbon or soot build-up. None of the air distribution holes appeared blocked. The nozzle was not disassembled further & was subsequently deemed unremarkable.

Borescope inspection of the gas producer turbine showed the 1st-stage nozzle in good condition with no apparent thermal or impact damage. Several 1st-stage blades exhibited impact damage on the outer 1/3 of their leading edges.

The general condition of the gas producer turbine was not sufficient to produce the lack of power observed on test; therefore, it was decided to remove a compressor case half for further evaluation.

In the process of accessing the internal flow path of the compressor, all but one of the split-line bolts could be removed with standard tooling. The last bolt/nut combination was corroded to the point where the bolt head required drilling out to facilitate removal.



1st-Stage Turbine Blade Damage

Upon exposure of the internal of the compressor, the removed case half exhibited substantial damage specifically in the 3rd & 4th stages. All of the 3rd-stage stator vanes were completely missing at the base of the airfoils. Numerous 4th-stage vanes were heavily damaged from fully rolled over to severely distorted or twisted. Considerable erosion of the black plastic case lining was noted at the base of the 1st & 2nd stage stator vanes.



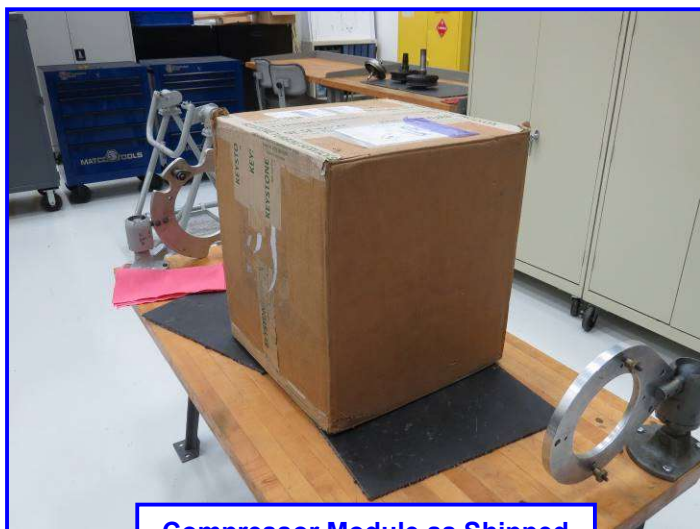
Removed Compressor Case Half with Noted Damage

Heavy impact damage was noted on the compressor rotor from the trailing of stage 3 back to the outer 1/3 of the 6th-stage. Full rotational examination of the rotor showed all of the blades were intact and accounted for. The compressor's condition accounts for the engine's power loss during the accident sequence. The engine was removed from the test stand and placed in a turnover/transportation stand for further evaluation.



Exposed Compressor Rotor with Noted Damage

At the approval of the NTSB-IIC, the compressor module was shipped to the Rolls-Royce Regional Customer Training Center in Indianapolis, Indiana for disassembly & metallurgical examination. On July 15, 2022, the compressor module was disassembled to gain access to the compressor rotor & case half assemblies to allow for metallurgical evaluation.



Compressor Module as Shipped

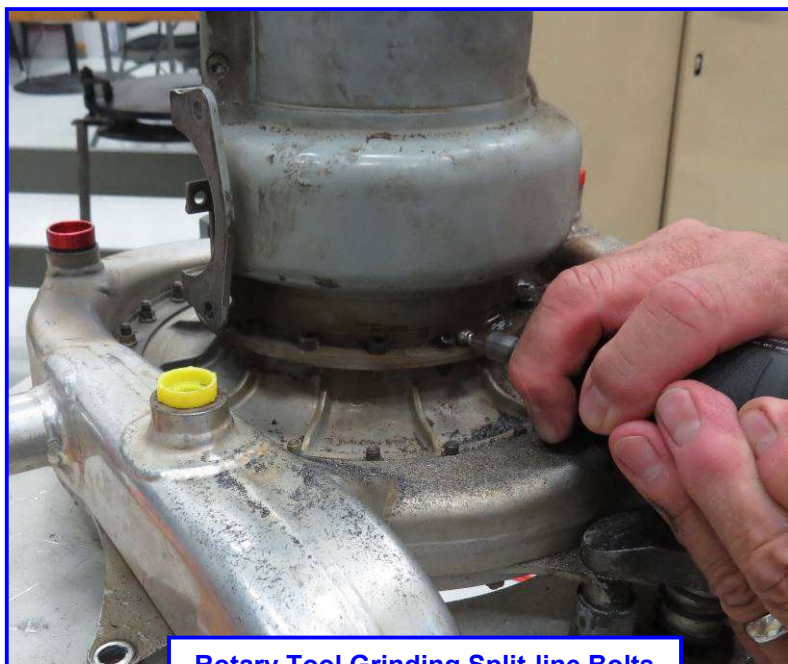


Compressor Module as Received

The compressor module was disassembled in accordance with procedures specified in the Model M250-C20 Series Overhaul Manual.

It was noted during the removal of the opposite case half, from that removed on the test stand at Keystone, that several of the split-line bolts adjoining the aft flange to the compressor front diffuser were significantly rusted and required rotary tool grinding for removal.

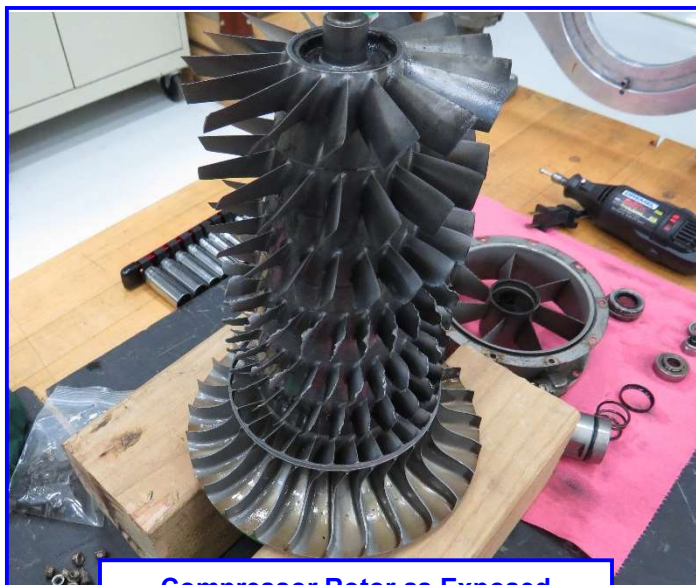
To facilitate removal of the compressor rotor, the front support was fully disassembled. The #1 bearing and surrounding components all appeared sufficiently oil wetted and unremarkable. The bearing spun free and smooth when rotated by hand.



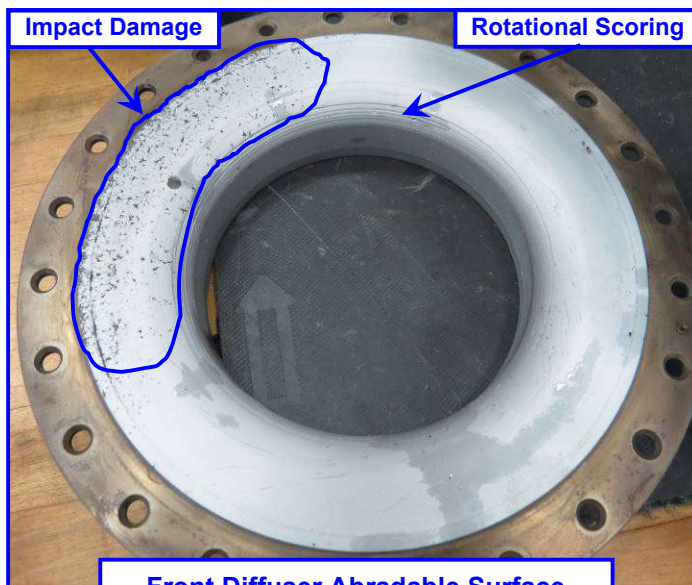
Rotary Tool Grinding Split-line Bolts

The #2 bearing and surrounding components including the inner races, oil slinger, spanner nut, spline adapter, and spur adapter gear-shaft were removed and exposed to their piece part level. All of those items appeared visually normal discolored, consistent with oil staining. The only noteworthy observation was a thin layer of brittle coked oil on the inside diameter of the #2 bearing forward inner race (not on the raceway). The #2 bearing was oil wetted and spun freely when rotated by hand.

The contoured interior surface of the front diffuser is covered with abradable sprayed aluminum. This surface displayed significant rotational scoring and impact damage. This is likely due to liberated compressor blade & vane airfoil material into the flow-path during engine operation.



Compressor Rotor as Exposed



Front Diffuser Abradable Surface

FAILURE ANALYSIS:

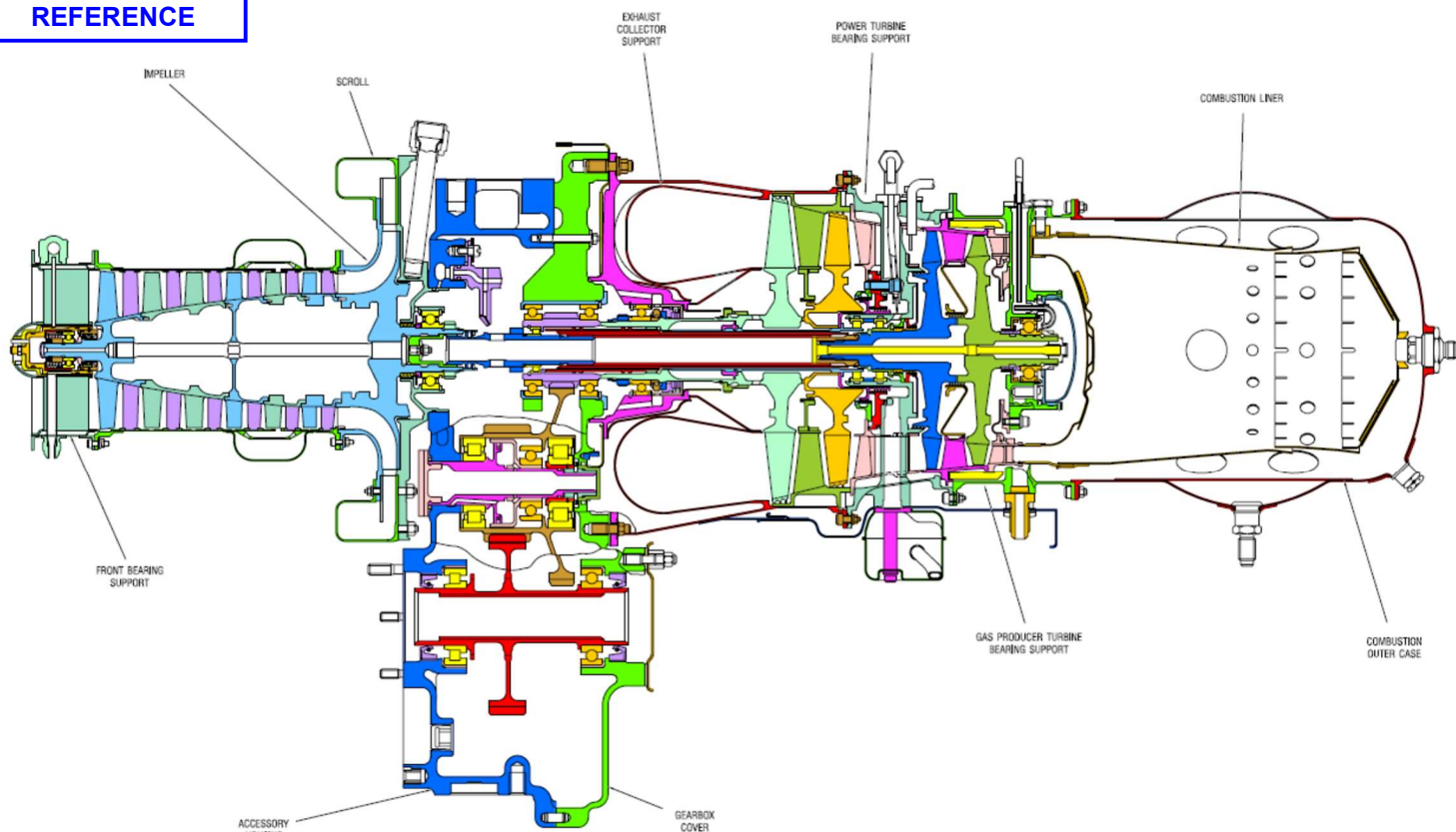
The following items were submitted to the Rolls-Royce Materials Lab for examination:

Part Name	Part Number	Serial Number
Compressor Case Assembly	23057142	42448
Compressor Rotor Assembly	6890529	28468
Spur Adaptor Gear Shaft	23034784	TH101908
No. 2 Bearing	6889093 FAA-PMA	0511859
Oil Slinger	6876877	Not Serialized
Spanner Nut	Unmarked	Not Serialized

METALLURGICAL LAB – SUMMARY OF FINDINGS:

1. All but four of the stage 3 compressor vanes were fractured and separated near the root. The fracture surfaces were too damaged to resolve fracture features.
2. Four stage 4 compressor vanes were fractured and separated near the root. The fracture surfaces were too damaged to resolve fracture features. The remaining vanes were dented and distorted due to secondary impact damage.
3. The compressor case exhibited erosion throughout. The polymer coating was eroded, exposing areas of the stage 1 and 2 compressor vane bands. Stage 1, 2, and 3 compressor vanes exhibited erosion of the leading edge, braze joint fillet, and mid-chord thickness of the airfoils.
4. Corrosion damage was present on the vanes. The leading-edge root of the stage 3 compressor blades exhibited corrosion pitting.
5. The EPS 10702 aluminum coating had been eroded from leading edge root and adjacent surfaces of the stage 3 compressor blades.

REFERENCE



M250-C20B Cross-Section

250-C20B ENGINE SERIES III

ADA024XP

Engine Maintenance and Records

Component	Serial Number	Part Number	TSO (hrs)	Total Time (hrs)
Engine	CAE-800953BA	6878470	N/A	8,253.4
Gearbox	CAG-32639F	6894171	N/A	4,190.1
Compressor	CAC-32506	6890550	347.7	Unknown
Turbine	CAT-38388P	23038241	2523.4	Unknown
Governor	24531	M250-10844	165.8	Unknown
Fuel Control	323485	23070606	429.9	Unknown
Bleed Valve	FF48297	23053176	100.2	Unknown
Fuel Pump	T104652	6899253	1594.8	Unknown
Fuel Nozzle	AG71004	23077068	1082.8	Unknown

SUMMARY OF FINDINGS

- Wreckage examination revealed no externally visually detectable evidence of pre-impact fire, damage, or malfunction of the engine.
- The engine remained securely attached to the respective mount struts on the engine accessory gearbox. The engine compartment area exhibited no apparent damage.
- Cockpit controls up to the power turbine governor (PTG) & fuel control unit (FCU) were continuous to the control cable rod ends.
- A vacuum check of the airframe to engine fuel system was successfully performed with no anomalies noted.
- Both N1 & N2 rotors were continuous & could be rotated by hand and were smooth and quiet.
- All engine B-nuts & fittings at least hand tight & marked with torque paint.
- An attempt to run the engine on the test stand was made but the engine failed to achieve 100% N2 speed with no load applied. Further testing was terminated.
- Post-test troubleshooting including removal of a compressor case half revealed significant airfoil damage to both compressor rotor blades & stator vanes.
- Lab assessment of the damaged compressor components revealed significant corrosion & erosion throughout. Numerous 3rd & 4th stage vane airfoils were fractured. The compressor case polymer coating was heavily eroded. Corrosion pitting was noted on the 3rd stage blades.
- The compressor's condition as documented following test attempts accounts for the engine's power loss during the accident sequence. Fracture liberation of the compressor vanes and subsequent rotor damage significantly compromised the compressor's aerodynamic efficiency. This scenario likely occurred shortly after lifting off from the support truck resulting in the power loss event.