



Rolls-Royce

Engine Investigation Report

**Rolls-Royce Corporation
Model 250-C20B
Engine CAE-836941**



Model 250-C20B/J

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Air Safety Investigations**

**US Dept. of Agriculture – OH-6A
Weston, Georgia**

**Accident date: 8 January 2020
Wreckage exam date: 16 January 2020
Engine exam date: 4-5 January 2020
Report date: 13 March 2020
NTSB Case: ERA20LA071**

Background

On 8 January 2020, at approximately 1415 Eastern Standard Time, a Hughes (MD Helicopters) 369A helicopter, registration number N6816U, impacted agricultural terrain after reportedly experiencing a droop in main rotor RPM. The pilot was uninjured and gunner sustained serious injuries. The helicopter was substantially damaged however there was no post-crash fire and the ELT did not activate. The 14 CFR Part 91 flight was part of a feral swine eradication program



conducted by the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Daytime visual meteorological conditions prevailed and no flight plan was filed for the local flight that departed from a remote location about 1 hour north of Albany, Georgia.

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 operator.

The purpose of the flight was to assist in the eradication of feral swine in the southwest Georgia area. The aircraft was configured with the pilot in the right front seat and a gunner in the left front seat. Both front doors were removed during the hunting flights. The aircraft had made several flights in previous days including the day prior to the accident all totaling approximately 9 hours with no reported discrepancies.

On the day before the accident flight and after 1.7 hours the pilot reported what appeared as a low side governor failure. Main rotor RPM decayed to 94% with the governor beeped to max on the collective control. The pilot proceeded to land at a local LZ (landing zone), shut down, and inform maintenance personnel of the issue. The aircraft was secured overnight in anticipation of a replacement Power Turbine Governor (PTG) & mechanic dispatching to the site.

On the day of the accident, the replacement PTG was fitted to the engine at the remote site. The aircraft was pre-flighted, started and the collective beep range checked on the ground. A maintenance test flight was completed with no discrepancies. The pilot hovered the helicopter, adjusted the N2 beep switch to the minimum position and found that it held at 98% with collective pulls. Total test flight time was 0.2 hours.

After the maintenance test flight was completed and the aircraft shut down, maintenance re-inspected the engine with no reported discrepancies. The aircraft was refueled from a service truck to approximately $\frac{3}{4}$ -full, which allows for maneuverability. After approximately 1 hour of flight time the aircraft was operating normally with no discrepancies and no engine RPM fluctuation. Without any advance notice the pilot reported hearing the engine and main rotor RPM decay while maneuvering at approximately 100' over tall trees. The pilot lowered collective, turned toward open field and away from trees. He increased engine beep to max while simultaneously checking to ensure engine throttle was fully open. Engine RPM continued to decrease.

The aircraft contacted the ground apparently with the tail stinger first and with some amount of forward speed. The tail boom had been fracture separated approximately 12-15" forward of the vertical stabilizer and was laying a distance away from the main wreckage. The aircraft touched down and nosed over allowing the main rotor blades to contact the ground. The aircraft rotated approximately 180° from its original direction of flight. The pilot stated that the engine appeared to have run at idle or less for about 3 seconds. He doesn't recall if he shut off fuel or if the engine had FOD'd itself out.



Aircraft at Accident Site



Aircraft at Accident Site

Aircraft Information

Model	Hughes OH-6A (MD Helicopters 369A)
Serial Number	60-1418
Registration Number	N6816U
Airframe Total Time	13,002.2 Hours (at time of accident)
Hobbs	2,361.3
Last Inspection (100 Hr)	12,987.8 Hours (10-Dec-2019)

Engine Information

Engine Model	Rolls-Royce 250-C20B
Rating:	420 HP
Serial Number	CAE-836941
Engine Total Hours/Cycles	7,541.5 Hours/6,049 Cycles (at time of accident)
Last Inspection (100 Hr)	7,527.1 Hours (10-Dec-2019)

Wreckage Examination Details

Recovery examination was conducted 16-January-2020 at the Georgetown Scott County Regional Airport in Georgetown, KY. The NTSB-IIC did not participate in the recovery examination and elected to delegate oversight to representatives from the Louisville, KY FAA-FSDO. Additional party members included the Rolls-Royce, MD Helicopters, and Thoroughbred Aviation.

The aircraft sustained substantial damage upon impact fracturing the entire left hand skid and strut assembly. The windscreen was heavily fragmented.

The airframe also sustained major damage to the main rotor and transmission area as well as the surrounding fairing structure. The right hand skid was cut off to allow the fuselage to sit level for the purposes of the examination.

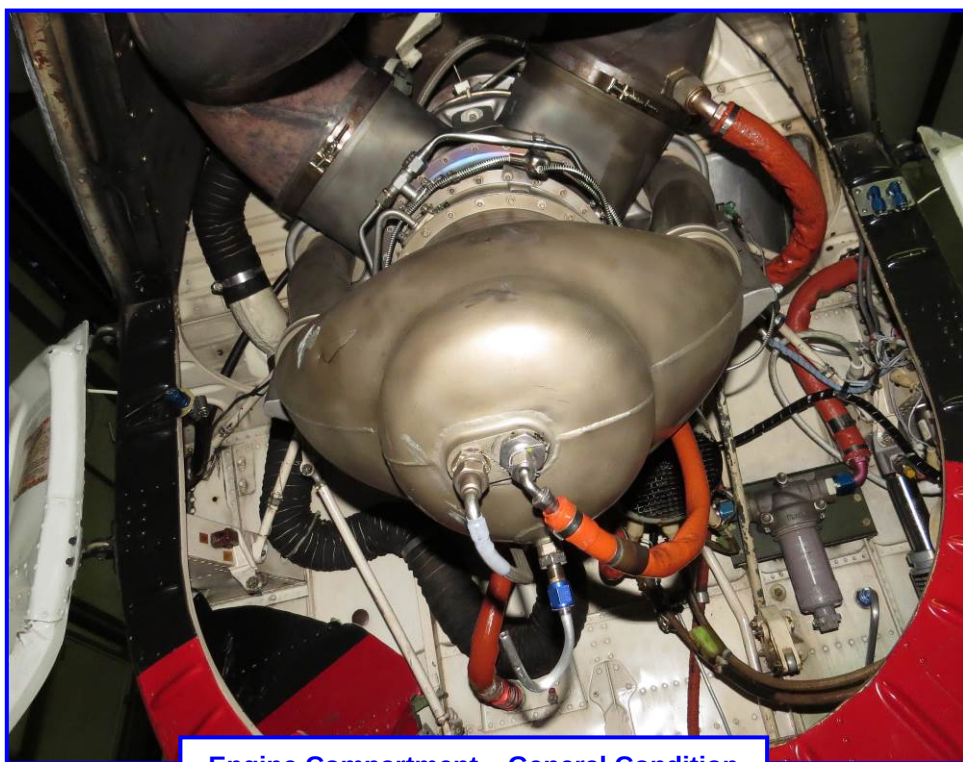
The tail-boom and tail rotor driveshaft were severed forward of the tail-boom's attachment point with the fuselage.

The helicopter was later positioned upright on a makeshift portable platform to facilitate engine removal. The engine remained within the engine compartment. All three mount struts were secure with no sign of bending, fracture or lateral displacement.

The output drive shaft coupling forward of the freewheeling unit was securely attached at the 4-bolt mount flange. The forward end of the interconnect shaft that engages with the main rotor transmission sustained heavy fracture damage and was disconnected from the transmission input.



As-Recovered Condition of Wreckage



Engine Compartment – General Condition

The control linkage providing movement of the Power Turbine Governor (PTG) was disabled due to fracture at the rod end and bell-crank support bracket at the firewall. Full stop-to-stop travel of the control arm was confirmed at the PTG.

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 as documented at the accident site.

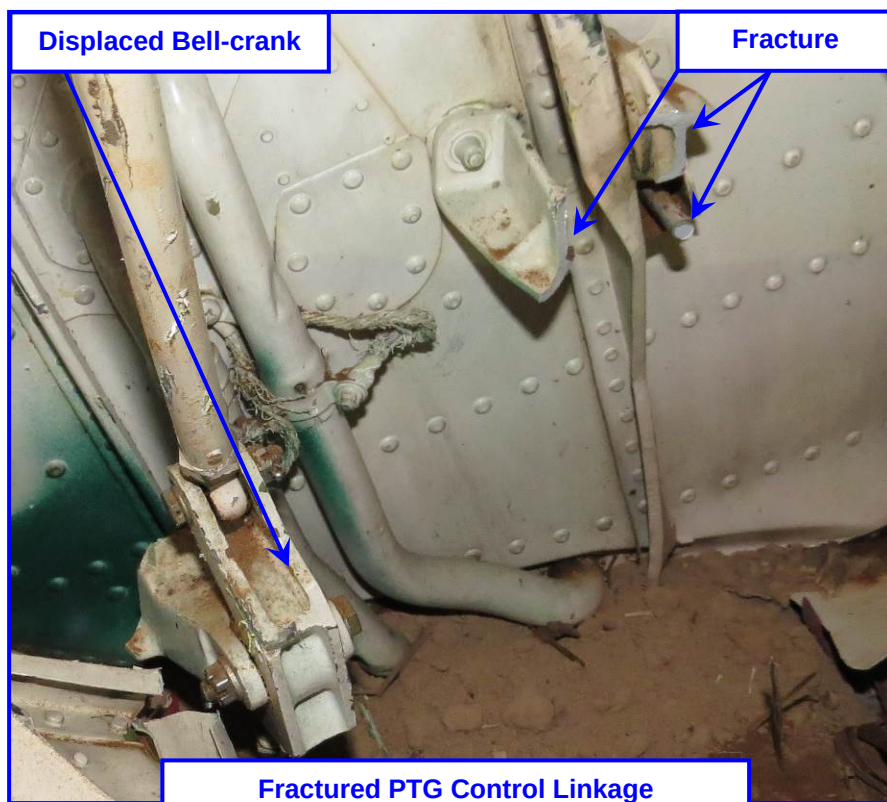
With the exception of minor impact damage to the left rear side of the Outer Combustion Case (OCC – described later in this report) and a bent/deformed burner drain valve extension tube, the engine exterior did not reveal any obvious additional signs of damage from impact forces, internal engine failure, or evidence of fire.

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 8-in.Hg; the vacuum held for the required 2 minutes. A second test was completed at 10-in.Hg for 2 minutes and the system held vacuum accordingly.

Following the vacuum check, approximately 2 tablespoons of clean, clear fuel was drained from the engine fuel pump filter bowl through the lower access plug.

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.

In preparation for further examination the engine was removed and installed into a maintenance stand.



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 upper and lower magnetic chip detectors, engine fuel filter, and engine oil pressure filter were not removed and examined as this would later be conducted at Keystone Turbine Services as part of the pre-engine test inspection process.

All 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 4th-stage turbine blades appeared undamaged when inspected as did the surrounding turbine sections and exhaust plenum.

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.

Following removal of the engine, a large amount of random liberated airframe debris from surrounding cowlings & nacelle fairing structure was noted on the inlet (last chance) coarse screen forward of the compressor inlet.

Per the direction of the NTSB-IIC, the engine was prepped for shipment by removing all airframe specific accessories and placed into a shipping container by Thoroughbred Aviation maintenance personnel. A separate box containing the original PTG was also placed in the same shipping container for later examination.



4th-Stage Power Turbine Blades



Debris at "Last Chance" Inlet Filter Screen

ENGINE EXAMINATION DETAILS

On 4 February 2020, the subject engine was removed from the shipping container at Keystone Turbine Services, in Coatesville, PA with regulatory oversight provided by representatives from the Philadelphia FAA-FSDO. Prior to prepping the engine for test a number of additional investigative actions were performed.

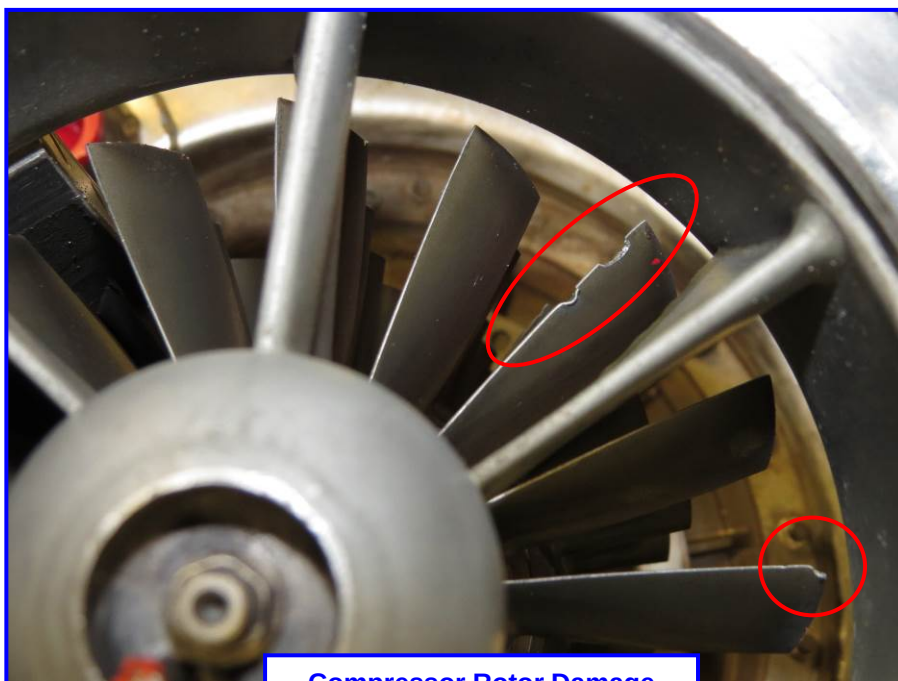
A check of the Pc system was conducted using shop air at the inlet side of the Pc air filter at 80 psi. A soapy water solution was applied to the Pc system B-nuts and rigid tubing. Pressure was then reduced to 20 psi to check for leakage at the governor diaphragm. No leaks were detected anywhere throughout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

Both N1 and N2 rotors could be rotated by hand and were smooth and quiet. The 4th-stage turbine blades appeared undamaged as did the surrounding turbine sections and exhaust plenum. The outer combustion case contained 2 areas of apparent accident related impact damage near the aft dome section.

The compressor front support and inlet guide vanes appeared undamaged. Several 1st-stage compressor blades contained areas of missing material from impact damage. The damage appeared jagged and was isolated primarily to the outer $\frac{1}{2}$ to $\frac{1}{3}$ of the airfoil leading edge. Borescope inspection revealed damage to a lesser extent back to the 4th-stage blades.

A compressor case half was removed in order to inspect the extent of damage throughout the compressor. The static vanes appeared mostly undamaged. Small bits of vegetation debris were noticed in the compressor.

The borescope was also used to assess the condition of the 1st-stage gas producer turbine nozzle and blades. Both appeared void of thermal distress and considered unremarkable.



The fuel supply line was removed from the fuel spray nozzle; about 1-1/2 teaspoons of clean, bright fuel drained from the line. The fuel spray nozzle was removed and examined. There was no evidence of obstruction in the fuel spray nozzle inlet. The spray face exhibited a light, uniform carbon and soot appearance. There did not appear to be any blockage within the air distribution holes. The nozzle was not disassembled prior to the engine run.

Both the upper and lower Magnetic Chip Detectors (MCDs) were removed and examined. No evidence of flakes or related metallic debris was noted on either MCD.



Fuel Spray Nozzle

The engine pressure oil filter was removed and inspected clean of ferrous metal, foreign debris, or similar contamination. Approximately 1 tablespoon of clean oil was in the bottom of the gearbox oil filter housing. The engine fuel pump filter was removed and inspected. A few very small bits of black debris were noted between adjacent pleats that were visible when shining light from the inside. The filter was refitted to the pump housing as is.

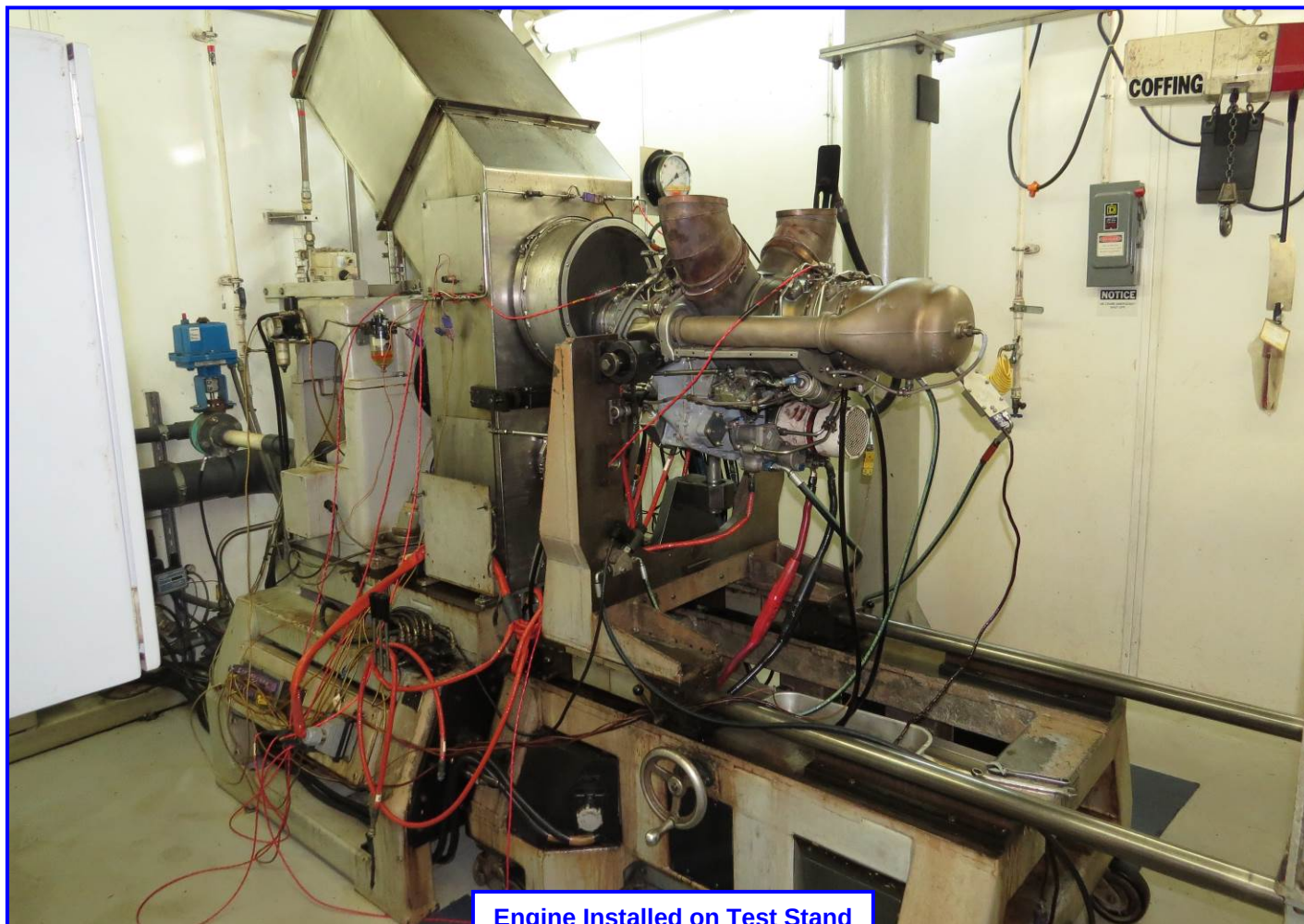


Engine Pressure Oil Filter



Engine Fuel Pump Filter

Upon completion of the standard test cell preparedness tasks by Keystone technicians, the engine was considered acceptable to for test operation. The engine was installed on a test cell with the intention of running a 6-point performance test to new engine production (model M250-C20B) standards, in accordance with the Rolls-Royce M250-C20 Overhaul Manual (Publication ref. 10W3) revision 15 dated 15 August 2019.



Engine Installed on Test Stand

The engine successfully started, ran and shut down. On initial engine start, it is recommended that the following seal run-in schedule be accomplished with speed changes between settings being accomplished in a slow methodical manner:

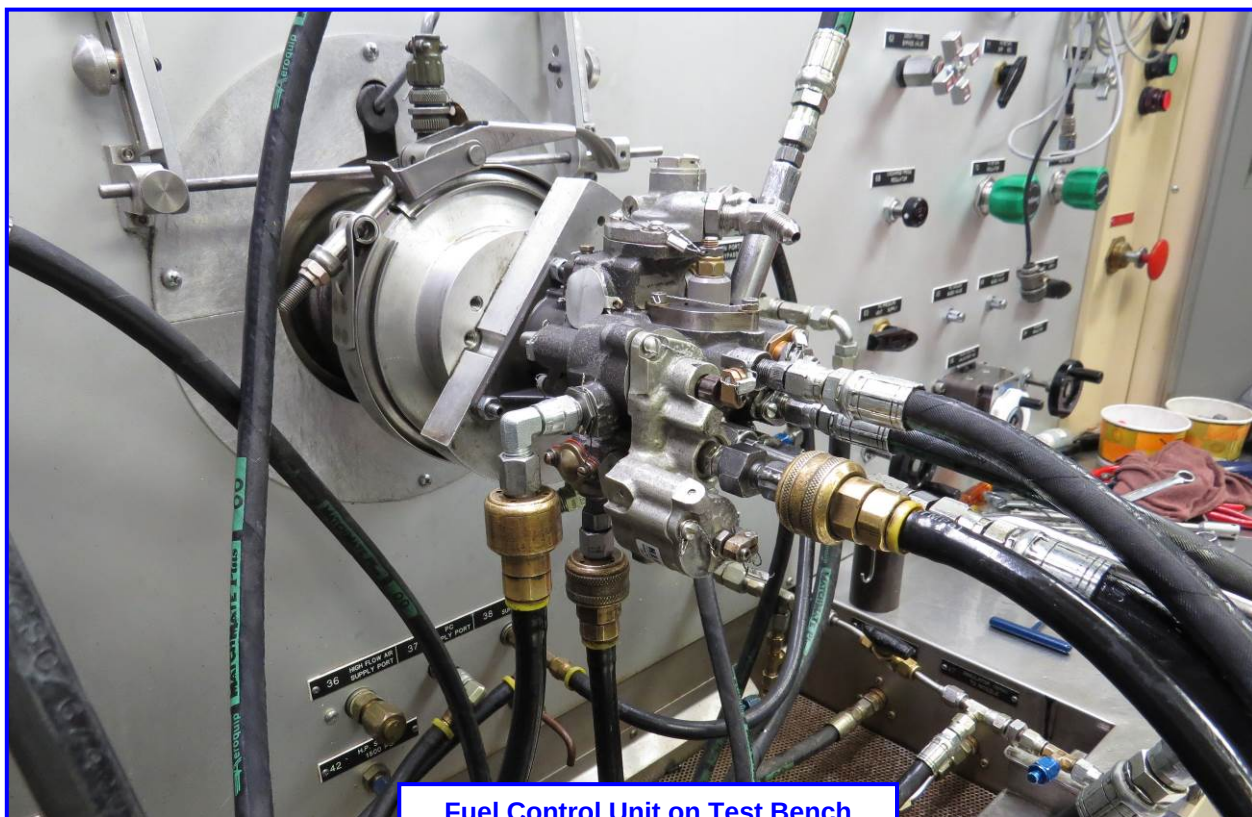
Idle speed	2 minutes
36,000 N ₁ rpm	30 seconds
42,000 N ₁ rpm	30 seconds
45,000 N ₁ rpm	30 seconds
47,500 N ₁ rpm	30 seconds
49,500 N ₁ rpm	30 seconds
Takeoff	2 minutes

During coast down following the seal run-in run the engine began to rock back and forth on the stand, essentially pivoting about the side mounts on the gearbox. This condition repeated itself during a motoring attempt but to a lesser extent given the comparatively low N1/N2 rotor speeds. Troubleshooting revealed that the lower engine mount attachment to the gearbox had come loose. The lower test stand mount contains a triangular shaped pad that is held to the gearbox with 3 bolts. Keystone mechanics typically only use 2 bolts for this connection. During the troubleshooting it was noted that 1 of the 2 bolts had fallen out completely and the 2nd bolt was backed off the mount by approximately 1/8-3/16". Further testing of the engine was not pursued given the uncertainty as to the cause for the lower mount issue.

Lack of additional running prevented the ability of performing the full test procedure including the power calibration, governor droop, and accel/decel checks. The limited amount of test stand running did produce acceptable results. When corrected for standard atmospheric conditions, the engine yielded performance +8.3% above new-production standards at "low cruise" (300 horsepower), +7.8% above new-production standards at normal cruise (370 horsepower), and +16.2% above new-production standards at maximum (Take-Off) power (420 horsepower).

In the absence of further engine testing the decision was made to bench test all of the accessories including the following: both of the Power Turbine Governors, Fuel Control Unit, fuel spray nozzle, and fuel pump (disassembly only). The accessories were tested in accordance with the Rolls-Royce Component Maintenance Manual procedures to serviceability specifications. All of the units tested satisfactorily.

The FCU was tested two separate times due to an anomaly with the minimum fuel flow set point. It was later determined that the Px air fitting (test stand component) was slightly leaking. This condition was corrected and the FCU performed satisfactorily. The FCU internal fuel filter was removed and inspected clean & free of blockage and debris.



Fuel Control Unit on Test Bench

The fuel spray nozzle displayed minor streaking at the high flow test point. The nozzle was disassembled and the internal screen was void of debris or evidence of collapse.

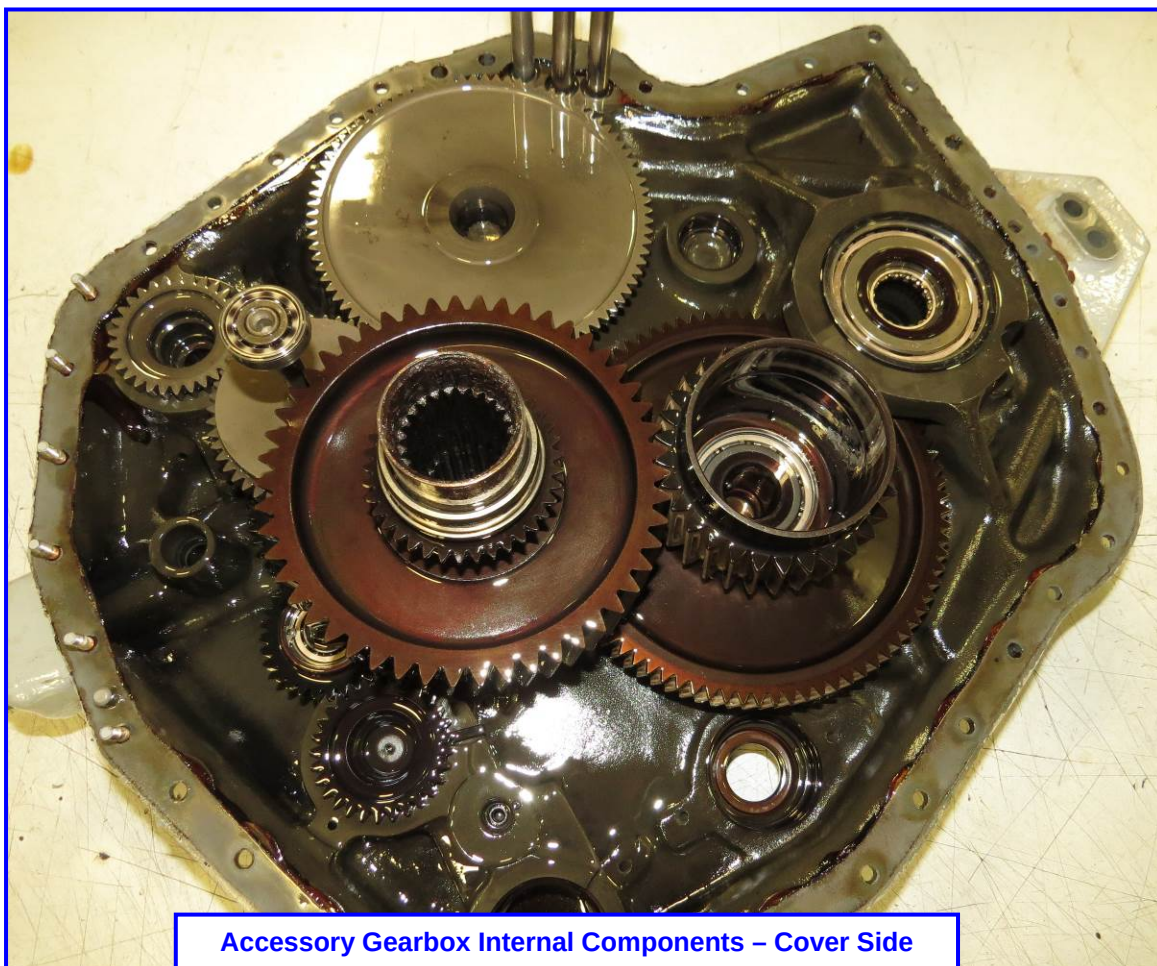
The fuel pump was disassembled. Minor bits of black debris were noted in the filter body housing. The pump was otherwise unremarkable.

Following completion of the accessories testing the gearbox assembly was opened to expose the internal gearing and components. The magnetic chip detectors were also removed following the engine test. Both MCDs appeared clean. The gearbox and internal components were oil wetted, void of suspended metallic debris, and visually unremarkable.

Following completion of the accessories testing and gearbox inspection, the decision was made to terminate any further investigative activities.



Fuel Spray Nozzle Internal Filter



Accessory Gearbox Internal Components – Cover Side

AIRFRAME FUEL SYSTEM EXAMINATION DETAILS

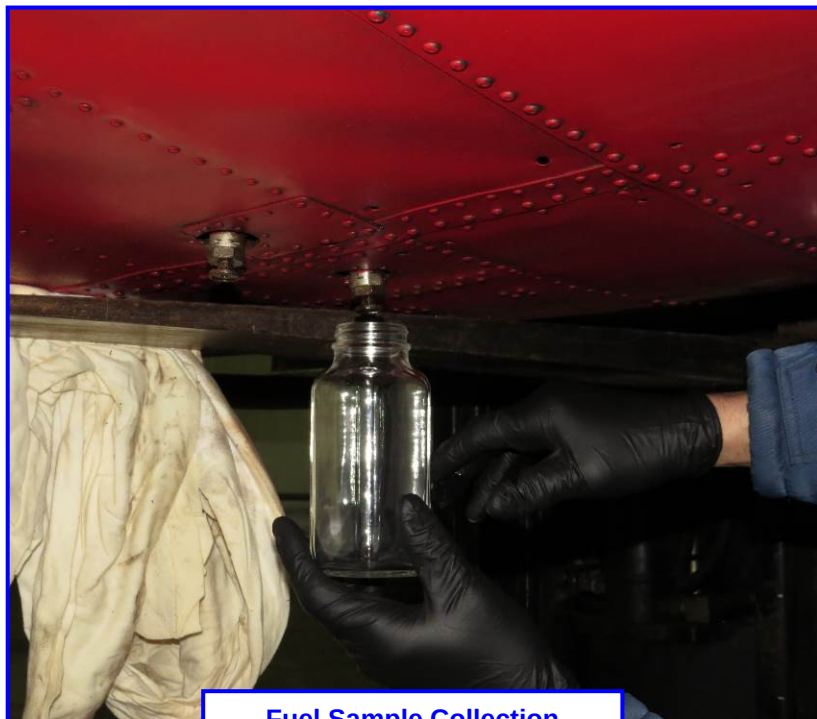
On 20 February 2020, an airframe fuel system examination was conducted at the Georgetown Scott County Regional Airport in Georgetown, KY. The NTSB-IIC did not participate in the fuel system examination and elected to delegate oversight to a representative from the Nashville, TN FAA-FSDO. Additional party members included Rolls-Royce, MD Helicopters, and Thoroughbred Aviation.

The airframe floor panels were removed to expose both sides of the main tank. The fuel shutoff valve was in the OFF (closed) position, which is the configuration it remained in from the fuel system vacuum check performed during the wreckage exam.

The fuel cell panels were removed allowing access to the internal bladder of the main tank. Prior to defueling the aircraft, a fuel sample (~ ½ liter) was collected via the petcock drain valve from the bottom of the fuselage. The sample was retained by the USDA for shipment to an external lab for further analysis. Test results appeared normal for the parameters measured by the lab; specifically water, bacteria, & fungus. Approximately 25 gallons of clean, clear fuel was subsequently drained from the tank.

Visual examination of the cross feed connection separating the tank appeared unremarkable. Fuel flowed through with no indication of blockage or restriction. The fuel boost pump appeared intact and secure to its mount flange on the bottom of the left side of the tank. The fuel pick-up area under the pump was clear of debris and void of obstructions.

The fuel pump was removed and tested using a spare 28-volt battery and a supply of drained fuel collected in a bucket. The pump operated normally. The boost pump was partially disassembled following the test to inspect for any signs of debris, blockage, or other abnormalities. The pump appeared unremarkable.



Fuel Sample Collection



Fuel Pump Assembly

Engine Maintenance and Records

Component	Serial Number	Part Number	TSO	Total Time
Engine	CAE-836941	6887190	592.4	7,541.5
Gearbox	CAG-42425	6894171	4218.5	7,541.5
Compressor	CAC-43180	6890550	592.4	3,969.6
Turbine	CAT-26525	23069745	592.4	7,095.9
Governor	BR44288	23086749	403.3	3,488.3
Fuel Control	198732	23070606	592.4	Unknown
Bleed Valve	FF57947	23053176	592.4	Unknown
Fuel Pump	T101359	6899253	779.9	Unknown
Fuel Nozzle	AG41873	23077068	592.4	6,114.8

Summary of Findings

- There was no evidence of pre-impact fire, damage or malfunction of the engine.
- Continuity was established for both N1 & N2 rotors. Both could be rotated by hand and were smooth and quiet.
- Control continuity was established from the collective twist grip to the FCU. The control linkage to the PTG was fractured at the engine compartment firewall.
- The engine was installed on a test stand with the intent of running a 6-point performance test in accordance with Rolls-Royce M250-C20 Series Overhaul Manual procedures.
- The engine performed satisfactorily at take-off power for 2 minutes as well as 2 lower power test points over a period of approximately 20 minutes of total run time.
 - Further testing was not pursued due to an engine to test stand anomaly whereby the lower mount came loose from the accessory gearbox.
 - This condition resulted in the engine rocking back & forth in the stand during coast down. Further engine testing was not pursued.
- In lieu of further engine testing the decision was made to bench test all of the accessories including the following: Power Turbine Governors (both pre- & post-accident units), Fuel Control Unit, fuel nozzle, and fuel pump (disassembly only).
 - The units were tested in accordance with the Rolls-Royce Component Maintenance Manual procedures to serviceability specifications.
 - The accessories performed satisfactorily. The fuel pump appeared visually unremarkable.
- The airframe fuel system was examined and a fuel sample analyzed. Both appeared normal and unremarkable.
- All available evidence suggests the engine was capable of producing sufficient power and responding to throttle inputs when installed in the aircraft.