

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



CEN23LA232

POWERPLANTS

Group Chair's Factual Report

August 5, 2024

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B. TABLE OF ACRONYMS

ALF	Aft Looking Forward
EDX	Electron Dispersive Xray
ESHP	Equivalent Shaft Horsepower
ESN	Engine Serial Number
FAA	Federal Aviation Administration
FCU	Fuel Control Unit
FP	Fuel Pump
HMU	Hydromechanical Unit
ID	Inner Diameter
MCD	Magnetic Chip Detector
NTSB	National Transportation Safety Board
PG	Propeller Governor
PPC	Propeller Pitch Control
SEM	Scanning Electron Microscope
SN	Serial Number
TBO	Time Between Overhaul
TCDS	Type Certificate Data Sheet
TSN	Time Since New
TSO	Time Since Overhaul

C. INCIDENT

Location: Bloomfield, Nebraska, USA
Date: June 7, 2023
Time: 14:00 CDT (Central Daylight Time)
Airplane: Grumman Aircraft ENG COR Schweizer G164B, Registration N48485
NTSB IIC: Timothy Sorensen

D. POWERPLANTS GROUP

Group Chair	Thomas Driscoll National Transportation Safety Board Washington, D.C., USA
Group Member	Stephen Yee National Transportation Safety Board Washington, D.C., USA
Group Member	Jay Eller Honeywell Phoenix, Arizona
Group Member	Jim Rosplock Woodward Inc. Loves Park, Illinois
Group Member	Les Doud Hartzell Propellor Dayton, Ohio

E. SUMMARY

On June 7, 2023, about 1400 central daylight time, a Schweizer G-164B airplane, N48485, was substantially damaged when it was involved in an accident in Bloomfield, Nebraska. According to the preliminary accident report, the aircraft departed runway 14 from the Bloomfield Municipal Airport (84Y) with an agricultural load for the second flight of the day. According to the pilot, the tail wheel lifted and wings started to rise but the aircraft would not climb. The pilot then applied full throttle but the aircraft would not respond. The airplane traveled past the end of runway 14 and into a neighboring soybean field, striking a fence and tearing the right landing gear off before finally nosing into the ground. The pilot was not injured in this accident. The airplane

was operated as a *Title 14 Code of Federal Regulations* Part 137 aerial application flight.

The airplane was recovered from the agricultural field and a wreckage examination was performed by Honeywell at the request of the NTSB. The engine was then removed from the airplane and shipped to the Honeywell facility in Phoenix Arizona for an engine exam which was performed on September 18-20, 2023 with persons from the NTSB and Honeywell and Hartzell Propeller present.

The engine did not show any signs of uncontainment or external fire damage. Hand rotation of the engine power turbine produced a corresponding rotation¹ of the propeller output shaft. The fuel pump and fuel control assembly, also known as the hydromechanical unit (HMU), was found loose with the retaining nuts not fully seated to secure the HMU to the gearbox flange. A fuel sample was taken from the fuel filter bowl and found what appeared to be a foreign liquid or contaminate with the fuel separated out.

The engine examination found the impellers and turbine rotors/blades to be present and intact. Earthen material was found from the stage 1 impeller through to the combustion chamber. The stage 2 impeller was intact and exhibited localized rotational scoring damage, the stage 1 turbine rotor blade tips exhibited rotational scoring marks and the torsion shaft was found fractured.

The stage 1 nozzle, the fractured torsion shaft, and the fuel sample were submitted to the Honeywell materials lab for further examination; the fuel control unit and propeller governor were also shipped to Woodward Inc. for further examination with NTSB and Honeywell present.

Honeywell's failure lab's evaluation of the stage 1 nozzle found no metal spray was present on the nozzle vanes but did reveal spots where the thermal barrier coating had spalled off. Honeywell's evaluation of the torsion shaft determined the fracture surface features were indicative of torsional overload. Honeywell's evaluation of the fuel sample taken from the fuel filter bowl determined the fuel was typical of Jet A fuel and the liquid contaminant was water.

The engine's fuel control unit and propeller governor were shipped to the Woodward Inc. facility in Loves Park, Illinois for examination and testing. Members from the NTSB, Woodward Inc., and Honeywell were in attendance for the examination on December 5, 2023. The propeller governor assembly was intact and undamaged, the input drive shaft rotated freely under hand pressure and the control arm rotated normally. Bench testing of the propeller governor resulted in normal operation and no

¹ Engine continuity was perceived due to corresponding rotation but during disassembly the torsion shaft was found fractured resulting in loss of continuity between the power turbine and the output shaft.

anomalies found and as such, the propeller governor was not disassembled. Bench testing of the fuel control unit revealed that several test points were out of range based on the test standards and is consistent with the cam gear having limited travel on the cam shaft, but not seized. Subsequent disassembly of the fuel control unit revealed the cam gear was seized (frozen) in position on the cam shaft. The cam gear (3D cam) and shaft were shipped to the NTSB lab for further examination.

The 3D cam and shaft assembly were examined at the NTSB in Washington D.C. on March 19-20, 2024, with party members from the NTSB and Woodward Inc. in attendance. Disassembly of the 3D cam and shaft assembly required cutting of the shaft between the 3D cam and the bearing, which then allowed the 3D cam to slide off the shaft. Examination of the cam shaft found two depressions on opposite corners of the cam shaft slot, one depression was round in shape while the other was rectangular in shape, corresponding to the round and square portions of the 3D cam and shaft alignment pin. The outer cam shaft diameter measured in the plane incorporating both areas of outward deformation was larger than the specified 3D cam bushing diameter. The 3D cam bushing appeared to have corresponding areas of wear and distinct gouges along the axis of the bushing and on either side of the shaft slot. One gear tooth on the cam shaft exhibited signs of spalling damage and cracking across the entire length of the tooth.

F. DETAILS OF THE EXAMINATION

1.0 Engine and Propeller Information and Description

1.1 Engine Description

The accident airplane was powered by one Honeywell (formerly AlliedSignal, Garrett, and AiResearch) model number TPE331-1-151A turbo propeller engine (**Figure 1**), engine serial number (ESN) P92203C. The TPE331-1-151A is a single-shaft engine with a two-stage centrifugal compressor, a reverse flow annular combustion chamber, a three-stage axial turbine that drives the compressor (gas generator) (**Figure 2**) and the reduction/accessory gearbox (**Figure 3**). The reduction gearbox is also sometimes referred to as the output gearbox (gear reduction section). The model number identification is broken down as follows:

TPE331-1-151A

“TPE” means turbo propeller engine

“331” is the series number assigned by Honeywell

“-1” identifies the FAA power class certification

“151” indicates the engine configuration in that specific components may be identified

"A" indicates the customer code for this engine model is Mitsubishi

According to the Federal Aviation Administration (FAA) Type Certificate Data Sheet (TCDS) E3WE, revision 8, dated February 1, 2000, the TPE331-1 turbo propeller engine, the engine has maximum continuous shaft horsepower power (SHP) rating limit of 665; 705 Equivalent Shaft Horsepower (ESHP); and output shaft rotation speed of 2,000 revolutions per minute (RPM). The takeoff (5 minute) power rating limit is as follows: 665 SHP, 705 ESHP, and output shaft rotation speed of 2,000 RPM, respectively. The maximum exhaust gas temperature is 1047°F (564°C) for maximum continuous and 1072°F (578°C) takeoff. Maximum allowable propeller shaft torque as sensed by the torque sensor, in pound-feet (lb.-ft.), is 1,890 for 5 minute torque limit and 1,746 lb.-ft. for maximum continuous.

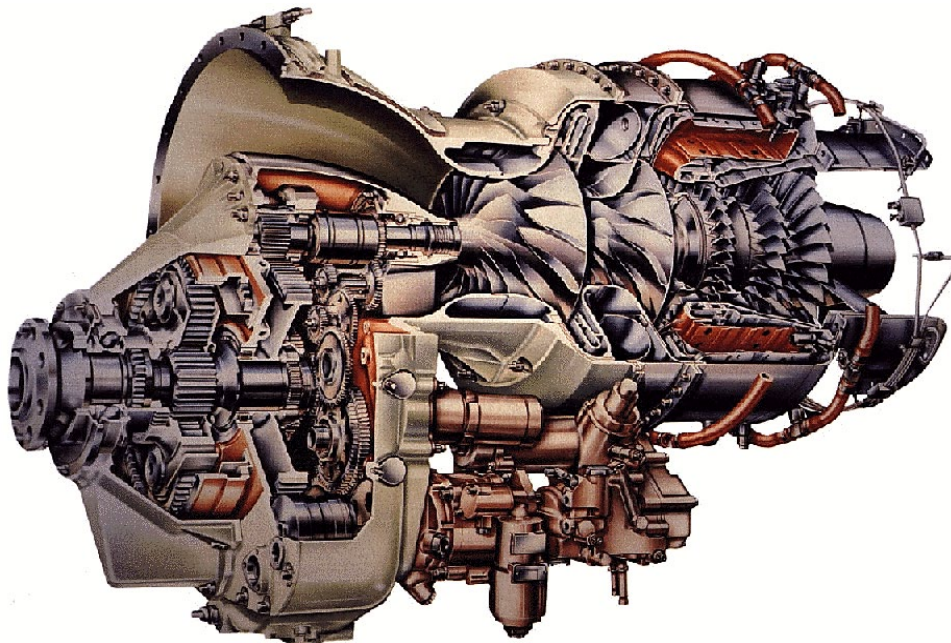


Figure 1. Generic Honeywell TPE331 engine

(Figure Courtesy of Honeywell)

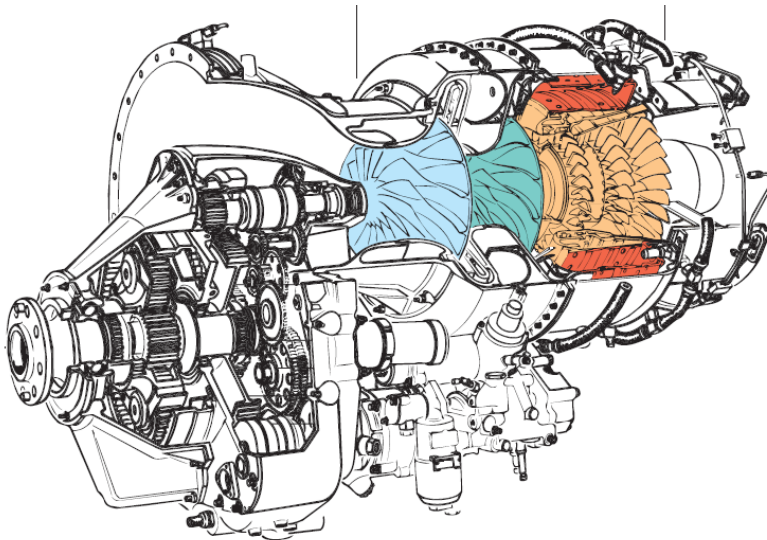


Figure 2. TPE331 Gas Generator Section (color)

(Figure Courtesy of Honeywell)

The TPE 331-1-151G is a clockwise rotating propeller installation. The gearbox incorporates a fixed planetary gear carrier assembly. The bull gear/sun gear assembly drives the planet gears, which drive the rotating ring gear. The ring gear is attached to the propeller shaft with a splined hub. With the ring and propeller shaft rotating as one assembly this produces clockwise rotation.

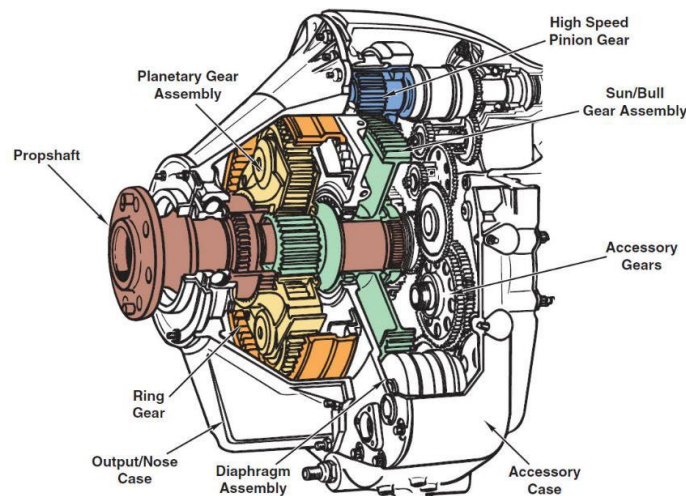


Figure 3. Reduction Gear Section Schematic

(Figure Courtesy of Honeywell)

All directional references to front and rear; left and right; top and bottom; and clockwise and counterclockwise are made aft looking forward (ALF). All numbering is in the circumferential direction starting with the No. 1 position at the 12:00 o'clock position or immediately clockwise from the 12:00 o'clock position and progressing

sequentially clockwise ALF. The direction of rotation of the engine compressor, turbine and the propeller shaft is clockwise ALF.

1.2 Propeller Description

The accident airplane was equipped with a Hartzell Propeller model HC-B3TN-5M (**Figure 4** and **Figure 5**). According to FAA TCDS P15EA, revision 31, dated December 13, 2018, model HC-B3TN-5 propeller is a three-bladed aluminum alloy variable pitch propeller with hydraulically operated blade pitch change mechanism providing “constant speed” operation mode, feathering, and reversing functionality. An internal beta feedback mechanism and start locks are included. Each propeller blade is supported in the hub using a two-piece steel clamp. The hub is a single piece alloy steel hub.

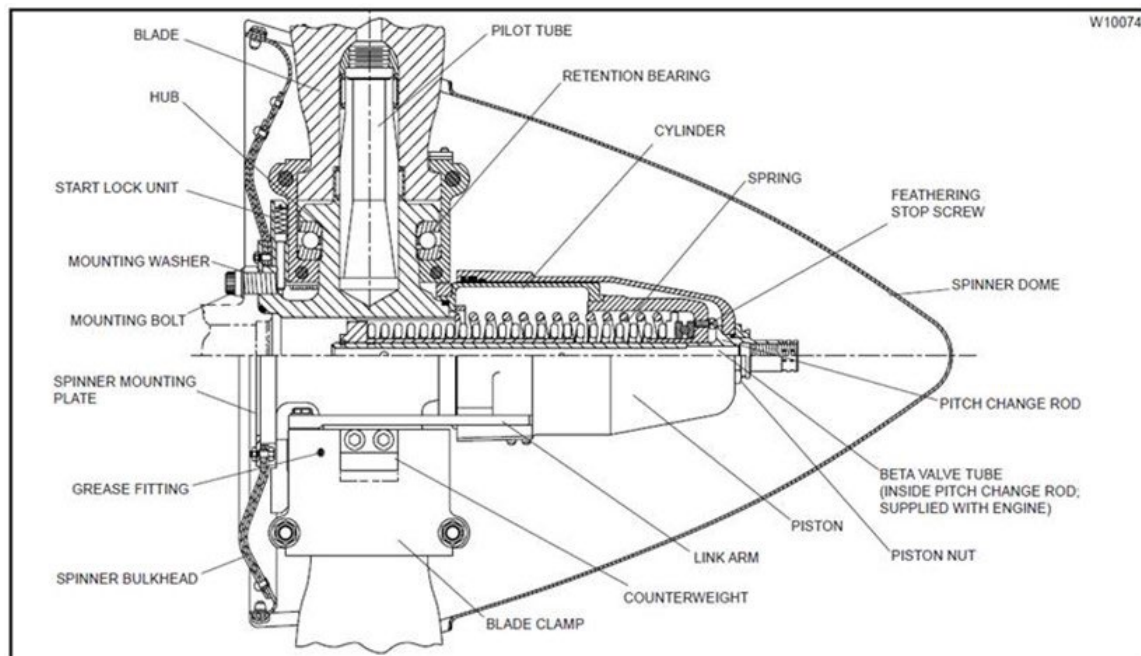


Figure 4. Hartzell Propeller Model HC-B3TN-5 Diagram

Figure Courtesy Hartzell

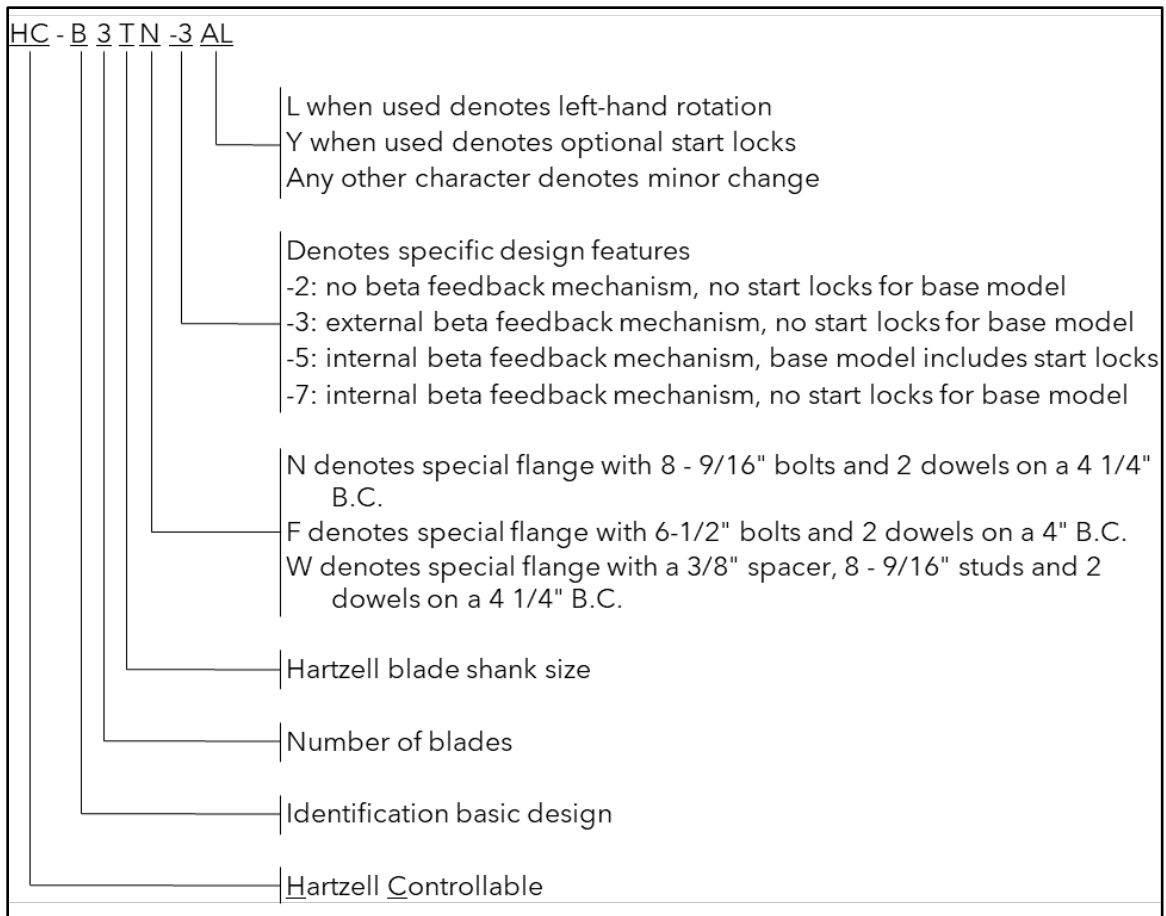


Figure 5. Hartzell Propeller Model Naming Convention

The propeller blade model was T10282N+4 (**Figure 6**). The Hartzell Installation Data Sheet IDS-1735 shows this installation was approved under Supplemental Type Certificate STC-SA7987SW. The propeller blade is an aluminum alloy construction with a tip diameter of 106.5 inches². This propeller blade has a maximum continuous rating of 725 horsepower (hp) at 1,591 rpm and a takeoff rating of 776 hp at 1,591 rpm.

² Actual blade diameter is 106 inches. Installation into the hub adds an additional 0.5 inches.

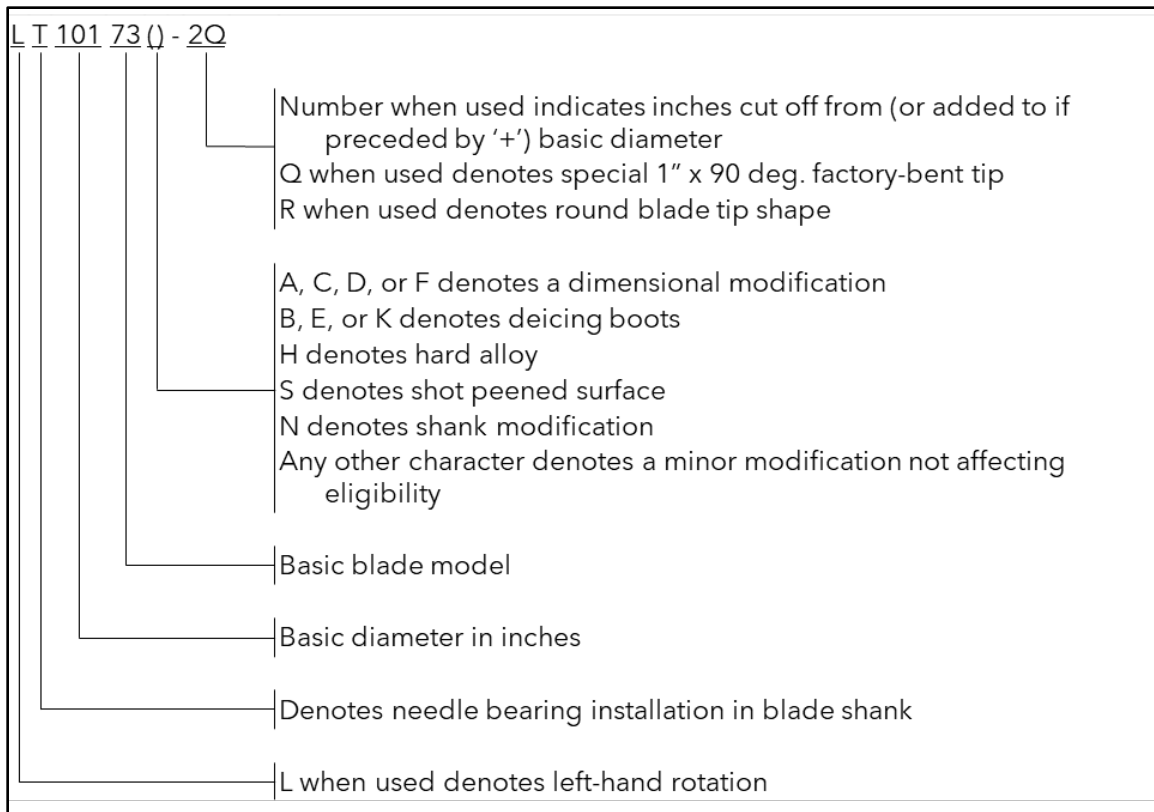


Figure 6. Hartzell Propeller Blade Naming Convention

2.0 Engine Maintenance History

2.1 Engine History - ESN P92203C

According to the initial accident report (NTSB Form 6120.1- Pilot/Operator Aircraft Accident/Incident Report) written by the pilot (owner) on June 18, 2023, ESN P92203C had a Time Since New (TSN) of 14,585 hours and Time Since Overhaul (TSO) of 8,428.2 hours.

The last recorded annual inspection of the airplane was performed on May 1, 2023 by Loup City Air Service, Nebraska, and found to be airworthy. The fuel filter element, located on the fuel pump, was removed/replaced on March 28, 2023 and the fuel nozzles were replaced with an overhauled set on March 2, 2022 by Bloomfield Ag and Ariel.

According to the engine logbook, the last engine removal recorded in the logbook was an entry dated July 17, 2014, with the engine being removed for scheduled maintenance by AG-Air Turbines Inc. in Midvale Indiana. The next engine logbook entry dated August 18, 2014, states work was performed on the hot section, propeller pitch control, gearbox, the fuel control, compressor, and turbine bearings, followed by

reinstallation of the engine into the aircraft. An aircraft logbook entry data August 29, 2014, states ESN P92203 was reinstalled and rigged to the airplane. There were no further logbook entries related to the fuel control unit (FCU), fuel pump (FP), propellor governor (PG), or the fuel shutoff valve (SOV) after the August 18, 2014, record.

The part number and serial number of the installed FCU correspond to the part number (PN) and serial (SN) listed on the component traceability sheet in the engine logbook entry dated September 4, 1987, by AG-Air Turbines Inc.

According to the engine logbook entry dated March 2, 2006, the FCU was removed to replace the stub shaft, the quill shaft, the spring assembly, the lock ring, and 3 rod ends, then reinstalled the engine and the rigging was checked.

A logbook page containing the engine's component traceability list shows that ESN P92203 was overhauled by GGASC PHX (Garrett General Aviation Service Center³) on September 4, 1987, with the corresponding TSO being reset to a value of zero and logbook entry, dated June 3, 2003, shows that ESN P92203 was installed in the aircraft. Logbook entries dated May 7, 2003 and August 18, 2014, show that Ag Air Turbines performed hot section inspections (HSI) on the subject engine.

The TSO and TSN times for these events as well as the times on the day of the accident are listed in the table below.

Sept. 4, 1987	Engine Overhaul	TSO= 0	TSN= 6,156.8
May 7, 2003	HSI	TSO= 4,907	TSN= 11,063.8 (calculated)
Jun. 3, 2003	Engine Installed	TSO= 4,907	(Hobbs= 0)
Aug. 18, 2014	HSI	TSO= 7,490.7	TSN= 13,647.5
Jun. 7, 2023	Accident	TSO= 8,428.2	TSN= 14,585

According to the Honeywell manual, TPE331-72-0402 (Time Between Overhaul (TBO) Intervals), the TBO for this engine is either 3600hrs or 5400hrs depending on the operator's chosen engine management approach. The engine logbook does not contain any record of an engine overhaul performed after the September 4, 1987 overhaul event and the recorded TSO values exceed the Honeywell TBO limits defined in TPE331-72-0402.

3.0 Engine and Propeller Examination

The accident engine was examined and disassembled at the Honeywell facility in Phoenix, Arizona with persons from Honeywell flight safety and the NTSB and

³ Garrett General Aviation Service Center (GGASC), was previously owned by AlliedSignal Garrett, which later merged with Honeywell in 2004.

Hartzell Propeller in attendance. The examination took place on September 18, 2023, and was completed on September 20, 2023.

The propeller was not attached to the engine when the engine container was opened at Honeywell. According to Honeywell, the propeller was removed from the engine at the owner/operator's location during the wreckage exam and locally retained. A tabletop review/evaluation of propeller photos from the wreckage exam was later performed by a Hartzell Propeller representative in lieu of a propeller exam.

3.1 As Received Engine Condition

The engine was secured in a cardboard shipping box in the Honeywell Product Integrity Laboratory when the investigation team arrived (**Photo 1**). Honeywell reported that with the prior approval of the NTSB investigator-in-charge the shipping container had been opened and the engine removed for a visual scan.



Photo 1. Shipping Container (L), Engine As Received (R)

The engine was removed from the shipping container and according to the engine data plate the ESN was P92203C (**Photo 2**). The engine did not show any signs of uncontainment or external fire damage.

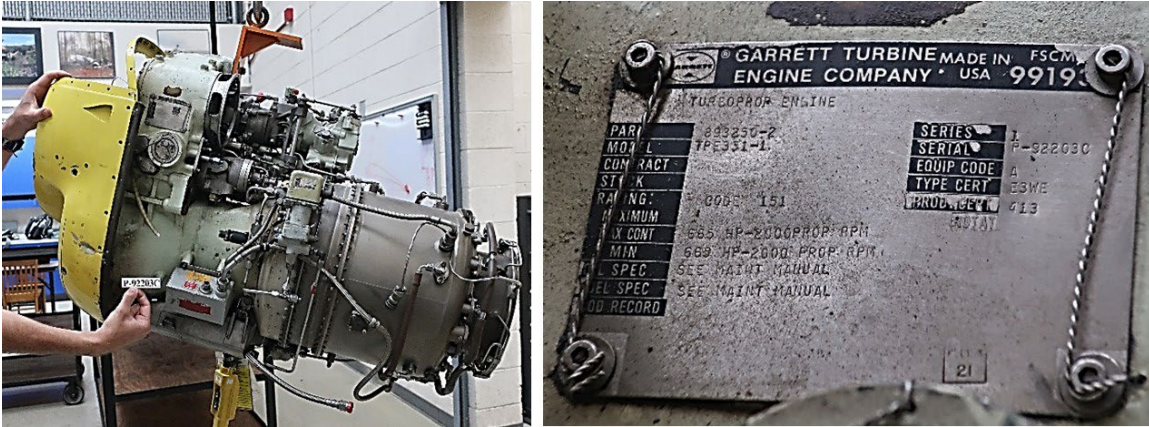


Photo 2. Engine Removed From Shipping Container (L), Engine Data Plate (R)

According to the on scene (wreckage exam) photos, the fuel control power lever indicator position showed a power setting at approximately the 40% position. With the engine still in the shipping container prior to teardown work at the Honeywell facility, the power lever indicator was observed to be at approximately the 20% position (**Photo 3**). Movement of the power lever linkage resulted in smooth and corresponding movement of the propeller pitch control (PPC) linkage.

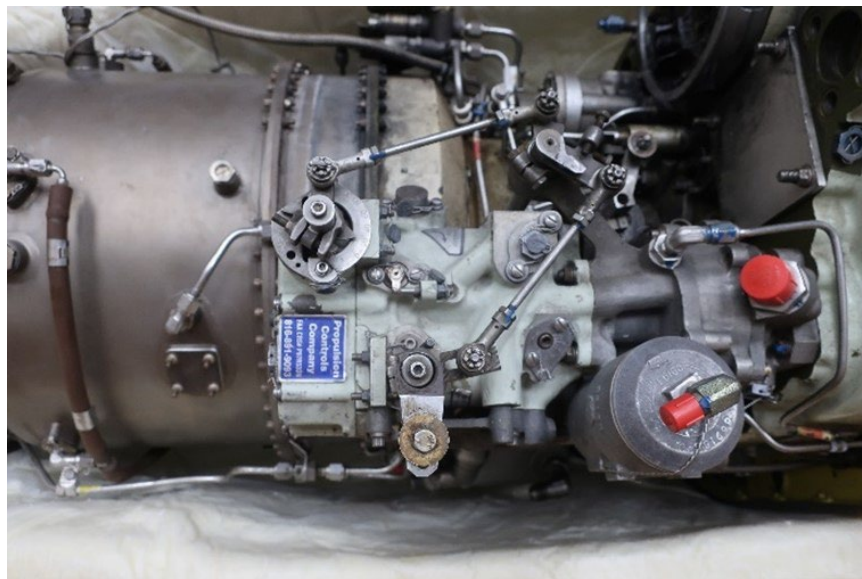


Photo 3. Fuel Control Unit - As Received

When looking through the exhaust, all the power turbine rotor blades appeared present, intact, and undamaged (**Photo 4**). Hand rotation of the power turbine rotor, as well as the starter generator shaft coupling, resulted in with smooth and continuous rotation of the propeller flange.



Photo 4. Power Turbine Rotor/Blades - Looking Through Exhaust Duct

The compressor inlet was covered with a film of earthen debris but otherwise the impeller appeared intact and undamaged (**Photo 5**).

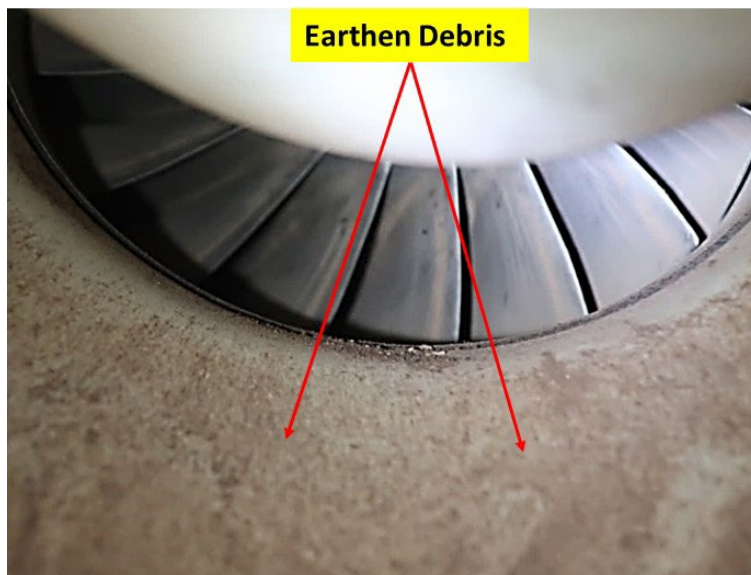


Photo 5. 1st Stage Centrifugal Impeller - Looking Through the Inlet

The starter/generator was not attached to the engine but was found separated during the on-scene wreckage exam. During the engine exam, a portion of the starter/generator drive shaft was found still contained within the accessory gearbox coupling. (**Photo 6**).

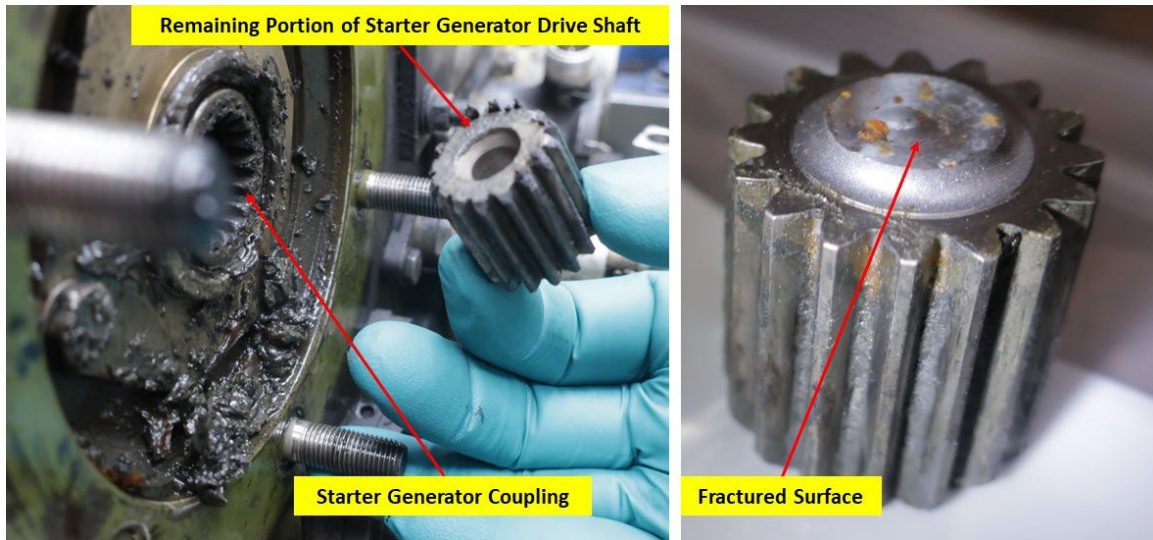


Photo 6. Remaining Section Starter Generator Drive Shaft

The oil bypass valve indicator, located on the side of the accessory gearbox (accessory case), was found in the extended (out) position and according to Honeywell this could have occurred as a result of the aircraft impacting the ground (**Photo 7**).

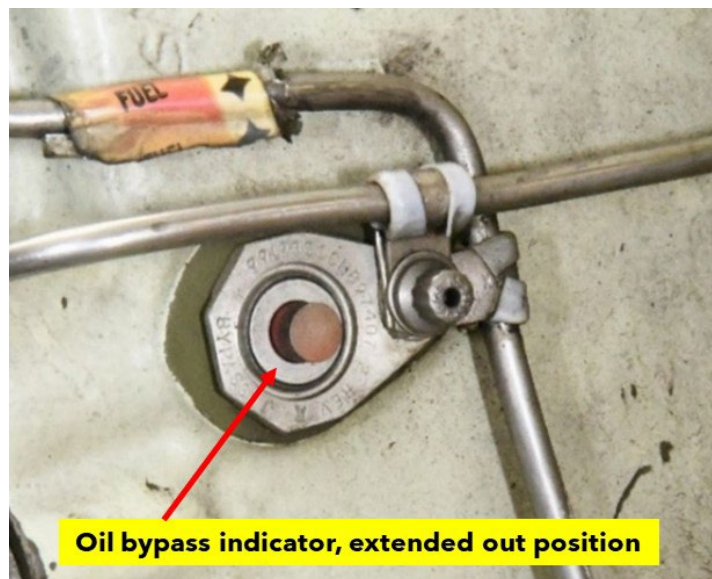


Photo 7. Oil Bypass Indicator - Extended/Out Position

During the as-received inspection, the FCU was found to be loose and displaced slightly aft of the accessory gearbox mount pad. The two bottom stud nuts were not fully seated, nor in contact with the fuel pump flange (**Photo 8**). The blue torque indication stripes, typically put in place at the time of installation, were also broken.

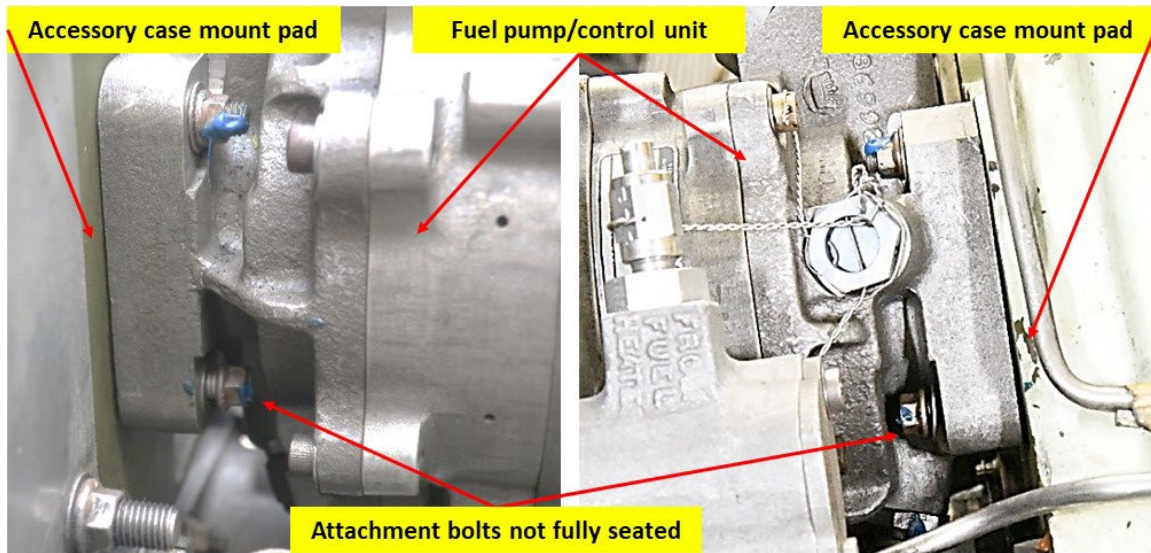


Photo 8. FCU Lower Left Side (L) and Lower Right Side (R)

The FCU mounting bracket, located at the lower left side and at the aft end of the FCU and attached to the compressor case flange, was found to be broken at the FCU bolt location (**Photo 9**).

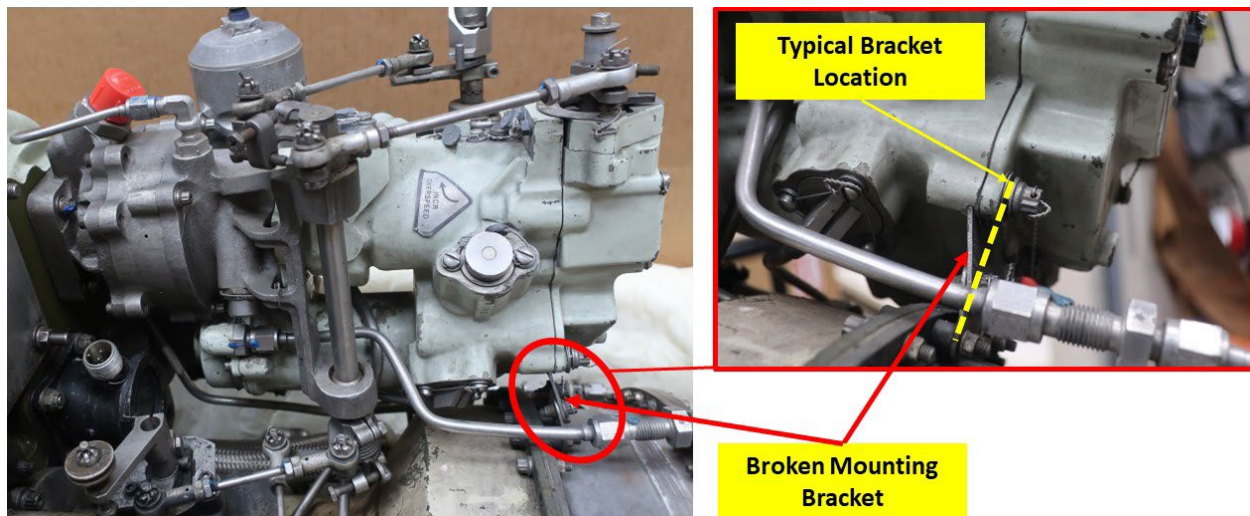


Photo 9. Broken FCU Attachment Bracket

The magnetic chip detector (MCD) was removed from the lower forward sump area of the accessory gearcase and inspected. The MCD appeared clean with no observed metallic particles adhered to the magnet (**Photo 10**).



Photo 10. Magnetic Chip Detector

3.2 Engine Teardown and Inspection

The oil was removed from the oil tank and, it had the appearance and odor typical of engine run oil and was unremarkable.

A fuel sample was taken from the bottom of the FP filter bowl. Visual examination of the fuel samples revealed what appeared to be a separation of two different density liquids; the fuel sample was held for future analysis (**Photo 11**). The fuel filter element was removed from the fuel filter housing; no evidence of damage or contamination was observed.

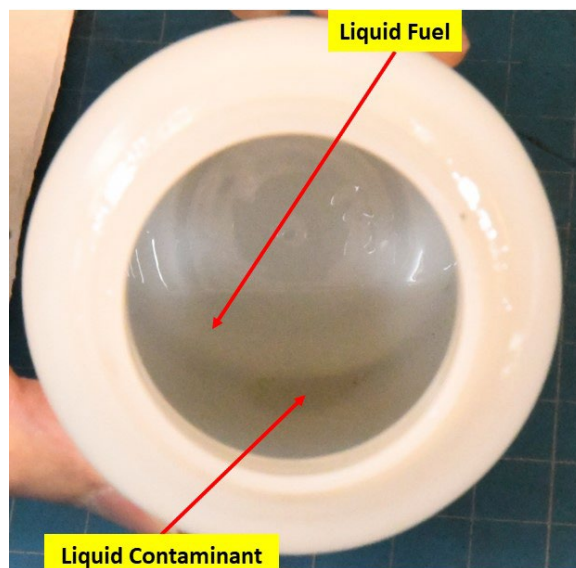


Photo 11. Fuel Sample with Contamination

The mechanical indicator of the fuel shutoff valve was observed to be in the open position as seen by the indicator line (**Photo 12**) being in line with the valve body. However low pressure air could not be passed through it confirming that in fact the fuel shutoff valve⁴ was actually in the closed position.

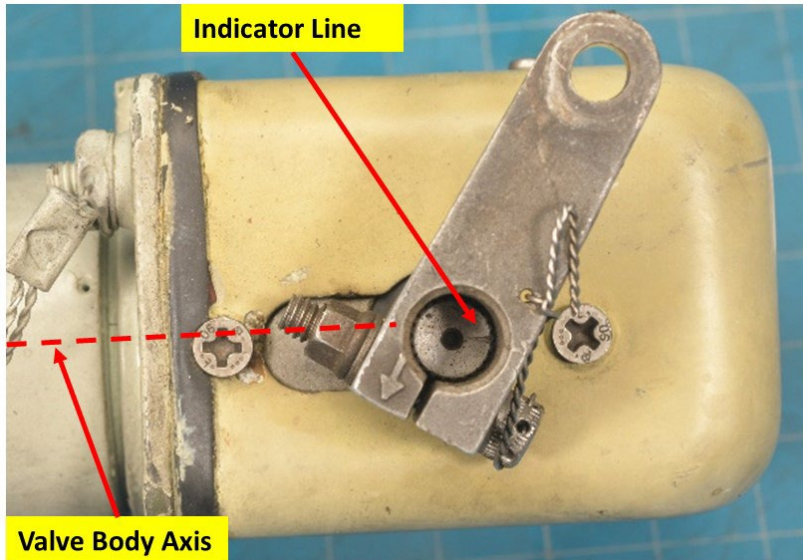


Photo 12. Fuel Flow Shutoff Valve, Shown Mechanically in the Open Position

The FP and FCU was removed as one assembly from the accessory gearbox, which required removal of four stud nuts (between the gearbox and the FP). Three of the stud nuts were removed normally, however, the fourth nut (lower right side nut) was seized in place and could not be unthreaded off the stud. This fourth stud was cut with a reciprocating saw (**Photo 13**) in order to facilitate removal of the FP/FCU assembly. Once the FP drive shaft was exposed, the drive shaft splines were found intact with no evidence of damage (**Photo 14**).

⁴ The fuel shutoff valve can be electrically opened or closed but can not be mechanically opened once closed.



Photo 13. Removal of the Fuel Control Unit



Photo 14. Fuel Pump Drive Shaft

With the nose cone removed, there was no evidence of damage found on the exposed ring gear (**Photo 15**) nor the planetary carrier (**Photo 16**).

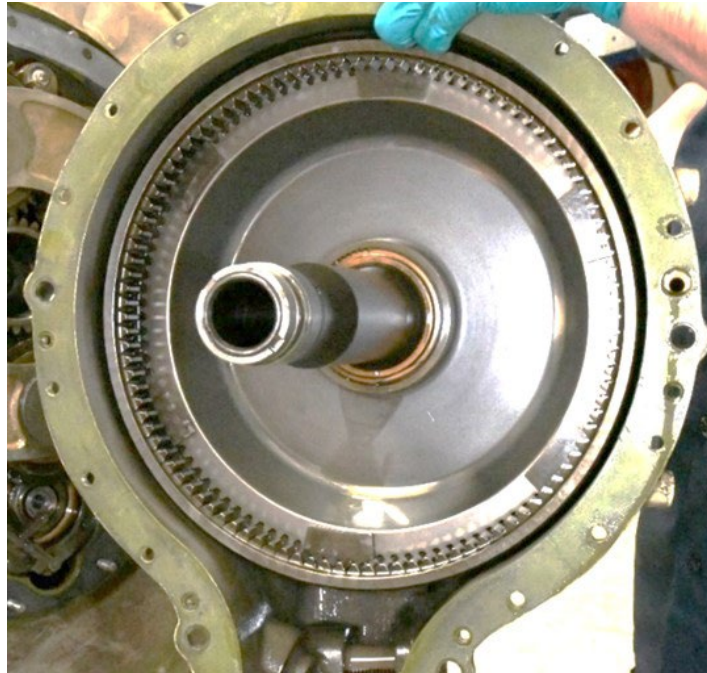


Photo 15. Ring Gear

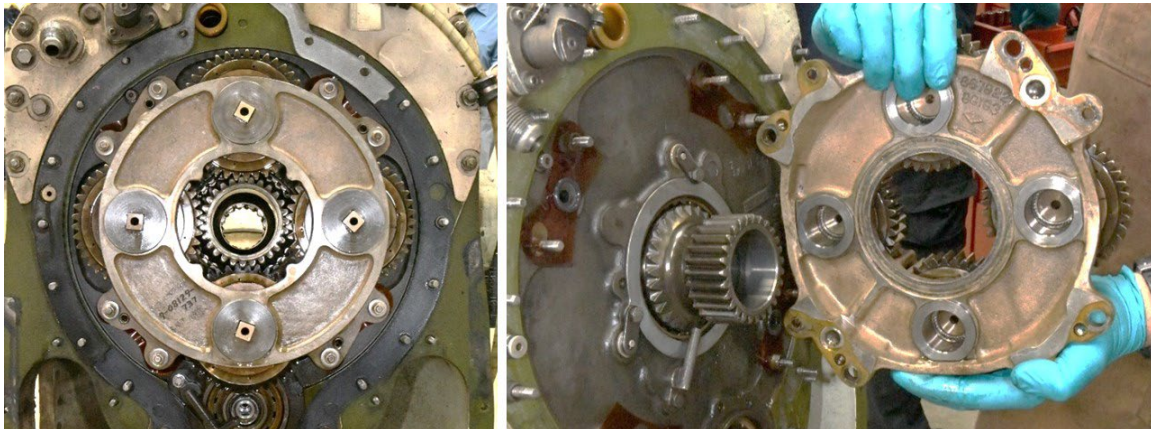


Photo 16. Planetary Carrier

Removal of the diaphragm exposed the accessory gearbox interior which appeared in good condition with no evidence of damage. The exposed gears and bearing elements appeared shiny and oil wetted. Continuity between all gears was reconfirmed. The sun gear exhibited localized raised metal on the inner diameter (ID) bore of the gear (**Photo 17**)

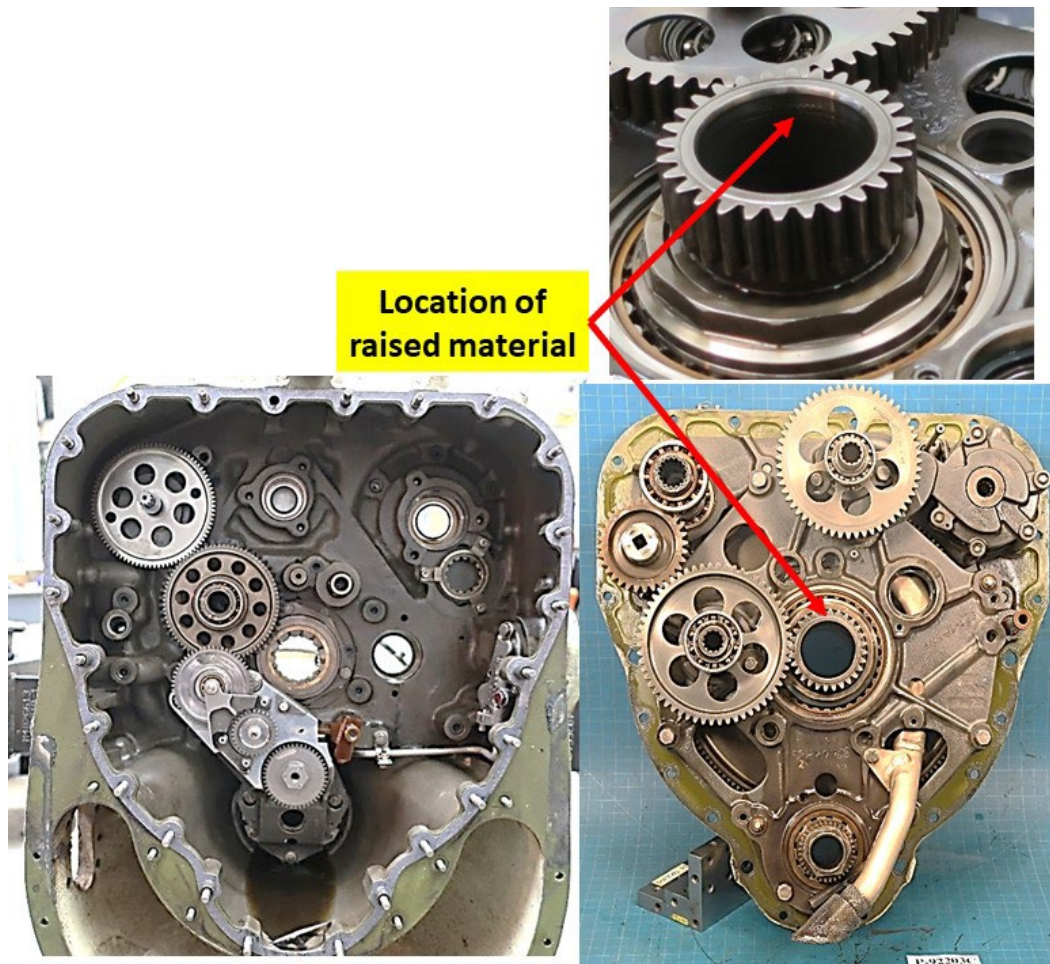


Photo 17. Gearbox Accessory Case (L) and Accessory Gearbox Diaphragm (R)

A circumferential score mark was found on the propeller shaft, approximately 1.5 inches in length near the mid shoulder (?) which corresponds to an area of rough (raised material) on the aft ID of the gear bore (**Photo 17**). Additional rubbing contact was observed on the aft end of the propeller shaft (**Photo 18**).

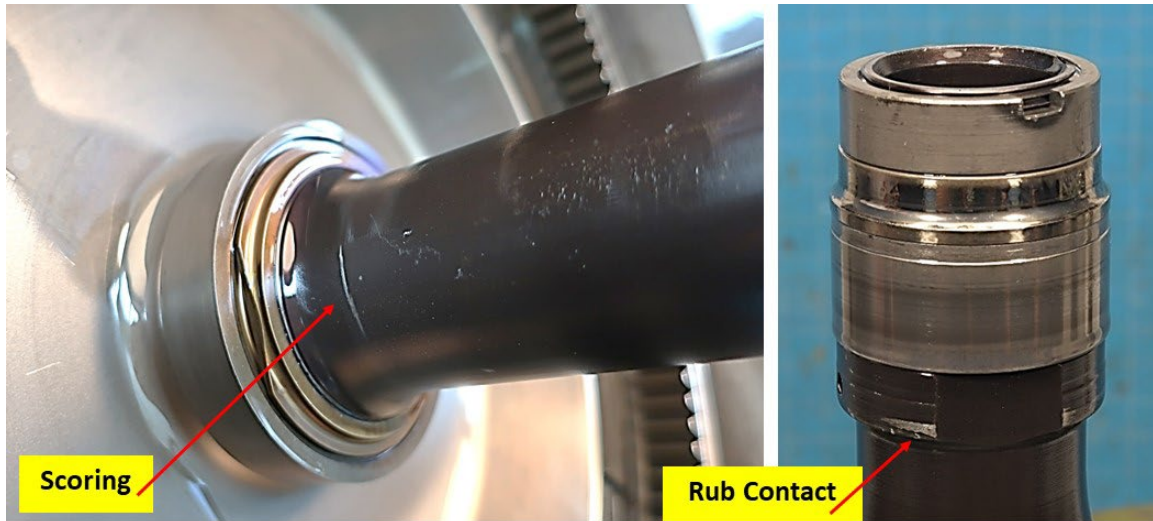


Photo 18. Propeller Shaft Scoring (L) and Shaft Rub/Contact (R)

The quill shaft, which is located inside the coupler shaft and preloads the coupler and torque sensor in a positive direction, appeared to be straight with no evidence of damage (**Photo 19**).



Photo 19. Quill Shaft

All stage 3 turbine rotor blades were present, intact, and found to be undamaged with no signs of blade tip rub/contact. The stage 3 turbine rotor curvic coupling teeth, located on the forward side of the disk, were in good condition. The stage 3 nozzle exhibited no evidence of damage but earthen material was found on both the turbine 3 rotor and nozzle. (**Photo 20**).

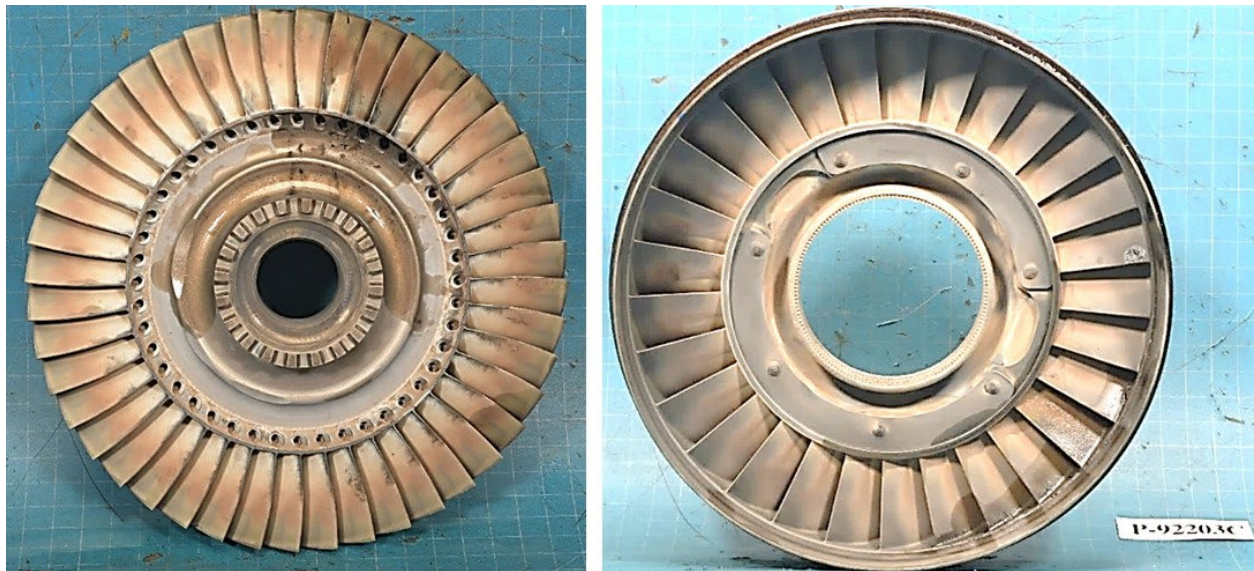


Photo 20. Stage 3 Turbine Rotor (L) and Stage 3 Nozzle (R)

All stage 2 turbine rotor blades were present, intact, and found to be undamaged with no signs of rub/contact on the blade tips. The stage 2 turbine rotor curvic coupling teeth on both the forward and aft sides were in good condition. Similarly, the stage 2 nozzle exhibited no evidence of damage. Earthen material was present on both the stage 2 turbine rotor and nozzle (**Photo 21**).

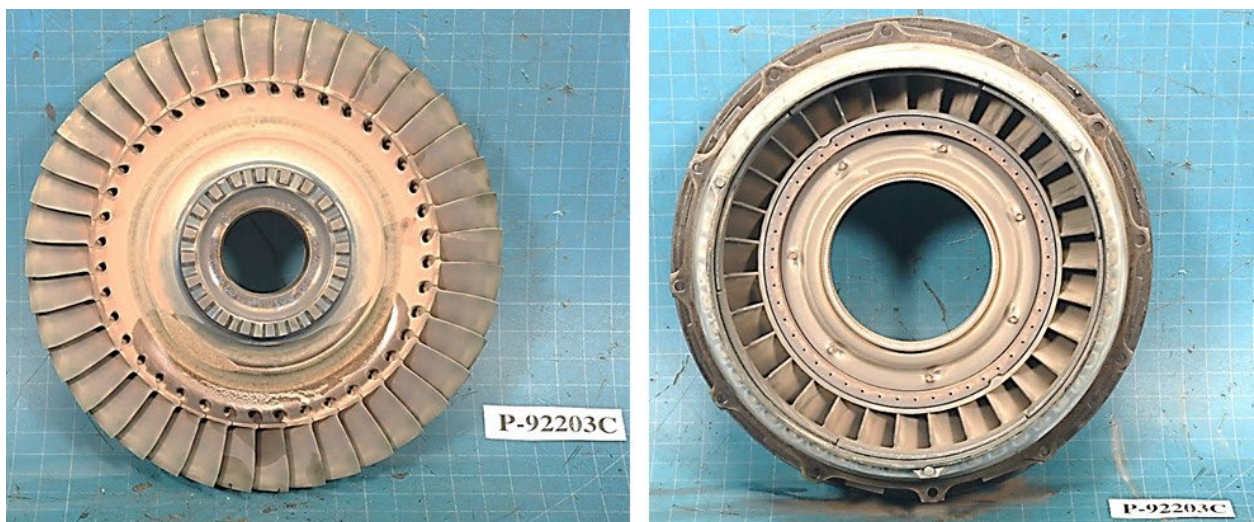


Photo 21. 2nd Stage Turbine Rotor (L) and Stage 2 Nozzle (R)

All stage 1 turbine rotor blades were present, intact, and found to be undamaged with no signs of rub/contact on the blade tips. The stage 1 turbine rotor curvic teeth were in good condition and earthen material found on the turbine 1 rotor. (**Photo 22**)

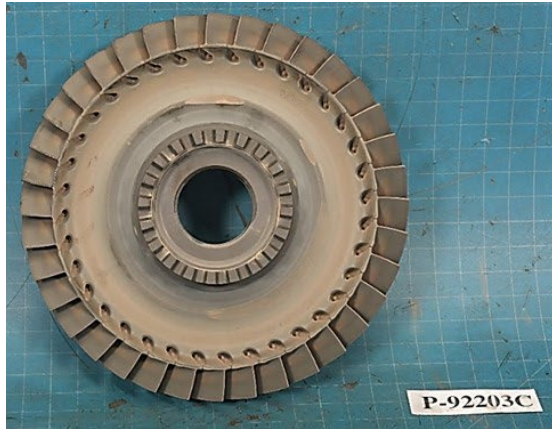


Photo 22. Stage 1 Turbine Rotor (L) and Stage 1 Turbine Blade Tips (R)

All the vanes of the stage 1 nozzle were present and intact but were found with cracks emanating from the trailing edge of the majority of the vanes (**Photo 23**) and earthen material was observed on the stage 1 nozzle.

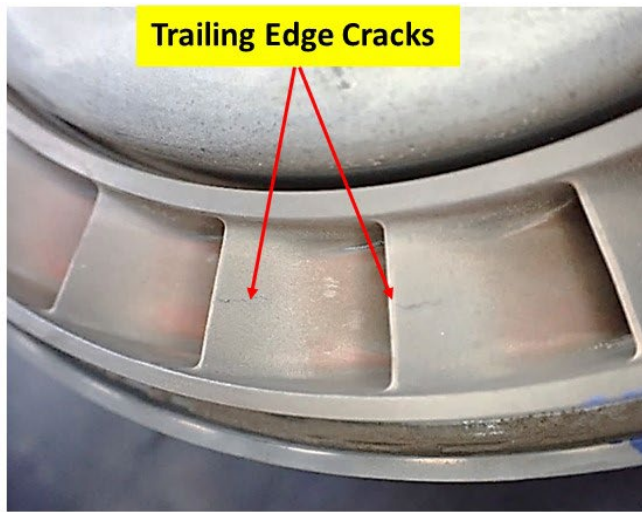


Photo 23. Stage 1 Nozzle (L) with Trailing Edge Cracks (R)

The combustion chamber appeared in good condition and the presence of earthen debris within the combustor was observed. There was no evidence of burn-throughs, hot spots, or fuel nozzle streaking patterns on any of the combustor panel (**Photo 24**).

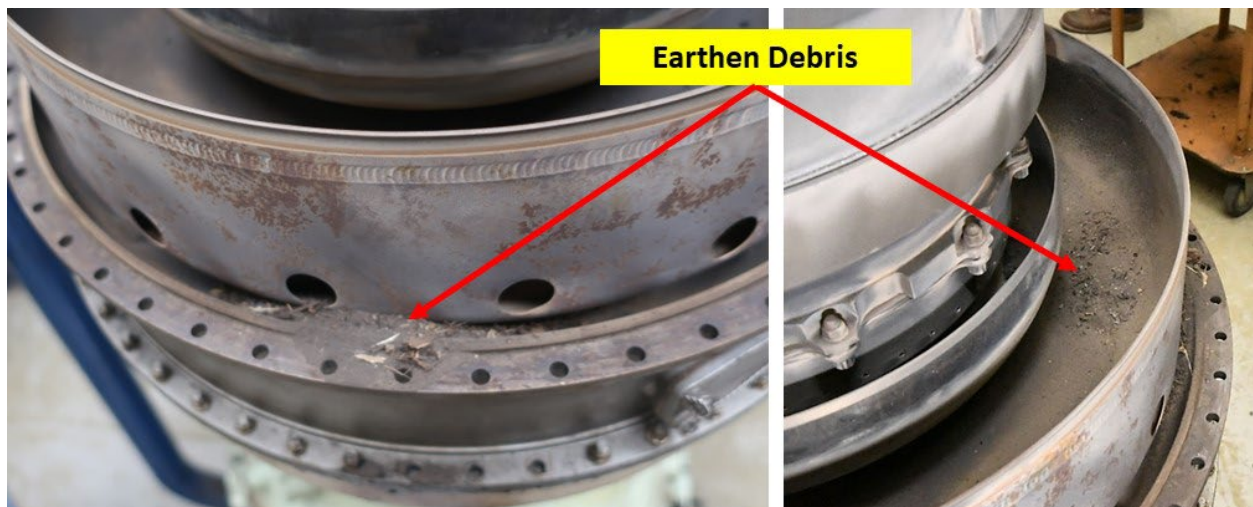


Photo 24. Earthen Debris Within the Combustion Chamber

The fuel nozzles and the swirlers did not exhibit evidence of streaking or coke accumulation (**Photo 25**).



Photo 25. Fuel Nozzles

Earthen debris was found on the aft side of the stage 1 crossover duct (**Photo 26**) at the 6:00 o'clock position.

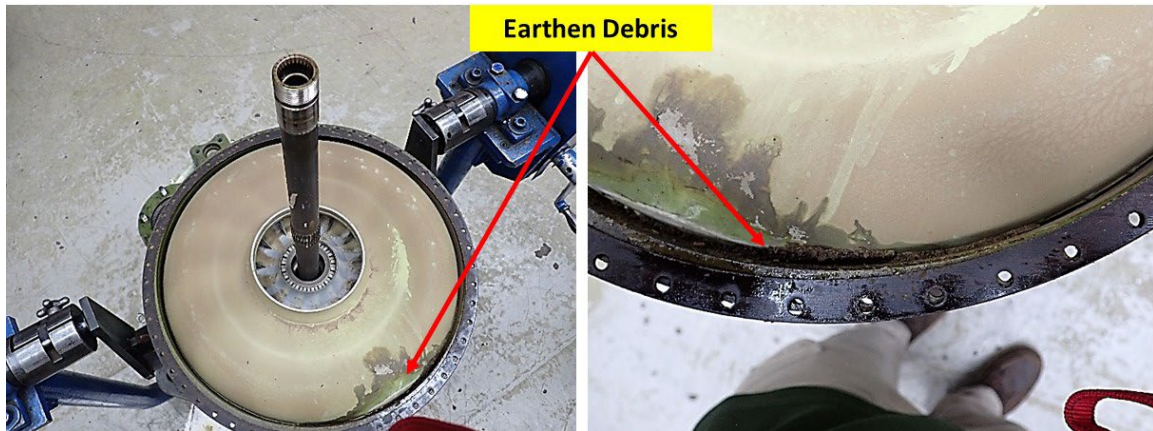


Photo 26. 1st Stage Compressor Crossover Duct (L), Earthen Debris (R)

The aft end of the torsion shaft was found fractured and still splined into the main shaft with the fracture surface approximately 1.25 inches from the aft end of the torsion shaft (**Photo 27**).

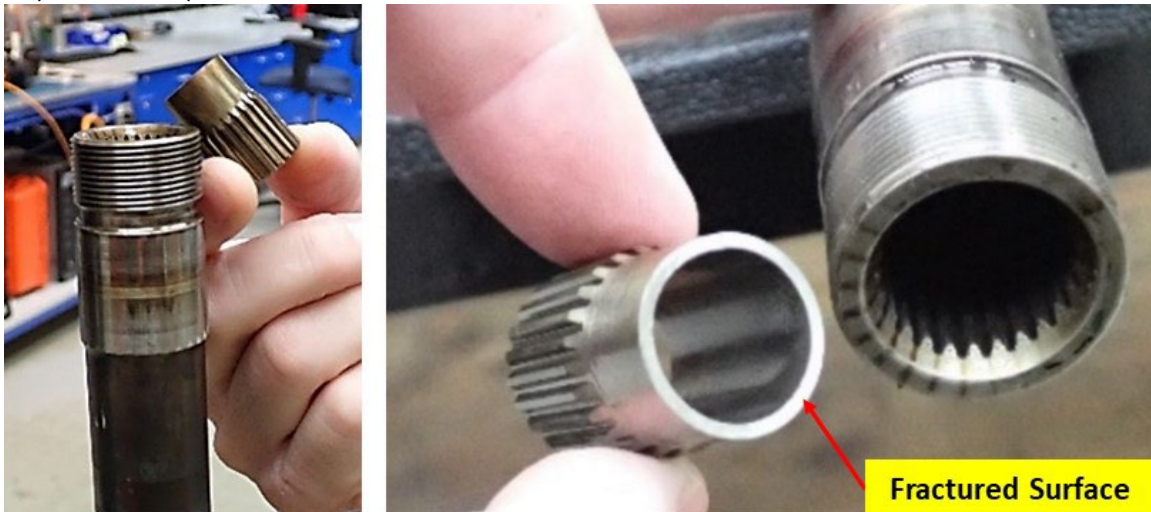


Photo 27. Torsion Shaft (L), Fractured End Piece (R)

The forward end of the stage 2 impeller curvic coupling teeth showed even wear consistent with operation and no evidence of damage (**Photo 28**).



Photo 28. Forward End (Inducer) of the Stage 2 Impeller (Installed)

The stage 2 impeller showed evidence of circumferential rub on all of the impeller blades (**Photo 29**) that corresponds with the circumferential rubbing located on the impeller shroud (**Photo 30**). Honeywell indicated the leading edge of the impeller (inducer) appeared to be misshapen and all leading edge blade fillets contained a scallop-like feature.

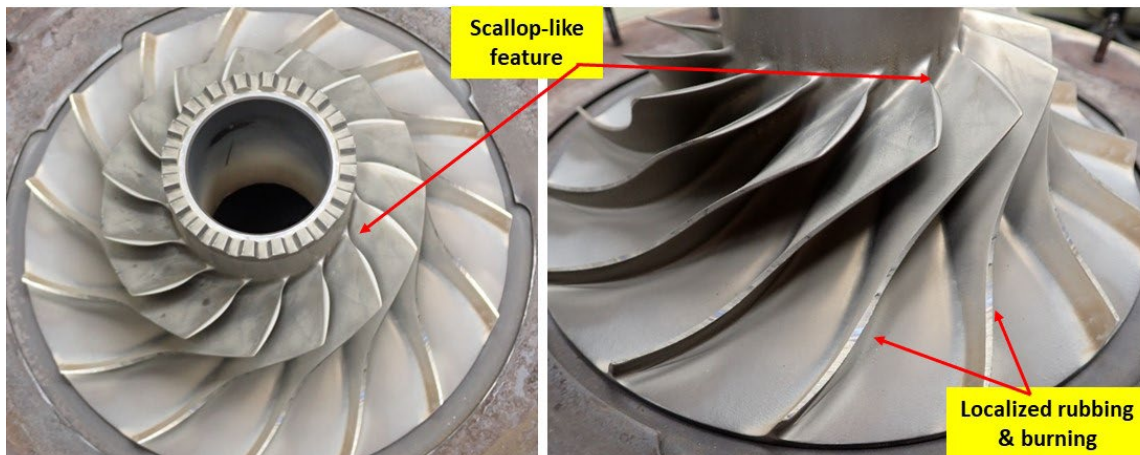


Photo 29. Stage 2 Impeller, Localized Circumferential Rubbing Contact

The stage 2 impeller shroud and crossover duct showed evidence of circumferential rub (**Photo 30**) corresponding to the rub observed on the stage 2 impeller.

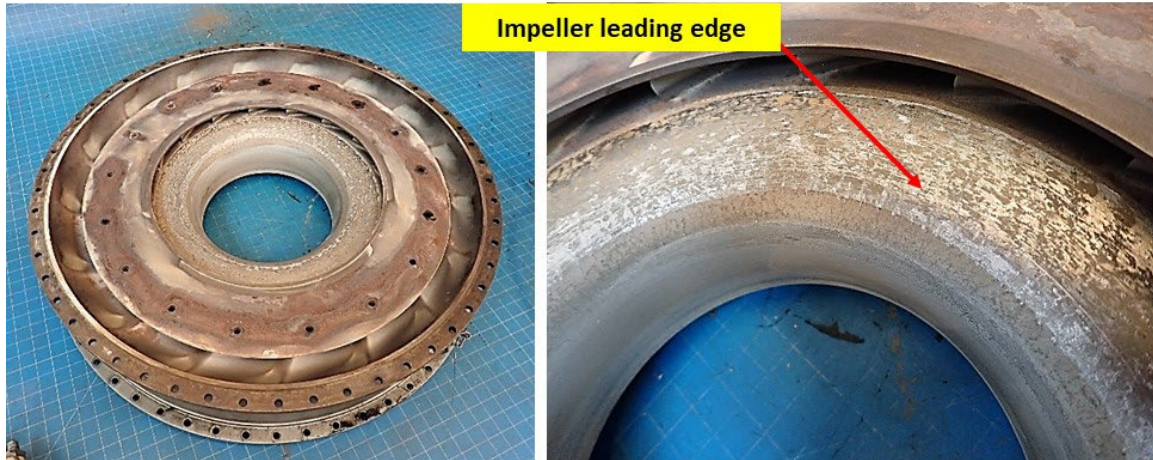


Photo 30. Stage 2 Impeller Shroud with Circumferential Contact/Rub

The stage 1 impeller showed no evidence of damage or rubbing contact but earthen debris was present (**Photo 31**).

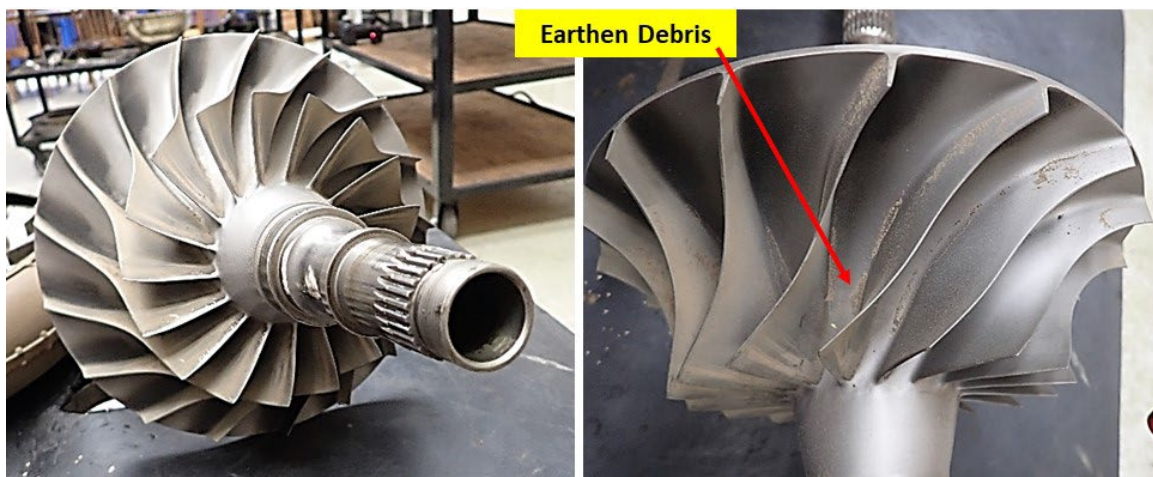


Photo 31. Stage 1 Impeller & Main Shaft (L) with Earthen Debris (R)

The last chance screen in the fuel flow divider was removed and inspected. No debris/particles were present and no evidence of damage was found (**Photo 32**).



Photo 32. Fuel Flow Divider Assembly (L) and Filter Screen (R)

The FP was removed from the FCU. The FP filter screen was removed and it exhibited no debris/particles and no evidence of damage. The FP drive shaft exhibited no evidence of damage and hand rotation was found to be smooth and continuous (**Photo 33**).

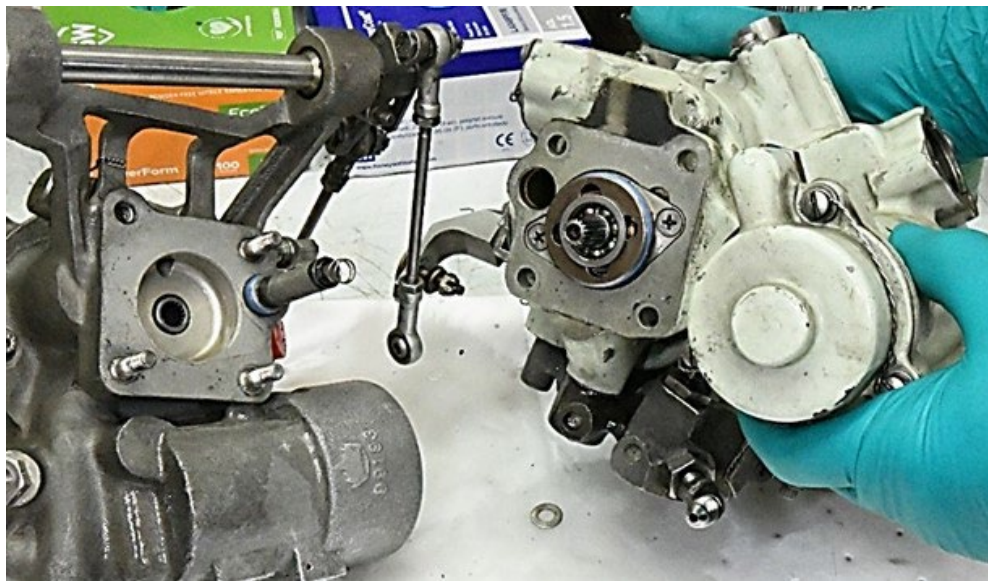


Photo 33. Fuel Pump AND Fuel Control Unit - Separated

4.0 Hartzell Propeller Exam

The propeller was not examined as part of the engine exam at Honeywell but a representative of Hartzell Propeller reviewed photographs taken during the on-scene wreckage exam. According to Hartzell, the propeller to be under at least partial power

based on the condition and damage seen in the photographs. Hartzell's assessment stated: all three propeller blades exhibited chordwise/rotational scoring on what appears to be predominantly on the camber (front) side of each blade, all three propeller blades exhibited compound bending/twisting and what appears to be bending in the direction opposite of rotation, one propeller blade exhibited a tip fracture and one propeller blade exhibited some bending in the forward/thrust direction (**Photo 34**).



Photo 34. Three Bladed Hartzell Propeller (Courtesy of Honeywell)

Hartzell's assessment also stated: the two propeller blades/clamps that pulled from their link arms appear to have forcefully rotated towards high pitch, this might explain the forward bending on the one blade (**Photo 35**). This is a common signature of producing thrust at initial impact.

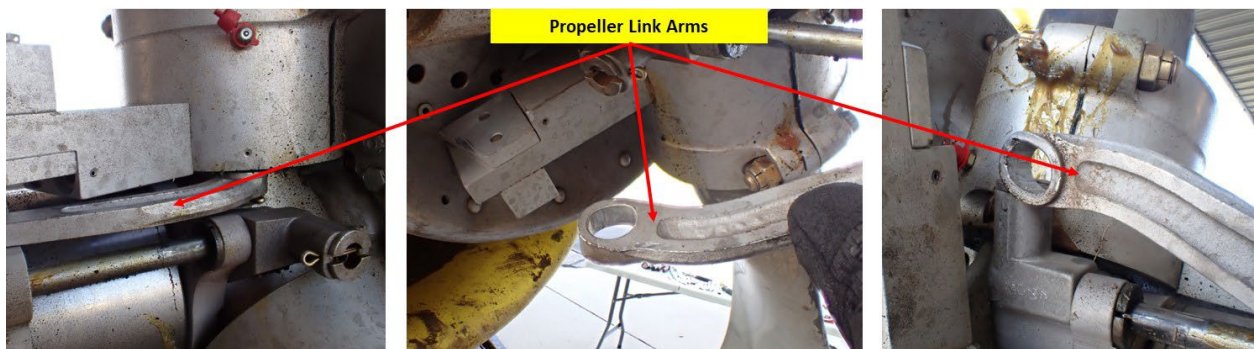


Photo 35. Propeller Blade Clamps (Courtesy of Honeywell)

5.0 Honeywell Metallurgy (Stage 1 Nozzle, Torsion Shaft, Fuel Sample)

The stage 1 turbine nozzle and the fractured torsion shaft were submitted to Honeywell's metallurgy lab in Phoenix, Arizona for analysis.

Honeywell used scanning electron microscopy (SEM) and energy dispersive x-ray (EDX) to evaluate the stage 1 nozzle for and the presence of metal spray and to determine the fracture mode of the torsion shaft. Honeywell's analysis of the stage 1 nozzle found no metal spray present on the nozzle vanes but did reveal spots where the thermal barrier coating had spalled off and exposed based metal material.

The torsion shaft had separated 1.224 inches from the aft end. Honeywell performed SEM examination of the fracture surface on the torsion shaft that revealed fracture features indicative of torsional overload as indicated by elongated dimples in the counterclockwise direction. Analysis of the torsion shaft base material by EDX found the material conformed to the material specification.

The fuel sample taken from the fuel filter bowl containing a separated, liquid, contaminant was also submitted to Honeywell's metallurgy lab for analysis. Honeywell's analysis was performed with Fourier Transform Infrared (FTIR) spectroscopy, which showed the fuel was typical of Jet A fuel and the liquid contaminant that had separated out was water.

Refer to Attachment 1 for Honeywell's lab analysis report.

6.0 Fuel Control Unit and Prop Governor Examination

The FCU and PG were shipped to Woodward Inc. in Loves Park, Illinois for further examination. The examination occurred on December 5, 2023, with representatives from Woodward, NTSB and Honeywell in attendance.

6.1 Fuel Control Unit Exam

The accident FCU, Honeywell PN 869199-25, Woodward PN 8070-186, SN 923051, appeared intact and with one piece of customer (non-Woodward) hardware was attached as received (**Photo 36**).

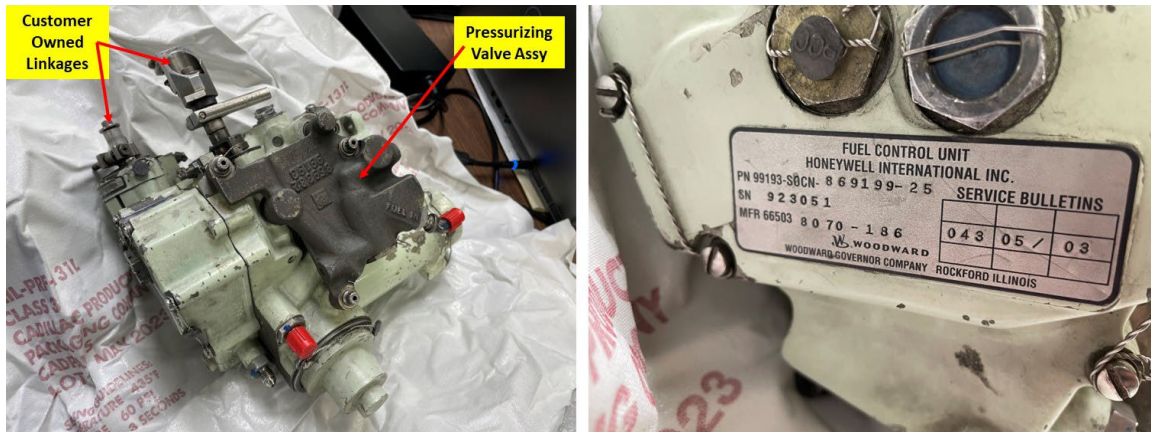


Photo 36. Fuel Control Unit - As Received (L), FCU Data Plate (R)

Bench testing of the FCU was performed according to acceptance test specification TSP-1629. Several test points were out-of-range based on the test standard as noted on the test report (Attachment 1). Test results appeared consistent with the cam gear travel being limited, but not seized, on the cam shaft during testing. A position indicator installed during testing verified that the cam shaft was able to translate, but with limited travel. The position indicator revealed movement of the cam shaft stop with a Pt2 of about 11 pounds per square inch absolute (psia).

Removal of the cam shaft and gear from the FCU housing could not be accomplished during normal disassembly because they were seized together, also preventing any further disassembly. Portions of the FCU housing were machined/milled out to facilitate removal of the cam gear and cam shaft from the FCU as one piece (**Photo 37**). According to Woodward Inc., all other internal FCU components appeared undamaged and typical of a used FCU. The 3D cam shaft assembly was shipped to the NTSB metallurgy lab for further examination.

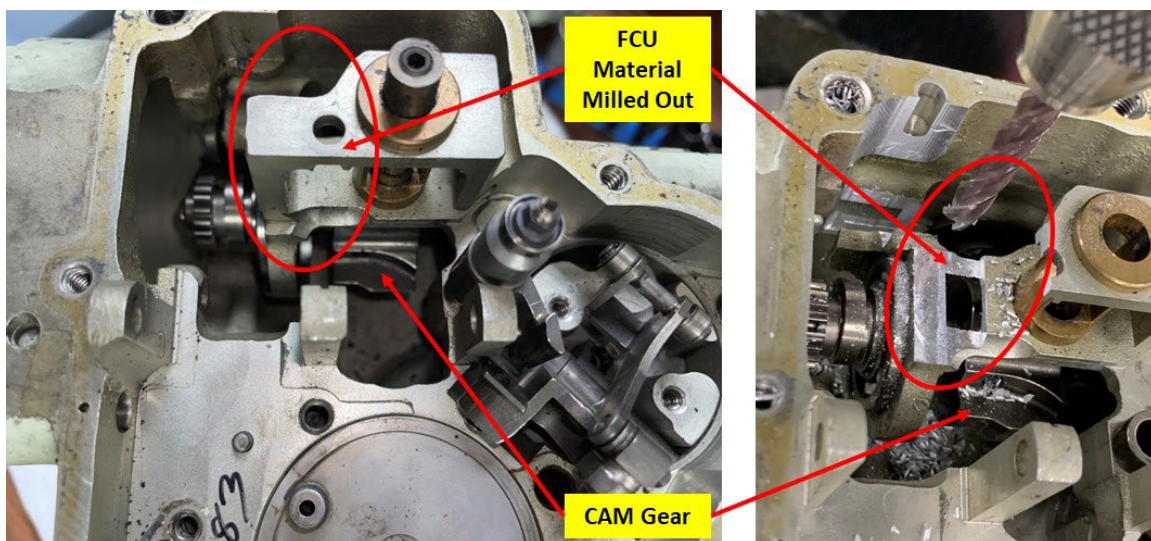


Photo 37. Cam Gear and Cam Shaft Removal

6.2 Propeller Governor Exam

Propeller governor Woodward PN 210736, SN 1113178, appeared intact and undamaged (**Photo 38**) The as received visual inspection was performed revealing the maximum speed lever and connecting hardware were customer owned hardware. The input drive shaft rotated freely under hand pressure and the control arm appeared intact and rotated normally. There were no findings to prevent performance of the As Received bench test.

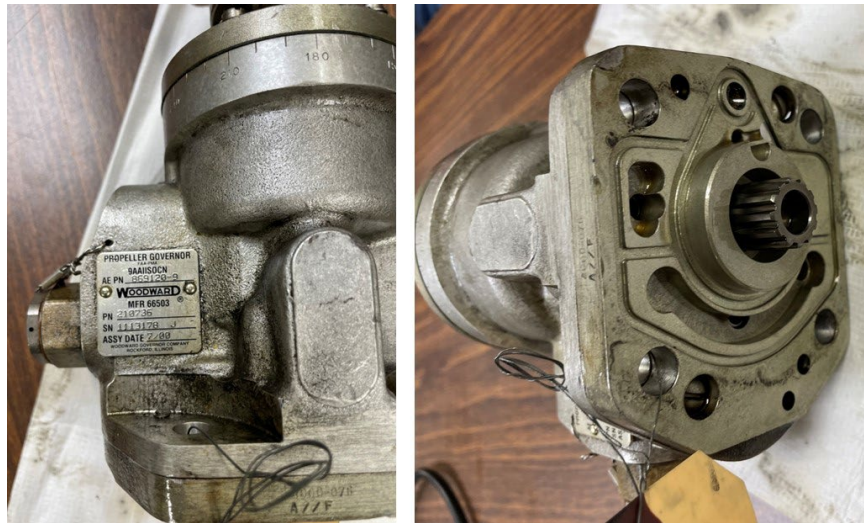


Photo 38. Propeller Governor

The as received bench test found all test points within limits except for the three parameters listed below. Refer to Attachment 2 for the full test results.

- Maximum RPM was out of limits high at 3865 rpm (Limits: 3574 +/- 10 rpm)
- Minimum RPM was out of limits high at 3560 rpm (Limits: 2815 +/-10 rpm)
- Arm Travel - Max to Min" was out of limits low at 20 degrees (Limits: 60 +/- 5 degrees)

According to Woodward Inc., these three parameters (Maximum RPM, Minimum RPM, and Arm Travel) are common field adjusted parameters and the presence of non-Woodward lockwire indicates a field adjustment was performed on this propeller governor. These three parameters being outside of standard Woodward Inc. defined limits would not preclude normal operation. Given the bench test results in parallel with no other findings or anomalies found, it was determined that further disassembly of the propeller governor was not warranted.

7.0 FCU Component Metallurgical Examination

The FCU 3D cam and shaft assembly was shipped to the NTSB Laboratory in Washington D.C. for group examination. The examination began on March 19, 2024 and concluded on March 20, 2024, with representatives from the NTSB and Woodward Inc. in attendance.

As received photography and visual examination (**Photo 39**) was performed and, as noted in the FCU testing section, the 3D cam was seized in place on the cam shaft. To facilitate examination, the remaining FCU housing that houses the cam shaft bearing was cut away, exposing the bearing out race, and the assembly was ultrasonically cleaned in an acetone bath.

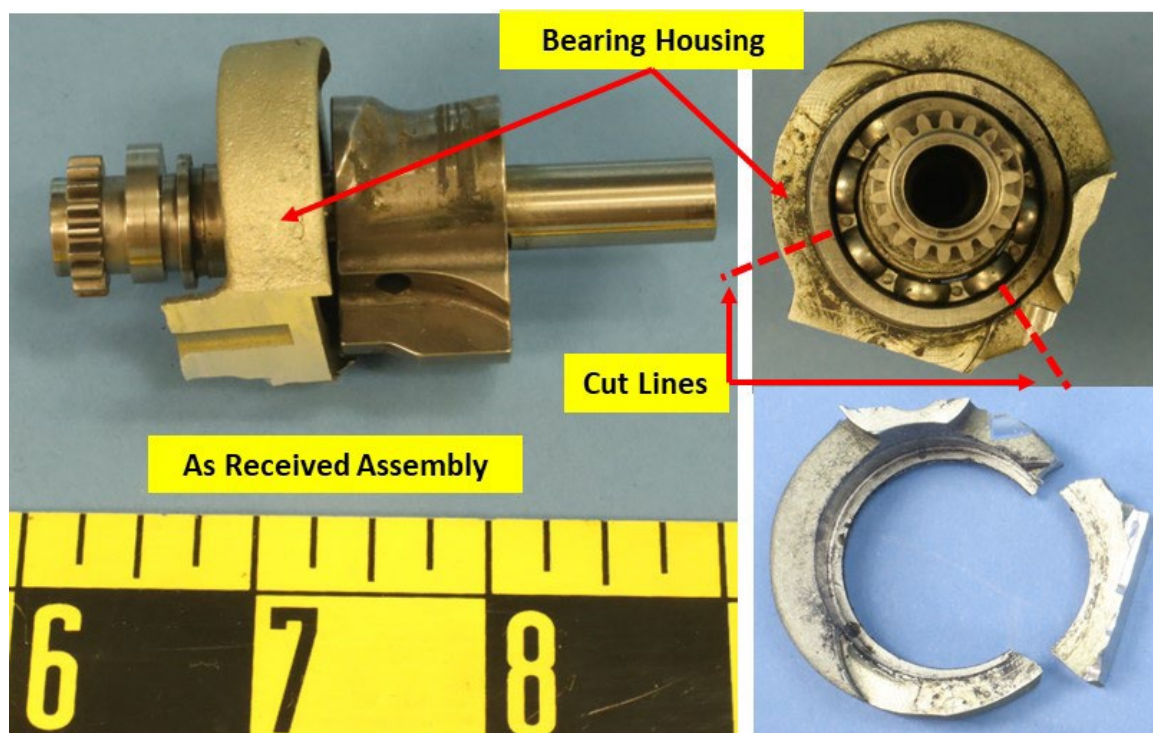


Photo 39. 3D Cam Shaft Assembly As-Received (L), Bearing Housing Removed (R)

To facilitate separation of the 3D cam and the cam shaft, the cam shaft was cut between the 3D cam and the bearing, once the cam shaft was cut the 3D cam slid off the cam shaft (**Photo 40**).

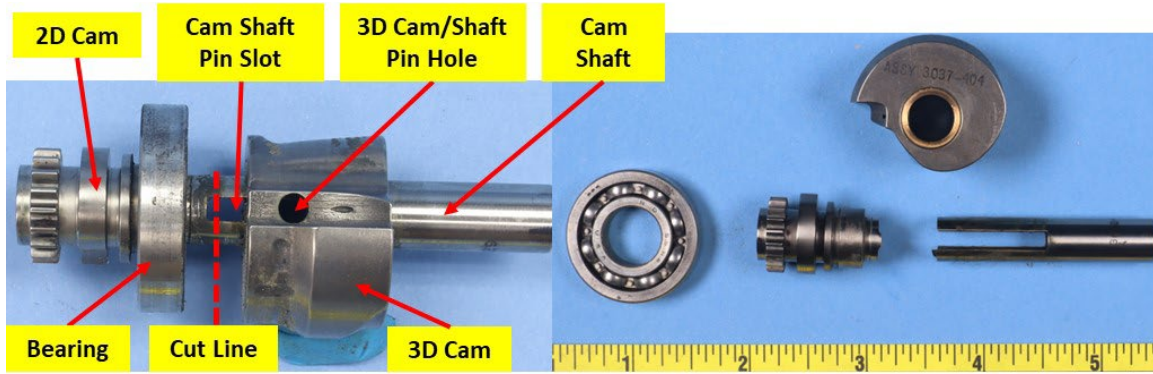


Photo 40. Cam Shaft Pre-Cut (L), Post-Cut (R)

Examination of the cam shaft found two depressions on opposite corners of the cam shaft slot, one depression was round in shape while the other was rectangular in shape (**Photo 41**). The shaft outer diameter, away from the areas of deformation damage measured 0.3735 inches, whereas the outer diameter measured in a plane incorporating both the areas of shaft deformation was as wide as 0.3780 inches. Reexamination of the 3D cam shaft pin by Woodward personnel revealed corresponding damage to the square portion of the pin shank.

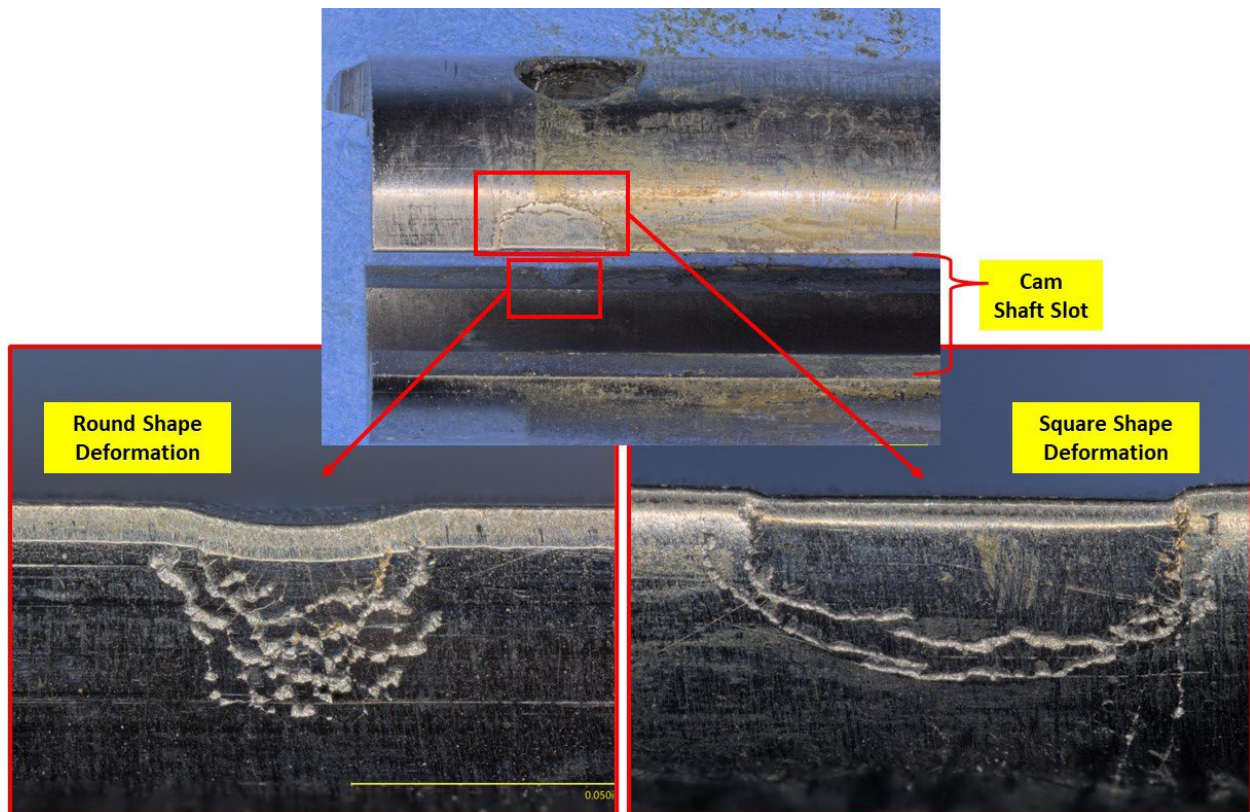


Photo 41. Cam Shaft Damage

The 3D cam bushing, made of a copper alloy, located at the inner diameter of the 3D cam, appeared to have areas of wear and distinct gouges located axially within the cam bushing on either side of the assembly pin hole (**Photo 42**) and correspond to the cam shaft slot edges. The 3D cam was sectioned in half to expose the surface of the bushing (**Photo 43**).

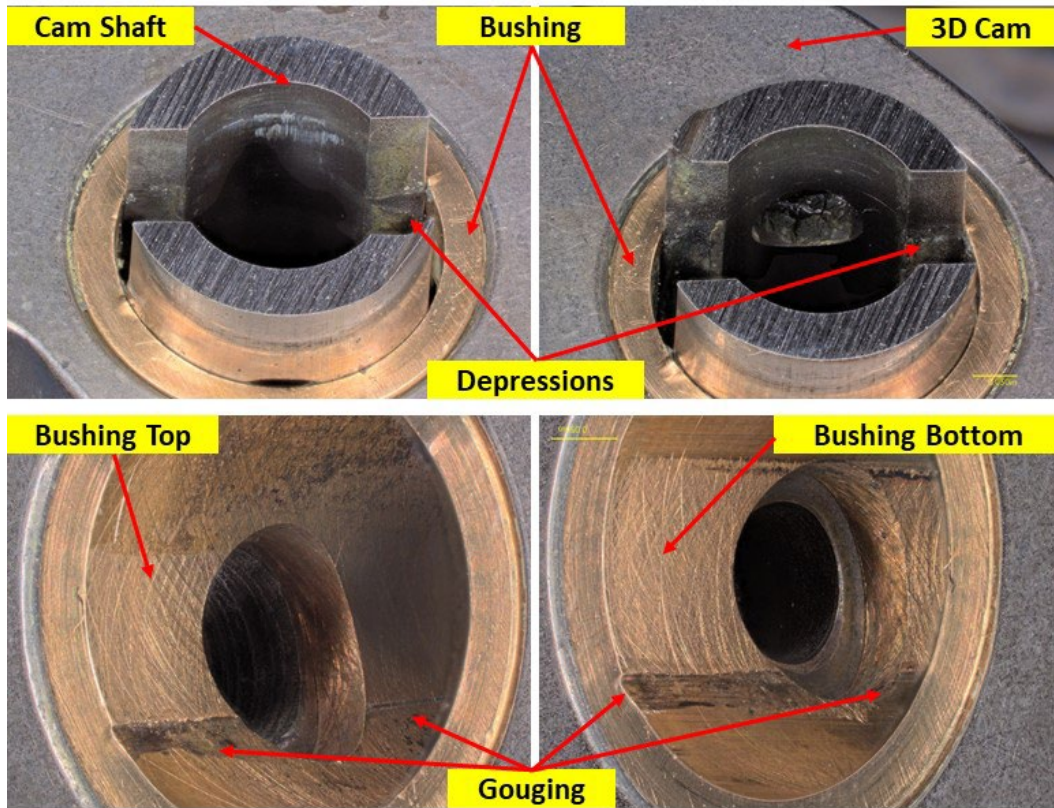


Photo 42. 3D Cam Bushing Damage

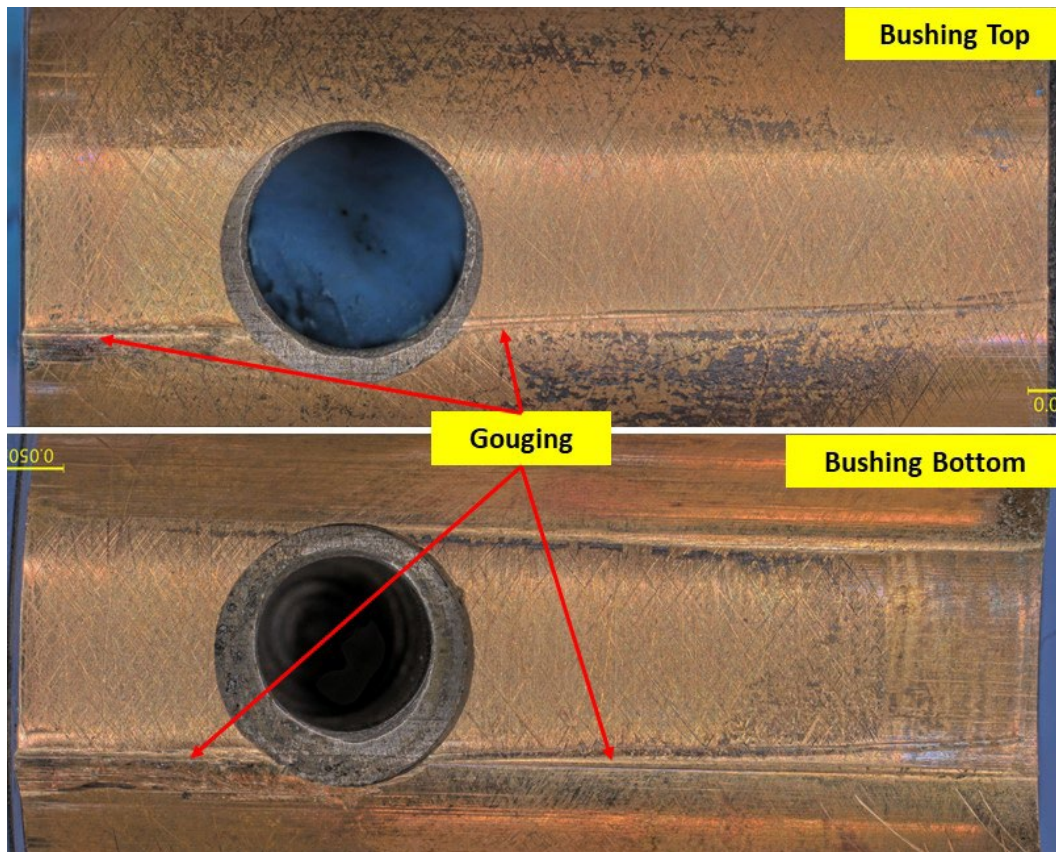


Photo 43. 3D Cam/Bushing Cut in Half

Examination also found that one gear tooth on the cam shaft exhibited signs of spalling damage and cracking across the entire length of the tooth (**Photo 44**). Woodward personnel reexamined the rack gear, which drives the cam shaft gear, and found damage between two gear teeth that corresponds to the damage found on the cam shaft gear tooth.



Photo 44. Cam Shaft Gear - Damaged Tooth

Refer to NTSB's Materials Group Factual report for the examination's complete evaluation.

ATTACHMENTS

1. Honeywell Lab Analysis Report (the version for the public docket)
2. Component Exam Test Results
3. Woodward Inc.'s Final Report

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