

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



CEN21LA237

POWERPLANTS

Group Chair's Factual Report

July 27, 2023

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A. ACCIDENT

Location: Celina, Ohio
Date: May 27, 2021
Time: 0750 Eastern Daylight Time (EDT)
1150 Coordinated Universal Time (UTC)
Airplane: Grumman G164B, N8376K

B. POWERPLANTS GROUP

Group Chair Robert Hunsberger
National Transportation Safety Board
Washington, DC

Member Dana Metz
Honeywell
Phoenix, Arizona

C. SUMMARY

On May 27, 2021, about 0750 eastern daylight time, a Grumman G-164B airplane, N8376K, was substantially damaged when it was involved in an accident near Celina, Ohio. The pilot sustained serious injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 137 aerial-application flight.

The engine was removed from the airplane and shipped to the Honeywell Product Integrity Laboratory in Phoenix, Arizona for examination and teardown. There was no evidence of pre-impact engine failure or other anomalies that would have precluded normal operation. Rotational scoring was observed at multiple locations including the compressor impeller blades, impeller shrouds, and propeller shaft. Light metal spray was adhered to the 3rd stage turbine stator vanes. Surfaces throughout the engine gaspath were coated with earthen debris.

The fuel control unit and propeller governor were shipped to Woodard in Loves Park, Illinois for examination and testing. The fuel control Standard Day Acceleration Schedule had significantly high out-of-limits fuel flow discharge at all test points and fuel control pressure readings did not respond normally to speed input changes. The Deceleration Schedule fuel flow discharge readings were low out-of-limits during testing. All other schedules were within the expected range for similar service run units that have undergone customer adjustments. The fuel control was disassembled and there was no evidence of internal failure. All springs were

intact, and all bearings and levers moved freely. The propeller governor was tested, and all test points were consistent with similar service run units.

The fuel pump was examined and tested at Honeywell in Phoenix, Arizona. The fuel pump was unable to hold pressure during bench testing and was subsequently disassembled. The high pressure gear stage carbon bushing was found fractured. According to Honeywell, fracture of the carbon bushing is common during impact.

D. DETAILS OF THE INVESTIGATION

1.0 Engine Information

1.1 Engine Description

The accident airplane was equipped with a Honeywell TPE331-1 turboshaft engine. The TPE331-1 is a single spool turboprop engine with a two-stage centrifugal compressor, reverse flow annular combustor, three stage turbine, and hydromechanical fuel control.

According to FAA Type Certificate Data Sheet E3WE, Revision 8, dated February 1, 2000, the Honeywell TPE331-1 engine has maximum continuous and maximum takeoff sea level thrust ratings of 665 shaft horsepower (SHP) at 80°F (27°C) ambient temperature.

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF). A cutaway illustration of the engine is shown in **Figure 1**.

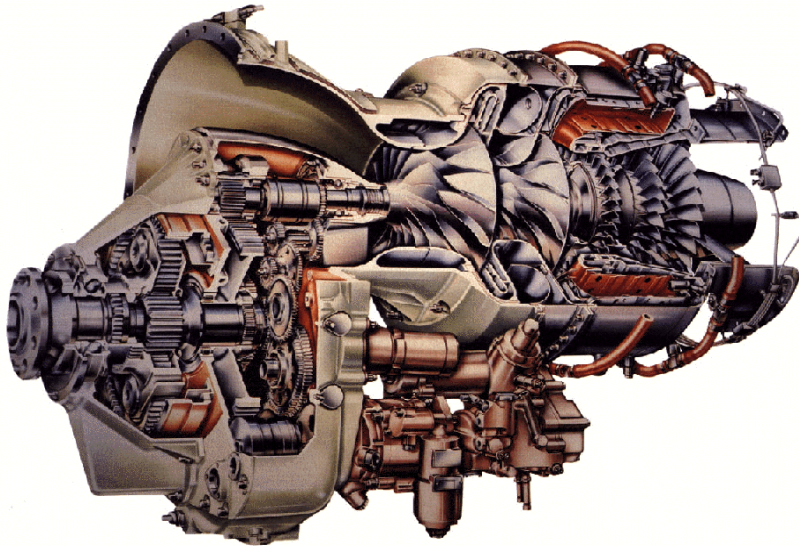


Figure 1- Honeywell TPE331 Cutaway

1.2 Engine Operating History and Maintenance

According to the engine logbook, engine serial number (ESN) P-92143, had accumulated 7,733 hours since new and 521.2 hour since the last overhaul completed on May 17, 2019. A 100-hour engine inspection was performed on May 19, 2021 (8 days prior to the accident) and the engine was found to be airworthy. The engine primary and secondary fuel nozzles were replaced with an overhauled set on August 20, 2020.

The engine was previously installed on a Mitsubishi MU-2B-20 and was removed on November 12, 2014. The engine was installed on the accident airplane, N8376K, on March 24, 2015.

2.0 Engine Serial Number P-92143 Examination and Disassembly

2.1 Visual Examination

The engine was secured in a cardboard shipping box in the Honeywell Product Integrity Laboratory when the investigation team arrived (**Photos 1-4**). Earthen debris was adhered to the engine cases, external accessories, and lines. There was no evidence of undercowl engine fire or radial uncontainment. The 1st stage impeller was manually rotated by hand through the inlet and there was concurrent rotation of the 3rd stage turbine. The fuel pump mount studs on the accessory gearbox

(AGB) were partially pulled out the gearbox case, but the fuel pump drive shaft remained engaged. The lower forward edge of the fuel tank exhibited impact deformation. The magnetic chip detector was free of debris/metallic "fuzz" (**Photo 5**). The oil filter bypass indicator was extended (bypass mode) on the AGB case.



Photo 1- Engine Shipping Box, as Received at Honeywell



Photo 2- Left Side of Engine, as Received



Photo 3- Right Side of Engine, as Received



Photo 4- Engine Data Plate



Photo 5- Magnetic Chip Detector

According to Honeywell, the propeller pitch control (PPC) linkage arm was found disengaged from the PPC input shaft when the airplane wreckage was

documented on scene. The PPC indicator dial was aligned with the 28 degree mark¹ (**Photo 6**). The fuel control unit (FCU) was intact, and the power lever indicator dial was aligned with the 20 degree mark (**Photo 7**). The fuel shutoff valve (FSOV) remained secured to the engine and the scribe mark on the input shaft was at the 12 o'clock (auto) position² (**Photo 8**). Following FSOV removal, a low pressure air check was performed, and air did not pass through the valve. The fuel and oil filters were both free of debris. After the propeller governor was removed, a section of the governor spider gasket was found broken and it partially obstructed the check valve orifice (**Photo 9**). The torsion shaft aft spline was separated 1¼ inch from the aft end (**Photo 10**)³. During on scene documentation, Honeywell also noted that the feather valve linkage was not connected.

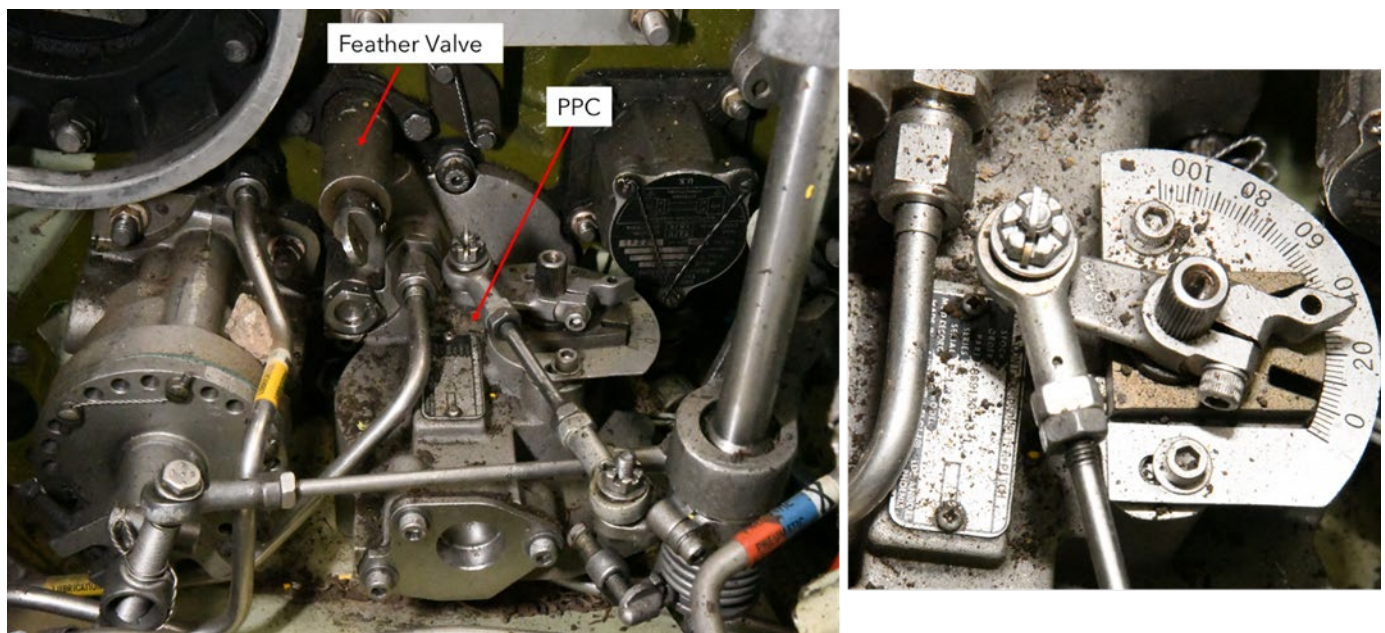


Photo 6- (L) Propeller Pitch Control and Feather Valve, (R) Propeller Pitch Control Position Indicator

¹ According to Honeywell, when the engine is rigged in accordance with the maintenance manual procedure, the PPC dial and FCU power lever indicators dial should point to the same value.

² The fuel shutoff valve indicator is aligned with the 12 o'clock position in auto mode or the 3 o'clock position when the condition lever is retarded to the emergency shutoff position in the cockpit. According to Honeywell, the fuel shutoff valve is in the closed position at either the 3 or 9 o'clock positions.

³ According to Honeywell, separation of the torsion shaft forward of the aft spline are commonly seen during the teardown of accident engines. The break is caused by torsional overload of the shaft associated with a sudden stoppage of the propeller, typically associated with propeller strikes with the ground, runway, or trees.

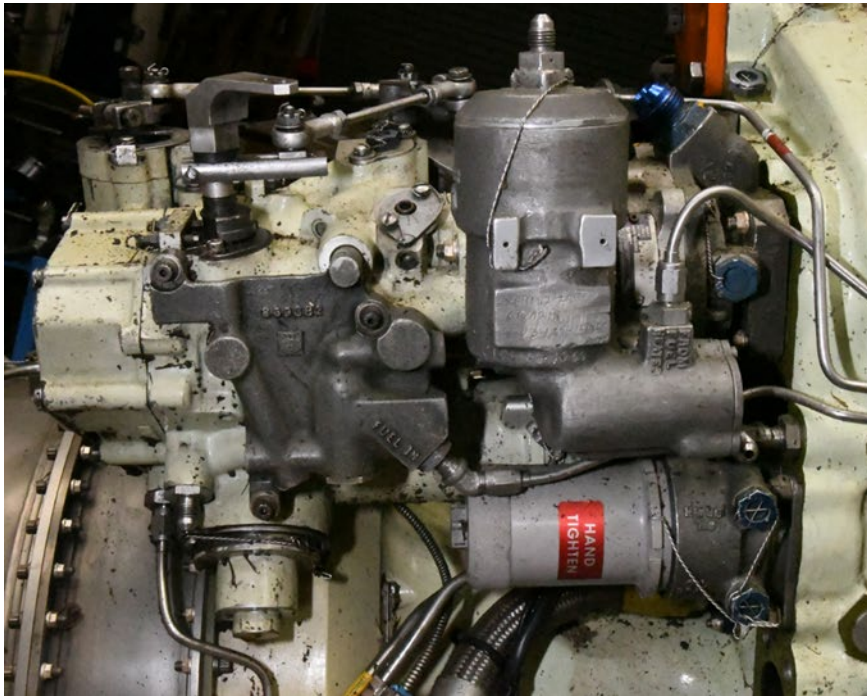


Photo 7- (L) Fuel Pump and Fuel Control, (R) Fuel Control Power Position Indicator



Photo 8- Fuel Shutoff Valve, Input Shaft Scribe



Photo 9- Gearbox Case, Propeller Governor Spider Gasket, Check Valve Orifice



Photo 10- Torsion Shaft, Aft Spline Separated

2.2 Nose Cone Assembly and Accessory Gearbox (AGB)

The nose cone and propeller shaft were both intact. The propeller shaft had one localized score mark $\frac{1}{2}$ inch aft of the retaining nut and four axial score marks 3-4 inches aft of the retaining nut (**Photo 11**). The ring gear, sun gear, bull gear and planet gears were intact and rotated smoothly. The diaphragm assembly was intact, appeared undamaged, and all gears rotated smoothly (**Photo 12**). The torque sensor assembly was in good condition and rotated smoothly.

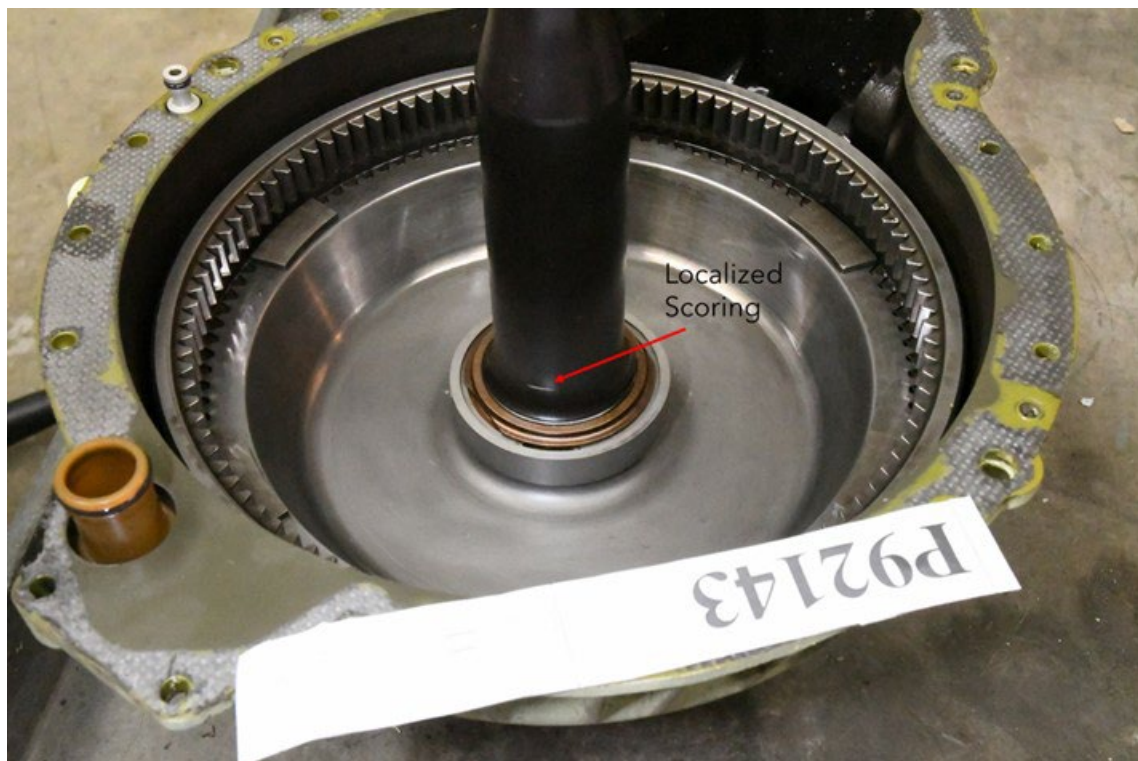


Photo 11- Propeller Shaft



Photo 12- Diaphragm Assembly, AGB

2.3 Turbine Section

The 1st stage turbine rotor blades were all complete and appeared undamaged. Light rotational scoring was observed on the 1st stage turbine shroud from the 9 to 10 o'clock positions, coincident with the trailing edge of the turbine blades. The 2nd stage turbine blades were complete and appeared undamaged. The 2nd stage stator had six vanes with cracks on the suction side surface between the 9 and 10 o'clock positions (**Photo 13**). The 3rd stage turbine rotor blades were intact but had white discoloration near the trailing edge tip on the pressure side and along the full blade tip on the suction side. The 3rd stage stator had rotational scoring over approximately 90 degree arc of the aft inner diameter vane platform. Metal spray⁴ was present on the 3rd stage stator suction side vane surfaces (**Photo 14**). The curvic couplings of all three turbine stages were in good condition and the contact marks were consistent with nominal assembly. Dirt was adhered to the blade/vane surfaces of all three stages (**Photo 15**). The rear (turbine) bearing was oil wetted and rotated smoothly.

⁴ Metal spray are molten metal deposits that occur when metal is liberated due to rub or internal failure and then passes through the combustor where it is melted and subsequently adheres to surfaces downstream.



Photo 13- (L) 2nd Stage Turbine Stator, Suction Side, (R) Suction Side Vane Cracks



Photo 14- (L) 3rd Stage Stator, Suction Side, (R) Light Metal Spray, Suction Side Vanes



Photo 15- Earthen Debris on 1st Stage Stator Vanes, Pressure Side/Leading Edge

2.4 Combustor

The combustion liner was intact and had no indications of fuel nozzle streaking or uneven wear (**Photo 16**). All the fuel nozzles were properly seated. Earthen debris was adhered to the combustion liner walls. There was no metal spray visible in the combustor.



Photo 16- Combustion Liner, Fuel Nozzles

2.5 Compressor Section

The 1st stage compressor impeller was intact. All impeller blades had light 360 degree tip rub at the exducer. There was light 360 degree rotational scoring on the aft hub, forward curvic coupling (**Photo 17**). The main shaft was intact and appeared undamaged. The 1st stage shroud had yellow/green discoloration. The shroud had 360 degree rub at the exducer and light rub at the knee⁵ from the 7 to 1 o'clock positions (**Photo 18**).

⁵ Honeywell's description of the compressor impeller shroud divides the part into three regions: inducer, knee (curved surface coincident with the impeller blade tips), and exducer.



Photo 17- (L) 1st Stage Compressor Impeller, (R) Aft Hub Rotational Scoring

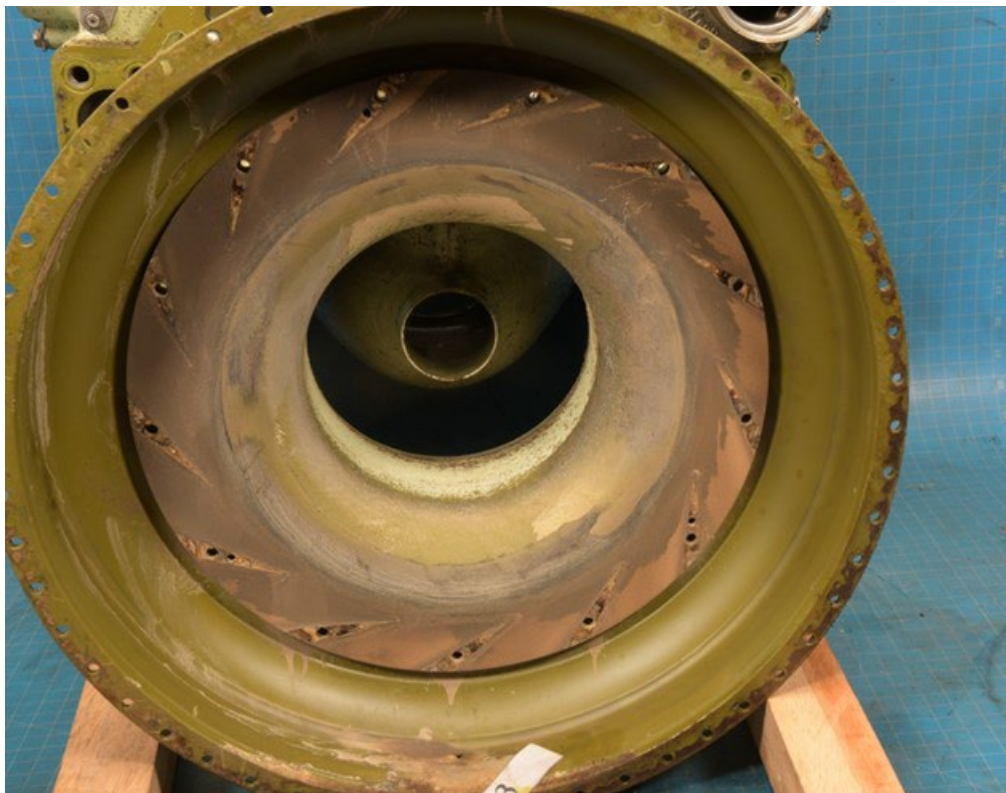


Photo 18- 1st Stage Compressor Shroud

The 2nd stage compressor impeller blades were all complete (**Photo 19**). The impeller blades tips had light tip rub from the inducer to the exducer. The impeller had 360 degree rotational scoring on the hub aft of the forward curvic. The 2nd stage impeller shroud had light 360 degree rotational scoring at the inducer, knee, and exducer (**Photo 20**).

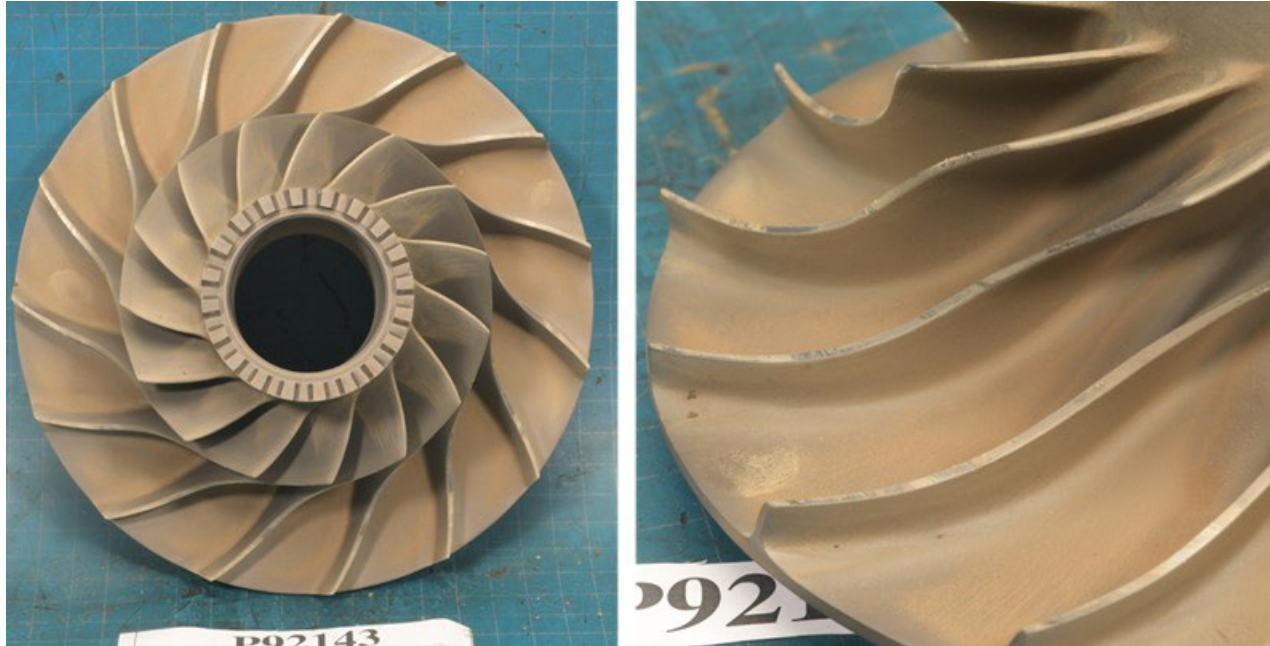


Photo 19- 2nd Stage Compressor Impeller



Photo 20- 2nd Stage Compressor Shroud

The curvic couplings of both compressor stages were in good condition and the contact marks were consistent with nominal assembly. Dirt was adhered to the blade and shroud surfaces of both stages. The yellow/green discoloration noted on the 1st stage compressor shroud was observed throughout the compressor section. The front (compressor) bearing was oil wetted and rotated smoothly.

3.0 Engine Accessories

3.1 Fuel Pump

The fuel pump was tested at Honeywell in Phoenix, Arizona under FAA oversight on November 10, 2022. During initial bench testing, the pump could not be pressurized for testing and was subsequently disassembled for visual examination. The carbon bushing on the high pressure gear stage was found broken. Rotational scoring was observed in the center bores of the drive and idler gears (**Photo 21**). The relief valve was functionally tested and operated normally. According to Honeywell engineering, the carbon bushing fracture was consistent with impact damage.



Photo 21- (L) High Pressure Gear Stage Carbon Bushing Fracture, (R) Drive and Idler Gear Center Bore Scoring (Photos Courtesy of Honeywell)

3.2 Fuel Control Unit

The FCU was shipped to Woodward in Loves Park, Illinois for examination and testing with party members from Honeywell and the NTSB present between August 24-25, 2022 (**Photo 21**). The FCU housing had minor damage near the Pt2 (inlet total pressure) bellows and one of the main cover attaching screws was separated and missing. The power lever, speed setting lever, and driveshaft all rotated freely. The inlet fuel filter and inlet transfer tube that mate the FCU with the fuel pump were removed during the engine teardown and were not shipped to Woodward. A slave filter and transfer tube were installed to perform as-received bench testing.

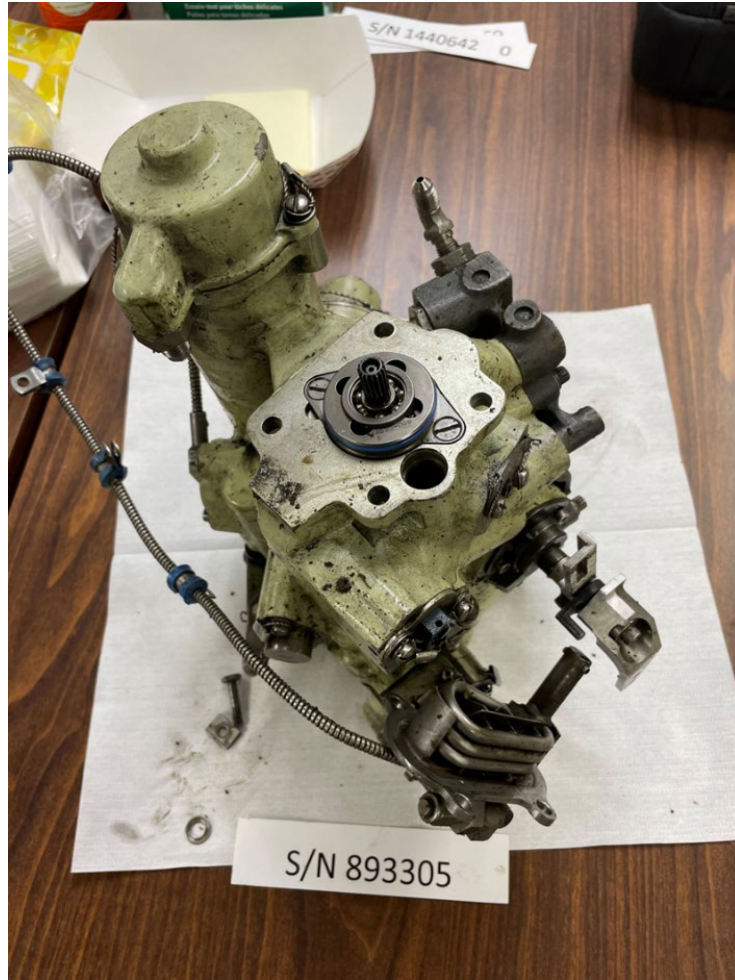


Photo 22- FCU, as Received at Woodward

During initial startup, a leak was observed from the overboard drain port. The leak decreased when boost pressure was increased to the normal setting of 15psi. The Standard Day Acceleration Schedule discharge fuel flow readings were high at all test points. The discharge fuel flow and P1-P2 pressure increased irregularly with speed input. The bypass valve was removed, and the bronze bypass plug was found stuck in the valve sleeve. The bypass plug o-rings were red and were visibly compression set. According to Woodward, red o-rings were replaced with blue o-rings in 1983. New o-rings were installed on the bypass plug and the Standard Day Acceleration Schedule was run again with similar high fuel flow discharge readings. The bypass plug was then replaced with a Woodward slave unit and the fuel flow discharge readings remained high.

The Underspeed Governor Speed Schedule showed lean/low fuel flow at each test point. According to Woodward, the minor out of tolerance results are not considered significant.

The Power Lever Schedules including the Max Power and Flight Idle settings were slightly out of limit but were within the range of customer adjustments normally seen by Woodward on similar service run units.

The FCU was disassembled and inspected. There were no internal anomalies noted. All springs were intact, and all bearings and levers moved freely. The Woodward FCU teardown report and test run sheets are available in the docket titled "Attachment 1- Woodward Fuel Control Teardown Report and As Received Test Run Sheets."

Woodward engineering was unable to determine the cause of the out of limits bench test readings recorded during the Standard Day Acceleration and Deceleration Schedule runs. According to Woodward, the Acceleration Schedule controls start and acceleration fuel flow up to approximately 65% engine speed. At takeoff, the engine speed is controlled by the propeller governor and fuel flow is determined by the power lever schedule.

3.3 Propeller Governor

The propeller governor was shipped to Woodward in Loves Park, Illinois for inspection and testing with party members from Honeywell and the NTSB present between August 24-25, 2022 (**Photo 23**). The governor was received intact with minimal damage. All as received test points were within the expected range for similar service run units according to Woodward. The propeller governor run sheet is available in the docket titled "Attachment 2- Woodward Propeller Governor Test Run Sheet."



Photo 23- Propeller Governor, as Received at Woodward

Submitted by:

Robert Hunsberger
Aerospace Engineer- Powerplants