

**TEARDOWN REPORT
OF A MODEL TPE331-5-511K
TURBOPROP ENGINE
SERIAL NUMBER P-40426C AND P-40427C**

1. INTRODUCTION AND SUMMARY

1.1 PURPOSE

This report, prepared by Honeywell Aerospace, presents the findings of a tear down and examination conducted on two National Flight Services Model TPE331-5-511K turboprop engines, Serial Numbers P-40426C installed in the left nacelle and P-40427C installed in the right nacelle of the accident aircraft. The inspection took place at the Honeywell Investigation Laboratory in Phoenix, Arizona, between March 11th and March 13th, 2013.

The inspection was conducted at the request of and under the cognizance of the National Transportation Safety Board (NTSB).

1.2 BACKGROUND

On February 3, 2014, about 1655 Central Standard Time, a Gulfstream Commander 690C, N840V, operated by a private pilot, was destroyed when it impacted terrain near Bellevue, Tennessee, while on approach to the John C. Tune Airport (JWN), Nashville, Tennessee. The private pilot and three passengers were fatally injured. Instrument meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the flight that departed Great Bend Municipal Airport (GBD), Great Bend, Kansas. The personal flight was conducted under the provisions of 14 Code of Federal Regulations Part 91.

The flight progressed toward Nashville without incident and the pilot was cleared for a GPS approach to runway 2 at JWN. During the approach, air traffic control informed the pilot that the airplane was about 1/2 mile east of the final approach course, and the pilot reported that he was correcting. The pilot subsequently performed a missed approach and was cleared for a second GPS approach to runway 2. During the second attempt, the airplane was on the final approach course when it veered to the left and began a descent. The airplane had turned to a heading of about 210 degrees before radar contact was lost. There were no distress calls received from the pilot prior to the accident.

The airplane impacted trees and a field adjacent to a building, about 9 miles south of JWN. The airplane impacted the ground at about a 70 degree angle, consistent with being in an inverted position. It was severely fragmented with debris scattered on a course of about 320 degrees, for about 450 feet. In addition, a post crash fire consumed a majority of the airframe.

The airplane was powered by two National Flight Services Inc. supplemental type certificate modified Honeywell TPE331-5-511K engines, equipped with Hartzell three-bladed propeller assemblies. Initial review of maintenance information revealed that at the time of the accident, the airframe and both engines had been operated for about 4,460 total hours since new.

A weather observation taken at JWN at 1655 included an overcast ceiling at 800 feet, and a visibility of 5 statute miles with reports of light to moderate rime icing in the accident area just prior to the accident.

1.3 SUMMARY

The teardown and examination of the left engine, S/N P-40426C, revealed that the type and degree of damage was indicative of an engine that was not operating at the time of impact. In addition, the type and degree of damage was indicative of an NTS'ing, wind milling propeller at the time of impact. No pre-existing condition was found that would have prevented normal operation.

The teardown and examination of the right engine, S/N P-40427C, revealed that the type and degree of damage was indicative of an engine that was under power and operating at the time of impact. No pre-existing condition was found that would have prevented normal operation.

4. ANALYSIS AND CONCLUSIONS

4.1 ANALYSIS OF TPE331-5-511K, TURBOPROP ENGINE, SERIAL NUMBER P-40426C (LEFT)

Engine rotation at the time of impact was evidenced by:

- The propeller shaft displayed rotational scoring through 360 degrees immediately aft of the propeller shaft nut with corresponding rotational score marks on the sun gear forward inner bore. (Figure 22)
- The propeller shaft displayed rotational scoring through approximately 180 degrees on the aft taper, with corresponding rotational score marks on the sun gear aft inner bore. (Figure 23)
- After cutting of the mainshaft to expose the torsion shaft, the torsion shaft was broken, in torsional overload, within the center carbon bushing area between the carbon bushing flanges. (Figure 83)
- The first-stage compressor diffuser displayed rotational scoring on the inner diameter of the crossover duct housing seal area (Figure 97) with corresponding rotational scoring on the forward hub of the second-stage compressor impeller.
- The shroud line edge of all second-stage compressor impeller vanes displayed rotational scoring and static impact damage (Figure 106 and Figure 107) with corresponding rotational and static impact damage to the second-stage impeller shroud.
- The second-stage compressor impeller displayed rotational scoring on the forward hub of the second-stage compressor impeller (Figure 104) with corresponding rotational scoring on the inner diameter of the crossover duct housing seal area.
- The first-stage turbine rotor displayed rotational scoring on the aft blade platforms (Figure 116 and Figure 117) with corresponding scoring to the forward inner vane support for the second-stage stator.
- The second-stage turbine rotor had 37 (out of 38) blades with corner separations on the blade-tip trailing edges. (Figure 125)
- The second-stage turbine rotor displayed rotational scoring on the aft hub face (Figure 126) with corresponding scoring to the forward inner vane support for the third-stage stator.
- The third-stage turbine stator displayed rotational score marks on the forward face of the inner vane support (Figure 133) with corresponding score marks on the aft face of the second-stage turbine wheel blade platforms.

Minimal engine rotation at the time of impact was evidenced by:

- The starter/generator input shaft was intact.
- The ring gear support (bumper plate) exhibited witness marks on the forward face (Figure 29 and Figure 30).
- The bull/sun gear nut displayed static impact marks made by contact with the 4th DDFC gear (Figure 37). The web of the 4th DDFC gear and the tach generator gear were both bent as a result of this contact.
- There was a static impact mark on the aft face of the HSP shaft (Figure 39)
- The gearcase oil-scavenge pump housing displayed a static impact mark on the aft face (Figure 35) corresponding to a manufacturing hole in the web of the fuel pump drive gear.
- The forward face of the torque sensor housing displayed static impact mark with a corresponding mark on the aft HSP shaft/nut. (Figure 64)
- The torque sensor housing displayed a static impact mark on the forward housing surface corresponding to contact with the sun gear nut. (Figure 65)
- There were static impact marks on the aft surface of the torque sensor indicating contact with the bull/sun gear aft bearing liner. (Figure 66)
- There were static impact marks on the aft inner diameter of the torque sensor housing corresponding to the gear teeth of the mainshaft DDFC drive gear. (Figure 67)
- The first-stage compressor impeller shroud displayed static witness marks corresponding to the first-stage compressor impeller vanes. (Figure 85 and Figure 86)

- The first-stage compressor impeller vanes had adjacent leading-edges bent opposite and with the direction of rotation. (Figure 89)
- The first-stage compressor impeller forward hub was bent outwards in one location (emanating from the inner bore) (Figure 90) with a corresponding mark/bend of the mainshaft and torsion shaft. There was no evidence of additional inner bore damage around the inner diameter of the forward hub.
- The first-stage compressor impeller aft curvic teeth were heavily damaged in two locations (Figure 92) with corresponding damage to the forward curvic teeth of the second stage centrifugal impeller.
- The second-stage compressor housing displayed static witness marks corresponding to the second stage impeller vanes. (Figure 101)
- The shroud line edge of all second-stage compressor impeller vanes displayed rotational scoring and static impact damage (Figure 106 and Figure 107) with corresponding rotational and static impact damage to the second-stage impeller shroud.
- The aft face of the second-stage compressor impeller displayed static impact marks (Figure 103 and Figure 105) associated with contact with the center curvic labyrinth seal retaining bolts.
- The second-stage compressor impeller forward curvic coupling teeth were heavily damaged through 90 degrees (Figure 102 and Figure 104) with corresponding damage to the aft curvic teeth of the first stage centrifugal impeller.
- The third-stage turbine rotor had 4 blade tips bent forward and 8 blade tips bent aft adjacent to one another in no particular order.
- There were impact marks to the inside of the turbine oil-scavenge pump housing (Figure 144) corresponding to contact with the flats of the turbine nut.

Operation at the time of impact was evidenced by:

- No evidence was identified that would indicate the engine was operating at impact.

4.2 ANALYSIS OF TPE331-5-511K, TURBOPROP ENGINE, SERIAL NUMBER P-40427C (RIGHT)

Engine rotation at the time of impact was evidenced by:

- Rotational scoring and chipping was displayed to the aft side of several of the planetary gear teeth.
- Three of the planetary gears exhibited rotational scoring to the aft face (Figure 204) with corresponding score marks on the ring gear support (bumper plate).
- Three of the planetary gears displayed metal transfer to the gear teeth (Figure 205) associated with rotational contact of the bumper plate.
- The ring gear support (bumper plate) displayed rotational scoring in three visible locations to the forward face (Figure 206 and Figure 207) with corresponding score marks on the aft face of 3 of the planet gears.
- The bull/sun gear nut displayed rotational scoring (Figure 213, green arrows).
- The HSP nut displayed rotational scoring. (Figure 216)
- The HSP aft nut displayed rotational scoring. (Figure 216)
- There were rotational score marks on the forward face of the forward (compressor) main-shaft nut. (Figure 223)
- There was rotational scoring to the forward face of the gear teeth of the main shaft gear. (Figure 223)
- The first-stage compressor impeller shroud was heavily rubbed.
- The first-stage compressor impeller displayed rotational scoring on the aft hub through 360 degrees (Figure 245 and Figure 246) with corresponding scoring on the inner diameter of the crossover duct housing seal area.
- The first-stage compressor impeller vanes were heavily bent back opposite the direction of rotation. Portions of numerous vanes were missing. (Figure 242 and Figure 243)

- The first-stage compressor impeller displayed rotational scoring through 360 degrees on the forward hub (Figure 244) with corresponding scoring to the inner diameter of the crossover duct housing seal area.
- The first-stage compressor impeller aft curvic teeth were smeared. (Figure 245 and Figure 246)
- The first-stage compressor diffuser displayed rotational scoring on the inner diameter of the crossover duct housing seal area (Figure 250) with corresponding rotational scoring on the aft hub of the first stage compressor impeller.
- The first-stage compressor diffuser displayed rotational scoring on the inner diameter of the crossover duct housing seal area (Figure 250) with corresponding rotational scoring on the forward hub of the second-stage compressor impeller.
- The second-stage compressor housing displayed a shroud rub through 360 degrees (Figure 255 and Figure 256) with corresponding rotational damage to the shroud line edge of the second-stage impeller vanes.
- The shroud line edge of all second-stage compressor impeller vanes displayed rotational scoring (Figure 261) with corresponding rotational scoring to the second-stage impeller shroud.
- The second stage compressor impeller vanes displayed bending opposite the direction of rotation (Figure 264)
- The second-stage compressor impeller forward curvic coupling teeth were smeared. (Figure 257 and Figure 259)
- The second-stage compressor impeller displayed rotational scoring on the forward hub of the second-stage compressor impeller (Figure 259) with corresponding rotational scoring on the inner diameter of the crossover duct housing seal area.
- The second-stage compressor impeller displayed score marks on the aft face (Figure 262 and Figure 263, red arrows) with corresponding score marks on the inner seal support retention bolts of the outer transition liner.
- The second-stage compressor impeller displayed rotational scoring on the outer diameter of the impeller aft face (Figure 262 and Figure 263, black arrows) with corresponding rotational scoring on the forward face of the combustor transition liner housing.
- There were rotational score marks on the inner seal support of the outer transition liner retention bolts (Figure 277, red arrows) with corresponding score marks on the aft face of the second-stage impeller.
- There were rotational score marks on the forward face of the combustion transition liner (Figure 277, black arrows) corresponding to rotational scoring on the aft face of the second stage compressor impeller.
- The first-stage turbine blade tip shroud displayed rotational scoring on all segments (Figure 286 and Figure 287) with corresponding rotational scoring to the shroud line edges of all first-stage turbine blades.
- The first-stage turbine rotor displayed rotational scoring on the shroud line edge of all blade tips (Figure 291) with corresponding rotational scoring on the first-stage turbine blade tip shroud.
- The first-stage turbine rotor displayed rotational scoring on the aft blade platforms (Figure 289 and Figure 290) with corresponding scoring to the forward inner vane support for the second-stage stator.
- The first-stage turbine rotor displayed trailing edge damage to all blades (Figure 291 and Figure 292).
- The second-stage turbine stator displayed rotational score marks on the forward face of the inner vane support (Figure 302) with corresponding score marks on the aft face of the first-stage turbine wheel blade platforms.
- The second-stage turbine stator displayed rotational scoring through 360 degrees of the shroud surface (Figure 297 and Figure 298).
- The second-stage turbine rotor displayed rotational scoring on the aft blade platforms (Figure 306, red arrows) with corresponding scoring to the forward inner vane support for the third-stage stator.
- The second-stage turbine rotor displayed rotational scoring on the aft hub face (Figure 306, green arrows) with corresponding scoring to the forward inner vane support for the third-stage stator.

- The second-stage turbine rotor displayed rotational scoring on the forward blade platforms (Figure 303 and Figure 305) with corresponding scoring to the aft inner vane support for the second stage stator.
- The second-stage turbine rotor displayed trailing edge damage to 11 blades (Figure 311) with corresponding leading edge damage to all vanes of the third-stage stator.
- The third-stage turbine stator displayed rotational score marks on the forward inner vane support (Figure 312 and Figure 316) with corresponding rotational scoring to the aft blade platforms of the second-stage turbine wheel.
- The third-stage turbine blade tip shroud displayed rotational scoring and battering through 360 degrees (Figure 317) with corresponding scoring on the shroud line edge of all blades.
- The third-stage turbine stator displayed leading edge damage to all vanes (Figure 318) with corresponding trailing edge damage to 11 blades of the second-stage turbine wheel.
- The third-stage turbine rotor displayed rotational scoring on the aft blade platforms (Figure 322, black arrows) with corresponding scoring to the forward face of the inner housing of the rear bearing support.
- The third-stage turbine rotor blades displayed rotational damage at the root of the blade on the aft side (Figure 322, example highlighted with red circle) corresponding to contact with the forward face of the inner housing of the rear bearing support.
- The rear curvic coupling displayed scoring to the aft face (Figure 329) with corresponding score marks on the turbine seal assembly bolt heads.
- The turbine bearing support housing displayed rotational scoring to the forward face on the inner housing of the rear bearing support with corresponding rotational scoring on the aft blade platforms of the third-stage turbine wheel.
- There were rotational score marks to the inside of the turbine oil-scavenge pump housing (Figure 337) with corresponding marks on the interface between the flats of the turbine nut.
- The aft (turbine) main-shaft nut displayed rotational score marks on the interface between the flats of the turbine nut (Figure 342) with corresponding rotational score marks to the inside of the pump housing.

Operation at the time of impact was evidenced by:

- The combustion chamber contained charred debris in several cooling holes, inner diameter seams and skirts of the combustor. (Figure 272, Figure 273, and Figure 274)
- There was charred debris in the dished area of the outer transition liner. (Figure 275)
- Cleaning of the first-stage turbine stator revealed compressor-shroud metal spray deposits on the suction side of the vanes. (Figure 284)
- There were compressor-shroud metal spray deposits on the pressure side of the first-stage turbine stator vanes. (Figure 285)
- There were compressor-shroud metal spray deposits on the suction side of the first-stage turbine rotor blades. (Figure 292)
- There were compressor-shroud metal spray deposits on the leading edge of the first-stage turbine rotor blades. (Figure 293)
- There were compressor-shroud metal spray deposits on the pressure side of the first-stage turbine rotor blades. (Figure 294)
- There were compressor-shroud metal spray deposits on the leading edge of the second-stage turbine stator vanes. (Figure 299)
- There were compressor-shroud metal spray deposits on the pressure side of the second-stage turbine stator vanes. (Figure 300)
- There were compressor-shroud metal spray deposits on the suction side of the second-stage turbine stator vanes. (Figure 301)
- There were compressor-shroud metal spray deposits on the suction side of the second-stage turbine rotor blades. (Figure 307)
- There were compressor-shroud metal spray deposits on the pressure side of the second-stage turbine rotor blades. (Figure 308)

- There were compressor-shroud metal spray deposits on the suction side of the third-stage turbine stator vanes. (Figure 314)
- There were compressor-shroud metal spray deposits on the leading edge of the third-stage turbine stator vanes. (Figure 315)
- There were compressor-shroud metal spray deposits on the pressure side of the third-stage turbine stator vanes. (Figure 315)
- The third-stage turbine rotor had compressor-shroud metal spray deposits on the suction side of the blades. (Figure 323)
- The third-stage turbine rotor had compressor-shroud metal spray deposits on the pressure side of the blades. (Figure 324)
- The third-stage turbine rotor had compressor-shroud metal spray deposits on the leading edge of the blades. (Figure 325)
- The turbine bearing support housing had compressor-shroud metal spray deposits on the bearing support struts. (Figure 334)

4.3 LEFT ENGINE (P-40426C) FUEL CONTROL EXAMINATION AT WOODWARD (Appendix A)

A visual as-received inspection was performed. The cover was missing therefore the unit could not be identified from the nameplate. The case number marked on the housing was identified as 722 and was cross-referenced to Woodward shipping records to determine the unit serial number. S/N 2132980 was last shipped from Woodward as model 8070-302 in January 1993. The presence of foreign lock wire indicates the unit was serviced by another facility since it was last shipped from Woodward.

The unit was found to have extensive impact damage. Portions of the housing were fractured and missing such that the internal mechanical linkage was exposed. The portion of the housing containing the Pt2 bellows and 3D cam shaft was fractured and missing. The majority of the computer linkage assembly was also missing.

The portion of the housing containing the Ps3 sensor was fractured and separated from the control. The Ps3 rack was bent and there was a hole in the Ps3 cap. The drive spline was intact but did not spin freely. The pump mounting pad was fractured and missing from the housing.

Due to the extensive damage to the unit, as-received testing could not be performed. The unit was then disassembled for inspection. The vespel stub shaft was removed and no evidence of damage or wear on the splines was observed. The accel limit bracket was bent such that the remaining portion of the computer linkage could not be removed from the bracket. The accel limit shaft was broken off in the fuel valve cover.

The overspeed and underspeed governors were disassembled and removed from the control. The bearings and flyweights in both governors were found to move freely.

No evidence of a pre-incident malfunction was found. All damage observed was consistent with impact.

4.4 COMPUTED TOMOGRAPHY (CT) SCAN OF TWO FUEL SHUTOFF VALVES

Appendix B provides the findings of a CT scan of both fuel shutoff valves.

Both valves were determined to be in the closed position. This was evident by the fact that, for both valves, the manual override shaft was in a manual position as well as the solenoid armature being in the closed position. In addition, the check ball appeared to be intact and seated in the shutoff position. It was unable to be determined if the accident sequence moved the valves to the closed position or if they were manually/electrically actuated prior to impact. The right engine (P-40427C) shutoff valve manual input arm was 180 degrees rotated from the left engine's (P-40426C) manual arm position. This indicates

some level of movement of the arms by impact forces was likely encountered by one or both shutoff valves.

4.5 TEARDOWN AND EXAMINATION OF TWO FUEL SHUTOFF VALVES

Appendix C provides the findings of a disassembly and examination of the fuel shutoff valves from the left and right engines.

No pre-existing condition was found that would have prevented normal operation.

4.6 DETERMINATION OF THE LEFT ENGINE (P-40426C) NTS OPERATION AT IMPACT

During normal operation where the engine is driving the propeller, positive torque is being produced. If the engine were to flameout in flight, the windmilling propeller would drive the gearbox and power section. If the blades were to remain in a flat pitch, operating position, this would result in a large increase in propeller drag forces on the aircraft and difficulty in maintaining directional control on a twin engine aircraft. The function of the negative torque sensing (NTS) system is to limit the amount of torque the engine can extract from the windmilling propeller by cycling the blades toward feather. As blade angle increases, negative torque decreases. The NTS system provides automatic drag reduction. It is not an automatic feather system. Since the NTS system provides automatic drag reduction and is not an auto-feather system, the pilot is required to manually actuate the feather valve (fuel shutoff and feather) from the cockpit before the engine decelerates to (below) 30% RPM. This prevents sustained operation in the vibration critical speed range of 18% to 28% RPM.

The damage identified to the left engine (P-40426C) is indicative of an engine rotating at a low RPM (20% or less) at the time of impact. The evidence also indicates the engine was not operating (not making power) at the time of impact. In Honeywell's experience, a non-operating engine that has an inoperative NTS will result in an engine rpm of approximately 50 to 60% at airspeeds of approximately 150 knots due to the relative wind driving the windmilling propeller. In addition, in Honeywell's experience, the resultant engine speed will be very responsive (speed up or slow down) with changes in aircraft airspeed. Conversely, an operative NTS will result in engine speeds of less than 20% (if allowed to continue without feathering the propeller) within 20 seconds of losing power. And the final stabilized speed will be largely independent of aircraft speed. Given the evidence of significant vertical impact damage to the airframe and both engines, it can be concluded that the aircraft airspeed at impact was high. As the evidence supports a high vertical rate of airspeed at impact, if the engine had experienced an inoperative NTS with a non-operating engine, one would expect to achieve a relatively high engine speed at impact (greater than 50%). The engine damage identified above indicates a slowly rotating (less than 20%), non-operating engine at impact. Therefore, it is concluded that the engine was not operating and the NTS system was operative at impact.

4.7 EXAMINATION OF S/N P-40426C COMBUSTOR PLENUM CASE FRACTURE

Appendix D provides the detailed failure analysis and findings of the section of combustor plenum case removed during an NTSB wreckage exam on May 20, 2014 at AMF aviation located in Springfield, TN. Only non-destructive assessments were allowed while the part was at Honeywell, under the direction of the NTSB.

The non-destructive examination of the fracture surface was unable to determine the fracture mode of the part. Subsequent to the non-destructive examination, the part was sent to the NTSB lab in Washington, DC for further analysis.

A final report of the examination performed at the NTSB lab in Washington, DC will be provided separate from this report.

4.8 CONCLUSIONS

The teardown and examination of the left engine, S/N P-40426C, revealed that the type and degree of damage was indicative of an engine that was not operating at the time of impact. In addition, the type and degree of damage was indicative of an NTS'ing, wind milling propeller at the time of impact. No pre-existing condition was found that would have prevented normal operation.

The teardown and examination of the right engine, S/N P-40427C, revealed that the type and degree of damage was indicative of an engine that was under power and operating at the time of impact. No pre-existing condition was found that would have prevented normal operation.