



NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

March 20, 2018

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT
NTSB No: ENG17IA017

A. INCIDENT

Location: Dayton, Ohio

Date: March 19, 2017

Time: 1100 eastern daylight time (EDT)

Aircraft: McDonnell Douglas MD-83, N881GA, Allegiant Air, LLC, Flight 636

B. POWERPLANTS GROUP

Group Chairman:	Robert Hunsberger National Transportation Safety Board Washington, DC
Member:	Jerry Ramos Federal Aviation Administration (LAACO) Lakewood, California
Member:	Eric Igama Federal Aviation Administration (LAACO) Lakewood, California
Member:	Edison Fabian Federal Aviation Administration (LAACO) Lakewood, California
Member:	Guy Roberge Allegiant Air, LLC Las Vegas, Nevada
Member:	Leon Saul UTC Aerospace Systems Rockford, Illinois

C. SUMMARY

On March 19, 2017, about 1100 eastern daylight time (EDT), a McDonnell Douglas MD-83, N881GA, operated by Allegiant Air experienced a No. 2 (right) engine fire at FL140 (14,000 feet), during approach to Dayton International Airport (DAY) - Dayton, Ohio. The crew followed the quick reference handbook procedures, discharged both fire bottles, and shutdown the No. 2 engine. The airplane made an uneventful single engine landing at DAY and was met by aircraft rescue and firefighting (ARFF) vehicles on the runway. ARFF crews determined the fire had been extinguished and the airplane was cleared to taxi to the gate under its own power. There were no passenger or crew injuries reported. The flight was a regularly scheduled flight from Orlando Sanford International Airport (SFB)- Sanford, Florida to DAY and was conducted under the provisions of 14 *Code of Federal Regulations* Part 121.

Allegiant Air maintenance crews performed a visual inspection of the No. 2 engine at DAY and reported significant thermal damage on the bottom half of the engine, concentrated around the constant speed drive (CSD) and generator. A section of the generator case was fractured and missing. Oil pooling and metal debris were observed at the 6 o' clock position in the engine cowling. Photographs were sent to the NTSB and after review, permission was given for Allegiant Air to remove the engine and prepare it for shipment to a repair facility in Oscoda, Michigan. The digital flight data recorder (DFDR) was shipped to Allegiant Air headquarters in Las Vegas, Nevada for download. The raw DFDR data was then transferred to the NTSB recorders laboratory in Washington, DC for data conversion and analysis. The determination was made that the failure was isolated to the CSD and/or generator and both components were shipped to UTC Aerospace Systems in Rockford, Illinois for examination and disassembly.

Investigation party members from Allegiant Air, UTC Aerospace Systems, the Federal Aviation Administration, and the NTSB met at UTC Aerospace Systems Rockford, Illinois facility from May 23-24, 2017.

The CSD was disassembled and fine metal debris was observed throughout the case on all internal components and on the magnetic oil plug. The CSD gears and bearings were intact and the gear train could be manually rotated with some resistance. The center section of the generator frame case was fragmented and missing. All generator rotating components exhibited severe thermal damage and deformation. The generator main rotor copper holding wedges, V-shaped steel wedges, and copper windings were separated.

D. DETAILS OF THE INVESTIGATION

1.0 GENERATOR AND CONSTANT SPEED DRIVE

1.1 Maintenance History

Component records for the CSD and generator were provided by Allegiant Air. The CSD, part number (P/N) 696233B, serial number (S/N) 2287 was last overhauled on September 10, 2014 by L.J. Walsh Company in Livermore, California. The generator, P/N 976J252-6, S/N TD-4489, was last repaired on November 22, 2010 By Aerotec International in

Phoenix, Arizona. According to UTC, the generator was manufactured in July 1982. An accurate record of total hours and cycles was not available.

1.2 Constant Speed Drive Description

The CSD consists of a hydraulic transmission with mechanical controls that govern the output rotation speed. The transmission is capable of either adding to or subtracting from the speed received from the engine gearbox to provide constant output speed to keep the generator on frequency. Mechanical (flyweight) governor action keeps the generator's output close to 400 hertz.

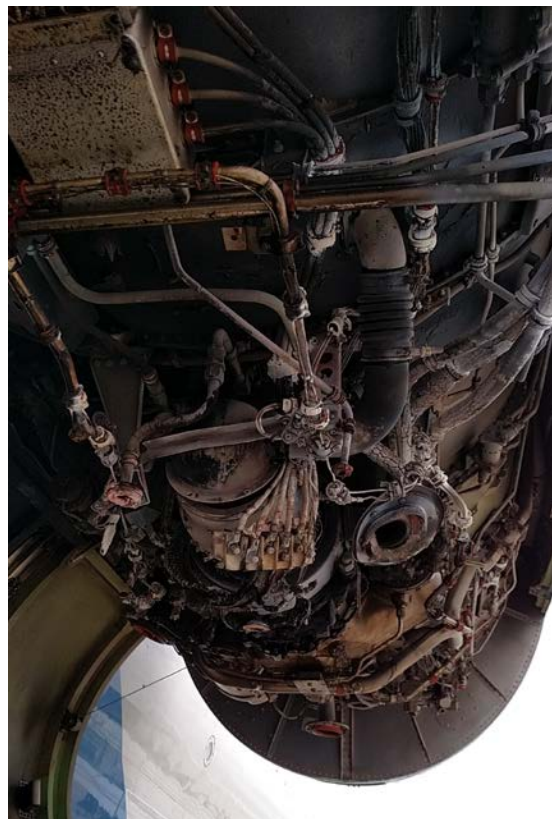
1.3 Generator Description

The generator is a self-excited, air-cooled, brushless machine designed for use in aerospace application to provide alternating current power for the electrical systems. It is driven and held within the speed range by a constant speed transmission, which is in turn driven by the aircraft engine. The generator consists of an exciter rotating armature, exciter stationary field, alternating current stationary armature, main rotating field, permanent magnet generator consisting of a permanent magnet stationary armature and a rotor, a three-phase full-wave rectifier bridge, and a capacitor.

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF).

2.0 JT8D-200 ENGINE DAMAGE – ON-SITE EXAMINATION

Allegiant Air maintenance crews provided photographs of the engine and cowl damage after the incident. Sooting and discoloration were concentrated at the 6 o'clock position around the generator and CSD (**Photo 1**). The external engine lines in the area exhibited thermal damage. There was oil pooling and loose metal fragments resting in the cowl at the 6 o'clock position. The CSD-to-oil cooler return line was severed in-line with the plane of rotation of the generator rotor (**Photo 2**). The generator case was fragmented and mostly missing.



↓
FWD

Photo 1- Bottom of the Engine Prior to Removal from Airplane



Generator

Oil Cooler
Return Line

Photo 2- Oil Cooler Return Line and Generator Case Damage

The DFDR file was sent to the NTSB recorders lab in Washington, DC for conversion and analysis. The No. 2 engine performance parameters including: N1¹ speed, N2² speed, and exhaust gas temperature³ (EGT) were nominal. Warning indications for No. 2 engine generator failure, and No. 2 engine fire warning were consistent with the incident official notification report.

The engine was packaged and shipped to HAECO in Oscoda, Michigan for CSD and generator removal. The Detroit, Michigan FAA Flight Standards District Office (FSDO) provided oversight of the generator and CSD removal and packaging at HAECO. The components were shipped to UTC Aerospace Systems in Rockford, Illinois for examination and disassembly.

2.0 CONSTANT SPEED DRIVE AND GENERATOR EXAMINATION AND DISASSEMBLY

2.1 Constant Speed Drive

The constant speed drive and generator were secured in a wooden crate as an assembly when the investigative team arrived (**Photo 3**). The CSD chip detector plug had been removed prior to shipment and was in a plastic bag attached to the CSD with a twist tie. The chip detector had metal debris accumulation on the magnetic electrode (**Photo 4**). All CSD and generator external surfaces were discolored and heavily sooted. The CSD harness spiral wrap and wires exhibited thermal damage, including charring and melting of the wire jackets. No oil was visible in the CSD oil sight glass. The CSD to engine accessory gearbox mounting lugs were all intact and in good condition. The CSD mounting pad forward face had witness marks from the 11 to 6 o'clock positions, consistent with gearbox adapter ring flat head screw contact (**Photo 5**). The cooling air exhaust duct that is integral to the shroud assembly between the CSD and generator had a crack at the elbow and the seal was thermally damaged. The metal surrounding the seal was deformed.

¹ N1 speed refers to the low pressure spool rotation speed that include the fan and low pressure turbine.

² N2 speed refers to the high pressure spool rotation speed that includes the high pressure compressor and high pressure turbine.

³ Exhaust gas temperature is measured by thermocouples that extend into the exhaust nozzle gas path.



Photo 3- CSD and Generator, As Received



Photo 4- CSD Chip Detector Plug



Photo 5- CSD Mounting Pad Forward Face, Witness Marks

The CSD was separated from the generator for disassembly. The CSD input spline could not be manually rotated. The oil filter was removed, and a small amount of fine metal debris was observed in the filter pleats. After removal of the CSD case, all visible gears were intact. Fine metal debris was observed on all internal surfaces and some larger ferrous objects, including hydraulic pump and motor piston fragments were separated and loose in the case (**Photos 6 and 7**). The CSD-to-generator disconnect was not extended.⁴ The CSD shaft and bearings were intact and the bearings could be individually rotated with some resistance.

⁴ A CSD disconnect switch in the cockpit activates a solenoid that extends a pawl to disconnect the CSD drive train when selected.



Photo 6- CSD Internal Gears

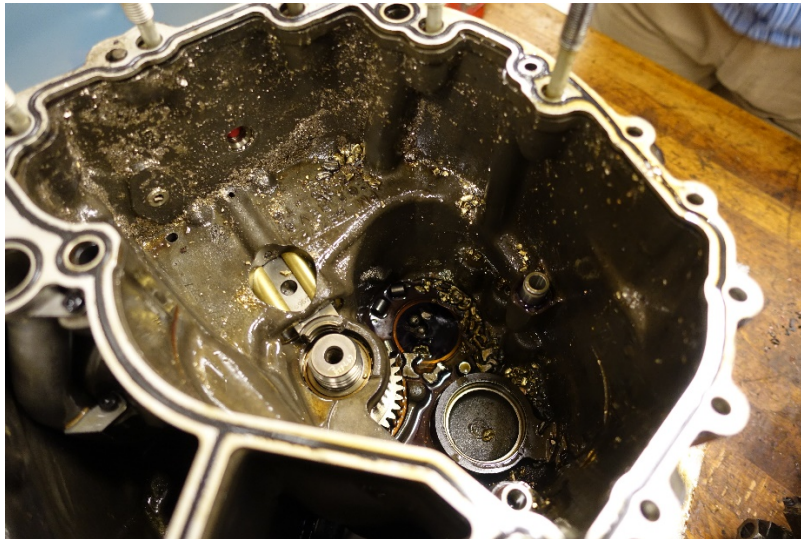


Photo 7- CSD Case, Metal Fragments, and Debris

2.2 Generator

The middle section (about 4.75 inches) of the main generator frame case was separated and missing 360 degrees around the generator. The main stator core was fractured into two pieces axially and the aft section was deformed and extruded about 5 inches radially out of the generator case (**Photo 8**). The cases over the exciter and permanent magnet generator (PMG) were mostly intact but exhibited circumferential scoring and thermal damage. The terminal block and leads were separated and missing. The impeller fan located on the aft end of the was missing all vanes and the remaining section of the fan forward frame exhibited heavy rub damage (**Photo 9**). The forward generator drive end was thermally damaged. The balls in the forward bearing were all present but the bearing shields were separated, and the grease was consumed. The bearing could be rotated with light resistance. The generator spindle splines were intact and in good condition (**Photo 10**). The generator spindle did not

have a defined shear section feature.⁵ The generator main rotor consists of laminated poles with copper windings that are retained with V-shaped steel wedges and copper alloy holding wedges. All copper holding wedges, V-shaped steel wedges, and copper windings were separated and only a few small fragments were recovered (**Photo 11**). The main rotor poles exhibited heavy rub damage including copper colored material transfer. The main rotor bands were broken and found heavily damaged. The exciter rotor poles were intact but exhibited rub and thermal damage. The damage was concentrated on the drive end of the exciter rotor and the drive end band was separated and missing. The exciter stator had substantial rub damage and the stator windings were frayed (**Photo 12**). The PMG rotor and stator were both intact with light rub and thermal damage. The anti-drive end bearing had discoloration (bluing) on the outer race. All balls in the bearing were present and the bearing rotated smoothly. The aft bearing grease seal was separated and missing.



Photo 8- Generator Case Damage

⁵ The defined shear section feature was incorporated as part of service bulletin (SB) 976J252-24-2, dated September 16, 1997. The SB applies to generator S/N 0-8234.



Photo 9- (L) Incident Fan, (R) Exemplar Fan



Photo 10- Generator Spindle

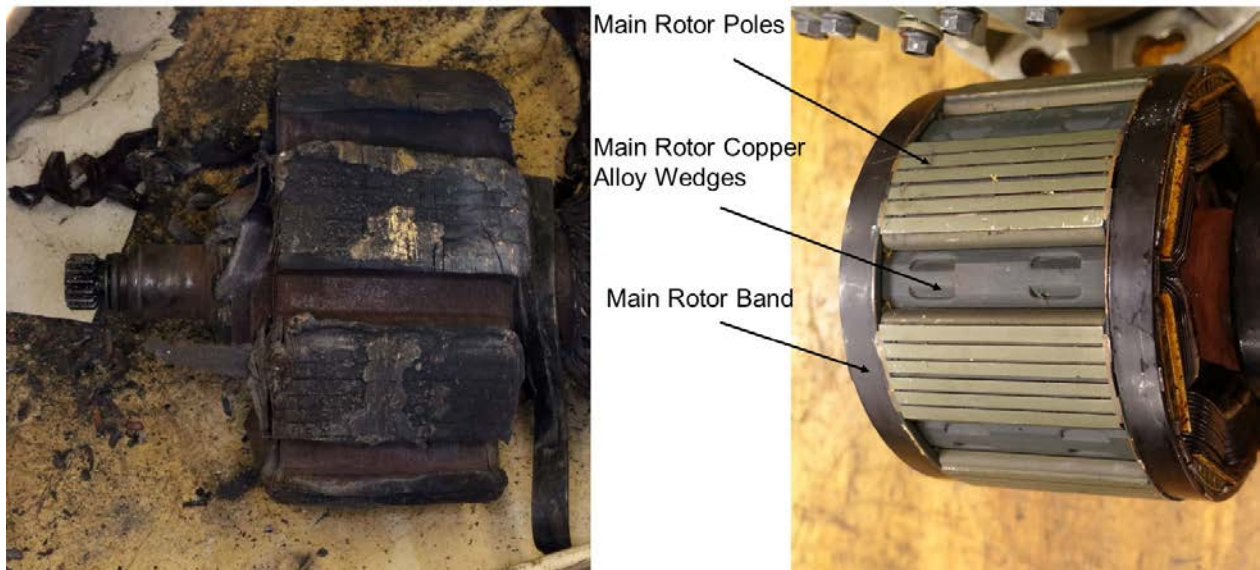


Photo 11- (L) Incident Main Rotor, (R) Exemplar Main Rotor

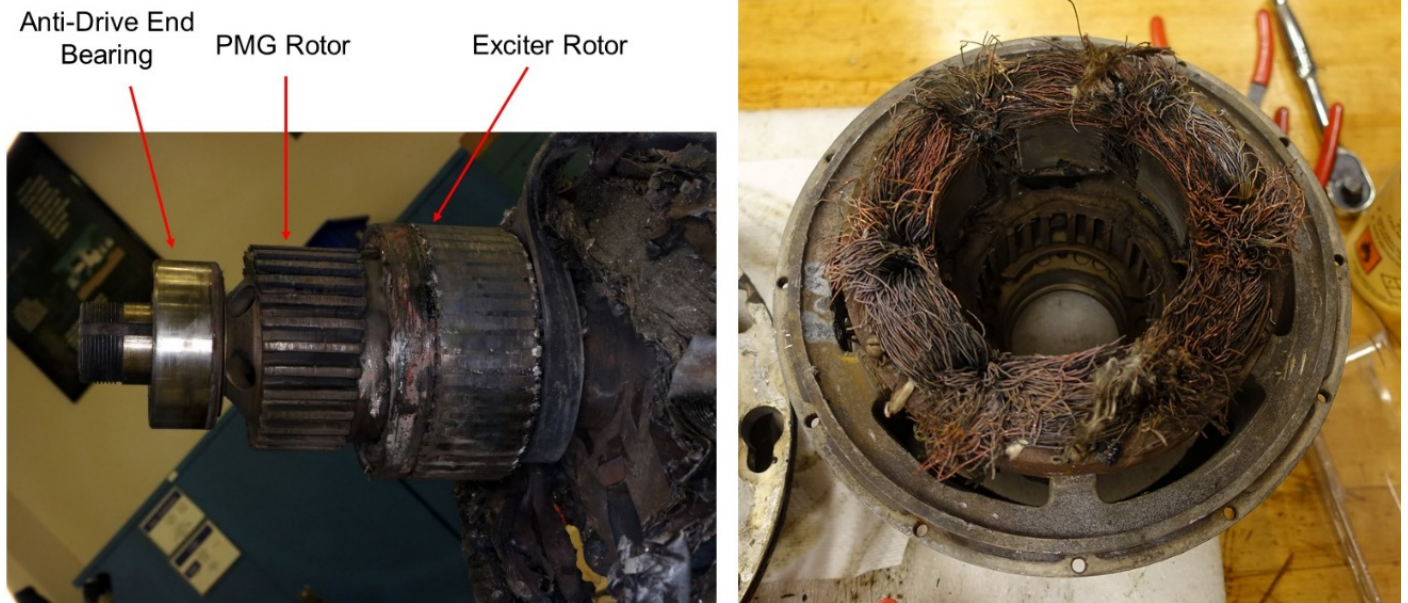


Photo 12- (L) Exciter Rotor, PMG Rotor, Anti-Drive End Bearing, (R) Exciter Stator

3.0 METALLURGY

Small fragments of metal that were believed to be the generator main rotor copper alloy wedges were submitted to the UTC Aerospace Systems materials laboratory in Rockford, Illinois for analysis. The material was confirmed to be copper, but the trace alloy elements were below the quantitative reporting level of the equipment. The findings could not confirm if the wedges were UTC Aerospace Systems manufactured parts or aftermarket. No additional laboratory work or final report was requested due to the level of thermal and impact damage to the recovered fragments.

4.0 GENERATOR FAILURE HISTORY

A record of uncontained generator failures on Douglas Aircraft DC-9/ McDonnell Douglas MD-80 series airplanes was requested from UTC Aerospace Systems and Boeing. Eleven prior uncontained generator failure events were reported since the year 2000. The event descriptions for each of the prior 11 events were based on crew statements, and from the statements an accurate count of generator failures that resulted in an engine fire was inconclusive. It was confirmed that none of the events to date have resulted in an uncontrolled fire⁶.

Following the events in 2010, Boeing provided the NTSB with a safety risk assessment. According to the assessment, any fragments released by an uncontained generator failure are low energy projectiles and do not pose a threat to the airframe. The assessment also states that design features including overboard drains, fire detection and extinguishing systems are in place to mitigate the risks associated with flammable fluid leaks in a designated fire zone.

In June 2005 Hamilton Sundstrand Corporation (now UTC Aerospace Systems) released service information letter (SIL) 449 recommending that air cooled generator rotors installed on Boeing 707, 727, 737, DC9, MD80, and DC10 airplanes should be overhauled and re-wound at 40,000 operating hours. As part of the overhaul, the interpole copper wedges are replaced. Boeing released a service letter, DC9-SL-24-104/MD-80-SL-24-104 in November 2005 notifying all operators of the SIL.

5.0 GENERATOR RECORDS

The generator is not a life limited part and is replaced on condition. Operators are not required to track generator hours or cycles. According to UTC Aerospace Systems and Allegiant Air party members, it is not uncommon for generators to be changed between engines and even if a record of hours/cycles was kept for the generator, the record is not always transferred when an airplane or engine is sold. For the incident generator, Allegiant Air had several documents that gave a rough estimate of time since new (TSN), but the accuracy of the records could not be confirmed and the component card itself had a note that stated "TSN, cycles since new (CSN), time since overhaul (TSO), and cycles since overhaul (CSO) unknown."

Robert Hunsberger
Aerospace Engineer
Propulsion

⁶ According to the Continued Airworthiness Assessment Methodologies (CAAM) committee, an uncontrolled engine fire is one that occurs outside the designated fire zones and cannot be controlled with on board extinguishing devices.