Aviation Investigation Final Report

Location:	Atlanta, Georgia	**Incident Number:**	ENG11IA035
Date & Time:	June 21, 2011, 00:07 Local	**Registration:**	N6714Q
Aircraft:	Boeing 757-232	**Aircraft Damage:**	None
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	3 Minor, 175 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

On June 21, 2011, about 0007 eastern daylight time, a Boeing B-757-232, N6714Q, powered by two Pratt & Whitney (P&W) PW2037 turbofan engines, experienced a left engine (No. 1) fire while taking off from Atlanta's Hartsfield International Airport (ATL), Atlanta, Georgia. The Captain declared an emergency, shutdown the No. 1 engine, and a turnback to ATL was initiated. The airplane made a successful overweight, single-engine landing, and an emergency evacuation was conducted on the right side of the airplane onto the runway. Of the 172 passengers and 6 crewmembers on board the flight, 3 passengers received minor injuries associated with the slide evacuation. The airplane was operated by Delta Airlines as a 14 *Code of Federal Regulations* Part 121 domestic passenger flight from ATL to Los Angeles International Airport, Los Angeles, California. Night visual meteorological conditions prevailed at the time, and an instrument flight rules flight plan was filed.

Examination of the engine found extensive fire damage and thermal distress in the fan and core compartments with the vast majority of the thermal distress and the most extensive fire damage located in the fan compartment between and including the intermediate case and the turbine exhaust case. The end housing of the fuel flow transmitter (FFT) was found backed-off from the main housing, which created a gap of about 0.3 inch at the bottom of the unit; correspondingly the FFT-to-fuel distribution valve (FFT-to-FDV) fuel line was found plastically deformed. An installation fit check coupled a deflection analysis of the FFT-to-FDV fuel line revealed that the deformation of the fuel tube was as a result of the FFT end housing separation; it did not cause the gap. Metallurgical analysis of the FFT hardware did not find any material defects or anomalies. Torque tension tests and a finite element analysis of the loads applied to the FFT revealed that under certain assembly variances and operational load and temperature variations, the load capability of the end housing-to-main housing bolted joint was marginal or less than marginal. With reduced load capability, the main housing threads would not be able to maintain the preload without eventually yielding, which would result in lessening of the preload and loosening of the joint. A review of the FFT component maintenance manual (CMM) found several areas where improvements could be made to ensure a more consistent FFT assembly practice and proposed changes have been initiated to the CMM.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

Fuel leaking from the fuel flow transmitter that ignited on contact with the engine's hot cases which resulted in an engine undercowl fire. The fuel leak resulted from the fuel flow transmitter end housing backing off from the main housing, creating a gap that allowed high pressure fuel to escape. Under certain assembly variances and operational load and temperature variations, the end housing joint may not be able to maintain the preload without eventually yielding, which results in the loosening of the joint and the resultant gap.

Findings

Aircraft	Accessory drives - Capability exceeded
Aircraft	Accessory drives - Related maintenance info
Organizational issues	Design of document/info - Manufacturer

Factual Information

History of Flight

Takeoff	Powerplant sys/comp malf/fail (Defining event)
Takeoff	Fire/smoke (non-impact)

HISTORY OF FLIGHT

On June 21, 2011, 0007 eastern daylight time, a Boeing B-757-232, registration number N6714Q, operated by Delta Air Lines (DAL) as flight 1323, and powered by two Pratt & Whitney (P&W) PW2037 turbofan engines, experienced a left engine (No. 1) fire while taking off from Atlanta's Hartsfield International Airport (ATL), Atlanta, Georgia. The Captain reported that during gear retraction she observed a small yaw followed a few seconds later, while climbing through 3,000 feet, by a left engine fire indication. The Captain declared an emergency, shutdown the No. 1 engine, and a turnback to ATL was initiated. The airplane made a successful overweight single-engine landing and stopped on runway 26L at ATL, and an emergency evacuation was conducted on the right side of the airplane onto the runway. When the Airport Rescue and Firefighting (ARFF) arrived at the airplane, the No. 1 engine was still on fire and they discharged fire retardant agent into the aft end of the engine to put out the fire. Of the 172 passengers and 6 crewmembers on board the flight, three passengers received minor injuries associated with the slide evacuation. The incident flight was a 14 *CFR* Part 121 domestic passenger flight from ATL to Los Angeles International Airport (LAX), Los Angeles, California. Night visual meteorological conditions prevailed at the time, and an instrument flight rules flight plan was filed.

ENGINE DAMAGE

Initial Visual Examination

After the passengers and crew members were evacuated, the airplane was towed to a DAL maintenance hangar where it was confirmed that the No. 1 engine had experienced an undercowl fire; the left-hand core cowl was installed but damaged and detached in some areas, and the right-hand core cowl was almost completely missing. The Powerplant Group, comprised of members from P&W, Boeing, DAL, Air Line

Pilot's Association (ALPA), Federal Aviation Administration (FAA), and the National Transportation Safety Board (NTSB), convened at the DAL maintenance hangar at ATL on June 22, 2011 to commence the in-situ examination of the incident airplane. All the No. 1 engine cowls exhibited varying degrees of thermal distress and fire damage except for the inlet cowl which was undamaged. The fan cowls, thrust reverser/fan duct assembly (also referred to as the TR), and core cowls all remained hinged to the strut (pylon) at the top and latched at the bottom. The No. 1 engine strut was distorted, some of the thermal blankets and electrical wires were fire damaged, and conductivity and hardness measurements taken at several locations were beyond Aircraft Maintenance Manual (AMM) serviceable limits. No other airplane damage was noted.

Detailed Engine Disassembly and Examination

Examination of the No. 1 engine confirmed fire damage to the outside of the engine in the fan and the core compartments with the vast majority of the thermal distress and the most extensive fire damage located in the fan compartment from the intermediate case back to the turbine exhaust case from the 2:00 to 6:00 o'clock (horizontal bifurcation panel) position. Of significance: 1) 14th-stage pilot control valve, located at about the 2:00 o'clock position on the intermediate case, was completely consumed and all that remained was the data plate and several pieces identified as coming from valve that was recovered in debris recovered from the TR; 2) the stator vane actuator (SVA), located at about the 4:00 o'clock position on the intermediate case, was thermally damaged, melted, consumed, and missing about half the outboard side of the main body housing and cover; 3) the end housing of the fuel flow transmitter (FFT) was found backed-off from the main housing creating a gap about 0.3-inches at the bottom of the unit and approximately the forward two-thirds of the outer shell was melted and consumed; 4) on the core side of the engine bifurcation panel (top), the air/oil heat exchanger (AOHE) muscle pressure OPEN and CLOSE fuel lines were found disconnected from their respective pass-through fitting at the braze joint; and 5) FFT-to-fuel divider valve (FDV) fuel line was intact but distorted.

TEST AND RESEARCH

Testing and Finite Element Modeling of Deflection of the FFT-to-FDV fuel line

The FFT and the FFT-to-FDV fuel line were both subjected to additional examination and testing. An installation fit check and a dimensional inspection of the FFT-to-FDV fuel line both found that it was plastically deformed about 1.3-inches vertically from its normal orientation at the outlet port end; when attached to the exemplar FFT the line would not line up with the FDV port while in the free state.

A deflection analysis of the FFT-to-FDV fuel line was conducted by first collecting strain measurements as the line was installed and removed on an exemplar engine and feeding that data into a finite elemental

model (FEM) of the FFT and its associated fuel lines and brackets for validation. The results of the FEM analysis showed that the installation and operational FFT-to-FDV fuel line loads, coupled with the displacement of about 1.3-inches vertically downward, had little impact on the loading of the FFT end housing and that the deformation of the fuel tube was the result, and not the cause, of the FFT end housing separation.

Detailed Visual and Metallurgical Examination of the Fuel Flow Transmitter Hardware

The FFT end housing is bolted to the main housing using four through bolts that engage threaded inserts in the main housing. All four of the threaded inserts were pulled out to varying lengths but remained engaged within the housing except for the insert located at the bottom of the main housing that was completely sheared from the housing. All the inserts and the bolts were in good condition; however, the main housing tapped threads that accommodate the inserts exhibited sheared and flattened threads at each of the four locations. All four of the end housing spot faces where the washers sit exhibited raised metal and impression marks; the washers showed evidence of coining (bolt head impression) on both surfaces, were distorted, and no longer flat. Metallurgical and dimensional examination of the FFT main housing, main housing inserts, end housing, end housing attachment bolts, and end housing attachment bolt washers found no material or dimensional anomalies and the parts conformed to their design and manufacturing specification. The FFT assembly procedures called for graphite lubricant to be applied to the end housing attachment bolts. All the bolts were found to have residue consistent with graphite compound; this same residue was found on only one surface of each of the four washers. In each case, the graphite was on the surface of the washer with the bolt head impression.

Torque Tension Testing of the Fuel Flow Transmitter Hardware

Torque tension tests were performed on exemplar main housing inserts and on the end housing bolts and washers to gather installation torque versus installation load data for this bolted joint. This data was plotted against yield load and pull-out capability curves at typical (nominal) and minimum property conditions as a function of temperature to assess the load capacity of the bolted joint. As a function of temperature, the load capability of the bolted joint decreases as the temperature increases. For purposes of this analysis, the maximum operational temperature that the FFT would be expected to experience was assumed to be a hot day engine soak-back temperature with zero fuel flow through the FFT, near zero undercowl vent flow, and a hot diffuser case, similar to an immediate engine shutdown. The results of the testing and analysis revealed that: 1) the quantity and location (bolt threads only versus threads and washer faces) of graphite lubricate applied to the end housing bolts greatly affects the installation preload and a wide range of values were observed, 2) at the higher installation torque value (bolt installation torque is 150±10 inch-pounds), the bolted joint hardware load capacity at the soak-back temperature is below the installation preload value for all material conditions, 3) at the lower installation torque value, the load capability of the main inserts, and the end housing attachment bolts, the end housing flange is above the installation preload, and 4) the load capability of the washers was marginal or less than marginal at room temperature and less than the installation preload well before reaching the soak-back temperature. This

indicates that the main housing threads may not be able to maintain the preload without eventually yielding and resulting in lessening of the preload and loosening of the joint.

Examination of the end housing bolt washers used in the torque tension tests showed evidence of deformation ('coining') at the low and high bolt installation torque levels. Examination of the event washers showed similar evidence of this condition but the coining was observed on both surfaces consistent with the washers having been used multiple times. The distortion of the washers was predicted by the FEM analysis. The mating surface of the washers used the event end housing also showed similar distress and the coining condition.

Fuel Flow Transmitter Maintenance Instructions and Corrective Actions

A review of the AMETEK FFT Component Maintenance Manual (CMM) found several areas where of improvements could be made to ensure a more consistent FFT assembly practice. First, the review found two different end housing bolt installation torque values; one referenced in the Test and Fault Isolation section and one referenced in Service Bulletin (SB) 757/FF/8TJ124-73-03 that had been incorporated into the FFT and was integrated into the CMM. To eliminate this confusion, AMETEK proposed changes that would only reference the correct required installation torque (for the SB). Second, the assembly procedures call for the application of a graphite lubrication to the end housing bolts but it does not specify the amount to be applied. FFT torque tension tests of the bolts and washers showed that by varying the amount of lubricant applied and whether the lubricant gets on the washer, inadvertently or intentionally, is a significant factor affecting the end housing bolt installation preload. To help ensure the proper preload for the given installation torque, AMETEK proposed changes that clarify the procedures for the application of the lubricant. Third, although the SB 757/FF/8TJ124-73-03 required that end housing bolt washers not be reused, the actual disassembly procedures did not require that used washers be discarded nor the assembly procedures require that new washers be installed. Testing showed that distorted washers, either caused by reused washers or over-torqued end housing bolts, do have an adverse effect on the ability of the joint to maintain proper torque. Thus, AMETEK proposed changes that would modify the disassembly procedures to require discarding removed washers and would modify the assembly procedures to require installing only new washers.

Information

Certificate:	**Age:**
Airplane Rating(s):	**Seat Occupied:**
Other Aircraft Rating(s):	**Restraint Used:**
Instrument Rating(s):	**Second Pilot Present:**
Instructor Rating(s):	**Toxicology Performed:**
Medical Certification:	**Last FAA Medical Exam:**
Occupational Pilot:	**Last Flight Review or Equivalent:**
Flight Time:	

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	**Registration:**	N6714Q
Model/Series:	757-232	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	30485
Landing Gear Type:	Tricycle	**Seats:**	178
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	P & W
ELT:		**Engine Model/Series:**	PW2037
Registered Owner:	DELTA AIR LINES INC	**Rated Power:**	37530 Lbs thrust
Operator:	DELTA AIR LINES INC	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	DALA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Night
Observation Facility, Elevation:		**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:		**Visibility**	
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:			
Departure Point:	Atlanta, GA	**Type of Flight Plan Filed:**	IFR
Destination:	Los Angeles, CA (LAX)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	6 None	**Aircraft Damage:**	None
Passenger Injuries:	3 Minor, 169 None	**Aircraft Fire:**	In-flight
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	3 Minor, 175 None	**Latitude, Longitude:**	33.639167,-84.428054

Administrative Information

Investigator In Charge (IIC):	Scarfo, Jean-Pierre
Additional Participating Persons:	David Keenan; FAA; Washington, DC Chris Demers; Pratt & Whitney; East Hartford, CT Chris Leoni; Pratt & Whitney; East Hartford, CT Shannon Masters; Delta Air Lines; Atlanta, GA Richard Smith; Delta Air Lines; Atlanta, GA Paul Terjak; Boeing; Seattle, WA Pat Paris; Air Line Pilot's Association; Atlanta, GA
Original Publish Date:	November 20, 2013
Last Revision Date:	
Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=80835