Aviation Investigation Final Report

Location:	Danville, California	**Incident Number:**	WPR13IA144
Date & Time:	March 5, 2013, 11:20 Local	**Registration:**	N417QX
Aircraft:	Bombardier DHC-8-402	**Aircraft Damage:**	Minor
Defining Event:	Fire/smoke (non-impact)	**Injuries:**	51 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

The flight was climbing through flight level 200 when the flight crew received a No. 2 engine audible fire warning, which was accompanied by a bang sound. The crew subsequently shut the No. 2 engine down and discharged both of the engine's fire extinguishing bottles. The cabin crew reported no visible fire, but the flight crew continued to receive a fire indication. The captain then declared an emergency, began a descent to the departure airport, and landed about 9 minutes after the event. After the airplane was stopped on the runway and the No. 1 (left) engine was shut down, an emergency evacuation was conducted using the main cabin door. An initial assessment by company personnel indicated that the fire damage to the airplane was limited to what was visible on the aircraft's exterior.

A visual postincident examination of the engine revealed that sooting was present on external case surfaces, which were concentrated on the aft half of the No. 2 engine. A disassembly of the engine confirmed that about half of the SED outer dome within the combustion section had separated and was subsequently ingested into the gas path. To determine the reason for the separation, three locations on the outer dome were sectioned and examined. All three locations exhibited insufficient weld penetration so that the welds remained totally contained within the SED outer dome and did not penetrate through to the inner duct as required by the manufacturing specifications.

Probable Cause and Findings

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

The failure and separation of a section of the No. 2 engine's combustion chamber's small exit duct (SED), which created an airflow disruption that led to an engine surge and subsequent fire. Contributing to the accident was the insufficient weld penetration that remained totally contained within the SED outer dome and did not penetrate through to the inner duct as required by the manufacturing specifications.

Findings

Aircraft	Combustion section - Damaged/degraded
Organizational issues	Equipment manufacture - Manufacturer

Factual Information

History of Flight

Enroute-climb to cruise	Fire/smoke (non-impact) (Defining event)
Emergency descent	Off-field or emergency landing

HISTORY OF FLIGHT

On March 5, 2013, about 1120 Pacific standard time, a Bombardier Inc. DHC-8-402 airplane, N417QX, sustained minor damage following an in-flight engine fire during initial climb near Danville, California. The airplane, which was registered to Horizon Air Industries of Seatac Washington, was being operated in accordance with 14 Code of Federal Regulations Part 121. Visual meteorological conditions prevailed at the time of the accident, and an instrument flight rules (IFR) flight plan had been filed and activated. The flight departed the Norman Y. Mineta San Jose International Airport (SJC), about 1108, with its destination being the Boise Air Terminal (BOI), Boise, Idaho.

In a written statement provided to the National Transportation Safety Board (NTSB) investigator-in-charge (IIC), the pilot-in-command (PIC) reported while climbing en route through 18,000 feet mean sea level (msl), the flight crew heard a muffled "boom" in the flight deck, immediately followed by the crew noticing that the number 2 engine's internal turbine temperature (ITT) was exceeding limits. The PIC stated that some yaw was observed as well, which indicated a loss of power on the number 2 engine. The flight crew received and engine fire warning for the number 2 engine, which was then followed by the crew performing the emergency Engine Fire Checklist. At this time an emergency was declared with Air Traffic Control (ATC). The PIC revealed that in accordance with the emergency checklist, the crew discharged the first [fire] bottle; however, the fire warning on the flight deck continued. A second bottle was discharged, which was consistent with the emergency checklist, but the fire warning remained illuminated. The flight crew then requested ATC clearance directly back to SJC. The PIC revealed that while the Oakland International Airport (OAK), Oakland, California was slightly closer in terms of miles, the aircraft's altitude would have required circling, so the crew elected to proceed directly towards SJC. At this time the PIC reported that the flight crew advised ATC of the situation, and asked them to have the fire trucks ready on landing. The PIC stated that the weather at the time was consistent with visual meteorological conditions, with inflight visibility better than 25 miles. The pilot revealed that after touchdown at SJC, the aircraft was brought to a complete stop on the runway. The flight crew asked emergency personnel if the fire could be seen on the exterior of the engine; no smoke or fire was reported. The flight crew then elected to make an evacuation through the main cabin door. The passengers were taken to the side of the runway and the crew secured the airplane. Buses were used to transport the passengers and crew to the airport terminal.

ENGINE EXAMINATION

General

According to an NTSB powerplants aerospace engineer who participated in the postaccident examination of the engine, the engine was removed from the airplane and shipped to the Pratt and Whitney Canada (PWC) facility in St. Hubert, Quebec, Canada where it was inspected and disassembled. During disassembly, a section of the small exit duct (SED) located within the combustion section was found to have separated and been ingested into the gaspath. All internal hardware aft of the combustion section exhibited varying degrees of thermal damage and sooting consistent with an airflow disruption. The remaining intact section of the SED was examined at the PWC materials lab where improper weld penetration between the SED outer dome and the combustion housing inner duct was identified based on drawing specifications.

The advanced pneumatic detection (APD) fire loop exhibited thermal distress including deformation of internal diaphragm switches. The deformation resulted in a fire warning to the flight crew that remained latched even after temperatures levels had decreased below warning limits. In response to APD system related failures, Kidde Aerospace made design improvements to the system and Bombardier released service bulletins (SBs) 84-26-08A, 84-26-09A, and 84-26-12A for removal and replacement with the updated model. Airworthiness directives (ADs) were subsequently released by Transport Canada and the United States Federal Aviation Administration (FAA) mandating replacement.

A quality investigation into the improper weld penetration during production of the SED assembly identified an inadvertent adjustment to the electron beam (EB) current level during the manufacturing process as the probable cause. A lot of five SED assemblies were identified as being potentially affected by the quality escape. Two of the assemblies, including the SED in the incident aircraft engine experienced an in-flight failure and the remaining three engines containing suspect assemblies were removed for repair.

Engine Information

History

According to Horizon Air's maintenance records, engine serial number (ESN) PCE-FA0184 had accumulated the following hours and cycles: 18,764 hours time since new (TSN), 19,351 cycles since new (CSN), 4,244 hours time since repair (TSR), and 4,391 cycles since repair (CSR).

Engine Description

The PWC model PW150A engine is a three spool free-turbine turboprop engine incorporating a three-stage axial compressor followed by a centrifugal compressor stage, each driven by independent axial turbines, a reverse flow annular combustor, and a two-stage power turbine that drives an offset reduction gearbox. The engine fuel flow is controlled by a Full Authority Digital Electronic Control. The engine has a maximum rating of 5,071 shaft horsepower (SHP) and a continuous rating of 4,580 SHP.

Engine Disassembly Examination and Documentation

An initial visual examination of the engine was conducted at SJC. Sooting was observed on external case surfaces, concentrated on the aft half of the engine. The engine's flexible lines exhibited thermal distress including melting and charring of line sheathing. A borescope examination of the engine revealed that a piece of the SED located in the combustion section had separated. The 1st stage turbine nozzle vanes exhibited hard particle damage along the leading edge. The engine was shipped to PWC in St. Hubert, Quebec, Canada for further inspection and teardown.

As Received

Upon receipt of the engine at the PWC facility in Quebec, it was reported that the engine was intact without indications of case breaches or deformation. The external engine components were sooted from the aft turbine support case flange forward to the accessory gearbox (AGB). Soot concentration was heaviest on the aft portion of the engine and was progressively lighter moving forward. The indicated turbine temperature (ITT) harness exhibited thermal distress including charring and blistering 360° around the engine. Other flexible lines such as the flexible fuel manifold harness exhibited blistering and had a grayish color consistent with thermal exposure, but maintained flexibility. The oil pressure supply line to the No. 7 bearing was thermally damaged exposing the internal braided cord.

The engine magnetic chip detector plugs were removed and inspected for indications of abnormal metal wear accumulation. The reduction gearbox (RGB) scavenge plug and A/C generator plug were free of debris. The turbo machine (T/M) magnetic chip detector plug had metal "fuzz", consistent with normal engine operation according to PWC. The RGB and main oil filters were removed and were free of debris or blockages.

Power turbine gear train continuity was verified by manually spinning the propeller shaft and observing concurrent rotation of the 2nd stage power turbine.

Disassembly and Inspection Findings

The reduction gearbox (RGB) was not disassembled due to the absence of evidence suggesting internal damage. The RGB propeller shaft spun freely without binding.

The compressor assembly/impeller assembly was intact and in good condition. Impeller blade tips exhibited light rub with corresponding rub marks on the impeller exducer. No damage was noted on diffuser or axial compressor stages.

The accessory gear box (AGB) was not disassembled due to the absence of evidence suggesting internal damage.

The combustion section's fuel nozzles were intact and in good condition with light sooting consistent with engines of similar hours/cycles. The outer combustion liner had dark uniform sooting on the liner walls and material burn through in two locations. Small metal fragments were found resting in the bottom of the outer liner. The inner combustion liner was intact but exhibited sooting of liner walls. There were no indications of thermal damage or burn through. Fuel nozzle floating collars had thermal erosion which is considered a normal condition on the PW150A engine.

The high pressure turbine (HPT) vane assembly includes the SED inner duct and outer dome that are welded together and function to direct combustion gas flow. Pieces of the outer dome had separated from the vane assembly and were subsequently ingested into the gas path. A section of the SED outer dome was submitted to the PWC materials lab for weld analysis. The exposed inner duct of the SED exhibited localized thermal distress including burn through and distortion at approximately the 11 O' Clock position. Sooting, metal splatter and discoloration were noted on all HPT vanes with some metallic fragments adhering to the leading edge of the vane airfoil. Two metal fragments were found resting at the bottom of the HPT blade shroud against the aft side of the vanes.

The HPT disk assembly exhibited impact damage and metal splatter along the blade leading edges 360 degrees around. All blades were heavily sooted. Material loss was noted on leading edge blade tips resulting in exposure of internal blade cooling passages. Uniform tip rubs were present on HPT blades around the disk as evidenced by shiny metal and material smearing.

The low pressure turbine (LPT) stator was intact and in good condition. Sooting was present on the stator vanes between the 2 and 11 o'clock positions and was most heavily concentrated on the suction side. Soot could be removed with a cloth and light pressure. A small amount of metal spray was adhered to leading edge of multiple vanes. The low pressure turbine disk exhibited discoloration and sooting consistent with thermal exposure. Metal spray was adhered to leading edge of turbine blades along the length of the blade span.

The power turbine's inter-stage turbine vane ring was intact but exhibited sooting from 2 to 11 o'clock, and was most concentrated on the suction side. Impact damage was noted at several locations along the outside diameter of the case. Damage to the honeycomb seal was observed in two locations at approximately 9 and 10 o'clock. The first stage power turbine disk exhibited sooting from 2 to 11 o'clock and a fine metal spray along the leading edge of the turbine blades. The second stage power turbine stator and second stage power turbine disk were both in good condition with light sooting. The exposed engine bearings were intact and rotated freely.

PWC LAB RESULTS

Metallurgy

The intact portion of the SED outer dome was submitted to the PWC materials lab for analysis of the EB weld. The EB weld is a dual beam weld that runs 360 degrees around the SED outer dome circumference. Three locations on the outer dome were selected and sectioned for examination between 15x and 50x magnification. All three locations exhibited insufficient weld penetration so that the welds remained totally contained within the SED outer dome and did not penetrate through to the inner duct as required by the manufacturing specifications.

Chemical Analysis

A swab sample of white residue that was found on a majority of external engine and nacelle surfaces was collected and submitted to the PWC chemistry lab for composition analysis. The sample was analyzed used Fourier Transformed Infrared (FTIR) and Scanning Electron Microscopy (SEM) and was identified as silicon in the presence of oxygen. According to PWC, this suggests the residue was silicon dioxide, a byproduct of high temperature silicone when exposed to hot gases or fire.

ADDITIONAL INFORMATION

Engine Monitoring Unite (EMU and Quick Access Recorder (QAR) Data

The EMU and QAR data files were downloaded by Horizon Air on-scene at the SJC airport. The files were analyzed by Horizon Air and Bombardier and parameter plots were reviewed during the powerplant group teardown at PWC. EMU data confirmed that the engine experienced a surge event and subsequent flame out condition. A detailed summary of EMU and QAR data is available in the Flight Data Recorders Group Factual Report.

SED Failure History and PWC Quality Investigation

In December 2012, a PW150A engine, ESN PCE-FA0225 was removed from an All Nippon Airways Trading Company DHC-8-402 due to a slow loss of ITT margin over the course of several months. Following engine removal, a borescope inspection identified unusual hot section distress including a missing portion of the SED outer dome. The engine was disassembled and the remaining section of the SED was sent to the PWC materials lab for analysis. As seen with the Horizon Air incident engine, findings of the Nippon Airways incident revealed that the EB weld had not fully penetrated the SED outer dome resulting in a weak connection between the outer dome and the inner duct.

As a result of the findings, PWC launched an internal investigation to determine the probable cause of the quality escape. The investigation initially concluded that a low current setting on the EB weld machine during the manufacturing process resulted in improper weld penetration and subsequent SED outer dome separation.

In September 2013, PW150A engine, ESN PCE-FA0024 was removed from a Philippines Airlines Express Bombardier Q400 after a borescope inspection identified SED damage following an in-flight shutdown due to an engine flameout. Analysis of the SED confirmed the failure was consistent with what was documented on the ANA and Horizon Air engines.

According to engine build records, the SED assemblies installed in the ANA and Horizon Air engines were both manufactured as part of the same lot. The Air Philippines Express SED assembly was identified to be part of a different lot. PWC determined it was unlikely an inadvertent adjustment to the EB weld machine during the manufacturing process would affect two different production lots so the quality investigation was re-opened to look into other factors that may have contributed to the failures. After a series of tests, the team identified variation in the EB cathode filament tip radius and variation of filament installation position in EB machine as two factors that can affect weld depth. It is unknown if one or both of the above findings may have been the causal factor in the three SED failures.

Prior to the three events detailed above, weld integrity was verified by testing a random sample once every quarter. After the ANA event, the SED manufacturer began collecting test samples both before and after each production lot. The sample articles are welded according to specification and then examined by a materials lab for proper weld penetration and absence of voids. A serrated strip that is tack welded in place around the SED outer dome, over the EB weld prohibits visual inspection after assembly is complete. The manufacturer has since implemented an additional x-ray computed tomography scan on 100 percent of SED assemblies prior to installation.

To eliminate variation in cathode filaments, acceptance inspection criteria has been established for all filaments prior to use. The EB weld machine used during production of the failed assemblies has also since been replaced. The new machine eliminates cathode filament installation variation and is currently used for all SED assembly production.

Fire Detection System

The Bombardier DHC-8 is designed with a single fire zone nacelle (zone 1). During operation air enters the nacelle through the propeller spinner gap and dedicated NACA scoops and utilizes negative pressure generated by exhaust gases to circulate air out through a gap between the engine exhaust pipe and exhaust nozzle. The nacelle has an APD fire loop system manufactured by Kidde Aerospace. The system features helium filled wire with a shielded hydrogen filled core and a series of equally spaced pressure sensors to detect and alert the crew of overtemperature conditions and fire. When exposed to spot heat, hydrogen escapes from the core resulting in a loss of internal pressure that the sensors detect. On the incident aircraft APD system, a high heat exposure over an extended period of time caused permanent deformation of internal diaphragm switches not allowing the system to reset even after the fire had been extinguished.

Kidde Aerospace developed an improved APD system to address the fire warning reset issue and Bombardier released SBs 84-26-08A and 84-26-09A on May 12, 2011 and SB 84-26-12A on December 13, 2011 for all affected airplanes. The improved APD system is less susceptible to diaphragm switch deformation and has improved hydrogen core gas transfer so in events where temperatures decrease below established limits the system will sense the decrease and reset the fire warning. Incorporation of these SBs was mandated by Transport Canada by Airworthiness Directive (AD) CF-2012-07, effective February 10, 2012. The AD requires replacement of all affected APD's within 6,000 flight hours or 30 months, whichever comes first, from the AD effective date. The United States (FAA) released equivalent AD, 2013-16-25 on August 1, 2013, with an effective date of October 4, 2013.

For a complete review of the powerplant engineer's report, refer to the NTSB Powerplant Group Chairman's Factual Report, which can be found in the docket for this report.

Pilot Information

Certificate:	Airline transport	**Age:**	55
Airplane Rating(s):	None	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	November 15, 2012
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 4, 2012
Flight Time:	26000 hours (Total, all aircraft), 1000 hours (Total, this make and model), 25000 hours (Pilot In Command, all aircraft), 179 hours (Last 90 days, all aircraft), 69 hours (Last 30 days, all aircraft), 2 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Commercial	**Age:**	30
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Powered-lift	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	August 6, 2012
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	November 5, 2012
Flight Time:	3300 hours (Total, all aircraft), 200 hours (Total, this make and model), 2000 hours (Pilot In Command, all aircraft), 135 hours (Last 90 days, all aircraft), 53 hours (Last 30 days, all aircraft), 2 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Bombardier	**Registration:**	N417QX
Model/Series:	DHC-8-402	**Aircraft Category:**	Airplane
Year of Manufacture:	2004	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	4086
Landing Gear Type:	Retractable - Tricycle	**Seats:**	81
Date/Type of Last Inspection:	March 2, 2013 Continuous airworthiness	**Certified Max Gross Wt.:**	40112 lbs
Time Since Last Inspection:	49 Hrs	**Engines:**	2 Turbo prop
Airframe Total Time:	22123 Hrs as of last inspection	**Engine Manufacturer:**	Pratt and Whitney
ELT:	C126 installed, not activated	**Engine Model/Series:**	PW 150
Registered Owner:	Horizon Air Industries Inc.	**Rated Power:**	5071 Horsepower
Operator:	Horizon Air	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	QXEA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	CCR,26 ft msl	**Distance from Accident Site:**	10 Nautical Miles
Observation Time:	10:53 Local	**Direction from Accident Site:**	20°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	13 knots /	**Turbulence Type Forecast/Actual:**	/ None
Wind Direction:	190°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.03 inches Hg	**Temperature/Dew Point:**	13°C / 4°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	San Jose, CA (SJC)	**Type of Flight Plan Filed:**	IFR
Destination:	Boise, ID (BOI)	**Type of Clearance:**	IFR
Departure Time:	11:08 Local	**Type of Airspace:**	

Airport Information

Airport:	Norman Y. Mineta San Jose Int SJC	**Runway Surface Type:**	Asphalt
Airport Elevation:	62 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	12L	**IFR Approach:**	None
Runway Length/Width:	11000 ft / 150 ft	**VFR Approach/Landing:**	Forced landing;Straight-in

Wreckage and Impact Information

Crew Injuries:	4 None	**Aircraft Damage:**	Minor
Passenger Injuries:	47 None	**Aircraft Fire:**	In-flight
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	51 None	**Latitude, Longitude:**	37.839443,-122.003334(est)

Administrative Information

Investigator In Charge (IIC):	Little, Thomas
Additional Participating Persons:	Gregory J Minarik; Federal Aviation Administration; San Jose, CA Marc Hamilton; Transport Safety Board of Canada; Gloucester Lacey Pittman; Horizon Air; Portland, OR
Original Publish Date:	September 30, 2014
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=86396