



Aviation Investigation Final Report

Location:	Denver, Colorado	Accident Number:	DCA17LA182
Date & Time:	July 2, 2017, 13:19 Local	Registration:	N796SK
Aircraft:	BOMBARDIER INC CL 600 2C10	Aircraft Damage:	Substantial
Defining Event:	Fire/smoke (non-impact)	Injuries:	59 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

After the scheduled air carrier flight touched down on the runway, a left engine undercowl fire occurred. The fire occurred after leaked fuel accumulating inside the engine core compartment (a fire zone) ignited from contact with a hot engine surface. The fuel accumulated inside the core compartment because the nacelle drainage system was overwhelmed by the release of about 34 gallons of fuel during the landing roll, at which time the high rates of ventilation through the nacelle were reduced.

The leak occurred during landing when the removal of fuel leakage depends in part on gravity drainage. A nacelle drainage capability assessment found that the core compartment contained about 20 gallons of fuel at the time of ignition. After engine shutdown, fuel draining from the core compartment was no longer carried overboard by the fan exhaust, and the fuel pooled in the fan duct. Some of this fuel drained to the ground through the transcowl drain holes. The fire became uncontrolled when it escaped the fire zone and spread to areas where expelled/drained fuel had accumulated in the nacelle and on the ground. The draining fuel led to a fire on the ground and on the underside of the left pylon. The fire was extinguished by airport rescue and firefighting personnel.

On-site investigation found that a rosan -05 to -06 expander fitting had pulled out from the fuel supply port of the operability bleed valve (OBV), which is part of the left engine's environmental control system (ECS). Also, two ECS support links (which attach and support the ECS hardware, including the OBV, to the engine) were found severely worn.

Metallurgical examination of the OBV upper housing fuel supply port found evidence of advanced thread wear and fatigue damage, consistent with side-to-side fitting cyclic movement and insufficient remaining threads to prevent the fitting in the upper housing from pulling out. Modal testing demonstrated that ECS link wear can shift the OBV natural operating frequency into the engine operating frequency range, significantly increasing the fuel tube loads into the fitting. OBV design evaluation testing found that fitting joint preload loss permits relative

motion to occur between the fitting and upper housing port threads, initiating upper housing thread wear and leading to upper housing thread failure and fitting pullout. The rosan -05 to -06 expander fitting with the cast aluminum housing lacked the design margin to maintain sufficient preload against engine vibration loads and fitting pullout.

A review of CF34-8 maintenance engineering sheets and field maintenance documents found that rod end alignment instructions critical to preventing ECS support link wear were not provided in the base engine assembly drawing and that the ECS support links were not part of any scheduled airplane- or engine-level maintenance. As a result, maintenance personnel did not inspect for wear caused by poor rod end alignment. Worn or misaligned ECS support links increase fuel tube fitting loads and can result in fitting pullouts.

Probable Cause and Findings

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

The fuel supply tube fitting pulling out of the left engine's operability bleed valve (OBV) during the landing rollout, allowing fuel to leak and contact hot engine cases, which ignited a fire that caused thermal damage to the engine pylon. Contributing to the fitting pullout from the OBV was an undetected progressive environmental control system (ECS) support link wear condition that allowed excessive OBV movement relative to the engine, and the lack of alignment instructions in the base engine assembly drawing and the lack of maintenance tasks to assess the operational condition of the ECS links.

Findings

Aircraft	Compressor bleed valve - Design
Aircraft	(general) - Inadequate inspection
Aircraft	Compressor bleed valve - Capability exceeded
Aircraft	Nacelle/pylon misc structure - Failure

Factual Information

History of Flight

Landing-landing roll	Powerplant sys/comp malf/fail
Taxi-from runway	Fire/smoke (non-impact) (Defining event)

On July 2, 2017, about 1319 mountain daylight time, a SkyWest Airlines CL-600-2C10 (CRJ 700) airplane, N796SK, experienced a left engine undercowl fire after landing at Denver International Airport, Denver, Colorado (DEN). None of the 59 occupants aboard the airplane were injured, and the airplane sustained substantial damage. The airplane was operating under Title 14 *Code of Federal Regulations* Part 121 as a scheduled flight from Aspen/Pitkin County Airport, Aspen, Colorado, to DEN.

After the airplane touched down and while the thrust reversers were being stowed, the flight crew observed a “L ENG SRG OPEN” caution (indicating that the left engine’s operability bleed valve [OBV] failed while open) as the airplane exited the runway. The flight crew reduced engine power to idle and continued to taxi. The flight crew observed a “L ENG FIRE” warning (indicating a fire in the left engine) 1 minute 15 seconds later. The flight crew discharged both left nacelle fire extinguishing bottles, but the fire did not extinguish. The flight crew stopped the airplane on the taxiway and shut down the left engine. The cabin crew reported the odor but not the presence of smoke in the cabin and observed fire inside the left inlet cowl, at the left pylon, and in a pool of fuel on the ground beneath the airplane. The passengers evacuated the airplane through the main cabin door. The fire was extinguished by airport rescue and firefighting personnel.

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:	BOMBARDIER INC	Registration:	N796SK
Model/Series:	CL 600 2C10 700C	Aircraft Category:	Airplane
Year of Manufacture:	2010	Amateur Built:	
Airworthiness Certificate:	Commuter	Serial Number:	10300
Landing Gear Type:	Retractable - Tricycle	Seats:	
Date/Type of Last Inspection:		Certified Max Gross Wt.:	
Time Since Last Inspection:		Engines:	2 Turbo fan
Airframe Total Time:		Engine Manufacturer:	GE
ELT:		Engine Model/Series:	CF34-8C5B1
Registered Owner:		Rated Power:	0 Horsepower
Operator:		Operating Certificate(s) Held:	Flag carrier (121)

Each of the airplane's General Electric (GE) CF34-8C5B1 turbofan engines was equipped with a Parker Aerospace OBV, part number 4123T71P04, which is a fuel-actuated, electrically controlled butterfly valve that increases an engine's operability margin by unloading the high-pressure compressor during engine starts and at higher power settings. The valve opens to bleed stage 10 compressor air into the fan bypass air stream. Three Rosán-type expander fittings are installed in the OBV upper housing (housing cap). (Rosán was the trade name for this two-piece, ring-lock-type fluid fitting, which is now simply referred to as a rosan fitting.) The three fittings are for the supply, return, and drain ports. Fuel from the engine high-pressure pump is routed to the supply port and returned to the pump inlet through the return port. Residual fuel is drained through the drain port. The supply and return fittings, which are part of a high-pressure valve actuation circuit, have rosan expanders identified as -05 to -06.

The engine core is enclosed by the forward core cowls (core compartment). The OBV, which is part of each engine's environmental control system (ECS), extends away from the engine core to mate with an air exhaust port in the forward upper core cowl. The assembly is stabilized by four adjustable support link rod assemblies (ECS support links) that are installed between the 10th stage duct and bleed air manifold and the engine combustion chamber frame flanges.

The engine core compartment is a designated fire zone because CF34-8C engine case temperatures are capable of igniting fuel. High rates of ventilation through the core compartment cool the engine and remove flammable fluids and gases to prevent ignition due to contact with hot engine surfaces. Core ventilation rates decrease with engine power reduction. Fluids that are not removed with the ventilation airflow collect at the bottom of the core compartment and drain into the fan bypass duct (fan duct) through three holes in the lower core cowl that are 0.25 inch in diameter. Drained fluids are removed from the fan duct with the fan discharge airstream exiting the nacelle. With the engine shut down, fuel draining from the

core compartment is no longer removed by fan exhaust; this fuel accumulates in the fan duct and is routed overboard. The forward lower core cowl includes a pressure relief door that was designed to open to relieve excess pressure from the core compartment/fire zone.

Review of the operator's maintenance records found that the left and right engines and the left and right OBVs were original to the airplane and had not been removed. Both engines and OBVs had accumulated 22,419 total hours and 13,157 total flight cycles.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	Condition of Light:	Day
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:	Aspen, CO (KASE)	Type of Flight Plan Filed:	IFR

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Precipitation and Obscuration:			
Departure Point:	Aspen, CO (KASE)	Type of Flight Plan Filed:	IFR
Destination:	Denver, CO (KDEN)	Type of Clearance:	IFR
Departure Time:	Type of Airspace:		
	Class A		

Airport Information

Airport:	Denver International Airport KDEN	Runway Surface Type:	Concrete
Airport Elevation:	5434 ft msl	Runway Surface Condition:	Dry
Runway Used:	34R	IFR Approach:	Unknown
Runway Length/Width:	12000 ft / 150 ft	VFR Approach/Landing:	Unknown

Wreckage and Impact Information

Crew Injuries:	3 None	Aircraft Damage:	Substantial
Passenger Injuries:	56 None	Aircraft Fire:	On-ground
Ground Injuries:	N/A	Aircraft Explosion:	None
Total Injuries:	59 None	Latitude, Longitude:	39.861667,-104.67305(est)

Environmental Control System Link Alignment

Bombardier Shorts stated that ECS link rod end bearings must be properly aligned and securely clamped between the fork bushings to prevent lateral movement and premature wear. Bombardier Shorts found that the CF34-8 engine maintenance engineering sheets did not include rod end alignment procedures required to prevent lateral movement and premature wear and that the *CRJ700/900/1000 Aircraft Maintenance Manual* did not include any controls for ECS link condition. GE confirmed that instructions to align the ECS links during installation were missing from the base engine assembly drawing and that the ECS links were not part of any scheduled airplane-level maintenance.

In August 2017 and January 2018, GE published Service Bulletin (SB) 8C 75-0019 and SB 8E 75-0016, respectively. These SBs required a one-time inspection of the operability bleed valve (OBV) supply, return, and drain fuel fittings and ECS link rod assemblies and replacement of OBVs or related hardware that fail inspection. In November 2017, the FAA issued emergency Airworthiness Directive (AD) 2017-23-06 to mandate compliance with 8C 75-0019, which was then superseded in November 2019 by AD 2019-22-05, to require a more detailed inspection and mandate repetitive inspections of the OBV fuel tubes, ECS link rod assemblies, and OBV fuel fittings. In January 2020, a 16,000 flight hour ECS link special inspection was made an 8C Engine Manual Chapter 5 Table 803 Airworthiness Limitation. In February 2020, an improved-design P/N 4123T71P06 (P06) OBV was released to service by SB 8E 75-0020 and SB 8C 75-0026. In December 2021, the FAA published a notice of proposed rulemaking (NPRM) to supersede AD 2019-22-05 that would apply to both CF34-8C and CF34-8E engines and includes initial and repetitive inspections of OBV fuel tubes, ECS link rod assemblies, and OBV fuel fittings and replacement of OBVs or related OBV hardware that fail inspection; requires replacement of certain OBVs installed on GE CF34-8C and CF34-8E model turbofan

engines with the improved-design Po6 OBV and makes upgrade to the improved-design Po6 OBV the terminating action for the repetitive inspections.

Other containment actions addressing the OBV fittings and the ECS links and the final corrective actions are presented in the investigative docket for this accident.

Additional Information

Environmental Control System Link Alignment

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Tests and Research

OBV Modal Impact Test

GE tested the effect of worn ECS links on the OBV (part number 4123T71P04) vibratory response using ECS links from a fitting pullout event that occurred in January 2017. (Those links had similar wear as the accident ECS links but were less severely damaged.) Installation of the worn links shifted the natural OBV frequency into the engine operating frequency range.

Design Evaluation Tests

GE performed rotary flex and torque tension tests to understand the capability of the rosan expander-type fitting joint. The tests determined that the rosan -05 to -06 expander fitting was susceptible to wear at loads within engine vibration levels. The tests also demonstrated that a -06 to -06 standard fitting had substantially more resistance to external loads. A new-design OBV, part number 4123T71P05, with the larger -06 to -06 standard fittings was released to the field on December 21, 2018. Further tests determined that increasing the standard fitting installation torque would sufficiently increase the joint preload so that the possibility of port thread wear could be eliminated. As a result, the upper housing cap material of the new-design OBV was upgraded from cast to forged aluminum for increased resistance to thread deformation at operating temperatures, and more durable -06 to -06 supply and return fittings were specified. The more durable OBV, part number 4123T71P06, was introduced to the field on February 21, 2020. The changes to the OBV with improved durability resulted in a 21% average fitting preload increase compared with the previous model OBV.

Nacelle Drainage Capability Assessment

The CRJ-700 nacelle drain capability is about 1.5 gallons per minute with the engine at ground idle and the pressure relief door closed. GE's drainage capability assessment of the OBV fuel supply fitting pullout scenario found that about 34 gallons of fuel had been released into the core compartment during a 2-minute 6-second period (from fitting pullout to fuel firewall shutoff valve closure) and at a leakage rate of 16.2 gallons per minute. Fuel-laden air would then have been carried out of the undercowl ventilation exit. The assessment also determined that fuel spilled through the four 0.625-inch-diameter vent openings to the fan duct after about 2 gallons of fuel (2 to 3 inches fluid height) had accumulated and that about 19 gallons of fuel (7 to 9 inches fluid height) had been inside the core compartment 1 minute 15 seconds after the fitting failure, at which time fuel contacted a hot engine surface and ignited. After engine shutdown, the draining fuel would no longer have been carried overboard by the fan exhaust, so the fuel pooled in the fan duct. Some of this fuel would have drained to the ground.

Organizational and Management Information

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Administrative Information

Investigator In Charge (IIC):	Lovell, John	
Additional Participating Persons:	<p>Ken Wolski; GE Aviation; Evendale, OH James Easton; GE Aviation; Evendale, OH Carl Wager; SkyWest Airlines; St. George, UT John Frost; FAA ECO; Burlington, MA Michael Richardson-Bach; FAA-ECO; Burlington, MA Jeremy Katt; Parker Aerospace; Irvine, CA Maurice Montgomery; SkyWest Airlines; St. George, UT Eric West; FAA AVP-100; Washington, DC</p>	
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Note:		
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=95552	

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