Aviation Investigation Final Report

Location:	Riyadh,	**Incident Number:**	ENG22LA049
Date & Time:	March 31, 2022, 19:05 UTC	**Registration:**	9H-VIG
Aircraft:	Bombardier Global 7500	**Aircraft Damage:**	Minor
Defining Event:	Fire/smoke (non-impact)	**Injuries:**	
Flight Conducted Under:	Non-U.S., commercial		

Analysis

Post-event inspection of a GE Aviation Passport 20-19BB1A turbofan engine found light sooting aft of the fuel nozzles, along with minor thermal damage to an air duct thermal sleeve consistent with an undercowl engine fire. This corroborates the pilot's report of an in-flight engine fire during takeoff climb and during the throttle increases to troubleshoot the fire warning.

The engine was removed and sent to GE for evaluation and a fuel system leak check was performed but the source/location of the fuel leak could not be identified. At several fuel nozzle locations, Nos. 12, 14, 16 and 18, the fuel nozzle pigtail-to-fuel manifold b-nut connections were shiny, lacked sooting, and were thought to be possible leak locations. The fuel pressure and nitrogen check pressure used during the leak tests were well below the fuel pressure the engine experienced during the event and were determined to be insufficient to replicate the fuel leak.

A torque check of all the fuel manifold b-nut connections found five locations, all located on the left fuel manifold, which had very low torque values, less than 200 inch-pounds, when compared to the other b-nut connection locations and the required installation torque of 285 inch-pounds nominal. Two of the five - Nos. 16 and 18 - were identified as possible leak sources during the initial examination.

Detailed analysis of the fuel nozzle No. 18 pigtail-to-fuel manifold b-nut connection revealed evidence of fuel manifold outer diameter surface galling and elliptical and intermediate contact marks indicative of misalignment contact with the fuel manifold female ferrule sealing surface and signs of contaminants and imbedded material (hard particles) on the fuel nozzle male bullnose sealing surface; no other b-nut connection location exhibited this type of surface distress. The source of the hard particle damage could not be positively identified but the observed diagonally orientated abrasive material marks/material removal was consistent with

what appears to be a previous repair; there is no record of a repair operation being performed on this specific nozzle.

Since the post-event fuel system leak checks performed by GE could not induce a fuel leak, the exact location/source of the fuel leak could not be determined by testing and observations. However, the combination of low fuel manifold b-nut torque, misalignment between fuel nozzle No. 18 pigtail-to-fuel manifold b-nut connection and sealing surface distress created the conditions, and sealing surface distress created the conditions by which there was insufficient sealing allowing fuel to leak during high engine power and high fuel pressures. No other fuel nozzle locations had this combination of factors that would have allowed a fuel leak.

Commented [1]:

Probable Cause and Findings

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

An in-flight engine fire resulted from a fuel leak from fuel nozzle No. 18 pigtail-to-fuel manifold b-nut connection that contacted hot engine parts and ignited. Contributing to the manifold fuel leak was the misalignment between fuel manifold female ferrule and fuel nozzle male bullnose sealing surfaces coupled with distress of the ferrule sealing surface.

Findings

Aircraft	Fuel distribution - Design
Personnel issues	Installation - Maintenance personnel

Factual Information

History of Flight

Initial climb	Fire/smoke (non-impact) (Defining event)
Initial climb	Engine shutdown
Initial climb	Loss of engine power (partial)

On March 31, 2022, at 19:05 universal coordinate time (UTC), a Bombardier Global 7500 Business Jet, registration number 9H-VIG, powered by two General Electric (GE) Aviation Passport 20-19BB1A turbofan engine and operated by Vistajet, experienced a right (No. 2) engine fire during the takeoff climb from the King Khalid International Airport, Riyadh, Kingdom of Saudi Arabia (OERK). After the right engine fire warning annunciated, the pilots disengaged the autothrottles and retarded the right engine throttle to idle. When the right engine throttle was reduced, the fire warning annunciation ceased. With the fire warning annunciation out, the pilots incrementally increased the right throttle and the fire warning annunciated again. The pilots shutdown the right engine, performed an in-flight air turn back to OERK, and made an uneventful landing with no injuries reported.

Post-landing inspection of the right engine by GE on-wing support in the Kingdom of Saudi Arabia revealed indications of an undercowl fire and potential fuel leak locations (**Photo 1** and **2**).

Photo 1: Sooting Damage
Photo courtesy of GE

Photo 2: Fuel Manifold B-nut Wetted at Top of Engine – Possible Leak Source
Photo courtesy of GE

The Kingdom of Saudi Arabia Aviation Investigation Bureau (AIB) informed the NTSB of this event on April 14, 2022, and the investigation was ultimately delegated to the NTSB. Due to the similarities with an on-going NTSB investigation (ENG22LA020), a joint Powerplant Group Chair Factual Report was created to document the findings for these two events.

The engine has 18 fuel nozzles and fuel is provided to the fuel nozzles by two fuel manifolds mounted on the outside of the combustion case (**FIGURE 1**).

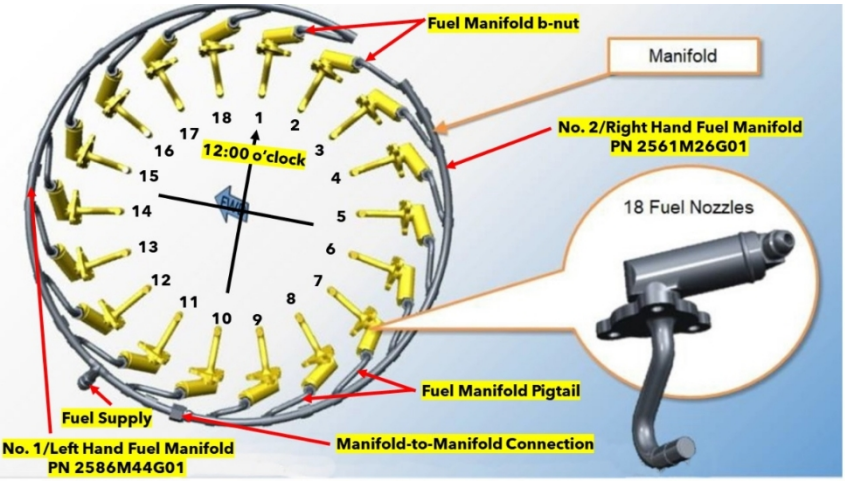

FIGURE 1: FUEL NOZZLE AND FUEL MANIFOLD DIAGRAM

Figure courtesy of GE (modified by NTSB)

The engine was shipped back to GE Cincinnati to be evaluated. At fuel nozzle locations Nos. 12, 14, 16, and 18, the fuel manifold b-nut connections appeared shiny and lacked sooting and were thought to be possible leak locations. A leak check using nitrogen at pressures well below normal and takeoff operational engine fuel pressures was attempted but no leak was produced in the fuel system. A torque check of all the fuel nozzle-to-fuel manifold b-nut connects found that five had very low torque values, less than 200 inch-pounds, when compared to the other b-nut connection locations and the required installation torque of 285 inch-pounds nominal. One of the five low torque locations was fuel nozzle No. 18. All the other fuel manifold b-nut connection torque values were within the expected ranged.

After all the fuel manifold b-nuts were loosened, an attempt was made to retighten them by hand. Several fuel manifold b-nuts on the left fuel manifold could not be run down using normal force. Loosening of the fuel nozzle attachment bolts at those locations enabled the fuel manifold b-nuts to be retightened freely by hand onto the fuel nozzle threads. This was indicative of a slight misalignment between the fuel nozzle and the fuel manifold.

Fuel nozzle No. 18 male bullnose sealing surface exhibited galling along with and elliptical and intermediate contact marks, indicative of misalignment contact with the fuel manifold female ferrule sealing surface. There were also signs of contaminants (hard particles) on the fuel nozzle male bullnose sealing surface in the form of craters, indentations, and imbedded material on the sealing surface, along with diagonally orientated abrasive material marks/material removal consistent with what appears to be previous repair (**PHOTO 3**). According to GE, there

was no record of a repair operation being performed on this specific nozzle at the fuel nozzle manufacturer or at the engine assembly site which would account for the observed abrasive material removal; therefore, GE concluded that this possible repair may have occurred sometime during engine assembly. The engine manual does not allow for any nicks or scratches but does allow for blending. However, blending is only allowed in the circumferential direction for conical/cylindrical parts; the blend/abrasive material removal marks on fuel nozzle No. 18 male bullnose sealing surface were in the diagonal direction along the axis of the part. Therefore, the observed blending in the area would be inconsistent with the engine manual blending instructions.

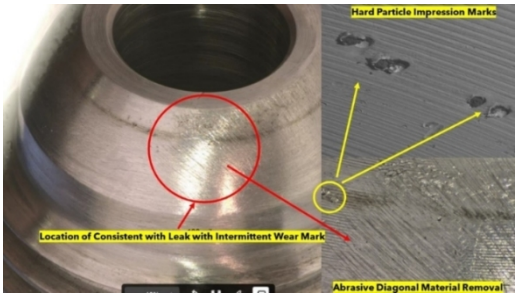

PHOTO 3: NO. 18 FN MALE BULLNOSE WITH ABRASIVE MARKS AND PARTICLE IMPRESSION
Photo courtesy of GE (modified by NTSB)

Only the fuel nozzle No. 18 male bullnose sealing surface showed evidence of rework/repair; however, hard particle damage was also observed on the male bullnose seal surfaces of fuel nozzles Nos. 12, 13, and 16 (**PHOTO 4**). GE was unable to confirm the source of the contaminates.

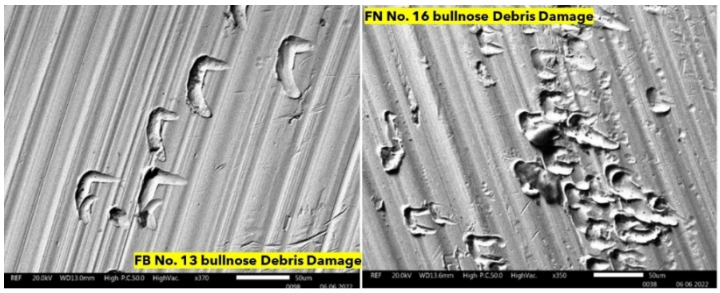

PHOTO 4: HIGH MAGNIFICATION OF SIMILAR SHAPED DEBRIS DAMAGE ON FUEL NOZZLE MALE BULLNOSE SEALING SURFACE ON NOS. 13 AND 16
Photo courtesy of GE (modified by NTSB)

During the investigation into the Palm Beach and Riyadh fuel manifold leaks event, two additional engines were found to have fuel manifold b-nut connection leaks; those were

discovered during inspections performed by Bombardier in response to the Palm Beach and Riyadh events. The two fuel manifold leak engines found by Bombardier did not show any evidence of an undercowl fire. GE performed similar leak, torque, and alignment checks on all those engines along with visual examination of the fuel nozzle and fuel manifold sealing surfaces to determine if there were common causes/anomalies for all the observed fuel manifold leaks. Additionally, GE conducted a series of acceptance test procedure engine runs, developmental engine runs, and component static rig tests to: 1) better understand the effects of fuel nozzle-to-fuel manifold pigtail misalignment, 2) gather assembly and operational loads/stresses on the fuel manifolds under a variety of installation sequence scenarios, 3) validate and develop fuel manifold and fuel nozzle installation best practices and procedures, 4) gather operational data on torque (clamp) relaxation on the fuel manifold b-nut connections, and 5) develop methods to minimize the amount of relaxation experienced in operation.

Based on all the data gathered from the event engines, the test engines, and component rig tests, several cumulative factors were found to have contributed to the fuel manifold leaks. Fuel manifold pigtail and fuel nozzle dimensional variation, combined with a given assembly sequence, can create potential misalignment between fuel manifold female ferrule and fuel nozzle male bullnose sealing surfaces, resulting in high resistance in the threads, low effective clamping force, and a false (high) torque reading. This low effective clamped connection can relax/loosen during engine operation as the manifold geometry normalizes and the connection shifts. All the leaking fuel manifold b-nut connections were found on those connections with lower than expected torque values. Since no fuel leaks occurred during the development engine tests, and leaks could be induced and stopped with slight variations in torque during the component rig tests, GE concluded that multiple factors can be present to create a leak and they are false (low) torques due to misalignment, higher than anticipated assembly loads due to dimensional variation, and poor/distressed sealing surface condition.

Several corrective actions were taken by GE and the Federal Aviation Administration to address and mitigate the risk of GE Passport 20-19BB1A engines fuel manifold leaks. GE issued service bulletins to borescope the engine compartment for signs of an undercowl fuel leak or fire damage (72-00-0141-00A-930A-D-001), and to retorque the fuel manifold b-nut connections as well as the fuel manifold-to-fuel manifold b-nut connection (72-00-0142-00A-930A-D-001); the Federal Aviation Administration followed up with Airworthiness Directive AD 2022-13-12 requiring a visual inspection of the core compartment, a retorque of the core compartment coupling nuts, a ground power assurance check, and a follow-up borescope inspection to ensure that there were no leaks before the airplane was returned to service. GE reviewed the fuel manifold and fuel nozzle installation and assembly procedures and made several changes to provide more specific guidance. The changes focused on eliminating possible ambiguities in the written procedures and to minimize any misalignments or unintended installation loads based on the results from the static rig and engine tests. In addition, feedback from the assembly mechanics were included to improve the overall effectiveness of the proposed installation and assembly changes. GE issued a “change in design” to finalize and clarify the optimum fuel nozzle and fuel manifold installation and assembly procedure using the best practices developed during testing.

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	**Registration:**	9H-VIG
Model/Series:	Global 7500	**Aircraft Category:**	Airplane
Year of Manufacture:	2021	**Amateur Built:**	
Airworthiness Certificate:	Unknown	**Serial Number:**	70086
Landing Gear Type:	Retractable -	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	General Electric
ELT:		**Engine Model/Series:**	Passport 20-19BB1A (No.1)
Registered Owner:	VistaJet Ltd	**Rated Power:**	
Operator:	VistaJet Ltd	**Operating Certificate(s) Held:**	Other operator of large aircraft

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	**Condition of Light:**	Not reported
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:	Riyadh, OF (OERK)	**Type of Flight Plan Filed:**	
Destination:	Dubai, OF (OMDB)	**Type of Clearance:**	Unknown
Departure Time:		**Type of Airspace:**	Unknown

Wreckage and Impact Information

Crew Injuries:	N/A	**Aircraft Damage:**	Minor
Passenger Injuries:		**Aircraft Fire:**	In-flight
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	N/A	**Latitude, Longitude:**	24.715122,46.658257

Administrative Information

Investigator In Charge (IIC):	Scarfo, Jean-pierre
Additional Participating Persons:	Sam Farmiga; General Electric Flight Safety; Cincinnatti, OH Dale Dennis ; General Electric Flight Safety; Cincinnati, OH Herman Mak; FAA ECO Branch; Burlington, MA Mark Taylor; FAA ECO Branch; Burlington, MA Scott Stevenson; FAA ECO Branch; Burlington, MA Dave Keenan; FAA Accident Investigations; Washington DC , DC Frank Zammit; Bureau of Air Accident Investigation Malta Jerome Ouellet; Transport Safety Board Canada Wael Rajkhan; Accident Investigation Bureau Michael Lemay; Bombardier
Original Publish Date:	June 13, 2023
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=106762