National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 3, 2014

In reply refer to: A-13-028

The Honorable Michael P. Huerta
Administrator
Federal Aviation Administration
Washington, DC 20590

We are providing the following information to urge the Federal Aviation Administration (FAA) to take action on the safety recommendation issued in this letter. This recommendation addresses undercowl fires due to fuel manifold leaks on the General Electric (GE) CF6-80C2[1] engine model. The recommendation is derived from the National Transportation Safety Board's (NTSB) investigation of a February 25, 2013, China Airlines incident and previous events and is consistent with the evidence we found and the analysis we performed. As a result of this investigation, the NTSB has issued one safety recommendation, which is addressed to the FAA. Information supporting this recommendation is discussed below.

China Airlines Incident

On February 25, 2013, a China Airlines Boeing 747-409F freighter, flight number CI-5254, registration B-18701, powered by four GE CF6-80C2B1F turbofan engines, experienced a No. 2 (left inboard) engine undercowl fire while taxiing after landing at Dallas/Fort Worth International Airport, Dallas, Texas.[2] After receiving the fire warning, the flight crew performed the Quick Reference Handbook fire emergency checklist and discharged a fire suppression bottle. After the fire suppression bottle was discharged, the fire warning went out. The three crewmembers on board were not injured. The incident airplane was operated under the provisions of 14 *Code of Federal Regulations* Part 129 as a regularly scheduled cargo flight. The flight originated from Taipei, Taiwan, destined for Dallas with stops in Anchorage, Alaska, and Atlanta, Georgia.

Postincident inspection of the No. 2 engine while it was still installed on the airplane confirmed sooting and thermal distress to the right side of the engine. A wet-motoring[3] of the engine showed a flammable fluid leak came from the right side of the fuel manifold in the vicinity of the No. 2 fuel nozzle fuel manifold shroud position. Examination of that area found

[1] The GE CF6-80E1 engine model has the same general configuration as the CF6-80C2 engine model.

[2] More information about this incident, NTSB case number ENG13IA016, can be found online at http://www.ntsb.gov/aviationquery/index.aspx.

[3] Wet-motoring is the process by which the engine is rotated at low speed mechanically, typically using the starter, and with the fuel lever in the open position to allow fuel to flow; however, no ignition is present, so no combustion occurs.

that the No. 2 fuel nozzle feeder line, an integral part of the fuel manifold commonly referred to as the pigtail line (see figure 1), was fractured due to high cycle fatigue under the fuel shroud (see figure 2) and had displaced aft against the snap ring; further, the rear o-ring was damaged, which allowed fuel to leak from the fuel shroud. The fuel manifold was configured with the drain line removed (drainless fuel manifold).[4]

The intent of the drainless fuel manifold is to prevent fuel from leaking and igniting an engine undercowl fire in the event of a fractured feeder line at the fuel nozzle connection or a loose feeder line-to-fuel nozzle connection by capturing the leaking fuel within the fuel shroud. However, the NTSB notes that GE has issued numerous SBs for CF6-80C2 and CF6-80E1 engine models in response to previous fuel manifold leaks, some of which resulted in engine undercowl fires, on the GE CF6-80C2 engine model with the drainless fuel manifold. The engine on the China Airlines incident airplane had incorporated most of these SBs, with the exclusion of the most recent SB. The most recent SB introduces a new drainless fuel manifold, which the NTSB believes would reduce the likelihood of a fractured fuel manifold failure causing engine undercowl fires. The previous events and SBs are discussed in the following section.

[4] This modification was performed in accordance with GE Service Bulletin (SB) 72-0253, which was issued in 1996.

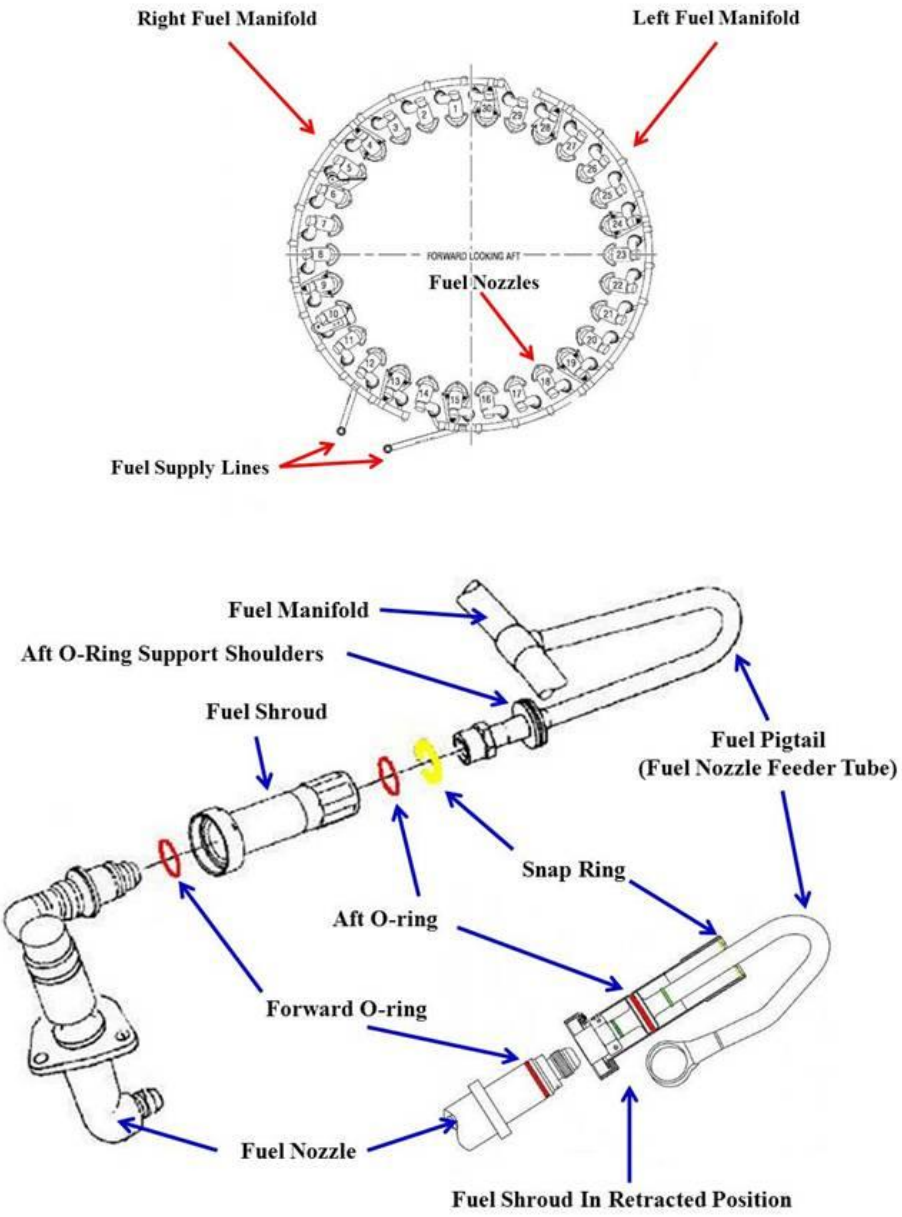


Figure 1. Exemplar fuel manifold configuration.

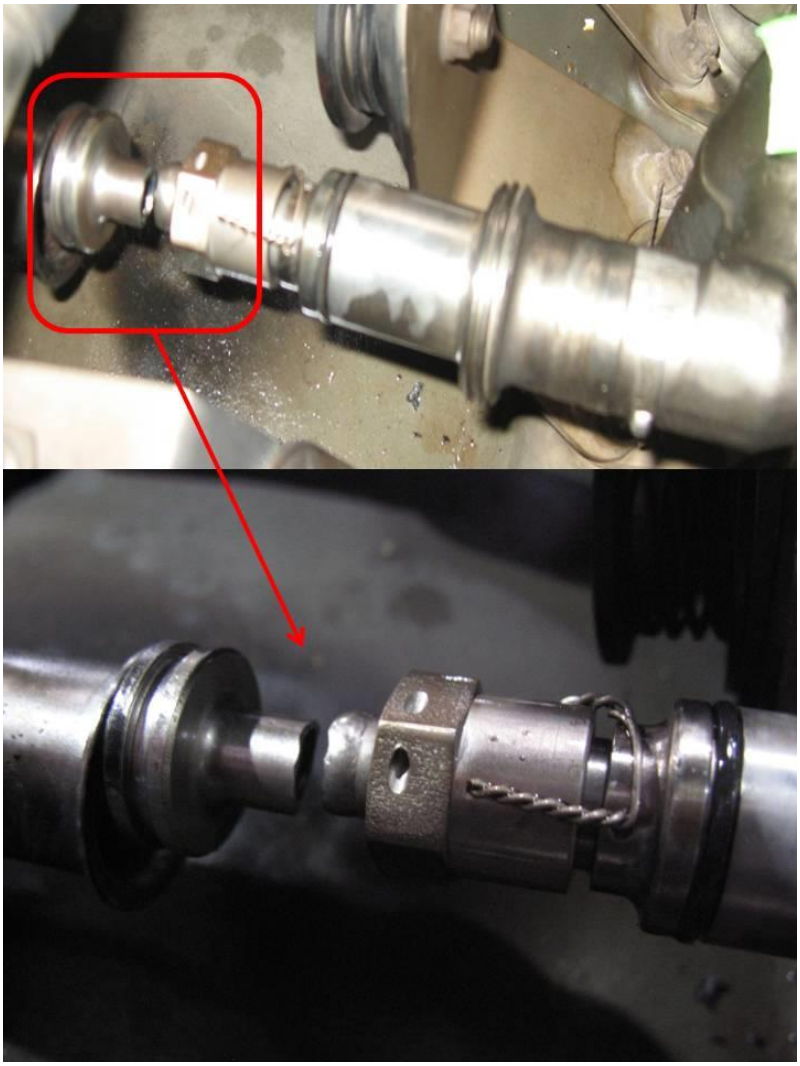


Figure 2. Fractured fuel nozzle feeder line on the China Airlines incident engine.

Previous Events and Service Bulletins

Leaks Due to Fractured Feeder Lines

The NTSB has investigated other engine undercowl fire events resulting from fuel manifold leaks caused by fractured feeder lines on GE CF6-80C2 engine models. On October 14, 2002, an Atlas Air Boeing 747-400F, N497MC, powered by CF6-80C2 engines, experienced an engine undercowl fire during the takeoff climb from Chiang Kai Shek International Airport, Taipei, Taiwan.[5] During the initial climb, the flight crew reported hearing a loud bang, the airplane immediately yawed, and a fire warning activated. The engine was shut down, both fire suppression bottles were discharged, and the airplane returned for an uneventful landing. Postincident examination of the engine revealed that two fuel nozzle feeder lines were distorted and displaced aft, the retaining rings had become dislodged from their fuel shroud retaining

[5] More information about this incident can be found in the docket for NTSB case number ENG13IA016.

grooves and were found loose on their respective feeder lines, and both feeder lines were fractured under the fuel shroud. Metallurgical examination found that the feeder line fractures were consistent with high amplitude fatigue, which had been attributed to a high pressure turbine rotor out of balance caused by a blade separation.

Before the Atlas Air event, two previous drainless fuel nozzle feeder line fractures had occurred where the fuel was not captured and held within the fuel shroud but instead leaked out past the o-rings. Neither case involved an engine undercowl fire. The Atlas Air event and these two events showed that the then-current retaining ring design did not provide adequate retention of a fractured fuel nozzle feeder line and allowed fuel to leak. As a result, GE issued SB 73-0337 (for CF6-80C2 engine models) in November 2004 and SB 73-075 (for CF6-80E1 engine models) in April 2005 to introduce a more robust C-shaped snap ring configuration to retain the fractured feeder line within the fuel shroud and prevent a fuel leak.

On December 1, 2005, a Skymark Boeing 767-300B, registration number JA767B, powered by CF6-80C2 engines, experienced high engine vibration and an engine undercowl fire just after takeoff from Kagoshima Airport, Kagoshima, Japan.[6] The flight crew shut down the engine and pulled the fire handle, and the fire warning went out. No fire bottles were reported to have been discharged. The right core cowl was breached, and an area measuring about 2 feet by 5 feet had melted away (see figure 3). Similar to the Atlas Air event, examination of the Skymark incident engine revealed that a fuel nozzle feeder line was displaced aft, the retaining ring had become dislodged from the fuel shroud retaining groove and was found loose on its feeder line, and the feeder lines were fractured under the fuel shroud. The last shop visit for the engine was before SB 73-0377 introduced the new snap ring configuration; therefore, the retaining ring was the same configuration (the older design) as that on the Atlas Air airplane, which in both cases failed to hold the fuel within the fuel shroud and resulted in an undercowl fire. After the Skymark event, the FAA mandated the incorporation of the new snap ring configuration with Airworthiness Directive (AD) 2007-11-20, effective July 10, 2007. The China Airlines incident engine had complied with AD 2007-11-20, and the new snap ring configuration had been installed in all of the fuel shrouds on the incident engine.

[6] The Japanese Aircraft and Railway Accidents Investigation Commission investigated this incident, and the NTSB assigned a US accredited representative per Annex 13 to the Convention on International Civil Aviation as the state of manufacture of the engines and the airplane. More information about this incident, NTSB case number ENG06RA004, can be found online at http://www.ntsb.gov/aviationquery/index.aspx.



Figure 3. Fire damage to the right core cowl on the Skymark incident engine.

Leaks Due to Chafing of the Fuel Manifold

Along with fuel manifold leaks due to fractured feeder lines, fuel manifold leaks can also be caused by chafing of the fuel manifold due to support clamps (P-clamps) with missing or damaged cushion material, also resulting in an engine undercowl fire. On December 30, 2006, an Air New Zealand Boeing 767-300ER, powered by CF6-80C2 engines, experienced an engine undercowl fire after landing at Auckland Airport, Auckland, New Zealand, while stowing the thrust reverser.[7] The flight crew pulled the fire handle, discharging a single fire suppression bottle that extinguished the fire. Postincident inspection of the engine revealed chafing and a pin hole in the fuel manifold with its corresponding support clamp exhibiting extensive wear of the rubber cushion material, allowing metal-to-metal contact. As a result, GE issued SB 73-0365 (for CF6-80C2 engine models) in May 2008 and SB 73-098 (for CF6-80E1 engine models) in

[7] The New Zealand Transport Accident Investigation Commission investigated this incident, and the NTSB assigned a US accredited representative per Annex 13 to the Convention on International Civil Aviation as the state of manufacture of the engines and the airplane. More information about this incident, NTSB case number ENG07WA010, can be found online at http://www.ntsb.gov/aviationquery/index.aspx.

August 2008 calling for the installation of Polytetrafluoroethylene tape[8] under the support clamps to provide a protective layer of material between the clamps and the fuel manifolds. The China Airlines incident engine had complied with SB 73-0365.

Discussion

Following these past events, GE found that the resonance frequency of the drainless fuel manifold configuration was within the engine operating region leading to large relative movement of the fuel manifold, causing the feeder line to fracture and the clamps to wear through the manifold. To address these issues, GE issued SB 73-0371 (for CF6-80C2 engine models) in July 2011 and SB 73-099 (for CF6-80E1 engine models) in March 2011, both titled "Engine Fuel Control—Fuel System (73-00-00)—Introduction of New Fuel Manifold System," releasing an entirely new drainless fuel manifold that avoids the resonance frequencies within the engine operating range and adds brazed-on clamps and support brackets to eliminate the chafing issue. The China Airlines incident engine did not have this latest configuration.[9]

As a result of the China Airlines engine undercowl fire, GE changed the compliance category of SB 73-0371 and SB 73-099 from Category 5 (meaning that the SB should be complied with only when the affected part is removed from the engine) to Category 3 (meaning that the SB should be complied with at the next shop visit regardless of the reason for the shop visit and, if maintenance was not planned, it may be necessary to accomplish the task). The NTSB recognizes GE's attempt to accelerate compliance with SB 73-0371 and SB 73-099; however, the NTSB notes that SBs are only recommendations by the manufacturer, unlike ADs, which mandate compliance. The FAA has not issued an AD to mandate compliance with these SBs.

The CF6-80C2 and CF6-80E1 engine models use snap rings and o-rings to prevent a fuel leak and potential fire in the event of a fuel nozzle feeder line fracture at or near the feeder line-to-fuel nozzle junction. The snap ring is used to ensure that the fuel shroud stays in position to encapsulate the fractured area, and the o-rings are intended to prevent fuel from leaking onto the hot engine cases and igniting a fire. In the China Airlines incident, the redesigned snap ring worked as intended, and the fuel shroud stayed in position; however, the aft o-ring failed to prevent fuel from leaking and subsequently starting a fire. Initial examination found that the aft o-ring was pliable and exhibited no compression set or thermal distress, but it was rolled, pinched in one area, and exhibited a spiral-like separation. The exact cause of the o-ring failure is still under investigation. During the development of the new CF6-80 engine model fuel manifold configuration (SB 73-0371 and SB 73-099), GE tested the capability of the o-rings and found that they could withstand 120% of the maximum operating pressure without leaking. The China Airlines fire event occurred while the airplane was on the ground taxiing, at a much lower power setting and fuel pressure than at which the o-rings were tested. Although the fire initiated on the ground, it is uncertain when and at what power setting or fuel pressure the actual fuel manifold fractured and the fuel leak occurred because these are two separate failures. The failure of the

[8] Polytetrafluoroethylene, a synthetic fluoropolymer of tetrafluoroethylene, is known by the brand name of Teflon®, manufactured by DuPont Corporation.

[9] The SB was issued just 7 days before the installation of the event fuel manifolds on the event engine; therefore, the operator was unable to install the most current fuel manifold design.

fuel manifold would not have necessarily resulted in an immediate fuel leak. Further, it is possible that the fracture of the manifold may not have even occurred during the event flight but on a previous flight and the flight crew only became aware of the fracture when the conditions were appropriate for the fuel leak and ignition. Thus, the NTSB believes that there is insufficient evidence to recommend a redesign of the o-ring seal capability. However, the NTSB concludes that mandating the incorporation of the new fuel manifold design as described in GE SB 73-0371 and SB 73-099 would significantly reduce the likelihood of a fractured fuel manifold failure causing engine undercowl fires.

Therefore, the National Transportation Safety Board makes the following recommendation to the Federal Aviation Administration:

> Require operators of airplanes equipped with General Electric (GE) CF6-80C2 and CF6-80E1 engine models to comply with GE Service Bulletin (SB) 73-0371 and GE SB 73-099, "Engine Fuel Control—Fuel System (73-00-00)—Introduction of New Fuel Manifold System," to prevent undercowl fires on these engines due to fuel manifold leaks caused by fractured or worn feeder lines. (A-13-028)

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in this recommendation.

The NTSB is vitally interested in this recommendation because it is designed to prevent accidents and save lives. We would appreciate receiving a response from you within 90 days detailing the actions you have taken or intend to take to implement it. When replying, please refer to the safety recommendation by number. We encourage you to submit your response electronically to correspondence@ntsb.gov.

[Original Signed]

By: Deborah A.P. Hersman