National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 28, 2013

In reply refer to: A-13-22 and -23

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 recommendations issued in this letter. These recommendations address safety issues relating to the accessory gearbox heat shield and fire detection systems for General Electric (GE) CF6-80C2 engines installed on Boeing 747 airplanes. The recommendations are derived from the National Transportation Safety Board's (NTSB) assistance in the investigation of the February 3, 2010, incident involving a Thai Airways International Boeing 747-400 and are consistent with the evidence we found and the analysis we performed. As a result, the NTSB has issued two safety recommendations, both of which are addressed to the FAA. Information supporting these recommendations is discussed below.

On February 3, 2010, about 1041 coordinated universal time, a Thai Airways International Boeing 747-400, HS-TGB, powered by four GE CF6-80C2B1F turbofan engines, experienced a No. 1 engine fire shortly after takeoff from Suvarnabhumi Airport (BKK), Bangkok, Thailand. After takeoff, the flight crewmembers reported that they felt minor vibrations and observed a No. 1 engine oil filter message on the engine indicating and crew alerting system. The flight crew corrected the vibration problem by cycling the landing gear. Before the pilots could address the No. 1 engine oil filter message, they heard an explosion and smelled smoke in the cockpit, then noted a No. 1 engine fire warning and a No. 1 engine overheat indication. The flight crew shut down the No. 1 engine, discharged both fire extinguishing bottles, and returned to BKK to make an uneventful three-engine landing. The passengers disembarked normally through passenger boarding stairs, and no injuries were reported.[1] The airplane sustained damage to the No. 1 engine. The flight was scheduled from BKK to Chiang Mai International Airport, Chiang Mai, Thailand.

[1] More information about this incident, NTSB case number ENG10RA014, can be found online at http://www.ntsb.gov/aviationquery/index.aspx.

The Thailand Department of Civil Aviation, Aircraft Accident Investigation Division, is investigating this incident. The NTSB has assigned a US accredited representative per Annex 13 to the Convention on International Civil Aviation as the state of manufacturer of the engines and the airplane. Although this investigation is ongoing, the NTSB has identified safety issues relating to the accessory gearbox heat shield for GE CF6-80C2 model engines and fire detection systems for CF6-80C2 model engines installed on Boeing 747 airplanes that, if addressed, will improve flight safety.

Damage to the Incident Airplane

Initial examination of the No. 1 engine nacelle after landing revealed burnthrough holes in the outboard thrust reverser and core cowl. Figures 1 and 2 are photographs of the nacelle fire damage and thrust reverser core cowl fire damage to the engine.

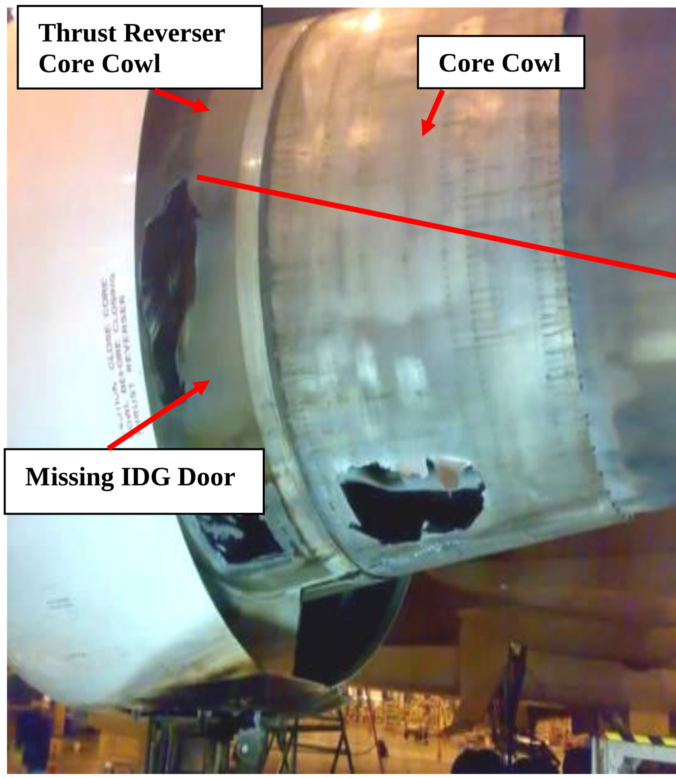

Figure 1. Nacelle fire damage.

Figure 2. Thrust reverser core cowl fire damage.

Internal examination of the No. 1 engine revealed evidence of a fire in the No. 5 bearing compartment (compressor rear frame aft sump assembly).[2] The No. 5 roller bearing inner race pierced the No. 5 roller bearing stationary air/oil seal support, creating a 3-inch gash. The breach of the B-sump structure (No. 4 and 5 bearing compartment) allowed compressor discharge pressure air to mix with the sump oil and oil vapor, resulting in the compartment fire. The high-temperature air/oil mixture then flowed out of the bearing compartment and melted the

[2] The cause of the No. 5 bearing failure is still under investigation by the Thai authorities.

external B-sump oil supply and vent lines and the upper, middle, and lower low-pressure turbine (LPT) recoup lines. The high-temperature and high-pressure air from the LPT recoup line ducts impinged on the accessory gearbox heat shield and burned through the structure, damaging components beneath it. Specifically, the accessory gearbox heat shield exhibited four burnthrough holes of various sizes in the starter air duct and accessory cooling tube and above the integrated drive generator (IDG), and the aft edge of the heat shield was completely missing in the vicinity of the air starter valve and accessory gearbox pad drain line. The IDG housing was partially consumed by fire, exposing the internal gearing, and only about a cup of oil remained in the IDG.[3] Figure 3 shows the fire damage on the left side of the No. 1 engine.

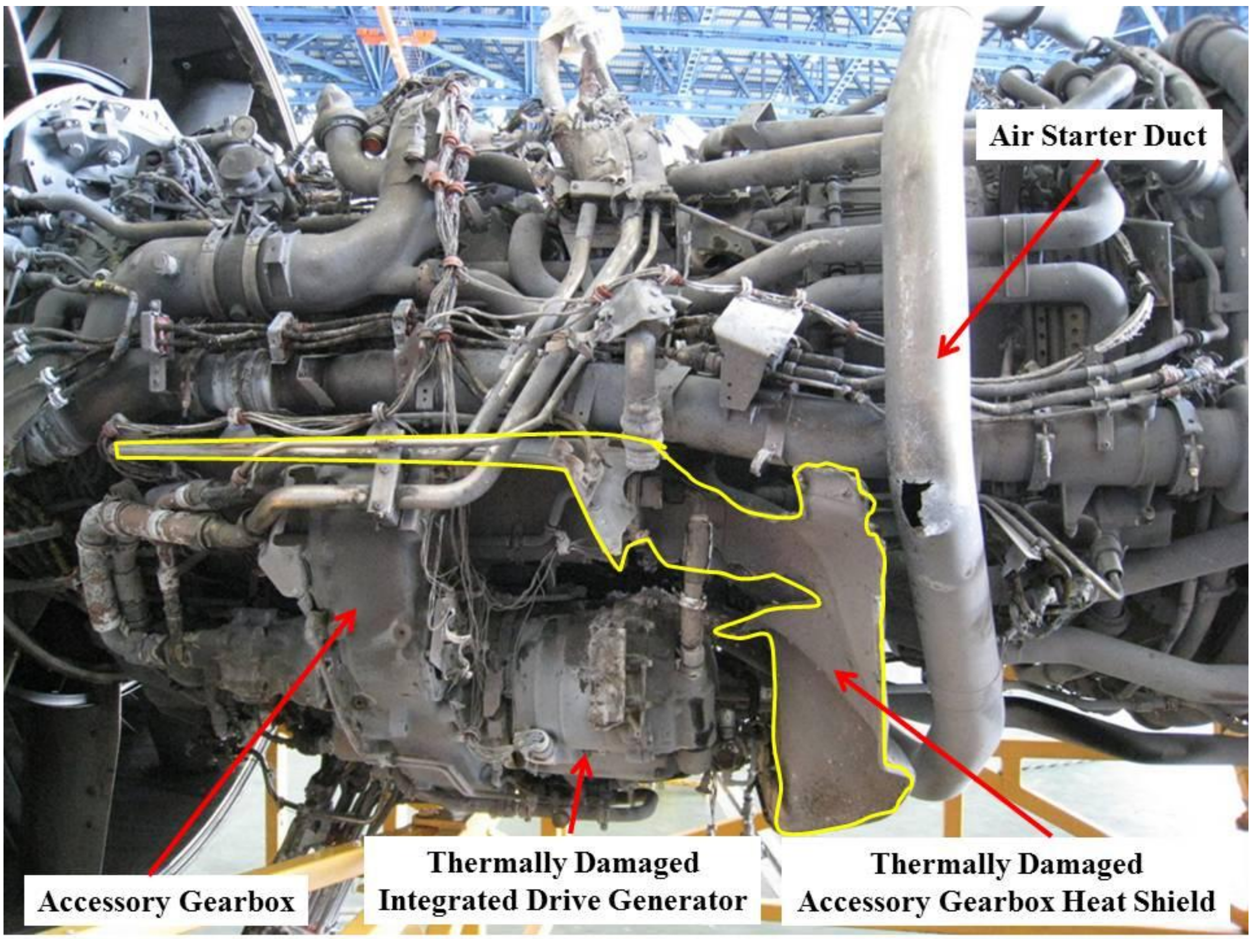

Figure 3. Fire damage on the left side of the No. 1 engine.

Accessory Gearbox Heat Shield

GE CF6-80 model engines have a titanium accessory gearbox heat shield that separates the accessory gearbox and the components attached to it from flammable fluid lines that run beneath it and the hot engine case surfaces and air lines that convey high-temperature air located above it. The accessory gearbox heat shield was not certificated to provide fire protection; it has

[3] IDG capacity is 1.2 gallons or about 19 cups.

no fire protection capability or fire progression prevention. According to GE, the original design of the accessory gearbox compartment did not consider fire protection against possible B-sump fires.

On August 16, 1987, a GE CF6-80A engine on a Boeing 747 experienced a No. 5 bearing failure and compartment fire that led to the burnthrough of an LPT recoup line and accessory gearbox heat shield, resulting in damage to a fuel line and subsequently creating a secondary fire in the accessory compartment. In response, on March 1, 1988, GE issued Alert Service Bulletin 72-A0152, "ENGINE—Accessory Drive Compartment—Addition of Fire Shields to Accessory Compartment," for CF6-80A/A1/A2/A3 model engines, and the FAA issued Airworthiness Directive (AD) 89-16-08, effective August 31, 1989, requiring that fire shields be installed on the heat shields of these model engines to provide added fire protection in the event of fire escaping from the LPT recoup line, which could lead to fuel leakage and possible engine fire.

On November 1, 1988, GE issued Service Bulletin (SB) 72-276, "ENGINE—Accessory Shield Assembly—Addition of Fire Shields," for CF6-80C2A/B model engines[4] to provide a fire shield and dished cover with a coating that would provide increased fire protection and reliability to the accessory compartment in the event of fire escaping from the LPT recoup line.[5] The FAA did not issue an AD mandating SB 72-276.

On June 8, 1996, a GE CF6-80C2 engine on a Boeing 747 experienced a No. 4 and 5 bearing compartment fire that resulted in the burnthrough of both an LPT and a high-pressure turbine (HPT) recoup line that allowed molten metal and hot gasses to impinge on the accessory gearbox heat shield. Beneath the HPT recoup line, the accessory gearbox heat shield was burned through, and a fuel hose suffered thermal distress; however, the accessory gearbox heat shield was not burned through beneath the LPT recoup line. In response, on December 16, 2008, GE issued SB 72-0956, "ENGINE—AGB [Accessory Gearbox] Heat Shield—Auxiliary Heat Shield," for CF6-80C2 model engines to add a heat plate with a thermal barrier coating to the accessory gearbox heat shield beneath the HPT recoup line to maximize the protection and reduce the possibility of accessory gearbox heat shield burnthrough resulting from an HPT recoup line burnthrough. According to SB 72-0956, the accessory gearbox heat shield did not burn through beneath the LPT recoup line because of the protection provided by the fire shield installed in accordance with SB 72-276. The new heat plate to be installed beneath the HPT recoup line would provide protection similar to the fire shields introduced by SB 72-276. The FAA did not issue an AD mandating SB 72-0956.

Visual inspection of the incident airplane's accessory gearbox heat shield (part number 1378M49G05) confirmed that a fire shield and dished cover were installed in accordance with SB 72-276, but the heat plate introduced by SB 72-0956 was not installed. Figure 4 shows the incident airplane's accessory gearbox heat shield damage and fire shield locations.

---

[4] The heat shields for CF6-80C2A/B model engines have a slightly different configuration than those for CF6-80A1/A2/A3/A4 model engines.

[5] SB 72-276, revision 1, was issued on December 20, 1989, and revised the heat shield part numbers that were affected. This SB introduces a fire shield and dished cover that are plasma sprayed with zirconia and are attached to the accessory gearbox heat shield.

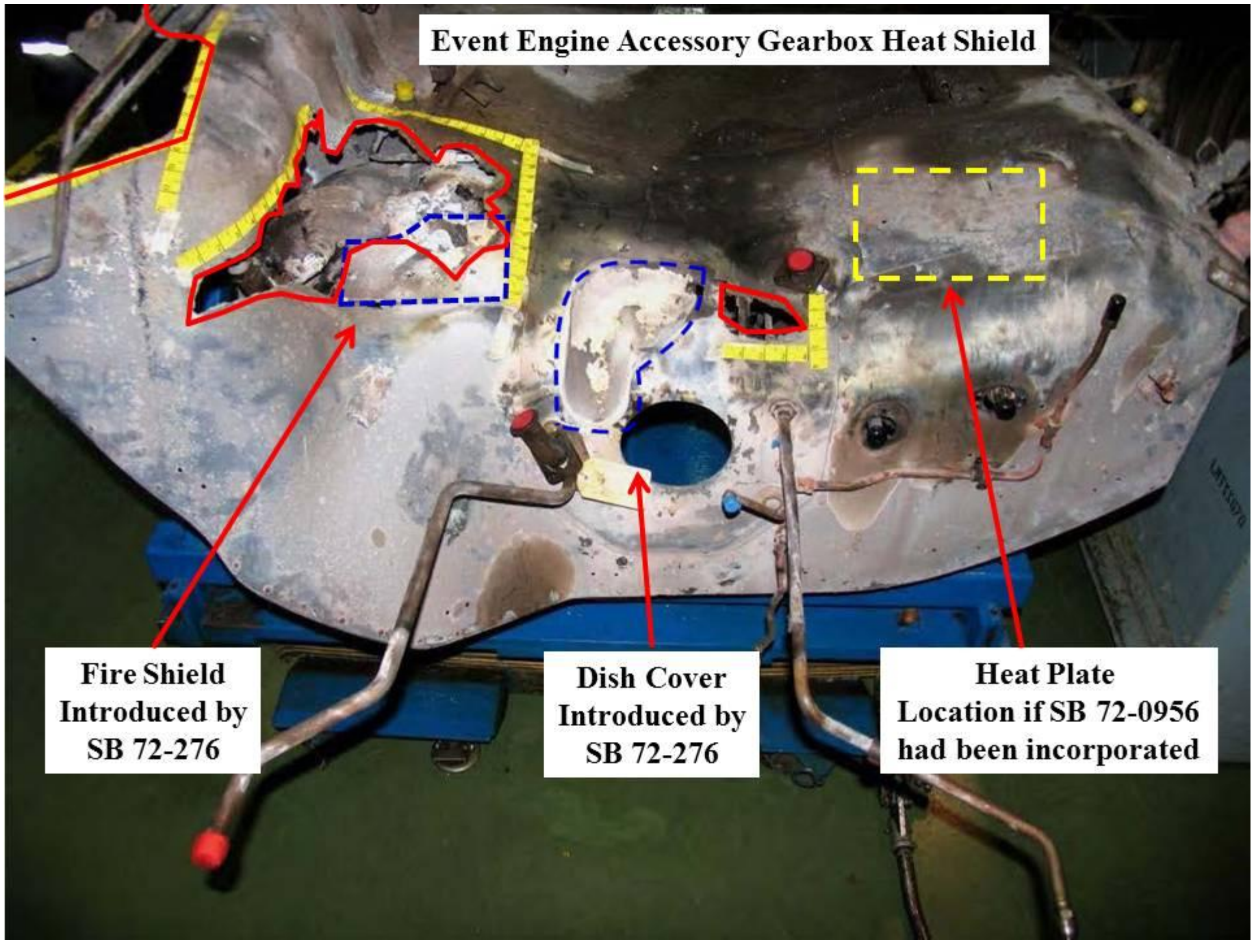

Figure 4. Incident airplane's accessory gearbox heat shield damage and fire shield locations. The red outlines indicate holes and missing materials, the blue outlines indicate installed patches/dished covers, and the yellow outline on the right indicates where the patch from SB 72-0956 would have been, had it been installed.

When GE performed heat shield patch component tests in conjunction with the development of the SBs to assess the effectiveness of different patch configurations, GE determined that the patches with a thick coating of plasma-sprayed zirconia provided a significant increase in the time before burnthrough, offering better fire protection than the existing heat shields to the flammable fluid lines that run beneath the heat shield and giving the flight crew additional time to properly assess and address the fire emergency before the heat shield is breached and the flammable fluid lines are potentially exposed to the fire. However, visual inspection of the Thai Airways incident airplane revealed that the fire shield and dished cover with plasma coating added in accordance with SB 72-276 did not provide sufficient coverage and fire protection for the LPT recoup line in this incident. As evidenced in figure 4, the fire shield and dished cover were too small and were not in the proper place to provide adequate fire protection. Further, if a heat plate had been added in accordance with SB 72-0956, it would not have provided increased coverage and fire protection for the HPT recoup line in this incident because there was no fire damage in that area. In addition, during the course of this investigation, GE has informed the NTSB of previous GE CF6-80C2 bearing compartment fire incidents[6] that were caused by a breach of the sump structure that allowed compressor discharge pressure air to mix with the sump oil and oil vapor, resulting in a bearing compartment fire. In these events, the high-temperature air/oil mixture flowed out of the bearing compartment and melted the external No. 4 and 5 bearing compartment oil supply and vent lines and the LPT recoup lines. The high-temperature and high-pressure air from the LPT recoup line ducts impinged on the accessory gearbox heat shield and burned through the structure, damaging components beneath it. The NTSB is concerned that without adequate protection of the accessory gearbox heat shield, a fire could spread and ignite flammable fluids, resulting in a serious in-flight fire. The NTSB is also concerned that the coated patches that GE has added to the accessory gearbox heat shield in accordance with the SBs only address the fires that have previously occurred and do not consider other possible fire scenarios. The NTSB concludes that the current accessory gearbox heat shield design does not provide sufficient protection from fire migrating to the accessory compartment where components with flammable fluid are located. The accessory gearbox heat shield itself is not designed for fire protection, and the thermal barrier-coated patches added in accordance with the SBs are too small and do not adequately address all of the possible fire scenarios to maximize fire protection. Therefore, the NTSB recommends that the FAA require that GE redesign the accessory gearbox heat shield for GE CF6-80C2 model engines to provide fire protection from bearing compartment fires, failures, gas escaping from the LPT and HPT recoup lines, and any other possible fire sources that would affect the accessory compartment, and mandate the incorporation of the redesigned accessory gearbox heat shield in a timely manner.

CF6-80C2B1F Engine Fire Detection System

The CF6-80C2B1F engine installed in Boeing 747-400 airplanes is equipped with dual-loop fire and overheat detectors that provide the flight crew with visual and aural alarms. Each fire and overheat detector system is comprised of two separate loops, and each loop is comprised of sensing tubes with a gas-charged core and helium under pressure and a responder with two pressure switches (normal/open position and closed/alarm position). The detector system can respond in two modes: an overall “average” temperature rise and a highly localized “discrete” temperature rise caused by an impinging flame or hot gases. The increase in the sensing tube temperature causes a corresponding increase in internal gas pressure, which in turn activates the alarm switch in the responder. Each fire loop has three detector elements installed in the lower forward and upper and lower aft sections of the engine that are electrically connected so that any element can trigger the alarm. The overheat loop is installed on the upper forward section of the engine and has a single detector element in each loop.

Airplane manufacturers strategically place fire and overheat detectors around the engine in known flammable fuel leak, ignition source, and/or hot gas leak areas to provide a rapid detection and alert to a fire or overheat condition. In the incident airplane, there were no detectors in the vicinity of the HPT and LPT recoup lines and the upper surface of the accessory gearbox heat shield. According to Boeing, HPT and LPT recoup line breaches were not considered in the placement of the fire detectors.

---

[6] The NTSB did not investigate any of these events, all of which occurred outside of the United States. GE provided the NTSB with information about these events as part of the Thai Airways incident investigation.

The NTSB notes that there is some time delay between the initiation of a fire or hot gas leak and the detection and annunciation of the fire or overheat alarm, and the length of the delay is based on the intensity of the fire or hot gas leak and its proximity to a detector. Since the digital flight data recorder (DFDR) and the quick access recorder (QAR) only record when a fire or overheat warning has been activated (not necessarily when the fire or leak starts), the exact time when the LPT recoup lines were breached and how long the thermal damage to the engine continued before the fire warning was annunciated to the flight crew could not be positively determined. However, the NTSB developed an estimated fire sequence and timeline using pilot statements, DFDR and QAR data, and an assessment of the thermal damage. According to the incident pilot statements, no fire warning or overheat alerts were annunciated before the reported explosion and subsequent fire warning. The DFDR and QAR data showed that the fuel cutoff for the No. 1 engine was commanded 15 seconds after the fire warning was annunciated, and the fire warning ceased 19 seconds after that (the fire warning went out 34 seconds after the fire warning was annunciated).

Examination of the burnthrough holes in the LPT recoup manifolds and the accessory gearbox heat shield and the collateral fire damage to the engine and to some of the accessories, such as the IDG housing and engine's overboard drain module, shows that the initial breach of the LPT recoup manifolds created a focused fire in the incident airplane. While redesigning the heat shield as requested in Safety Recommendation A-13-22 will provide increased fire protection, it is imperative that the fire detection system respond rapidly to the initiation of the fire to provide the flight crew with adequate time to respond. While there is insufficient data to assess the responsiveness of the fire or overheat detectors to HPT and LPT recoup line breaches, the NTSB is concerned about the overall effectiveness of the fire or overheat detection and warning system installed in Boeing 747 airplanes if it does not take into account HPT and LPT recoup line breaches. If the fire or overheat detectors do not immediately alert the flight crew at the onset of a fire in the area of the HPT and LPT recoup lines, the fire could potentially ignite combustible fluids before detection, which could increase the size and severity of the fire. The NTSB concludes that HPT and LPT recoup line breaches should be considered in the placement of fire detectors on Boeing 747s. Therefore, the NTSB recommends that the FAA require Boeing to assess the effectiveness of the engine fire and overheat detection and warning system for the GE CF6-80C2 model engines installed in Boeing 747 airplanes, and if deficiencies are found in the placement or responsiveness of the alerts, either provide sufficient data to support the current configuration or redesign the engine fire or overheat detection and warning system.

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

> Require that General Electric (GE) redesign the accessory gearbox heat shield for GE CF6-80C2 model engines to provide fire protection from bearing compartment fires, failures, gas escaping from the low-pressure turbine and high-pressure turbine recoup lines, and any other possible fire sources that would affect the accessory compartment. Mandate the incorporation of the redesigned accessory gearbox heat shield in a timely manner. (A-13-22)

> Require Boeing to assess the effectiveness of the engine fire and overheat detection and warning system for the General Electric CF6-80C2 model engines installed in Boeing 747 airplanes. If deficiencies are found in the placement or responsiveness of the alerts, either provide sufficient data to support the current configuration or redesign the engine fire or overheat detection and warning system. (A-13-23)

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

The NTSB is vitally interested in these recommendations because they are 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 them. When replying, please refer to the safety recommendations by number. We encourage you to submit your response electronically to correspondence@ntsb.gov.

[Original Signed]

By: Deborah A.P. Hersman,
Chairman