

Cockpit Visibility Impairment from an Electronic Flight Bag with Lithium Batteries in Thermal Runaway

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Tests were conducted on board a fully operational Boeing 737 aircraft to evaluate the potential safety hazard resulting from the thermal runaway failure of the lithium batteries in an Electronic Flight Bag (EFB). EFBs are electronic devices used to replace the paper materials typically found in the pilot's flight bag, and are divided into three classes:

- **Class I** – Portable electronic device (PED), Commercial off the Shelf (COTS) equipment that is used as loose equipment and stowed during portions of flight. There is no active charging on board the aircraft.
- **Class II** – PED, can be COTS equipment, and is mounted and connected to aircraft power during flight for use and charging.
- **Class III** – Considered installed equipment, these are not PED or COTS equipment, but rather are pieces of equipment built and tested specifically for aircraft EFB use. They are connected to aircraft power during flight for use and charging.

Class I and II EFBs are considered PEDs that are not subject to airworthiness standards, however the mounting/charging connection hardware used for the installation of a class II EFB is required to be airworthy. Class III EFBs are subject to airworthiness standards, as they are considered installed equipment. The primary concern is the resulting fire/smoke hazards should one of the lithium-ion (Li-ion) batteries installed in these units fail and experience thermal runaway, a failure causing rapid increases in temperature, significant smoke production and at times, explosion and/or rocketing of the battery cell.

To examine this potential safety hazard, one or two (depending on the test criteria) individual battery cells in a COTS laptop was replaced with a small cartridge heater. This small heater was utilized to replicate a single battery cell going into thermal runaway, causing adjacent cells within the 9 cell, 7.2 Ah Li-ion battery pack to subsequently go into thermal runaway. This laptop was installed in the cockpit of the Fire Safety Branch's Boeing 737 test aircraft, which was instrumented with thermocouples, gas sampling probes, smoke meters and video cameras to examine the results of the battery failure. In order to protect the 737 test article, the cockpit was fire-hardened. In addition, at any sign of fire, Halon 1211 was immediately disbursed into the cockpit in order to extinguish the flames. Therefore, the focus of these tests was the smoke hazard resulting from the propagation of thermal runaway in the lithium batteries inside an EFB, during fire extinguishment.

The testing showed that even with a very high ventilation rate of one air exchange per minute within the cockpit, a typical COTS Li-ion battery could pose a significant smoke hazard within the flight deck environment. . The initial battery event occurred, at times, without warning (i.e. no visible smoke or audible event prior to failure). The battery cells failed in a very vigorous manner, at one point with enough pressure to forcefully push open the unlatched cockpit door. The most striking safety hazard however, was the volume and density of smoke that emanated from the failed battery cells. During one test in which only four of the nine battery cells

went into thermal runaway, the installed smoke meter recorded greater than 10% light obscuration/ft for a period of greater than 5 minutes and a peak value of greater than 50% light obscuration/ft, resulting in severe lack of visibility within the flight deck.