

Review of Canadian Flight Deck and Cabin Smoke and Fire Incidents: 2001-2010

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ABSTRACT

This paper presents a review of the flight deck and cabin fire and smoke incidents reported to the Canadian airworthiness authorities over a ten year span. The fire and smoke related diversions are categorized to identify areas where efforts could be increased to improve safety. The costs of diversions are estimated to identify areas where operators could reduce costs by seeking technologies to reduce the number of diversions without any impact on safety. Only twenty-eight investigation reports into fire and smoke incidents onboard aircraft have been published over the past three decades. These reports are not sufficient to identify areas where operators can reduce their operating costs. The Canadian airworthiness authorities received over 1,000 smoke and fire incidents from the years 2001 to 2010, of which, over 680 reported fire and smoke in the flight deck and cabin compartments for various makes and models of aircraft. Some of these flight deck and cabin incidents were related to in-flight entertainment or galley systems that were remedied while in-flight and did not require a diversion in most cases. The remaining incidents were found to be related to ingestion of oil, de-icing fluids and equipment and electrical failures that, in many cases, prompted the pilots to declare an emergency and divert. This paper categorizes the flight deck and cabin related fire and smoke incidents to suggest specific areas for airframers and operators to focus their efforts in reducing flight diversions that will not only reduce costs, but improve safety.

CITATION: Lebbin, P., "Review of Canadian Flight Deck and Cabin Smoke and Fire Incidents: 2001-2010," *SAE Int. J. Aerosp.* 6(1):2013, doi:10.4271/2013-01-2307.

INTRODUCTION

In 2010, the United States Federal Aviation Administration (FAA) released an "Information for Operations" (InFO) notice that informed carriers and operators to place an emphasis on finding new ways to identify areas susceptible to smoke (FAA 2010). The FAA continues to receive over 900 reports a year on smoke or fumes in the flight deck or cabin but the FAA did not list the causes of these incidents in the InFO notice. The United States National Transportation Safety Board (NTSB) reported in-flight smoke and fire incidents were a result of failures related to the wiring, electrical components, lightning strikes, and pneumatic systems (NTSB 2004). Wiring failures were the leading cause of in-flight fires but NTSB did not report the frequency for any of the causes of in-flight fires.

The Transportation Safety Board of Canada (TSB) reviewed data on twenty-seven in-flight fires that occurred between January 1967 and September 1998 to determine the response time between detection of the in-flight and first contact with the ground (TSB 2003). In 15 of 18 cases that

did not land successfully, the response time was between 5 and 35 minutes. TSB found that 37% of the in-flight fires were detected in cruise phase with the remainder of fires occurring during other phases of flight.

A few publications reviewed military smoke or fume incidents. During a 10 year period starting in 1970, there were 89 incidents of smoke and/or fumes in the cockpit during flight in United States Air Force aircraft (Rayman and McNaughton 1983). The Australian Defence Force reported approximately 0.5 in-flight smoke and fume incidents per 1,000 flying hours for a 5 year period starting in 2000 (Eklund 1996).

It is unclear how many incidents were one or two slices of Swiss cheese away in the Swiss Cheese model from an accident resulting in serious or fatal injuries. During a diversion, the flight crew workloads increase during the process of diverting to the nearest suitable airport. There is an increased risk of human error when pilots are rushed to land the aircraft at unfamiliar airports. Pilots may have to exercise extra care as aircraft may be overweight during landing. Pilots would like to see technologies developed that would

help them distinguish less dangerous cases from an all-out electrical fire that have resulted in fatal incidents ([Air Safety Week 2003](#)).

Barring new regulatory requirements, air carriers or operators are not compelled to invest in new procedures and technologies to improve safety unless there is a clear business case to do so ([Rosenkrans 2011](#)). The challenge is that airline engineering and operations departments do not appear to fully understand the costs of diversions due to the complex contributions from many diverse sources of direct and indirect costs ([Learnmount 2010](#)). There are tools available to assist airlines to better understand the costs of diversions. Captain (ret'd) John Cox and Professor Triant Flouris have developed a tool to estimate the cost of diversions with known inputs such as aircraft maintenance costs, fuel burn, labor, average passenger load factor, average ticket price, airport fees, catering costs, lost revenue due to aircraft out of service, aircraft repositioning, passenger expenses (hotels, meals), emergency-slide repacking (if applicable), gross profits, and operating profits (Cox and Flouris 2011).

The scope of this paper is to suggest new procedures and technologies that airframers, Tier 1 integrators, and operators may adopt to reduce the cost of diversions. This paper starts with the review of aviation investigation reports dating back to the 1980s to summarize the cause of fire and smoke incidents and to identify recommendations that have already been put forward. The Canadian Aviation Safety Reporting System (ASRS) database was reviewed from a 10-year time span to classify, quantify, and estimate the costs associated with different causes of aircraft flight deck and cabin fire and smoke events. The analysis of these costs was used to suggest potential areas for improvement by airlines and manufacturers to enhance safety while reducing costs for the operators.

MAJOR INVESTIGATION REPORTS IN TO CABIN FIRE AND SMOKE

Twenty-eight investigation reports into fire and smoke incidents onboard aircraft have been published over the past three decades. The reports were authored by various air safety agencies in Canada, United States, United Kingdom, Germany, Sweden, Switzerland and Saudi Arabia. Of the 28 fire and smoke incidents, eleven (39%) were determined to have started in the cargo hold, nine in the flight deck (32%), six in the cabin (21%), one in the environmental control system (ECS), and one from oil released by an engine.

Canadian Aviation Investigation Reports

Over a two-decade period from 1990 to 2010, there were fifteen TSB AIRs of fire or smoke in the flight deck or aircraft cabin. The reports indicated that the fire and smoke events were created by faults with the electrical system, ECS, avionics, and in-flight entertainment (IFE) equipment. None of the AIRs included fire or smoke incidents caused by galley equipment, oil from the engine, Auxiliary Power Unit (APU),

de-icing fluids, or malfunctioning sensors and associated equipment falsely reporting the presence of a fire.

Six AIRs reported fires or smoke events within the flight deck. Three AIRs were related to the failure of the flight deck windshield heater. The following list summarizes the key cause from each AIR.

1. A fire started in the area of the left front cockpit windshield after an odor was detected by the cabin crew ([TSB 2002c](#)).
2. Electrical arcing caused by damaged braid leads to the flight deck windshield heater terminal block and generated smoke ([TSB 2009b](#)).
3. A very similar incident occurred on another aircraft where the copper braid conductors were suspected to have severed, initiating the electrical arcing ([TSB 1997b](#)).

The other three flight deck related AIRs were fires caused by arcing in confined spaces which are not easily accessible to aircrew. The following summarizes the key cause of the electrical arcing for each AIR.

1. The pilots noticed an electrical smell followed by flames and smoke behind the electrical breaker panel while in-flight at cruising altitude ([TSB 2007a](#)). The fire was caused by improperly routed wires at the turbine engine that chafed to the conductor core, allowing high-voltage power surge back to the electronics box on the flight deck.
2. The pilot reported smoke on the flight deck which was likely caused by a fault associated with an avionics relay ([TSB 1997a](#)). The pilot, the sole occupant, was fatally injured following incapacitation by heavy smoke on the flight deck.
3. A wire arcing event ignited flammable thermal acoustic insulation blankets which propagated the fire above the flight deck ceiling (TSB 2003). Initially the aircrew believed the smoke to come from the ECS and did not understand the severity of the problem. The resulting fire led to the loss of control of the aircraft in which 229 people were fatally injured.

There were four AIRs related to fires caused by arcing electrical wiring leading to ignition of contaminant, debris, or flammable materials in the cargo hold. The following summarizes the key cause of the incident from each AIR.

1. While on approach to the airport, the aircrew received an aft cargo bay warning light that extinguished approximately 50 seconds after activation of the fire extinguishers ([TSB 2002a](#)). A heater ribbon attached to the aft water supply line had failed at the site of a recent repair and ignited contaminated thermal acoustic insulation. The insulation contamination was caused in part by the open cargo floor design which allowed contaminants and debris to accumulate.
2. The pilot and sole passenger noticed an electrical odor and observed a small fire and smoke emanating from the instrument panel ([TSB 2007b](#)). Arcing from a light switch

had failed which ignited nearby dust accumulation and contributed to the fire.

3. An unattached battery cable arcing through the battery compartment igniting flammable nylon survival gear bags in the adjacent baggage compartment (TSB 2000a).

4. The aircrew of a helicopter noticed an electrical burning odor followed by the illumination of a fuel boost pump caution light (TSB 2009a). Electrical arcing had occurred in an engine harness that likely breached a nearby fuel line, resulting in the hull loss of the helicopter.

Two AIRs were found that reported an incident of fire and smoke in the cabin. While on approach to the airport, the passengers reported the presence of smoke in the cabin (TSB 2010a). The fire was caused by arcing between the connector and lighting electrical power supply of a cabin interior panel. Another AIR reported a fire within the cabin entertainment system while the aircraft was prepared for boarding at the airport (TSB 2002b). An internal switching regulator in an IFE controller generated excessive heat causing the process board to ignite. Even though power was removed, the system battery maintained power to the IFE processor board, likely extending the duration of the fire.

One AIR reported a cabin compartment fire that was not noticed by the aircrew until after the aircraft landed and a flight attendant opened the forward baggage compartment, revealing white smoke and reddish flames (TSB 1996). The baggage compartment was designed to contain the fire but no smoke detectors were installed on the aircraft.

One fire and smoke AIR was suspected to have been caused by a passenger (TSB 1995). There was evidence that a fire in an overhead luggage bin was started by a lit match with 100% polyester passenger service blankets.

One AIR was related to the failure of an ECS fan that overheated and generated smoke in the cabin (TSB 2000b).

United States Aircraft Accident Summary Reports

There were eight NTSB Aircraft Accident Summary Reports (AASRs) found over a 27-year period from 1984 to 2010 that involve fire or smoke in the flight deck or aircraft cabin. All eight reports investigated fire or smoke incidents caused by cargo hold fires, avionics equipment malfunctions, or electrical arcing. There were no fire or smoke AASRs identified that found galley equipment, engine/APU/ECS oil, de-icing fluids, or malfunctioning sensors and associated equipment to falsely report the presence of a fire.

Five cargo hold fires were investigated. The following summarizes the key contributors for each cargo hold fire.

1. One cargo flight experienced an in-flight cargo fire that was detected by the cargo hold smoke detectors (NTSB 1998). The aircrew was able to land and evacuate with minor injuries.
2. The aircrew received a cargo fire indication and was able to land safely with a cargo fire (NTSB 2007).

3. Undeclared and improperly packaged hazardous materials loaded into the cargo compartment of a passenger airline resulted in a fire in the cargo hold while on approach to the airport (NTSB 1988). The aircraft was not required to be equipped with cargo smoke detectors or fire suppression equipment. The aircrew, upon receiving reports of smoke in the cabin, believed that the smoke was caused by a faulty APU and did not declare an emergency.

4. There was one near miss involving a shipment of improperly packaged lithium-ion batteries that caught fire while loaded on a cargo transport aircraft (NTSB 2005).

5. One passenger flight accident was attributed to chemical oxygen generators illegally placed in the Class D cargo compartment (NTSB 1997a).

Two AASRs reported in-flight fires that appeared to have started in the cabin. The flight attendants of a passenger flight discovered fire in the aft lavatory but miscommunication between the aircrew and flight attendants delayed the decision to land immediately (NTSB 1984). Twenty-three people were fatally injured in a flash fire that started one minute after the aircraft doors were opened. In another incident, the supernumerary compartment, or the space between the flight deck and cargo compartment, caught fire while the aircrew was preparing the aircraft for flight (NTSB 2009a). The probable cause of the fire was a short circuit in proximity to the oxygen hose, which released oxygen that fed the fire.

One AASR reported in-flight fire on the flight deck. The weather radar system on a small aircraft was suspected to be the cause of a cabin fire incident that led to the aircraft crash, which fatally injured two people on board and three on the ground (NTSB 2009b).

International Reports

Eight major flight deck or cabin related fire or smoke incidents were found in various countries other than Canada and the United States, including the United Kingdom, Sweden, Germany, Switzerland, and Saudi Arabia over a three decade span of time from 1980 to 2010.

Five reports investigated fire or smoke incidents started by an electrical fault. The following summarizes the key causes of each electrical fault.

1. One passenger flight experienced electrical arcing and associated thermal damage to a wiring loop adjacent to an improper installation of a galley chiller unit (AAIB 2000). The aircrew was unaware of the seriousness of the problem as the resulting smoke was insufficient to activate the bay smoke warning system.
2. An electrical short caused by abrasion of a wire loom started a smoldering fire in the insulation mats behind the freight hold cladding (BFU 2009).
3. An internal failure of a main circuit relay resulted in electrical arcing that dropped molten metal droplets, igniting

the cabin insulation blankets while the passenger aircraft was prepared for taxiing (AAIB 2009).

4. A flight deck fire was caused by electrical arcing following several assembly defects (AAIB 2006).

5. Debris or foreign objects were suspected to have started an electrical fire behind a panel in the flight deck (AAIB 2010).

Two reports investigated fires in the cabin or cargo hold. During cruise altitude for a passenger flight, ingestion of de-icing fluids created an odor onboard the aircraft that resulted in breathing difficulties for three people (SAIB 2009). In the other report, the aircrew of one passenger aircraft received cargo bin smoke detector warnings while in flight (PCA 1980). After landing and roll-out, the aircraft cabin was consumed by fire without any of the doors opened. All 301 occupants were fatally injured.

One report found that a fractured bearing floating sealing ring allowed engine oil to leak into the ECS causing some occupants to feel sick (AAIB 2009).

Past Safety Recommendations

Out of the 28 fire and smoke investigation reports, there were over 75 safety recommendations related to preventing fire and smoke incidents that were made to the appropriate airworthiness regulation authorities. In summary, the safety recommendations included

- the installation of smoke detectors in the lavatory, cargo holds, and electronics and equipment bays, and supernumerary compartment commonly found on cargo aircraft;
- recommendations for dust and debris removal during maintenance actions;
- the installation of a cargo hold fire suppression system;
- the installation of a smoke or oil mist detector in the bleed air supply;
- decreasing the flammability of passenger service blankets and develop a fire performance test method for these blankets;
- improving the flammability standards for thermal acoustical insulation materials;
- the modification of a cargo hold lamp guard to reduce the potential for heat accumulation;
- procedures for removal of power to the flight deck window heat once any arcing or smoke is detected;
- a certification test regime with the goal of mitigating the risk of arcing in electrical wire or component failures;
- changes to how aircraft electrical systems are certified;
- the development of procedures for circuit breaker resetting;
- the installation of main power switch to remove all power to IFE;

- the use of arc-fault circuit breakers;

- guidance to pilots about the need to don oxygen masks and smoke goggles at the first indication of a possible in-flight smoke or fire emergency; and

- the redesign of aircrew oxygen hoses to prevent electrically energized oxygen hoses.

The airworthiness authorities have reviewed or are reviewing these recommendations, some of which have resulted in changes to how aircraft are certified and operated. The recommendations, unfortunately, do not suggest areas where airframers and operators should focus their efforts in improving safety while reducing costs and impact on passengers travelling on affected aircraft.

TSB AVIATION SAFETY INFORMATION SYSTEM REPORTS

For various reasons, most of the reported fire and smoke incidents are not investigated in detail by the air safety agencies. This paper takes a deeper look in fire and smoke incidents that have been reported to the TSB over a ten year span. The Canadian Aviation Safety Information System (ASIS) reports from 2001 to 2010 were reviewed to identify additional areas for improvements that may increase safety while reducing costs to the operators.

Methodology

The TSB reportable incident summary database for the 10-year time space starting at 1 January 2001 was provided to the author for analysis. Each reportable incident is classified as one of 14 incident types: Engine, Transmission Gearbox, Smoke or Fire, Difficult to Control, Failure to Remain, Unable to Perform, Depressurization, Fuel Shortage, Incorrect Fuel, Collision, ROC/LOC (Risk of Collision/Loss of Separation), Emergency/Priority, Slung Load Released, and Dangerous Goods Release (TSB 2012). The summary database lists each incident by occurrence number, year, month, class, incident type, airframe type, registration number, manufacturer, model, operator type, commercial service type, operation type, operator name, and up to eight event category identification and descriptions. The event category information(s) were concise with terms like "Fire/Explosion/Fumes," "Component/System Malfunction," and "ATS Related Event." The event descriptions were also concise with terms like, "Lubrication," "Emergency/Priority Handling," "Cabin Safety Event," and "False Warning/Alert."

There were a total of 9,814 incidents in the TSB reportable incident summary database for the 10-year time span. There were 1,210 incidents that used event descriptions of "Smoke," "Fire," or "Fume." Of these, 1,043 incidents involved Canadian registered aircraft. Incidents involving non-Canadian (foreign) registered aircraft in Canadian aerospace are required to report smoke and fire incidents to the TSB. However, a majority of these foreign incidents were