2009 FAA Fire Safety Highlights

CARGO FIRE CONTROL BY DEPRESSURIZATION

A test program was conducted in a pressure vessel to examine the effectiveness of aircraft depressurization, an FAA-accepted procedure for controlling fires in freighter (all cargo) aircraft, in response to an NTSB recommendation following a destructive freighter fire. Two series of test were conducted. In the first series, several scenarios with different fire sources were tested at varying altitudes to measure the effect of altitude (ambient pressure) on fire source intensity and burn time. For each scenario, the variation in mass weight loss versus time at different altitudes or the burn rate versus altitude were examined. The results demonstrated that cargo fires suppressed in this manner may re-ignite as the aircraft descends and ambient pressure rises. For the second series, tests were performed to determine the effect of varying altitude after a cargo fire was detected. Four flight scenarios or profiles were tested. Testing commenced for each flight profile at 8,000ft., which corresponds to the normal aircraft pressure in flight. Once a rapid temperature rise was observed, indicating that the cargo had ignited, a descent was simulated by increasing the pressure in the vessel over a 20 minute period of time. At the end of the 20 minute descent, the pressure vessel was brought back to a sea level condition.

Series one test results showed a reduced burn rate for all materials tested as the altitude increased (pressure decreased). The decreased burn rate was nearly linear, slightly greater than a reduced rate of 2% per 1000 feet. Testing of lithium metal and lithium ion batteries, a fire safety area of concern for all transportation modes, showed that altitude had little or no effect on the reaction. However, the time needed to heat the batteries to the point of reaction was increased, because of the reduced burn rate of the fuel supplying the heat, as altitude was increased (pressure reduced).

Series two test results showed that although depressurization reduced the initial burning, the fire intensity on decent was greatly accelerated. The highest depressurization altitude evaluated (25,000 feet) produced the best initial results but the largest fire on decent. The results of the depressurization tests were compared to the use of Halon 1301 under similar conditions. Halon 1301 is used to suppress cargo compartment fires in passenger-carrying airplanes. The use of halon provided much greater control of the fire. An FAA technical report for public distribution was drafted describing the findings.

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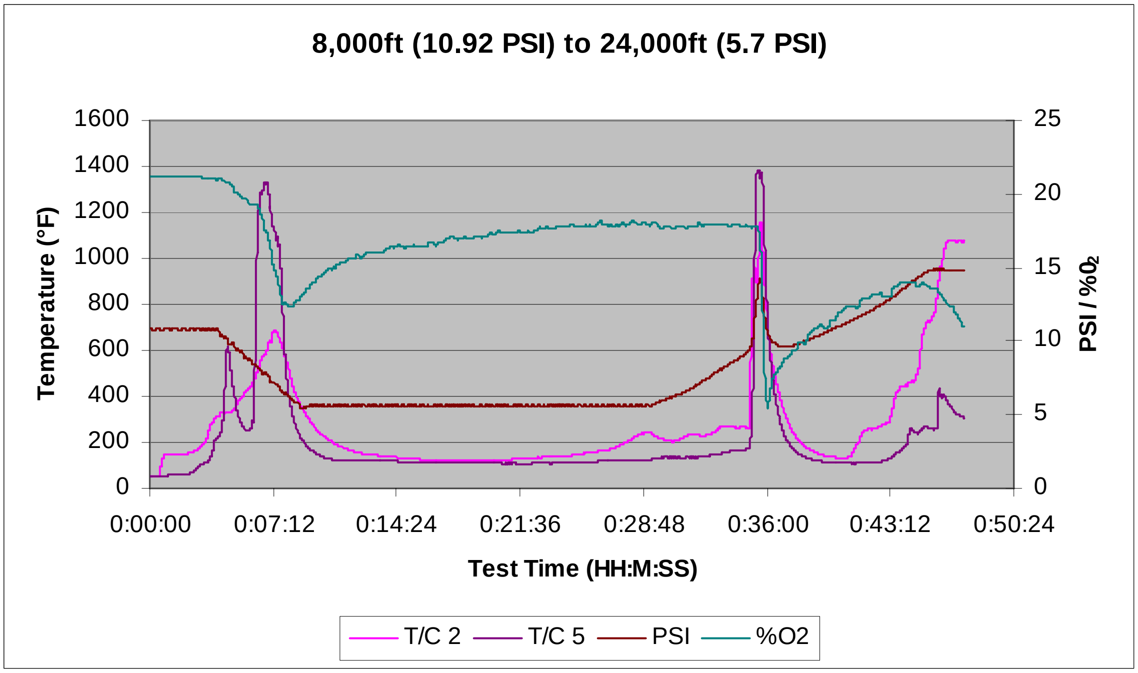

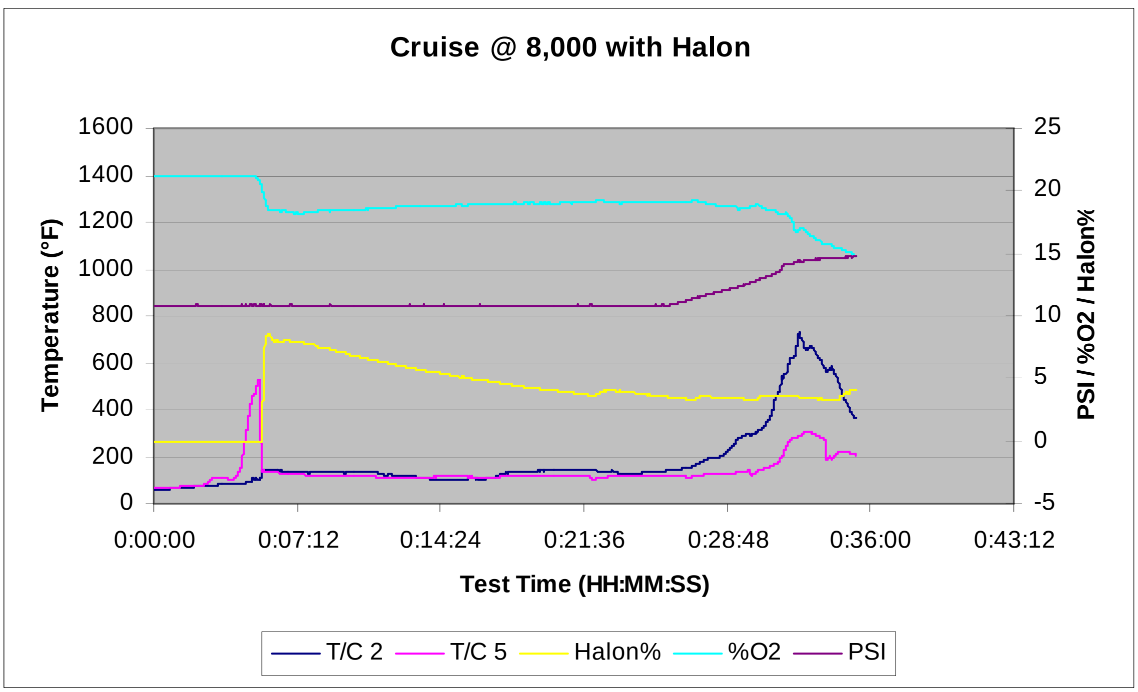

Comparing Depressurization (Top) to the Use of Halon 1301 (Bottom)

LAPTOP COMPUTER FIRE EXTINGUISHMENT

Laptop computers and other battery powered electronic devices can pose a significant fire hazard when carried aboard passenger aircraft. The lithium-ion batteries may malfunction and overheat, often during the charging process. This can cause the battery pack to catch fire. Laptop computer batteries contain up to nine lithium-ion cells. These cells become dangerous when the internal temperature reaches 350 degrees Fahrenheit. At that temperature the cell goes into thermal runaway. The cell gets extremely hot, then overpressures, releasing flammable liquid electrolyte and may explode. A single cell in thermal runaway generates enough heat to cause adjacent cells to also go into thermal runaway, a chain reaction process.

The FAA, in conjunction with the airline industry, embarked on a series of tests to determine the optimum procedure for fighting a laptop computer fire on board an aircraft. Halon 1211, the typical fire extinguisher installed in passenger aircraft, was effective in extinguishing the burning electrolyte, but did not prevent adjacent cells from going into thermal runaway and catching on fire. It was determined that water was the most effective agent in cooling the remaining cells and stopping the chain reaction. A training video was developed by the Fire Safety Team, which illustrates effective and practical methods of extinguishing a cabin fire involving lithium batteries in a laptop computer. The video, "Extinguishing In-Flight Laptop Computer Fires," may be viewed at the Fire Safety Team website: www.fire.tc.faa.gov.

The FAA issued a Safety Alert for Operators (SAFO 09013, June 23, 2009) entitled, "Fighting Fires Caused by Lithium Type Batteries in Portable Electronic Devices". The purpose of the SAFO is to recommend procedures for fighting fires caused by lithium type batteries in portable electronic devices. Based on testing by the Fire Safety Team of the FAA William J Hughes Technical Center, the SAFO recommends a two phase procedure: (1) extinguishment of the fire, and (2) cooling the remaining cells to stop thermal runaway. Halon 1211 or water fire extinguishers are effective at extinguishing the fire and preventing its spread to additional flammable materials. After extinguishing the fire, dousing the electronic device with water or other non-alcoholic liquids cools the device and prevents additional battery cells from reaching thermal runaway. The SAFO references the FAA training video, "Extinguishing In-Flight Laptop Computer Fires," for additional information and demonstration of the fire fighting techniques.

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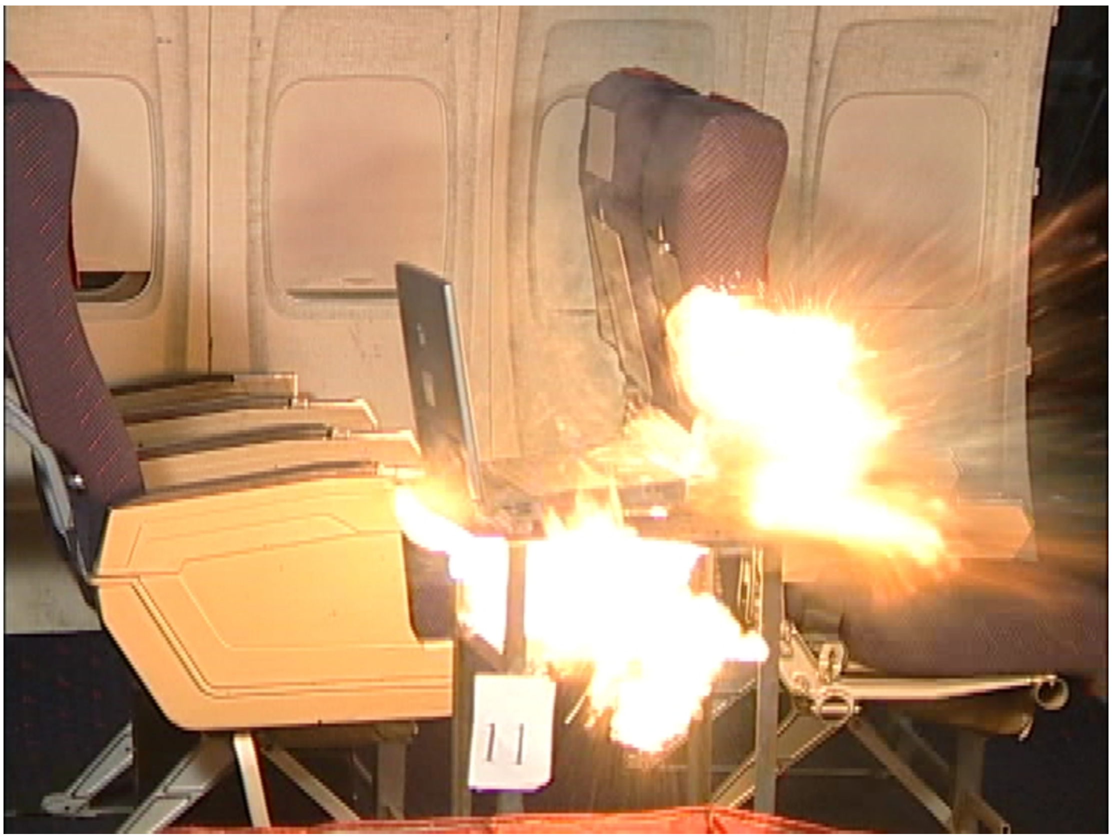

Laptop lithium battery fire extinguishment test

AIRCRAFT BATTERY FIRE SAFETY

Tests were performed at the William J. Hughes Technical Center by the Fire Safety Team of the Airport and Aircraft Research and Development Division to examine the fire safety hazards that cylindrical lithium-ion and lithium-ion polymer batteries may pose on aircraft. Tests were conducted on individual, manufacturer-supplied battery cells to determine how the cells would react in a fire situation. Tests were also conducted to determine what potential fire hazard the battery cells themselves may pose and to determine the effectiveness of a typical hand held extinguisher on a fire involving the battery cells. The battery cells that were tested were all commercial off-the-shelf products that are being considered by manufacturers for aircraft power-related usage. In recent years, there has been an increase in the use of lithium batteries for aircraft applications.

The results of the tests showed that both the cylindrical and polymer-type battery cells can react violently when exposed to an external fire. The cylindrical cells vented in a manner by which the electrolyte would spray out forcefully and ignite, accompanied by both a rise in temperature and pressure. The polymer battery cells did not have any vent locations. Instead, they were designed with a seam around the perimeter of the cell that would open thereby exposing the flammable electrolyte. The failure of the polymer-type battery cells greatly fueled the existing fire as the full amount of the electrolyte was exposed instantaneously to the fire source. In both single- and multi-cell tests, the lithium polymer battery cells, which consist of a different chemical reaction and possess a much higher energy density and power capacity, resulted in significantly higher temperature and pressure increases compared to the cylindrical cell types. Tests conducted with a hand-held Halon 1211 fire extinguisher showed that the halon was able to extinguish all three types of battery fires. However, for the polymer battery cells, even after several attempts, the halon extinguishing agent was not able to prevent the cells from reigniting.

The tests on lithium battery cells provided much insight into the potential hazards that these new battery technologies may pose. The results can be used to determine what requirements and safeguards need to be placed on the battery packaging system that house these cells. Such safeguards include proper vent placement and sizing, overcharge and thermal protection circuits, and barriers between cells to prevent thermal propagation from one cell to the adjacent cells. The next step will be to conduct tests on prototype lithium batteries for aircraft.

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Proposed Aircraft Battery Cells

CONTAMINATED INSULATION FLAMMABILITY

The fire resistance of aircraft thermal-acoustic insulation is critically important because most serious aircraft in-flight fires originate in hidden areas lined with insulation. In 2005, an FAA regulation requiring a more stringent flammability test method for thermal-acoustic insulation, developed by the Fire Safety Team, went into effect. Another aspect of the flammability of insulation is the effect of contamination that may accrue on the surface from various sources during service. FAA recommends that the insulation blankets be examined periodically to remove any contamination.

Thermal-acoustic insulation blankets having visible contamination were removed from a commercial passenger airplane which had experienced an in-flight smoke incident. The level of contamination on the polyester film encapsulating the fiberglass insulation was weighed, ranked by visual inspection, and characterized by microscale combustion calorimetry to determine the thermal combustion properties and fire hazard. The areal weight of the visible contamination was as high as 167 grams per square meter of film surface and its average heat of combustion was 13 kJ/g. Previous analysis by the aircraft manufacturer had determined that the contamination consisted of dried liquid corrosion inhibiting compounds and particulate matter that included glass fibers, synthetic and natural fibers, animal hair, cotton fibers, mineral particles, plastic, Styrofoam, metal fragments and insects.

The present study determined that the inert/mineral component of the contamination accounted for about 1/3 of the weight and was mostly broken glass fibers. The pyrolyzable (volatile) component accounted for the remaining 2/3 of the contamination weight and the specific heat of combustion of these volatile compounds ranged from 19-28 kJ/g, which is comparable to the polyester film. Insulation blankets and films were also tested for flame resistance and flame spread using the less stringent FAA regulatory standard in effect when the airplane was certificated. Tests were also conducted with a voluntary standard employed by industry. All samples of insulation blankets passed the 12 second vertical Bunsen burner flame resistance requirement of FAR 25.853 and FAR 25.855, but highly contaminated blankets failed the non-regulatory (voluntary) screening test for flame spread using a cotton swab ignition source. The attached photograph shows how a cotton swab soaked in alcohol was used to ignite the insulation blankets, and the results of test for uncontaminated, moderately contaminated and highly contaminated samples at 1 minute after ignition. Numerical modeling of the burning rate using the FAA-developed ThermaKin code, suggests that the flame-spread on contaminated samples, which tends to be erratic, may be associated with the non-uniform combustion properties of the contamination. Moreover, it was determined that insulation blankets with the highest levels of contamination would not be compliant with the current stringent FAA fire test requirement.

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Contaminated Thermal-Acoustic Insulation Fire Tests

Improved Electrical Wiring Fire Test Method

Serious aircraft in-flight fires usually occur in hidden areas, such as above the cabin ceiling, behind the side wall or beneath the floor, where it is difficult for the crew to locate and extinguish a fire. In hidden areas the most abundant materials are thermal-acoustic insulation, air condition ducting and electrical wiring and cable. The FAA's Fire Safety Team has been developing more stringent and realistic flammability tests for these three types of materials that will impart a much higher level of fire resistance in hidden areas and resultant enhanced in-flight fire protection. Improved flammability tests for insulation and ducting are now available from this work, and the FAA adopted a regulation requiring the improved test standard and criteria for insulation, which went into effect in 2005.

The Fire Safety Team initially examined the adequacy of the current fire test requirement for aircraft electrical wiring as part of this effort to improve in-flight fire safety in hidden areas. The current test requirement for aircraft electrical wiring is the sixty degree test, which is described in Title 14 Code of Federal Regulations Part 25, Appendix F Part I (b)(7) and chapter 4, "60-Deg Bunsen Burner Test for Electric Wire," of the *Aircraft Materials Fire Test Handbook* (FAA report DOT/FAA/AR-00/12). During large-scale fire tests it was determined that wiring compliant with the current FAA flammability requirement could allow a fire to propagate when subjected to a moderate ignition source (FAA Report DOT/FAA/AR-TN04/32), further emphasizing the need for an improved and more stringent flammability test method for wiring.

In 2008, the Fire Safety Team embarked on this effort, and coordinated the work with its industry stakeholders, who are members of the International Aircraft Materials Fire Test Working Group, which is also chaired and administered by the Fire Safety Team. The goal was to develop a test method capable of providing an equivalent level of fire safety as the previously developed test methods for insulation and ducting. After 12 months of evaluation work and hundreds of tests, ranging from small-scale to large-scale fire tests, an improved fire test method capable of meeting the project scope and objectives was determined. The key condition was that the new flammability test gave a good correlation, in terms of the ranking of materials for their relative flammability, with large-scale fire test results for a wide variety of aircraft wiring materials. An FAA technical report for public distribution was drafted describing the findings.

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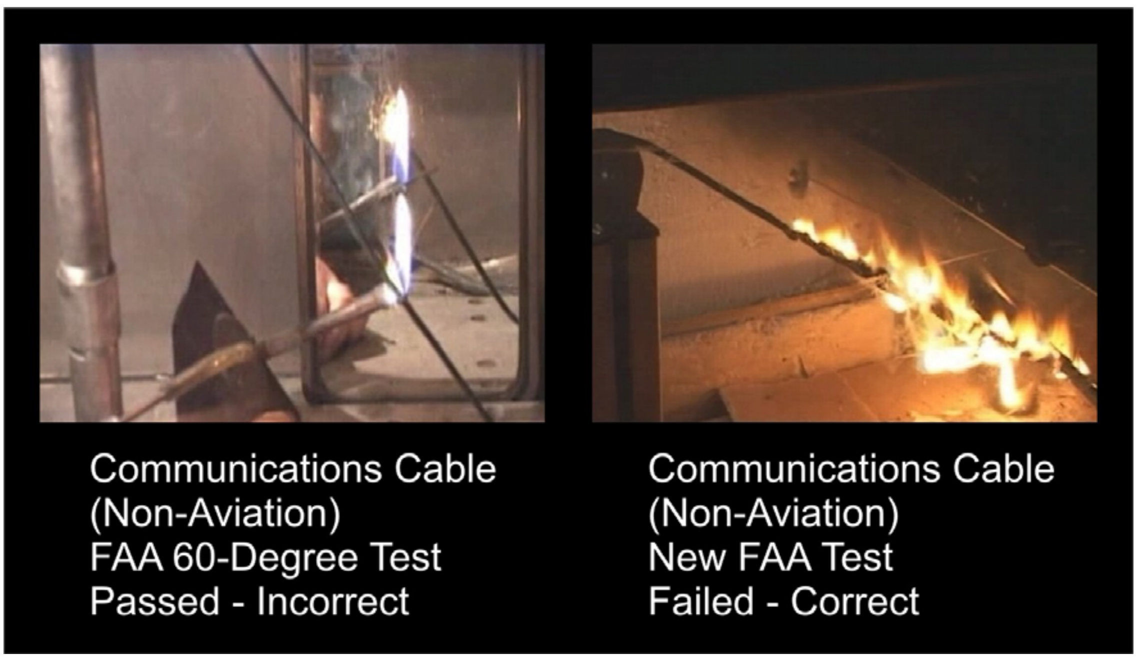

Flammability tests on aircraft electrical wiring - current FAA test method compared with improved test method

Freighter Fire Suppression Cost-Benefit Analysis

After a fire gutted a UPS DC-8 freighter in Philadelphia, the National Transportation Safety Board (NTSB) recommended the installation of fire suppression systems in the main cargo compartment of freighter (all cargo) airplanes. Currently, FAA does not require fire suppression systems in freighters and fire protection is provided mainly by early detection and aircraft de-pressurization. In order to develop a response respond to this recommendation, a cost/benefit analysis was conducted, related to the installation of on-board fire detection and extinguishment systems in freighter aircraft.

Potential benefits resulted from a reduction in fatalities and injuries to crew members, a reduction in the damage incurred to the aircraft and its cargo, and a reduction in the loss of life and to property on the ground. Potential costs are associated with the installation of the fire suppression systems and the operation of the aircraft with the systems. A mathematical model was developed to assess the benefit. The model utilized statistical distributions derived from data on in-service airplanes and accident information. Cost assessments were made for the installation of a halon total flooding fire suppression system, similar to the type installed in the cargo compartments below the cabin floor in passenger-carrying airplanes.

The results of the study indicated that crew fatalities and injuries, and the loss of the aircraft and cargo are likely the significant factors in the prediction of benefit. Collateral ground damage did not appear to contribute significantly to the prediction of benefit. It was concluded that a halon total flooding fire suppression system is unlikely to be cost beneficial for the cargo compartments of freighter aircraft. However, the study provided useful baseline data that can be used as a goal for the design of a cost-effective system. This work will commence in FY-2010 and is expected to provide even more needed information for replying to the NTSB recommendation. FAA report DOT/FAA/AR-09/17, "A Cost-Benefit Analysis for the Installation of Fire Suppression systems in Cargo Compartments of Cargo Airplanes", has been published and is available on the Fire Safety Team web site, www.fire.tc.faa.gov.

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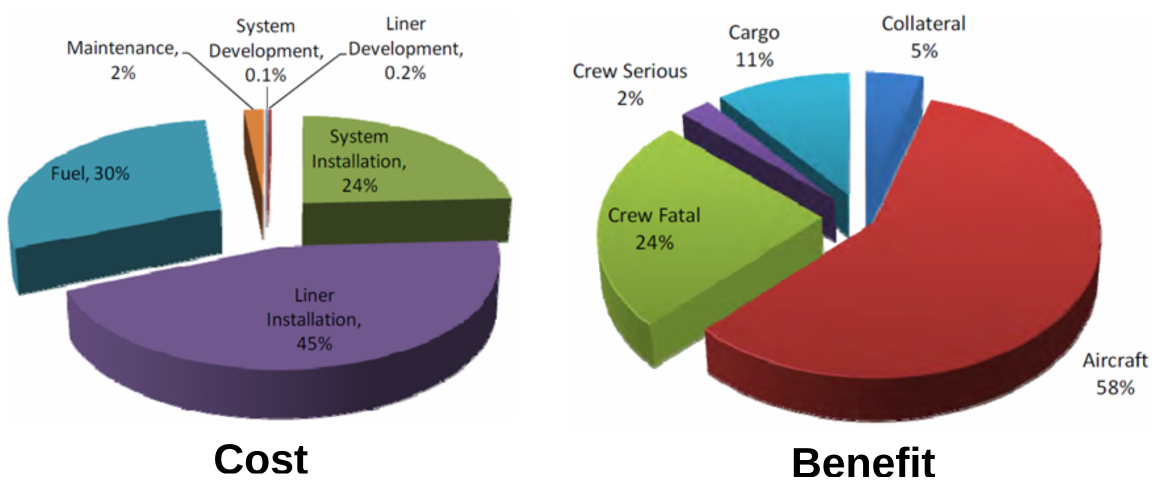

Breakdown of costs and benefits for the installation of freighter fire suppression systems

FREIGHTER FIRE DETECTION CERTIFICATION TESTING

FAA regulations require cargo compartment fire detection systems to alarm within one minute of the start of a fire and under all approved operating conditions. To show compliance with this regulation in the past, inflight tests were conducted using a variety of actual or artificial smoke sources. Traditionally, these tests have been conducted in empty cargo compartments with the smoke source placed in what was assumed to be the most difficult location to achieve detection.

This project was conducted in response to an NTSB recommendation based on the investigation of an in-flight main deck cargo fire on a freighter aircraft in 2006. NTSB determined that a significant amount of time had elapsed between the time the flight crew first smelled smoke and the smoke detectors alarmed. The recommendation requested that the FAA determine the influence of main deck cargo containers on smoke detection times. The Fire Safety Team conducted over 300 tests on the main deck of a 727 freighter aircraft and in the below floor aft cargo compartment of a 747SP. The same quantity of smoke was introduced into these cargo compartments at the location of every container position when they were both completely empty and fully loaded with cargo containers. Each test condition was replicated four times to account for the expected variability inherent in the transport of artificial smoke throughout the cargo compartments.

The results of these tests showed that detection times were typically faster in fully loaded compartment than in empty ones. This confirmed that the historic method of conducting certification tests in empty compartments generally represents the worst case scenario for smoke detection times and is a more conservative approach. An FAA technical report for public distribution was drafted describing the findings.

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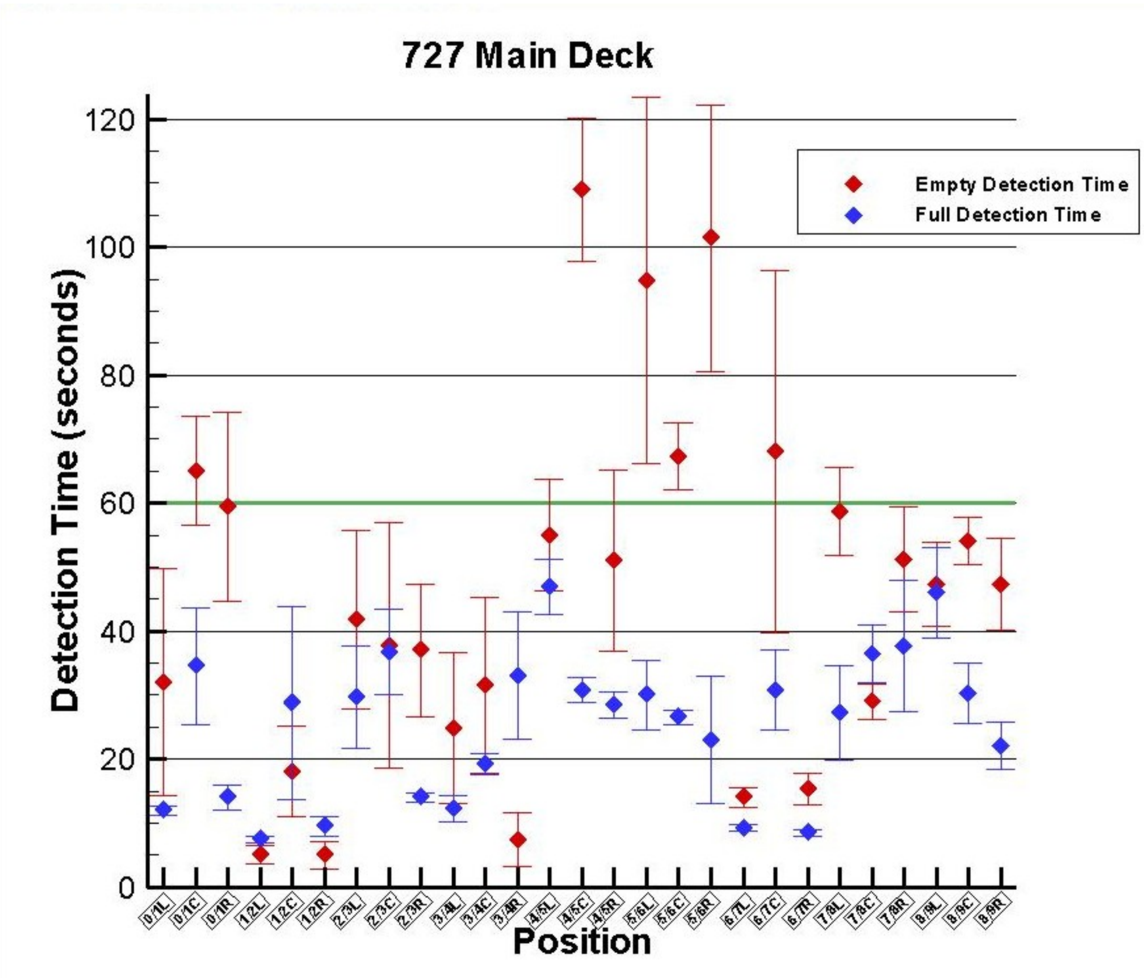

Freighter smoke test data compared for empty and filled main cargo compartment