Halon Replacement Fire Extinguishing Agents for Engines in Large Transport Category Airplanes

For more than 40 years Halon 1301 was used as a fire extinguishing agent to protect aircraft engines from fire. However, the agent is no longer being manufactured by international agreement because it is an ozone depleting chemical. FAA has been working with the aircraft industry to develop a realistic fire testing methodology to determine the fire extinguishing equivalency of replacement agents with Halon 1301, and to specify measurement criteria to demonstrate the effectiveness of replacement agent discharge during flight tests. The testing was conducted in a unique engine fire simulator located at the Technical Center which simulates a range of flight conditions and fire threats.

In FY 2006, a report was drafted that describes a multi-year effort to develop a Minimum Performance Standard for halon replacement agents. The report contains a description of the testing used to generate a process to replace halon for the engine nacelle and APU compartments, the test process itself, testing to establish equivalent quantities of 3 candidate replacements (HFC-125, CF_3I, Novec 1230), and guidance to quantify each of the 3 candidates for use in the nacelle to replace halon. The report will detail the testing completed to support Airbus Industries' effort to use 3M's Novec 1230 in place of halon 1301 in the nacelles of the Airbus A350. That work included on-site collaboration from Airbus Industries, Siemens, and 3M for the duration of the project. The output of this effort will be guidance regarding the quantity of Novec 1230 for use in a fire extinguishment system protecting the engine nacelle.

The formal description of the process to effect halon replacement in an engine nacelle or APU application, documented in the MPS, replaced an informal flow-chart to indicate the process. This accomplishment will enable a company to conduct a specific process and effect halon replacement using their own resources, and resulted from the collaboration of regulatory authorities, airframe manufacturers, system integrators, and extinguishing equipment manufacturers.

Doug Ingerson

609 485 4945

Flammability of Aircraft Ducting Materials

FAA has a multi-faceted R&D program to improved hidden in-flight fire safety. As part of this program, the adequacy of the current FAA fire test standards for hidden interior materials are being re-examined, including the vertical Bunsen burner test for aircraft ducting and conduit. The objective behind this evaluation is to determine if the test method, as judged by today's enhanced fire safety standards, can accurately determine the flammability characteristic of aircraft ducting materials when subjected to a realistic in-flight fire source, and to develop improved test criteria, if warranted.

After conducting a series of intermediate-scale fire tests, the results showed that not all the ducting materials that met the current vertical Bunsen burner test requirement were capable of preventing fire propagation from a standardized fire threat. The testing procedures and results were documented in report DOT/FAA/AR-TN05/36, "Evaluation of the 12-Second Vertical Bunsen Burner Test Used to Determine the Fireworthiness of Aircraft Duct Materials." Based on these findings, the Fire Safety Branch made a recommendation to develop a new test protocol that could better characterize the fire propagation behavior (flammability) of aircraft ducting materials.

Working with members of the International Aircraft Materials Fire Test Working Group, a joint activity was initiated to develop a new fire test protocol for aircraft ducting. Several existing tests, such as the OSU Heat Release test, Smoke test and Radiant Heat Panel test, were evaluated as possible replacement candidates. After screening various tests, the FAA concluded that the Radiant Heat Panel test, which is the new test protocol specified in FAR 25.856 for thermal acoustic insulation, was the most promising approach. Currently, the original test sequence and acceptance criteria are being modified in order to address issues related to the physical differences between aircraft ducting and insulation. Testing is underway to refine the test protocol, select new acceptance criteria and address concerns such as installation (hook & loop), fire blocking insulation, fire propagation critical path, etc. A finalized improved fire test method and criteria for aircraft ducting and conduit is planned for FY2007.

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Development of an Advisory Circular for Thermal Acoustic Insulation Burnthrough Resistance

On September 1, 2003, a new FAA regulation became effective pertaining to the flammability testing of thermal acoustic insulation used in transport category aircraft. The new rule established two new fire test methods, the first aimed at measuring the resistance to flame spread from an in-flight ignition source, and the second at measuring the resistance to penetration, or "burnthrough," from a postcrash external fuel fire. Although the new tests methods were well defined, many details existed with regard to the conduct of the tests and, related to optimal burthrough resistance, the installation of insulation blankets in an aircraft. It had previously been demonstrated that a highly burnthrough resistant blanket was of little value in a crash accident if it was easily displaced during the fire due to insufficient attachment hardware or method of installation.

In order to ensure that all of testing procedures and installation techniques were properly addressed, Advisory Circular (AC) 25.856-2 was developed and published on January 17, 2006. For example, the AC focuses on specific installation aspects, highlighting key areas that include blanket overlap at frame members, horizontal blanket overlap, penetrations, and types of installation hardware. Previous testing has shown that a certain level of blanket overlap at the frame member is essential in maintaining a continuous burnthrough barrier, as shown in figure 1. A detailed test methodology for evaluating the burnthrough resistance of two horizontally overlapped blankets is also included in the AC. Although schematic descriptions of acceptable installation techniques are included, the AC also describes the appropriate test methodology for evaluating system performance in the event that an alternative approach is desired.

This guidance material is primarily aimed at airframe manufacturers, modifiers, foreign regulatory authorities, and FAA type certification engineers and their designees. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations

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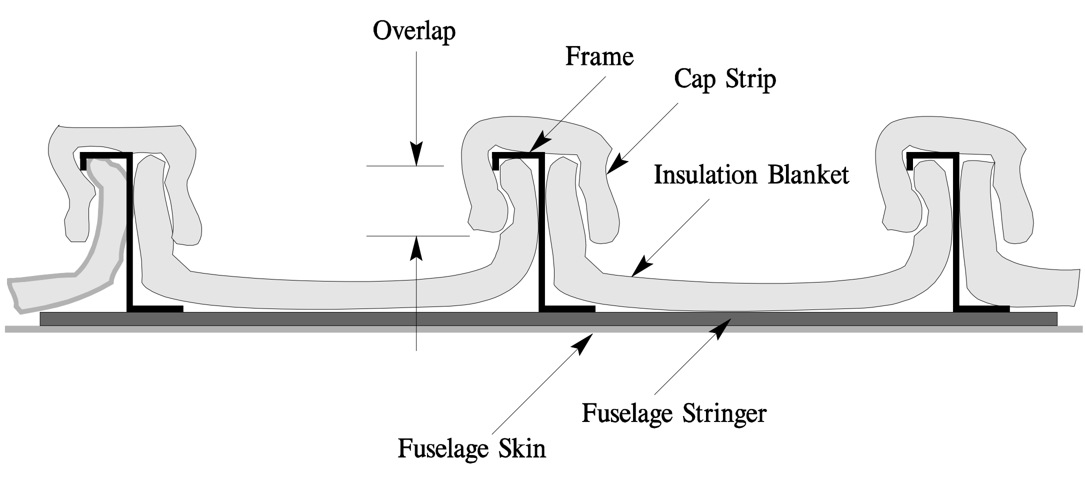


Figure 1. Description of Blanket Overlap to Ensure Continuous Burnthrough Barrier

FIRE HAZARDS OF LITHIUM ION BATTERIES

A series of tests were conducted to determine the flammability characteristics of type 18650 rechargeable lithium-ion batteries, both individually and as packaged for bulk shipment onboard cargo and passenger aircraft. The tests were designed to determine the conditions necessary for battery ignition, the characteristics of the battery fire, the effect of state of charge, the potential hazard to the aircraft as a result of the fire, and the effectiveness of the standard Halon 1301 fire suppression systems in extinguishing the fire. The work was precipitated by several serious fires on cargo pallets loaded with lithium batteries.

It was determined that a relatively small fire source is sufficient to heat the lithium-ion battery above the temperature required to activate the pressure release mechanism in the battery. This causes the battery to forcefully vent its highly flammable and easily ignitable electrolyte through the relief ports near the positive terminal. Halon 1301, the fire suppression agent installed in transport category aircraft, is effective in suppressing the electrolyte fire and easily extinguishes any fire at both the 5% knock down concentration as well as the 3% suppression concentration. The release of the electrolyte caused by heating a lithium-ion battery produces a pressure pulse that can raise the air pressure within a cargo compartment. Since cargo compartments are only designed to withstand approximately a 1-psi pressure differential, a fire involving a bulk-packed lithium-ion shipment may compromise the integrity of the compartment and cause the halon to leak out of the compartment, reducing its effectiveness. However, it was also shown that a cargo fire involving lithium-ion batteries does not present any unusual stresses on the cargo liner material.

The test findings are contained in FAA report DOT/FAA/AR-06/38, "Flammability Assessment of Bulk-Packed, Rechargeable Lithium Ion Cells in Transport Category Aircraft", published in September 2006.

Harry Webster, 609 485 4183

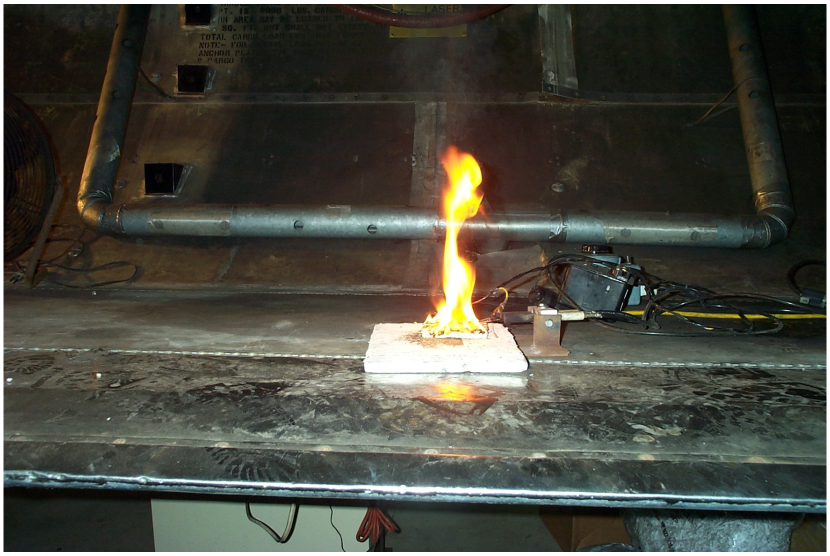
The Fire Safety Hazard of the Use of Flameless Ration Heaters On Board Commercial Aircraft

Flameless ration heaters (FRH) are devices used for the flameless cooking of a self-heating meal known as Meals, Ready to Eat (MRE). The technology behind flameless ration heaters is based on a combination of food grade iron and magnesium. When salt water is added to the iron-magnesium combination, the mixture results in an exothermic reaction, reaching temperatures of up to about 100°C in a relatively short amount of time. This rapid rise in temperature is used to then cook the MRE. They are used extensively by the military as a method of providing meals to soldiers while in the field; however, they are finding their way into other uses, and are now being used by campers, boaters, disaster response teams, etc. The potential use of these devices on board aircraft became of concern due to the high temperatures reached, as well as the release of hydrogen that occurs during heating of the meals.

Researchers performed experiments to determine if the amount of hydrogen generated during the heating of these meals would pose a fire safety threat to a commercial aircraft. Tests were performed with individual MREs under varying conditions in an open area, as well as multiple MREs placed in a confined space to examine the potential hazard associated with their use in an aircraft cabin, or the accidental activation of FRHs in a confined area aboard the aircraft such as in overhead storage bins or a cargo compartment. Temperatures in excess of 215°F and violent ignition events were observed, making it clear the release of hydrogen gas from these MREs is of a sufficient quantity to pose a potential hazard on board a passenger aircraft. Results of the testing was published in FAA Report DOT/FAA/AR-TN06/18, "The Fire Safety Hazard of the Use of Flameless Ration Heaters Onboard Aircraft".

Steve Summer, 609 485 4138

Standardized Fire for Cargo Compartment Fire Detectors



Testing was concluded and a final report was published in May 2006 for a project to develop a standardized fire source that could be used to evaluate cargo compartment fire detection systems. The fire source was a mixture of plastic resin pellets compressed into a 4” by 4” by 3/8” thick block with an imbedded nichrome wire heating element. The resin block could be used to simulate a smoldering fire by energizing the imbedded nichrome wire alone or it could simulate a flaming fire by simultaneously energizing the nichrome wire and igniting 2 ml of heptane poured onto the surface of the resin block.

The purpose of developing the standardized fire source was to ensure that the certification tests required for cargo compartment fire detection systems were consistent among different airplane models and to introduce a fire signature that contained all the components of an actual fire such as smoke, heat and combustion gases. This was desirable to allow for the certification of multi sensor fire detectors which could better discriminate between actual fires and false alarm sources. The ratio of false alarms to actual cargo fires detected on aircraft is on the order of hundreds to one.

The standardized fire source was never intended to be used on inflight certification tests. The purpose was to define the fire signature that should be detected and then develop a safe method to reproduce whichever aspects of the fire signature that a particular fire detection system was designed to respond to. Final report DOT/FAA/AR-06/21, “Development of a Standardized Fire Source for Aircraft Cargo Compartment Fire detection Systems”, describes the development of the standardized cargo fire source.

Dave Blake, 609 485 4525

INTRINSICALLY SAFE CURRENT LIMIT STUDY FOR AIRCRAFT FUEL TANK ELECTRONICS

This study was an investigation into fuel tank safety and, in particular, the minimum ignition energy of an easily ignitable flammable mixture in a fuel tank. Experimentation was performed to determine the ignition hazard presented by small fragments of steel wool making contact with energized electrical circuits in flammable environments that could be present in aircraft fuel tanks. Various types of steel wool were used and five different methods of shorting the circuit were investigated. A 28-volt direct current (dc) power supply was used to simulate energized aircraft electrical wiring, and the electrical current was limited using thin-film non-inductive resistors. An ignition detection technique was used to determine if the sparking or burning event could cause an ignition of a gaseous mixture with a known minimum ignition energy of 200 micro Joules (μJ), the accepted minimum ignition energy of hydrocarbon fuel vapor.

The ignition detection technique employed a 36-liter cubic aluminum chamber with a blowout hole on top and a clear acrylic front panel with thermocouple and lever mechanism pass-throughs. A standard flammable gas mixture was introduced into the chamber and a standard voltage spark ignition source (SVSIS) was used to calibrate the mixture with a 200-μJ voltage spark. Voltage and current traces were recorded for each test as was the temperature rise. A thin sheet of aluminum foil was used to seal the chamber blowout hole. Ignition was said to have occurred if a visual overpressure and inflation or rupture of the aluminum foil sheet was witnessed. The electrical current at which ignition occurred was recorded, and when the tests were completed, the results were compared to determine the minimum ignition current.

The tests showed that the lowest current causing ignition of the gas mixture was 99 milliamps (mA), with a wad of superfine steel wool contacting the open circuit. It was observed that the burning of the steel wool wad caused the ignition of the gas mixture; therefore, further investigation was concentrated on igniting a wad of steel wool. It was determined that the lowest current that could ignite a wad of steel wool was about 45 mA, although the ignition characteristics were found to depend on each particular wad of steel wool. Based on these tests, it was concluded that the maximum allowable steady-state current limit of 10 mA root mean square, specified by the Federal Aviation Administration in draft Advisory Circular 25.981-1C, can be considered sufficient to preclude an ignition source. The test findings are contained in FAA report DOT/FAA/AR-TN05/37, “Intrinsically Safe Current Limit Study for Aircraft Fuel Tank Electronics”.

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THERMAL ANALYSIS OF POLYMER FLAMMABILITY

A considerable amount of effort has been expended in industry and universities over the past few decades to relate laboratory thermal analyses to the flammability of polymers (plastics). The motivation for these studies is the desire for quantitative data to use in materials evaluation and the convenience of testing milligram-sized samples under equilibrium conditions. Most thermal analyses of flammability attempt to relate a single property such as char yield, heat of combustion, or thermal decomposition temperature to the fire test performance. Individually, these material properties have found limited success as descriptors of fire behavior because of the highly coupled gas and condensed phase processes of flaming combustion (heat and mass transfer), physical changes of the solid during burning (melting, dripping, swelling, char barrier formation), and combustion inhibition in the gas phase due to the presence (halogens) or absence (oxygen) of chemical species in the flame.

The Federal Aviation Administration (FAA) has developed a thermal analysis method, pyrolysis-combustion flow calorimetry (PCFC), that separately reproduces the condensed phase (pyrolysis) and gas phase (combustion) processes of flaming combustion in a single test and forces them to completion. Decoupling the pyrolysis and combustion processes in this way isolates the chemistry of the condensed phase from the test environment and provides the maximum potential (capacity) of the material to release heat in fires. The heat release capacity so measured is related to fire test results using a simple burning model that shows excellent agreement with experimental data. A physical basis for thermal analysis of polymer flammability is thus established and a material property is identified that is a good predictor of fire behavior and flame resistance.

The thermal analysis methodology for predicting flammability of polymers enabled the FAA to screen hundreds of new plastics and compositions for flammability using only research (milligram) quantities. This new capability greatly accelerated the discovery of ultra fire resistant plastics for a fireproof cabin. The thermal analysis method and underlying theory for measuring flammability parameters was published as "A Thermal Analysis Method for Measuring Polymer Flammability", *Journal of ASTM International*, 3(4), 1-18 (2006).

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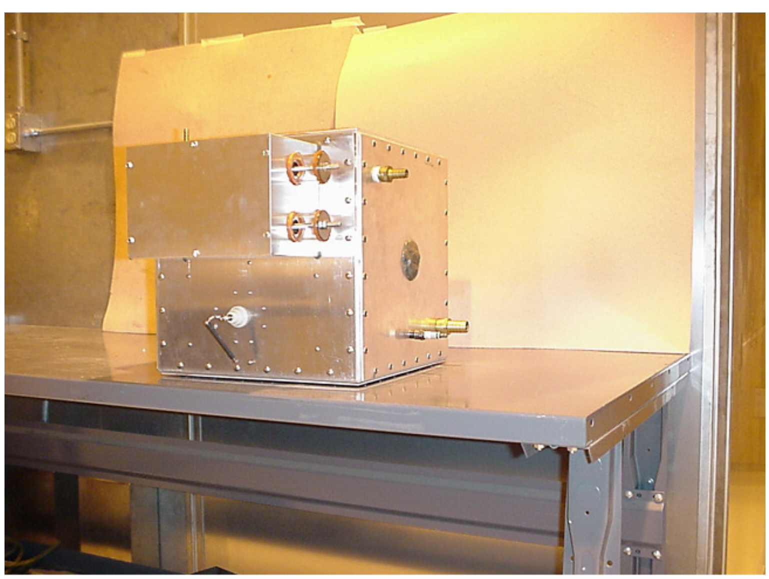

ULTRA FIRE RESISTANT DDE POLYMERS

In 1995, the Federal Aviation Administration (FAA) began a long-range research program to develop a fireproof passenger aircraft cabin with the goal of eliminating burning cabin materials as a cause of death in aircraft accidents. The technical objective of the program is an order-of-magnitude reduction in flaming heat release rate compared to current cabin materials when tested in accordance with FAA criteria for commercial aircraft described in Title 14 of the Code of Federal Regulations, Part 25. Because of the variety of polymers (plastics) used in aircraft cabin components, versatile, cost-effective polymer chemistry was required to satisfy both the technical and economic constraints on a fireproof cabin.

Previously, the FAA measured the microscale heat release rate of a polycarbonate containing the chemical group 1,1-dichloro-2,2-diphenylethene (DDE) and found it to be 13 times lower than conventional polycarbonate (LEXAN™) and 4 times lower than the polyetherimide (ULTEM™) that is currently used in thermoformed aircraft cabin parts. Because of the potentially low-cost of DDE plastics synthesized from bisphenol-C (BPC), which is a potential building block for an entire family of plastics, the FAA synthesized and evaluated over 30 different DDE plastics in order to identify the molecular mechanism responsible for their high level of fire resistance.

It was found that DDE plastics are low-cost, easily processed, and have good mechanical properties and toughness under normal conditions. Under fire conditions the "fire smart" DDE moiety undergoes a thermally-activated molecular rearrangement that produces hydrogen chloride (a noncombustible gas) and carbonaceous char (a noncombustible solid) in quantitative yield. The flammability and mechanical properties of DDE-containing polymers are described in an FAA Final Report DOT/FAA/AR-06/12, "Fire-Smart DDE Polymers," published in March 2006 and in an upcoming review article to be published in the journal High Performance Polymers.

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