Fire Safety

A New Flammability Test for Airline Blankets

In 1993, a fire erupted in a stowage bin aboard a Northwest Airlines Boeing 727-200 aircraft. The fire was noticed just as the aircraft was being pushed back from the loading gate at Dorval International Airport in Canada. Upon completion of their investigation, the Transportation Safety Board (TSB) of Canada determined that the original source of the fire was the 100% polyester airline blankets. Prior to this incident, there was no Federal Aviation Administration (FAA) regulation that required flammability testing of airline blankets. Because of this incident, the U.S. National Transportation Safety Board asked the FAA to develop a fire performance test method and performance criterion for blankets supplied to commercial airline operators.

At the time, many airlines only used blankets that met the FAA vertical Bunsen burner test specified in FAR 25.853-Appendix F. This test, however, was inappropriate as a measurement of ignitability for certain types of blankets since the polyester blankets involved in the Northwest 727 fire met the test criteria. For example, some polyester blankets compliant with the Bunsen burner test could be ignited with a match.

The FAA William J. Hughes Technical Center Fire Safety Section conducted a test program to evaluate a number of different flammability tests for airline blankets. This program led to the development of a 4-ply horizontal test method that produced consistent test results, correlated well with full-scale testing, and was more realistic since the blankets are folded and stored horizontally in the aircraft stowage bin.

A full report and test method was issued in March 1996. In August 1996, a Flight Standards Information Bulletin for Air Transportation (FSIB) went into effect, specifying the FAA recommendation that air carriers replace old blankets at the end of their service life with blankets that meet the 4-ply horizontal test. During 1997, the 4-ply horizontal test fixture was redesigned in order to simplify the test procedure for the operator. New drawings

Blanket Flammability Test

were also sent out to laboratories that perform this test to assure that the test results are reproducible among laboratories. Additionally, the test method will be included in the Materials Fire Test Handbook that is scheduled for release in early 1998. The handbook will be the most comprehensive, detailed description of aircraft material fire test methods and criteria available as guidance material for FAA certification engineers, designated engineering representatives, and test method operators.

Although not mandated, the majority of airlines require that replacement blankets be compliant with the new flammability test method. The addition of this test method is another step in the improvement of fire safety for the flying public.

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A Microscale Combustion Calorimeter for Determining Flammability Parameters of Research Materials

A microscale combustion calorimeter has been developed to measure flammability parameters of milligram polymer (plastic) samples under test conditions which approximate aircraft cabin fires. The test provides a quantitative measure of the fire hazard of new materials in an aircraft cabin fire when only research quantities are available for testing.

Figure 1 is the microscale combustion calorimeter showing, from left to right, the sample pyrolysis stage, the heated oxygen mixing manifold, and the combustion furnace and oxygen analyzer.

Figure 1. Microscale Combustion Calorimeter.

Figure 2 is a composite plot of microcalorimeter data for different plastics, some of which are used in aircraft interiors. A sharp, quantitative, and reproducible heat release rate peak is obtained in the test. After normalizing the curves for the sample size the results are independent of the physical form of the material (e.g., powder, film, fiber, etc.). The microscale heat release rate data are expressed in kilowatts per gram of original material. The best and worst samples tested differ by a factor of 100 in peak heat release rate.

Figure 3 compares the peak heat release rate (HRR) measured on milligram samples in the microcalorimeter to the heat release rate measured for 100 gram samples in a fire calorimeter. The heat release rate plotted along the vertical axis in figure 3 is the steady-state or average value obtained in a fire (cone) calorimeter at 50 kW/m^2 incident heat flux according to standard procedures.

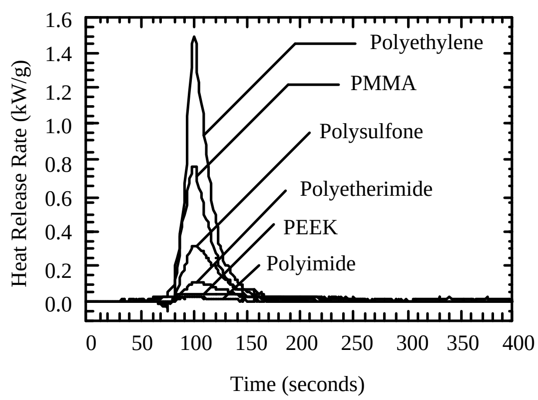

Figure 2. Heat Release Rate Curves for Various Polymers in the Microcalorimeter.

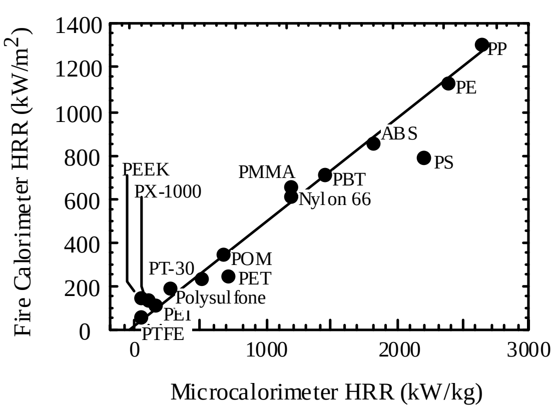

Figure 3. Correlation Between Microscale and Fire Calorimeter Results.

Full-scale fire tests at the FAA have shown that the heat release rate of interior materials measured in a fire calorimeter correlates with passenger escape time in a simulated postcrash fuel fire. The good correlation between fire and micro-calorimeter results in figure 3 shows that the microcalorimeter is also a good predictor of passenger escape time and, therefor, of full-scale fire hazard. A DOT/FAA patent has been filed on this invention.

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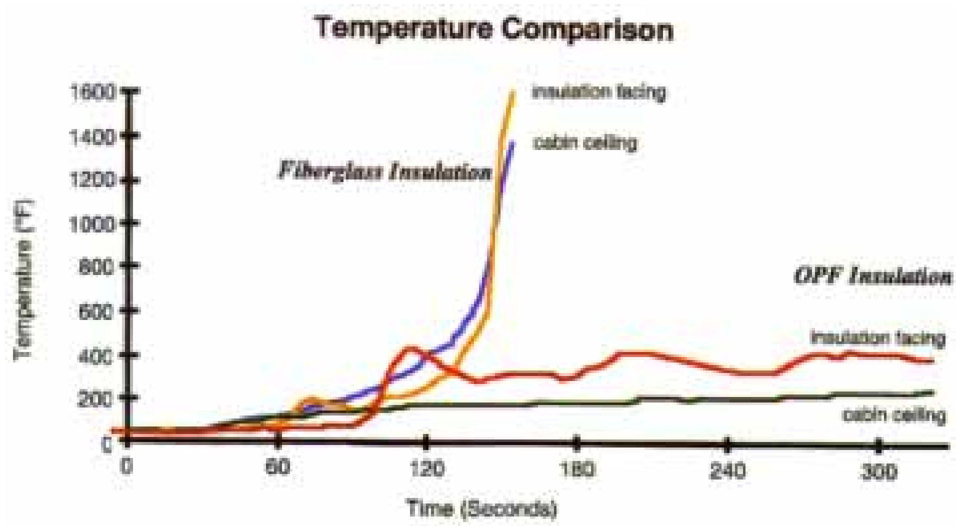
Fuel Fire Burnthrough Resistance Improvements

Fuselage burnthrough refers to the penetration of an external jet fuel fire into the interior of an aircraft. The time to burnthrough is critical because in a majority of survivable aircraft accidents accompanied by fire, ignition of the interior of the aircraft is caused by burning jet fuel external to the aircraft. Therefore, the integrity of the aircraft and its ability to provide a barrier against fuel fire penetration is an important factor related to the survival of aircraft occupants. Fuselage burnthrough resistance becomes particularly important when the fuselage remains intact following a crash. The best example of an accident where fuselage burnthrough was determined to be critical to the outcome was the Boeing 737 accident in Manchester, England, in 1985. In this accident, the investigators concluded that burnthrough occurred within 60 seconds and did not allow sufficient time for all occupants to escape (55 people died from the effects of the fire).

Fuselage burnthrough resistance may be simplistically viewed as the time interval for a fuel fire to penetrate three fuselage shell members: aluminum skin, thermal acoustical insulation, and sidewall panel/cabin flooring. Flame penetration may occur in other areas as well, such as windows, air return grilles, and seams or joints. The burnthrough resistance of the aluminum skin is well known. It takes only about 20 to 60 seconds for the skin to melt, depending on its thickness. The thermal acoustical insulation is the next impediment to burnthrough following the melting of the aluminum skin. In past FAA outdoor fuel fire burn tests on surplus fuselages, it was determined that the fiberglass insulation provided an additional 1 to 2 minutes of protection, if it completely covered the fire area and remained in place. Thus, the method of securing the insulation to the fuselage structural members is important. The sidewall panels and flooring offer the final barrier to fire penetration. Sandwich panels comprised of honeycomb cores and fiberglass facings are effective barriers; however, full-scale fire tests also show that the fire can penetrate into the cabin through air return grilles, seams, joints, or window reveals. Moreover, some airplanes use aluminum sidewall panels, which offer minimal burnthrough resistance. FAA researchers are focusing on the thermal acoustical insulation as the most potentially effective and practical means of achieving a burnthrough barrier.

A full-scale test article is used to accurately evaluate improved materials and concepts when installed realistically inside a fuselage and subjected to an external fuel fire. The test article is a 20-foot-long barrel section, constructed of steel framing members, inserted in the aft end of a Boeing 707 fuselage. A 10-foot-long by 8-foot-wide fuel pan subjects the test article to an intense fuel fire.

Aircraft thermal acoustical insulation batting is typically comprised of lightweight fiberglass encapsulated in a thin film moisture barrier, usually polyester or polyvinyl fluoride. Several materials have been tested which exhibit marked burnthrough resistance compared to the baseline thermal acoustical batting. The effective materials include a heat stabilized, oxidized polyacrylonitrile fiber (OPF) as a replacement for the fiberglass, a lightweight ceramic fiber mat used in conjunction with the present fiberglass, polyimide foam encased in quartz fiber



mat, and a polyimide film as a replacement for the polyester or polyvinyl fluoride films. A comparison of full-scale test temperature readings taken at the inside of the insulation and near the ceiling illustrate the burnthrough protection provided by the OPF insulation. Both the OPF and fiberglass insulation materials were securely attached to the framing members. It takes about 1.5 to 2 minutes for the fuel fire flames to penetrate the aluminum skin and fiberglass batting, whereas the OPF insulation did not burn when subjected to a fuel fire for over 5 minutes. A 5-minute window for passenger evacuation should cover most, if not all, crash accident scenarios.

Burn Test with Ineffective Insulation

Burn Test with Effective Insulation

In summary, full-scale fire tests have identified a number of promising materials that can significantly improve fuselage burnthrough resistance. The next step is to develop burnthrough design guidelines, including a small-scale fire test to evaluate materials and methods of attachment.

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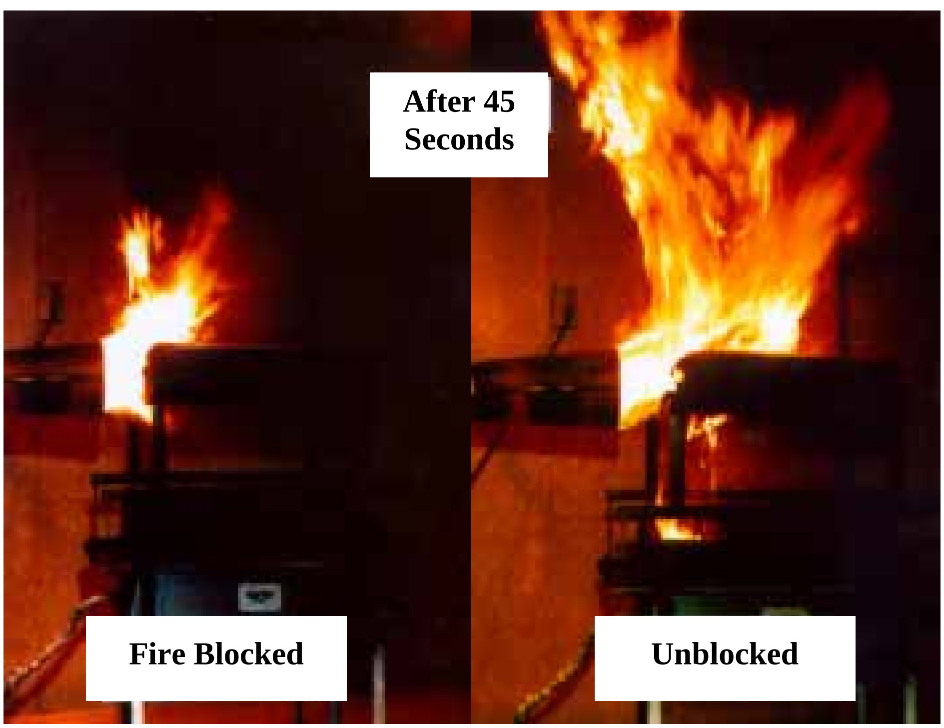
Continued Fire Worthiness of Seat Fire-Blocking Layers

On April 6, 1993, a China Eastern Airline MD-11 diverted to Shemya, Alaska, due to flight control problems. The aircraft was able to land without loss of life but suffered severe interior structural damage. During the subsequent investigation, the National Transportation Safety Board (NTSB) noticed interior cabin seat cushions with worn fire-blocking layers exposing the polyurethane foam. Typically, a fire-blocking layer encapsulates the passenger and crew seat cushions to minimize the fire hazard of the foam itself in the event of a cabin fire. As a result of the NTSB accident report, the Federal Aviation Administration (FAA) was charged with evaluating the continued fire worthiness of various cabin materials as they aged. The material particularly highlighted was the fire-blocking layer required on aircraft seat cushions. The fire performance for aircraft seat cushions is regulated through 14 CFR and FAR 25, §25.853; a fire test method for demonstrating compliance is given in Appendix II of that document.

The fire-blocking layers aboard the China Eastern Airline aircraft that was involved in the accident that lead to the FAA investigation were graphite-based fibers not commonly used by U.S. air carriers. To address the NTSB charge, the FAA investigation was shifted to focus on the U.S. civil fleet. Observations were made on in-service aircraft seat cushions to determine the level of degradation, and used materials were donated by cooperative U.S. air carriers.

On aircraft in-service seat cushions were examined at three airports: Newark International Airport (Newark, NJ), Stewart International Airport (Newburg, NY), and the Atlantic City International Airport (Pomona, NJ). The in-service conditions of the fire blocking layers in seat cushions on Shorts 360, ATR 42, Embraer EMB-120RT, McDonnell



Douglas DC9/MD80, Boeing 727, and Airbus A300 aircraft were evaluated. A total of 176 seats were examined. Evaluations of the in-service seat cushions indicated the materials were in satisfactory condition and were not the same materials found by the NTSB on the China Eastern MD11. U.S. air carriers also donated 38 seat cushion sets for destructive testing. The condition of the donated cushions was compared to the materials observed during the on aircraft in-service investigations. The donated materials possessed similar degradation characteristics. The donated materials were destructively tested to determine their compliance with Federal Regulations. The FAA specified test was used to evaluate the worn seat cushion materials. Although the test conditions were not precisely applicable, the test results provided a credible indication of whether or not the worn materials were within compliance intent. All the donated materials demonstrated an acceptable level of fire endurance even though materials on average were 7 years old. From these results, it was concluded that the seat fire-blocking materials commonly used by U.S. air carriers retain their fire endurance effectiveness during service. These results eliminated the need to add additional tests to determine the material degradation with age, which would have resulted in costly, periodic inspection of seat cushions, as recommended by the NTSB. This project was done in cooperation with participants from industry and government in the International Aircraft Material Fire Tests Working Group sponsored by the Fire Safety Section, AAR-422. A detailed report has been issued describing the work, “A Study of Continued Fire Worthiness of Aircraft Seat Cushion Fire-Blocking Layers,” DOT/FAA/AR-95/49, published in March 1997.

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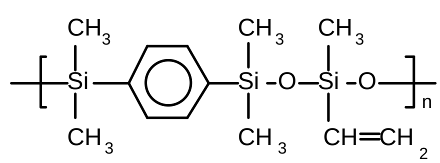
Fire-Resistant Elastomers for Aircraft Seat Cushions

Commercial transport aircraft contain between 1000 and 2500 pounds of flammable elastomers (rubber) as seat cushions, pillows, and sealants. Polyurethane rubber seat cushions are favored for their durability and recovery but they are among the primary contributors to the fire hazard in aircraft interiors.

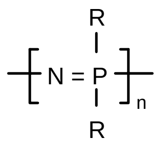
In 1987 the FAA imposed regulations on the flammability of aircraft seat cushions to delay their involvement in cabin fires. Manufacturers responded to these regulations by wrapping the polyurethane seat cushion in a fire-resistant barrier fabric. Seat fire blocking allowed manufacturers to pass the FAA certification test but the cushions burn vigorously when the fire-blocking layer is consumed after minutes of exposure to a fire.

The flammability of foamed rubber depends on the chemical composition of the polymer from which it is made. Rubbers made from carbon-hydrogen-based (organic) polymers are the most flammable because of their high fuel value. Replacing carbon and hydrogen atoms in the polymer with inorganic atoms such as chlorine, silicon, nitrogen, sulfur, or phosphorus results in a semiorganic polymer with reduced flammability because of the lower fuel value or increased heat resistance.

In the Fire-Resistant Materials research program we are focusing on semiorganic rubbers for seat cushions. Phenyl-silicon-oxygen backbone (silphenylene) elastomers which are crosslinkable and extremely heat resistant have been synthesized. The silphenylene whose chemical structure is shown below contains only 30% combustible material and can withstand temperatures of 600ºC (1100ºF).



Polyphosphazenes are semiorganic rubbers based on a phosphorus-nitrogen backbone as shown below



where R is an organic group which allows the material to be dissolved or crosslinked. Commercial production of polyphosphazene was recently discontinued despite the extremely low toxicity and ultra fire resistance of these foams because the process for making them was prohibitively expensive.

We are pursuing a new low-cost, low-temperature synthetic route to polyphosphazenes which eliminates a costly intermediate from the process and allows control over the molecular weight of the polymer. This new direct synthetic route has provided the first phosphazene copolymers including an 80-20 urethane-phosphazene copolymer which does not ignite in a flame.

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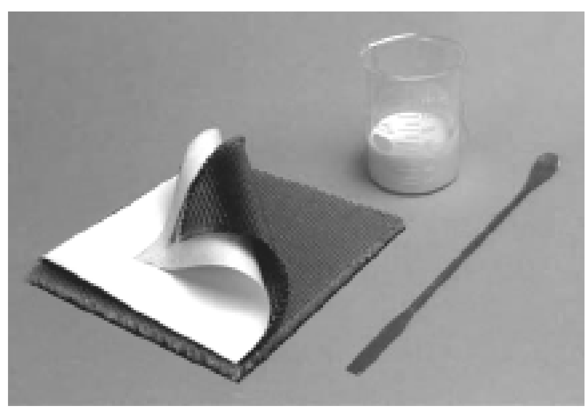
Fireproof Composites

The flammability of organic polymer matrix, fiber-reinforced composites limits the use of these materials in commercial aircraft where fire hazards are important design considerations because of restricted egress. At the present time, affordable, processable resins for fire-resistant aircraft interiors are unavailable since most organic polymers used for this purpose ignite and burn readily under fuel fire exposure conditions.

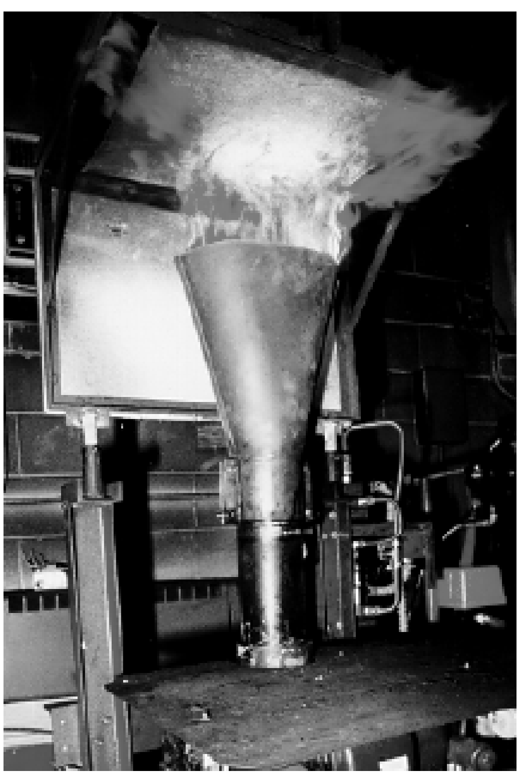
The Aircraft Safety R&D Branch, Fire Safety Section of the Federal Aviation Administration is conducting a research program to develop aircraft cabin materials with an order-of-magnitude reduction in fire hazard when compared to plastics and composites currently used as interior materials. The goal of the program is to eliminate cabin fire as a cause of postcrash death in aircraft accidents.



The Geopolymer resin in the beaker above is being evaluated as a resin for use in fireproof aircraft cabin interior panels and cargo liners (see test at right). Geopolymer is a two-part, water based, liquid potassium aluminosilicate resin which cures at 80^{o}C (176^{o}F) to a fireproof solid having twice the density of water.

Geopolymer has the empirical formula $Si_{32}O_{99}H_{24}K_7Al$. The fire response and mechanical properties of Geopolymer composites were measured and compared to lightweight organic matrix composites and aluminum used in aircraft.

Carbon fabric reinforced Geopolymer crossply laminates were found to have comparable initial strength to phenolic resin composites currently used in aircraft interiors. Unlike the phenolic laminates however, the Geopolymer composites did not ignite, burn, or release any heat or smoke even after extended exposure to high heat flux. Geopolymer composites retained 67 percent of their original flexural strength after fire exposure while organic (e.g., phenolic) composites and aluminum had no residual strength after the test. Geopolymer composites have higher strength and stiffness per unit weight, higher temperature capability, and better fatigue resistance than steel or aluminum.



Future work will focus on understanding how Geopolymer resin protects the carbon fibers from oxidative degradation at 800ºC (1500ºF) in air, optimizing processing to obtain maximum strength, and improving the toughness of laminated composites.

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Lavatory Fire Extinguisher Test Standard

The requirement for an automatic fire extinguisher which discharges into a lavatory trash container was proposed in FAA Notice 84-5 as a consequence of two aircraft accidents. The first involved an aircraft cabin fire (Air Canada, Cincinnati 1983) in which 23 people perished. The second occurred at Tampa International Airport in Florida on June 25, 1983, where passengers and crew evacuated the aircraft with no injuries or loss of life. Following these accidents, an inspection survey of the U.S. carrier fleet by the FAA revealed that the fire containment capabilities of trash containers may be compromised by the wear and tear typical of service. Considering the seriousness of inflight cabin fires, enhanced fire protection was considered necessary. As a result, rulemaking was implemented on April 29, 1987, that required each lavatory trash container be equipped with a built-in fire extinguisher which discharges automatically into the container when there is a fire.

Currently, all aircraft lavatory disposal receptacle fire extinguishers use Halon 1301 as the fire extinguishing agent. Due to environmental concerns, a total ban on the production of Halon 1301 was issued on January 1, 1994. Halons, and Halon 1301 in particular, are the mainstay of aircraft fire protection systems and thus environmentally acceptable replacements must be identified, as well as the means for their approval.

A standard test method is needed to establish that a replacement will provide a level of safety equal to Halon 1301. The FAA established the International Halon Replacement Working Group to address the development of performance standards for aircraft fire extinguishing systems employing halons. A specific task group was formed to develop a minimum performance standard for the lavatory trash receptacle fire extinguishing system. The minimum performance standard development process started with the test article, shown in the photograph below, based on input from the Boeing Commercial Airplane Group. The test article is representative of the largest trash receptacle currently in service. To provide sufficient air circulation combustion to start and continue until the lavatory extinguisher (Lavex) is discharged, ventilation was provided at both the top and bottom of the test article. The ventilation holes could be closed with damper flaps so that the agent wouldn't leak from the bottom of the test article after discharging.

Initial tests found that crumpled paper hand towels were the most appropriate material to represent lavatory trash. A pair of nichrome coils located close to the bottom of the trash receptacle provided the ignition source. This simulated a glowing cigarette buried in the trash, providing a deep-seated, smoldering combustion. To cover the range of aircraft operational conditions, a minimum test temperature was set to ensure the Lavex would function properly in cold environments, such as can result when an aircraft is parked for extended periods. Several other requirements were implemented into the minimum performance standard in order to obtain a repeatable test condition. These include standardization of the ignition source temperature, towel specification, a minimum number of required successful tests for acceptance, and tolerances on the actual “crumpling” tightness of the paper towels. The minimum performance standard for lavatory trash receptacle fire extinguishers is documented in FAA Report, “Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers,” DOT/FAA/AR-96/122, dated February 1997. The test standard may be used in certification testing of halon alternatives for lavatory trash receptacles. Policy Letter TAD-97-003, March 31, 1997, generated by the FAA Transport Airplane Directorate was circulated to the various Aircraft Certification Offices to serve notice that this new standard is now in place.

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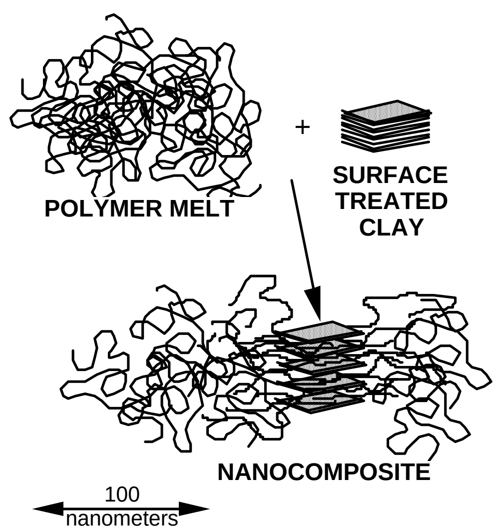
Nanocomposite Fire-Retardant Technology for Aircraft Interiors

Commercial transport aircraft contain between 1500 and 2500 pounds of flammable plastics as seat trim, windows, window shades, wire insulation, and miscellaneous parts. At present these molded parts are not required to meet the heat release rate regulations imposed on large area interior panels, stowage bins, ceilings, and partitions. The lower flammability requirement for molded parts is due to the fact that they are not considered to be a significant fuel load. High-temperature plastics that do pass the heat release rate test do not have the requisite toughness, durability, environmental resistance, and aesthetics to function effectively in aircraft interiors.

The Federal Aviation Administration is committed to developing the enabling materials technology for a totally fireproof cabin. The goal of the program is to eliminate cabin fire as a cause of death in aircraft accidents. To achieve this goal we will need interior plastics with an order-of-magnitude reduction in their fire hazard compared to that of current materials.

Nanocomposite technology is an entirely new generic approach to reducing the flammability of polymeric (plastic) materials using environmentally friendly, chemical-free additives. The fire-retardant effect of nanometer sized clay particles in plastics was discovered by the FAA through a research grant to Cornell University. The National Institute of Standards and Technology (NIST) subsequently confirmed the effect in fire calorimeter testing. The approach is to disperse individual, nanometer-sized, layered silicates in a molten polymer to create a clay-plastic "nanocomposite." The clay particles are about the same size as the polymer molecules themselves (less than one millionth of an inch in diameter) so they become intimately mixed and chemically bonded. This has the overall effect of increasing the thermal stability and viscosity of the plastic while reducing the transmission of fuel gases generated during burning.



The result is a 60% reduction in the rate of heat released from a burning nylon nanocomposite containing only 5% clay. This extraordinarily high degree of fire retardant efficiency comes with reduced smoke and toxic gas emissions and at no sacrifice in mechanical properties. The nylon nanocomposite has twice the stiffness and strength of the original nylon and a 150ºF higher softening temperature.

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Chemical Oxygen Generator Fire Testing

Fire Safety Section personnel at the FAA William J. Hughes Technical Center participated in the National Transportation Safety Board (NTSB) investigation of the crash of a ValuJet DC-9 near Miami on May 11, 1996. During the initial investigation, it was determined that up to 140 unexpended and improperly packaged sodium chlorate oxygen generators were in the forward cargo compartment of the airplane. As the investigation proceeded, burned pieces of oxygen generators were recovered at the accident site and the reconstruction of the forward cargo compartment showed increasing evidence of a severe inflight cargo fire. Although these types of generators were previously involved in aircraft fires, there was very little test data on the likelihood of an inadvertently activated generator starting a fire or the magnitude of a fire possible involving up to 140 generators.

The Fire Safety Section began tests to provide some of this data. Initial tests measured the temperature of the steel case of a variety of types of generators after activating the firing mechanism. The photograph shows the size of one of the generators. The temperatures were in the 300 to 400°F range, well below the manufacturers specification of a maximum temperature of 500°F.

The next series of tests involved activating the generators in a variety of packaging materials. In the majority of tests, the packaging materials ignited due to the temperature of the generators and the higher than normal oxygen concentrations within the packages. When multiple generators were packaged in the same box, the heat of the burning package was sufficient to initiate the chemical reaction in adjacent generators which produced even more heat and oxygen. The resulting fire quickly consumed all the generators and packaging materials present. The temperatures generated were high enough to melt steel which has a melting point of approximately 2500°F.

A series of three tests were then conducted in an instrumented DC-10 cargo compartment for the NTSB. The three tests were run as follows: (1) one box containing 24 generators, (2) five boxes each containing 24 generators, and (3) five boxes each containing 24 generators and suitcases and an aircraft tire inflated to 50 psi with nitrogen adjacent to the generators. The last test, shown below, was designed to be similar to the way the forward cargo compartment of the accident airplane was loaded. In all of the tests, all of the generators were consumed in the test fires, and, in the last test, the aircraft tire burst from the heat. The instrumentation in the cargo compartment was able to measure up to 3400°F; the temperature exceeded that value for a short period of time. The video recording of the last test was played at the NTSB public hearing for the accident in November 1996 and was released to the press by the NTSB. It was replayed nationwide by all the major networks. The tests corroborated the on-site accident investigation findings and demonstrated the unusual severity and rapid development of the fire. It provided NTSB with additional evidence to support their conclusion that the probable cause of the accident was the activation of an oxygen generator in the forward cargo compartment.

A last series of tests was conducted in two different volumes of cargo compartments using a Halon 1301 fire suppression system. Various quantities of oxygen generators were used for the tests. These tests had mixed results. Temperatures were kept under control when relatively small quantities of generators were involved in fires in the large compartment but the Halon had minimal impact when larger quantities of generators were used in the smaller compartment. The accompanying photos show a sodium chlorate oxygen generator and the fire test conducted for the NTSB in the DC-10 cargo compartment in the FAA Full-Scale Fire Test Facility.

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Fuel Fire Penetration Test and Destruction of a Transport Aircraft

In 1985, a British Airtours B737 experienced an engine failure while taking off from Manchester International Airport in Manchester, England. The left wing tank was punctured releasing fuel into the fire plume trailing from the damaged engine. The plane was safely brought to a halt on the runway, where fuel continued to spill from the wing tank creating a pool fire upwind of the aircraft. The wind carried the fire onto the left rear part of the aircraft where it penetrated the hull and ignited the interior. Fifty-five people lost their lives in spite of prompt airport fire-fighter response.

Survivors and accident investigators initially reported that the fire entered the aircraft in as little as 15 seconds after the aircraft was brought to a stop. This rapid burnthrough was inconsistent with previous accidents and FAA-conducted burnthrough tests. The aircraft should have resisted fire penetration into the cabin for up to 2 minutes.

In an effort to better understand the rapid burnthrough of the aircraft and resultant high loss of life, a test was designed and conducted at the FAA William J. Hughes Technical Center that incorporated many of the key elements of the Manchester accident. A Convair 880 was selected for use as the test article with modifications designed to emulate the Boeing 737 involved in the accident. The aircraft was equipped with instrumentation that provided temperature, heat flux, and toxic gas data designed to track the progress of the fire and the resultant cabin environmental conditions. Extensive video and motion picture camera coverage was provided to document both the external and internal fires. The photograph below shows that final stages of the test conducted at the Technical Center.

The test scenario was derived from the accident report and included sequenced

door openings, external pool fire size and location, and wind speed and direction. The external pool fire was lit and the fire was allowed to progress, eventually penetrating the aircraft and igniting the interior. The aircraft was allowed to burn until it was completely consumed by the fire.

This test provided what may be the most realistic accident reenactment conducted to date. Fire penetration points, cabin smoke patterns, and fire propagation within the cabin closely matched survivor and eyewitness accounts of the Manchester accident.

The data collected in this test has provided insight into the dynamics of external fuel fire penetration and propagation into an aircraft fuselage. The three factors that had the greatest bearing on survivability were clearly the resistance to burnthrough, the flammability of cabin materials, and the buildup of toxic gases. The forward part of the aircraft remained survivable, despite a raging fire in the rear, until a phenomenon called flashover occurred. Flashover is the sudden combustion of built up gases that occurs during an interior fire. When flashover occurs, the available oxygen is reduced and lethal levels of toxic gases are produced. The importance of reducing the incidence of flashover through the development of fire-resistant materials was clearly demonstrated. The toxic gases became the driving factor determining survivability in the forward cabin, reaching lethal levels minutes before the smoke and temperature levels become unsurvivable.

This test was used as the basis for an ongoing effort to improve the resistance of an aircraft to resist burnthrough from an exterior fuel fire through the development of improved insulation materials.

The data and conclusions derived from this test significantly increased our understanding of the mechanism of burnthrough and the factors that affect survivability in a postcrash fuel fire environment. For additional information regarding this test, please refer to the final report, DOT/FAA/AR-96/48, published in December 1996.

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