2007 Major Accomplishment: Improved Fire Test Method for Aircraft Ducting Materials

Because of the desire to improve in-flight fire safety, the Federal Aviation Administration (FAA) is conducting research to examine the adequacy of the fire test requirements for inaccessible area materials, including air conditioning ducts, and develop improved test requirements, if warranted. This activity is a continuation of prior work that resulted in the development and adoption of improved fire test criteria for thermal acoustic insulation. The current test requirement for air conditioning ducts is the 12-second vertical Bunsen burner test (Title 14 Code of Federal Regulations Part 25, Appendix F Part I (a)(4)). Intermediate-scale fire test results showed that this current test requirement for air conditioning ducts is not adequate to meet the same level of safety as it is now required for thermal acoustic insulation.

Current FAA Certification Test
Results: Material C Passed Test

Intermediate-Scale Fire Test
Results: Material C Failed Test

Developed Aircraft Ducting Fire Test
Results: Material C Failed Test

In 2004, the FAA and its stakeholders, the International Aircraft Materials Fire Test Working Group, initiated a project having as a scope the development of a fire test method capable of providing an equivalent level of safety as the test method now required for thermal acoustic insulation. After three years of evaluation work and hundreds of fire tests, from small- to intermediate-scale tests, the FAA and the working group was able to design and verify a small-scale fire test method capable of meeting the project scope and objectives. A detailed description of this improved fire test method will be published in 2007 as part of the final report documenting the test project.

In conjunction with the improved fire test requirements for thermal acoustic insulation, this more stringent fire test method for aircraft ducting materials will further reduce the likelihood of an uncontrollable hidden in-flight fire. The improved test for ducting will be recommended to the FAA's Transport Airplane Directorate for consideration as a replacement test method for the 12-second vertical Bunsen burner test, which it is currently used to certify ducting materials.

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HALOGEN-FREE FIRE RESISTANT MATERIALS

Halogen (chlorine, bromine, fluorine) containing polymers and flame-retardants are used in over 50% of the products that are required to pass some sort of fire safety testing. However, recent European environmental directives and eco-labels specifically target halogenated polymers and flame-retardants in consumer applications and are forcing global manufacturers of furniture, electrical/electronic products, and aircraft cabin materials to seek non-halogen alternatives to fire safety. At present, halogen-containing materials are widely used in transport category aircraft because they are low cost and highly effective at reducing the flammability of cabin materials. In the future, aircraft cabin materials will need to be halogen-free because the current halogen containing versions will no longer be available. These environmental and economic constraints on the chemical composition of aircraft cabin materials that must comply with 14 CFR Part 25 requirements for heat- and smoke-generation are having an immediate and negative impact on the cost, availability and performance of aircraft interiors. Moreover, an entire family of halogen-containing, ultra fire resistant materials was recently developed by the FAA to satisfy the requirements for a fireproof cabin, and these are no longer considered economically viable.

To address the need for halogen-free materials for a fireproof aircraft cabin fire, the feasibility of making ultra fire resistant materials with conventional (hydrocarbon) chemistry was explored. Clear plastics that comply with 14 CFR Part 25 heat and smoke requirements so that they could be used for large window covers and transparent partitions in newly designed aircraft cabins were of particular interest. New halogen-free dihydroxydeoxybenzoin (DHDB) polymers were synthesized, and pre-commercial plastics based on polyphenylsulfone (PPSU) and polyester carbonate (PEC) were evaluated for heat and smoke release rate according to 14 CFR Part 25. A parametric decomposition of the heat release rate by the component mechanisms of fire resistance including gas-phase flame inhibition and condensed-phase fuel replacement, heat resistance, and intumescence was developed to provide insight into the fire performance of the new non-halogen polymers and plastics.

The table lists the intrinsic flammability (heat release capacity/HRC) measured by microscale combustion calorimetry (MCC) and the 14 CFR Part 25 HRR for 1.5 mm thick samples of the clear/transparent grades of PPSU and PEC as well as the projected HRR of the amorphous, clear film-forming DHDB polymers. The PPSU plastic is fire resistant by virtue of its heat resistance, whereas the PEC and DHDB polymers utilize multiple mechanisms of condensed phase action by molecular design, which was particularly effective as they act in a multiplicative, rather than additive, fashion. As indicated by the projected peak HRR values in parentheses, the DHDB polymers have the potential for ultra fire resistance when low fuel value linking groups are identified in the future, being significantly lower than the current FAA peak HRR criteria of 65 kW/m2.

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POLYMER	MCC	14 CFR Part 25		
	HRC, (J/g-K)	Peak HRR (kW/m^2)	2-min HR ($kWmin/m^2$)	Smoke Density ^4D_s
Polyphenylsulfone	228	54 ±11	6±8	2±1
Polyestercarbonate	168	38 ±1	27±2	6
DHDB Polyphosphonate	80	(26)	N/A	N/A
DHDB Polyarylate	65	(23)	N/A	N/A
DHDB Poly(arylate-co-phosphonate)	35	(17)	N/A	N/A

<u>Structural Composite Flammability Characteristics</u>

New large transport aircraft, such as the B787 which will enter service in 2008, will have composite fuselage and wing structure in order to achieve weight and maintenance savings and improve operational economics. However, the replacement of traditional aluminum alloy with organic materials (epoxy/graphite composite) raises a number of concerns related to in-flight fire prevention and postcrash fire survivability which are not addressed by the current FAA regulations. New fire test standards and regulations will have to be developed to ensure that there is an equivalent level of fire safety with composite fuselage and wing structure compared to what has been achieved in the past with aluminum alloy structure.

The flammability characteristics of a carbon fiber/epoxy composite material for use in aircraft structures was examined. The objective was to establish a complete set of properties pertaining to the heating and burning characteristics of these materials in fires to be used for modeling and explaining the fire behavior. Thermodynamic properties were measured using the differential scanning calorimeter. Thermal decomposition properties and degradation kinetics were measured using a thermogravimetric analyzer. Flammability properties were measured using a microscale combustion calorimeter. The cone calorimeter was used to measure the flammability, ignition, and burning at different heat fluxes. FAA required flammability test results per 14 CFR Part 25 were also reported for the Ohio State University (OSU) calorimeter and the smoke density chamber. Flame spread measurements were made with a custom flame spread apparatus that promotes spread by radiative preheating. Physical attributes of the composite that related to its geometry were also observed during heating and burning. Data from these tests provided insight on how/if the composite ignites and burns in different fire scenarios.

The measured test data and derived values constitute the properties related to thermal heating, degradation, burning and the physical morphology of the material undergoing thermal degradation. These measured properties of the composite material can be used in modeling and explaining attributes of fire performance of this material. The results will also support the development of fire test standards and regulations to maintain the same level of fire safety in transport airplanes constructed of composite fuselage and wings as compared to what has been achieved in the past with metallic structure.

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New Fire Test Criteria For Lightweight Seat Cushions

With the introduction of newer materials and concepts, aircraft seat manufacturers are now capable of achieving the same level of comfort as traditional seats, but with considerable weight savings. Because of the substantial difference in weight between the new materials and traditional materials, the applicability of the FAA seat cushion flammability test criteria, which is based on a percentage weight loss, has been questioned. Although the new seating materials are often as fire resistant as traditional ones, the seat manufacturers claim the lighter materials are unfairly judged by a percentage weight loss criteria, which was originally based on heavier, polyurethane foam in conjunction with fire-blocking materials. For example, at 10% weight loss criteria, a traditional 5-pound seat can lose up to 0.5 pounds, while a new generation seat weighing only 3 pounds will exceed the weight-loss criteria losing the same 0.5 pounds (16.67% weight loss).

In order to examine this assertion, the FAA agreed to conduct full-scale tests to determine if there were any differences in fire spread and fire hazard between traditional and very lightweight seat materials under realistic postcrash fire conditions. Initial tests using seats comprised of polyurethane foam encapsulated in a fire-blocking barrier were run to establish baseline results, followed by several tests using various lightweight seat materials. Results indicated that several of the lightweight materials that failed the current weight loss criteria specified in Title 14 Code of Federal Regulations 25.853(c) Part II of Appendix F did not create a hazardous cabin environment when tested under realistic full-scale conditions. This finding corroborated the manufacturers' claim that the 10% maximum weight loss criteria, although an effective means of evaluating seat performance in the past, may not be completely nondiscriminatory for contemporary lightweight materials.

In order to more fairly evaluate a seat's performance without compromising safety, a corrected allowable weight loss (CAWL) criteria was devised, based on the cushion-to-cover weight ratio. As the cushion-to-cover ratio increases, the CAWL decreases. Moreover, the total seat test specimen weight cannot exceed 3 pounds. This would eliminate any slippage in the allowable weight loss for a traditional type of seat that somehow met the ratio (i.e., use of an extremely heavy dress cover), but performed poorly. In addition, a conservative corrected allowable burn length was also added to further limit the latitude given to the lightweight seats (Table 1). The test findings and corrected criteria were approved by the Transport Airplane Directorate, and a policy statement was issued to notify industry of the new acceptance criteria.

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TABLE 1. PROPOSED CAWL BASED ON CUSHION/COVER RATIO

Total Seat Weight (lbs)	Average Ratio of Cushion Weight to Cover Weight	Corrected Allowable Weight Loss (%)	Corrected Allowable Burn Length (Inches)
Less than 3	1.8 to 2.0	12	16
	1.5 to 1.79	14	15
	1.1 to 1.49	16	14
	.60 to 1.09	18	13
	0 to .59	20	12

<u>In-Flight Fire Fighting Training Video</u>

In 2004, the FAA issued Advisory Circular 120-80 containing guidance to increase the effectiveness of fighting inflight fires. The AC was in response to an NTSB recommendation to improve training following several incidents in which cabin crews and flight crews were hesitant to use hand held fire extinguishers on inflight fires. Although AC 120-80 contains a great deal of useful information, it was felt that a visual depiction of the topics covered in the AC would be a useful addition.

A training video was produced in 2007 that re-created inflight fire scenarios and demonstrated the appropriate response to those scenarios. The video illustrated the need to take immediate and aggressive action in response to inflight fires. Among the many topics shown in the video were: the rapid decrease in visibility due to smoke, the proper use of protective breathing equipment and hand held extinguishers, the need to remove panels and open cabinets to find the source of the fire, the effectiveness of Halon 1211 extinguishers on large flammable fluid fires, and the difficulty of fighting inflight fires in the presence of panicking passengers. It also depicted the proper response of the flight crew to inflight fires both inside and outside of the flight deck.

The training video will be released to the aviation community worldwide. It will provide a uniform and comprehensive guide that can be incorporated into existing training programs. The video was professionally produced and will provide very realistic scenes of actual and simulated fires in the aircraft cabin, galleys, lavatories, and hidden areas to better prepare cabin and flight crews to respond to actual inflight fires.

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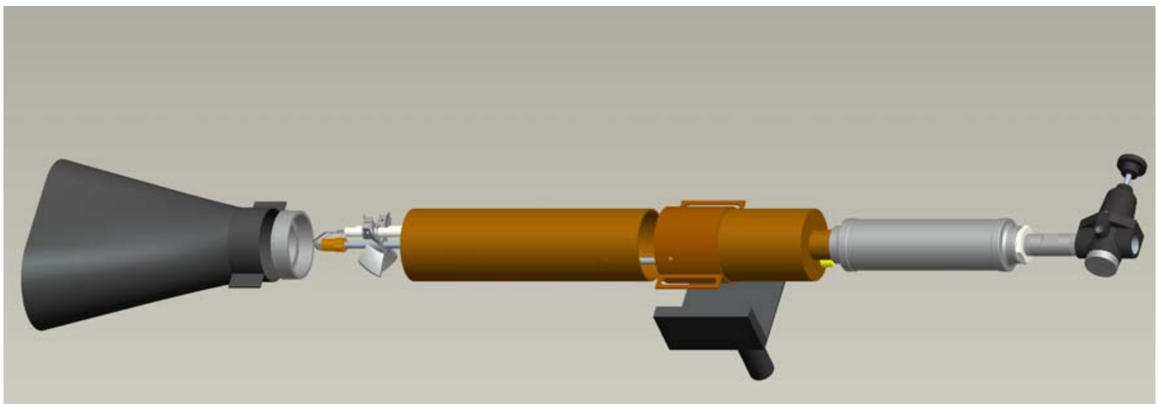
DEVELOPMENT OF A NEXT GENERATION BURNER FOR USE IN TESTING OF THERMAL ACOUSTIC INSULATION BURNTHROUGH RESISTANCE

Recently, the FAA finalized regulations related to improved postcrash fire survivability, requiring that the thermal acoustic insulation installed in transport aircraft fuselages be resistant to fire penetration (burnthrough resistant). Implementation of the rule was delayed because of problems with the specified burnthrough fire test standard. Of primary concern was the availability of the fire test test equipment. The specified test burner, a Park model DPL oil burner, is no longer produced by the manufacturer. Also, it was discovered that, for the same model number, two different castings of the burner were produced, resulting in different flame test conditions. It was also found that variations in air pressure, density, humidity, and electrical voltage differences had an impact on the performance of the burner in different labs. These problems indicated to the FAA that there was a need to develop a burner that is equivalent to the Park model DPL and is unaffected by the aforementioned issues.



A next-generation (NexGen) burner was developed based on the same operating principle as the Park oil burner, utilizing the same or very similar internal components to ensure consistent flame characteristics. The functions of the electric motor were replaced with metered and conditioned compressed air and the fuel pump with a pressurized fuel delivery system. Compressed air metered with a sonic orifice and conditioned to remove heat and moisture proves to be more consistent in quality over extended periods of time, thus increasing the repeatability of the burner. Fuel is provided by applying a head pressure of nitrogen gas on liquid fuel contained in a sealed pressure vessel, eliminating any fluctuations caused by the electric motor and fuel pump. The exit air velocity and the fuel flow rate were matched to that of the Park DPL specifications, and the burner produces a flame of similar temperature and heat flux. Comparitive testing indicated that the NextGen burner provides similar burnthrough results to that of the Park when comparing like materials. Multiple NexGen burners were produced and all were proven to provide the same results. NexGen burners were shipped out to participating laboratories, including Boeing and Airbus, where they were also tested with identical materials and were proven to be reproducible at different locations.

This effort was successful in determining that an equivalent burnthrough burner can be produced using readily available materials and can provide a consistently repeatable and reproducible flame regardless of external factors such as laboratory conditions or geographic location. This research now allows for aircraft manufacturers, material suppliers, and independent laboratories to obtain or build a compliant test burner and perform developmental, qualification, and certification testing of thermal acoustic insulation blankets for use in aircraft. The burnthrough penetration rule can now be enforced, when it comes into effect on September 2, 2009, thus improving the safety of the flying public. In the event of a survivable crash, there will be an effective fire barrier in place to increase the time for flames to penetrate into the cabin, allowing more time for passengers to escape the aircraft safely.

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