BY WAYNE ROSENKRANS

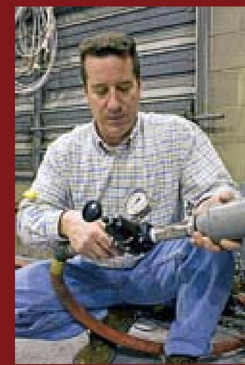
Blanket Protection

Upgraded thermal acoustic insulation should afford extra minutes to escape a fuel fire before fuselage burnthrough.

A long-awaited fire safety enhancement has moved closer to reality for the global airline industry, the U.S. Federal Aviation Administration (FAA) says. After Sept. 2, 2009, manufacturers of transport category airplanes with passenger seating capacity of 20 or more — including Airbus, ATR, Boeing Commercial Airplanes, Bombardier Aerospace and Embraer — will be required to ensure that thermal acoustic insulation materials installed in the lower half of the fuselage during manufacturing meet upgraded regulatory standards for fire-penetration resistance.

The standards, which also specify insulation flammability criteria and tests of flame propagation in these and smaller transport category airplanes, were issued in September 2003 by the FAA and are being harmonized with regulations of the European Aviation Safety Agency (EASA).[1] Specific considerations of type certification may supersede this rule. For example, the FAA determined in August 2007 that the composite fuselage structure of the Boeing 787 inherently will provide an equivalent level of safety in fire-penetration resistance.

Various factors delayed implementation of this rule, which was proposed in September 2000 and became final in July 2003. The provisions for fire-penetration resistance were to have been effective in September 2007. Most delays were attributed by the FAA to unforeseen circumstances in obtaining equipment such as identical nozzles and airflow vanes for burners in laboratory test rigs, and refining equipment configurations and procedures so that all materials laboratories can



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Above, Marker with a next-generation burner. Below, the FAA's "gold standard" insulation-burnthrough test with a Park burner.

All occupants evacuated safely during the China Airlines Boeing 737 pool fire in 2007 before the fire destroyed the cabin.

obtain results that match the FAA's own laboratory tests within accepted tolerances. Other delays involved airframe manufacturers' difficulty — as late as 2006 — procuring compliant insulation materials that would not be heavier or more expensive than those envisioned by the FAA, and their reluctance to commit to materials amid other uncertainties about compliance details.

As of March 2008, however, the FAA expressed confidence that these issues essentially have been resolved and — barring a new major glitch — the effective date stands. After a successful review of its facilities by the FAA, a materials laboratory becomes eligible to conduct certification testing. "At this point, the airframers have candidate materials identified that they will use in their implementations," said Tim Marker, an aerospace engineer and fire research specialist at the FAA William J. Hughes Technical Center. "The bulk of the work is behind us. We have interacted with industry to help set up their tests, especially [reviewing] that they are accurate and their results are traceable back to the results we got at the Technical Center. Their normal process of material screening, material selection and implementation seems to be pretty much on track. A couple of additional visits will be made to some airframers for last-minute tweaks on laboratory equipment, but at this stage, they are ready to start certifying insulation materials for use." The Technical Center also assists the FAA Air Transport Directorate, FAA aircraft certification offices and other civil aviation authorities in ongoing review of the industry compliance activities.

The motivation for the standards is *burnthrough accidents* — survivable events on the ground involving low or no impact forces, in which a large spillage of jet fuel erupts into a pool fire beneath or adjacent to an intact aluminum-skin fuselage. Since the 1960s, fatalities in burnthrough accidents have been rare, primarily because of successful evacuations. Nevertheless, any pool fire is assumed to present a lethal threat because typical 2024-T3 aluminum skin on the lower half of a fuselage can melt and be breached by such a fire in less than one minute. Two barriers beyond the aluminum skin — thermal acoustic insulation blankets and sidewall panels/cabin floors — historically have not been designed for fire resistance. Insulation simply has muffled slip stream noise and helped to maintain cabin temperatures comfortable for occupants.

Thermal Acoustic Materials

Among many possible ways for fire-hardening a passenger airliner,

upgrading insulation and its installation has seemed a simple solution. In past practice, the fuselage belly generally has been lined with two layers of 1-in (2.5-cm) lofted fiberglass batting encapsulated in one of many types of protective film that prevents absorption of condensation. "In the sidewall and up near the crown, there can be as many as five layers of 1-in lofted fiberglass," Marker said. "We don't see [manufacturers] abandoning anytime soon the use of lofted materials such as fiberglass for acoustic and thermal insulation."

Construction of a blanket, assuming proper installation, determines how well it can function as a fire barrier. To comply with the new standards, fire-resistant insulation can replace industry-standard fiberglass with a more fire-resistant material, including mixed layers of the new material and fiberglass; a thin fire-resistant material placed inside the lofted fiberglass batting of the blanket; or a fire-resistant film cover that surrounds the batting. For example, one alternate batting material — polyacrylonitrile (PAN) — in place of fiberglass can become the only fire barrier, Marker said. Blanket fabricators also can laminate a very thin barrier, such as ceramic paper, onto film so that the resulting cover itself becomes the fire barrier, he said.

The FAA recognizes that the fire-penetration test — from the airframe manufacturers' viewpoint — is just one of many criteria for selection of insulation materials. "Each [candidate] material probably has to [pass] some 20-odd internal tests for the airframers before it can be used, such as water absorption and thermal conductivity," Marker said. "Throw in weight, cost and burnthrough, and a small group of materials will fulfill all those needs."

More Time to Escape

"[With this rule] we were looking at how we could get people off the airplane before this type of fire — whether it be from a broken or cracked wing or a [ruptured] belly tank or [other fuel leak] — burns through the belly and gets access into the cabin," Marker said. "The whole [FAA fire research] program and all the new test methods that we have developed — not just the burnthrough tests — are really aimed at delaying flashover," a point in fire progression when the cabin environment suddenly becomes non-survivable.

"During flashover, off-gassing of the [cabin] materials that are being burned produces flammable gases, and at some point these all begin to combust with a large release of heat and oxygen [depletion] at the same time," he said. "If we can extend a flashover that normally would have happened at three minutes to five minutes, we have basically given passengers two additional minutes of escape time."

One "landmark" case in the study of burnthrough accidents is the British Air Tours Boeing 737 accident at Manchester, England, in August 1985 in which 55 passengers died, Marker said. Recent examples of burnthrough accidents in which all occupants survived were the Air France Airbus A340 landing overrun accident in Toronto in August 2005 and the China Airlines Boeing 737 pool fire on arrival at the gate in Okinawa, Japan, in August 2007. The China Airlines accident, according to preliminary findings by Japanese accident investigators cited by the FAA in two emergency airworthiness directives, is a reminder of the role that mechanical failures/malfunctions, including uncontained engine failures, may play in burnthrough accidents, Marker said.[2] One of the most recent fatal burnthrough accidents — with 89 fatalities — was the One-Two-Go Airlines McDonnell Douglas MD-82 crash at Phuket, Thailand.

An international search for solutions was prompted partly by safety-benefit analyses sponsored by the FAA in 1999 and 2003, analyzing 17 burnthrough accidents that occurred from 1966 to 1993. The authors argued that the industry would be able to achieve about 12 lives saved annually with fire-resistant insulation.

Full-Scale Awareness

The FAA in the early 1990s studied the effects of pool fires on full-scale surplus commercial jet fuselages by lighting large fuel fires underneath, exposing them to temperatures and heat flux approximating real postcrash fires. "Aluminum skin does vary slightly in thickness depending on where you are in the airplane … the thinnest material would probably last 30 seconds and the thickest material would last maybe 50 seconds [before melting]," Marker said. "But every [pool fire] accident is very scenario-dependent in terms of available exits, fire size and position, wind direction, passenger load, condition of passengers or [a passenger opening an exit to the fire] … all these are critical in the ultimate survivability. Two [identical] airplanes both may have 118 people on board, but you may have very different outcomes because of external [factors]." Researchers then wanted to focus on where external fuel fires entered the cabin.

In the mid-1990s, the FAA constructed a full-scale test rig at the Technical Center. It showed that after penetrating the fuselage skin and any insulation present, a pool fire typically penetrates entry points from below to the fuselage cheek area, then proceeds through cabin floor–level air-return grills. Another way fuel fires penetrate is through a window, which eventually will shrink from exposure to the fuel fire and will fall out of place.

"After a year or two of running full-scale tests [on blankets], we started to develop an appropriate lab-scale test," Marker said.

Laboratory-Scale Replication

The U.K. Civil Aviation Authority and the Direction Générale de l'Aviation Civile of France worked with Technical Center researchers on developing a method for measuring whether insulation blankets could resist for at least four minutes burnthrough caused by a jet of flame from the nozzle of a modified Park burner, the type already familiar to manufacturers for seat flammability tests and cabin panel heat-release tests. Burnthrough is determined either by noting the first appearance of a 0.25-in (0.64-cm) diameter hole or by reading data from thermal flux sensors on the "cold side" of a blanket showing when thermal limits were exceeded. "We used a higher fuel-flow rate so that we could get the thermal insult [flame radiation] needed to simulate the full-scale tests," Marker said. "If [the tester] sees the fire coming through before four minutes, the material fails; [when the tester] looks at the heat-flux trace data, if it was above 2 BTUs per sq ft per second, the material fails."

Industry Feedback

Beginning in 1999, the Technical Center enlisted airframe manufacturers and their insulation suppliers to conduct tests with sets of laboratory apparatus duplicating the Technical Center's "gold standard" rig and with blankets of known characteristics. In these round robin tests, they compared fire-penetration results. For years, results varied too widely to be acceptable; then in 2006 and 2007, the standard deviation dropped to acceptable levels. "Their people perhaps were starting to become more serious after the rule making, to really pay attention [to test details]," Marker said. "The [FAA and industry] refined the test until we were getting a very low standard deviation — significantly below 15 percent — and it became a repeatable test."

Physical characteristics of materials were another challenge. "By nature, thermal acoustic insulation is very light and its density is very low, so it can be influenced a lot by the nature of the flame — any deviations in the very intense fire are going to be magnified," Marker said. "We [issued] a very tight specification as to how to set up this equipment. We also had a very tight standard in terms of the output of the burner. From the [round robin], we were able to improve the apparatus, then we moved into even more refinement, providing calibration materials that we had tested." Specifically, the Technical Center later supplied to other laboratories its "next generation" burner, called a *sonic burner* because its air-choke regulator contains a sonic orifice, also called a critical flow venturi, that substitutes for the Park burner's large cast-aluminum pressure vessel. Either burner can be used for certification of materials.

The Way Forward

The Technical Center continues to conduct research that may or may not lead to standards that complement the current standards. "In an extension of the burnthrough test using the identical sonic burner [attached to an enclosure containing chemical assay instruments],[3] we are exposing the insulation from the standpoint of making sure that no toxic materials come off of it," Marker said. The toxicity test was derived from Technical Center research in fall 2005 on the combustion/non-combustion of composite fuselage materials. Several insulation materials underwent full-scale toxicity tests in late 2007 and early 2008. "If we see [toxicity becoming] a problem at all, I don't know [yet] how it would be handled, whether there would be a new regulation," Marker said. "Any regulation would be in addition to the current standards — it would not impact the compliance date of current standards."

Future Technology

Technological advances likely will be inevitable. "Lighter, better-performing materials can replace older ones, and I don't think insulation will be any exception," Marker said. "We are going to see lighter insulation that still meets this very rigid standard."

Research and development also will continue on intumescent coatings, which were discussed during the rule making process for fire-resistant insulation. When sprayed onto a substrate such as aluminum fuselage skin then exposed to fire, an intumescent coating swells to form a thick insulating barrier that can resist flame penetration. "We ran some tests where the external skin was coated with an intumescent, and it showed a lot of promise," Marker said. More work needs to be done to address the Technical Center's questions about in-service wear of the coatings on aerodynamic surfaces and other issues, and to establish a safety track record for them, he said. Comparatively, insulation in general already has proven to be robust and low-maintenance; blankets are not known to degrade during the service life of an airliner, he said.

Although the regulation allows airframe manufacturers to propose to the FAA alternate means of compliance with the standards, "everyone is sticking to the thermal acoustic insulation approach," Marker said. "However, there have been some variations." One airframe manufacturer is actively pursuing a design for protecting the bottom side of the cabin floor with insulation blankets as the burnthrough barrier. Another likely will continue its practice of attaching blankets to the floor of the cargo compartment rather than line the lowest part of the belly. Airframe manufacturers also are granted some flexibility in configuring the installation of insulation per the new standards.

All configurations have to follow, or provide an equivalent level of safety to, the examples in FAA Advisory Circular 25.852-2, *Installation of Thermal/Acoustic Insulation for Burnthrough Protection.* "We want to make sure they install blankets in such a way that if they do have a fire, the blankets don't fall out and the attachments don't break down," Marker said.

Airlines should expect no significant operational changes as a result of switching to airplanes that have upgraded insulation in the lower half of the fuselage. Extended evacuation time cannot be assumed. "There is no guarantee that occupants are going to get five minutes," Marker said. "There may be an accident where there is such a large fire threat that it completely overwhelms [the fire-resistant insulation barrier]. On the flip side of the coin, there could be an accident where the fire is relatively minor, and the occupants may get eight minutes of protection with this new type of insulation." ●

Notes

1. U.S. Federal Aviation Regulations Part 25.856(a). In the flame-propagation test, insulation material exposed to radiant heat and a propane-burner flame cannot propagate the fire more than 2 in (5 cm) from the flame, and any flame on the material cannot continue more than three seconds after burner removal.
2. FAA. Emergency Airworthiness Directive AD-2007-18-52 said in part, without specifying the accident, "In another case, an initial investigation revealed that following retraction of the slats after landing on a Model 737-800 airplane, loose parts of the main slat track downstop assembly punctured the slat can, which resulted in a fuel leak and a fire that ultimately destroyed the airplane. We issued [AD-2007-18-51] to detect and correct loose or missing parts from the main slat track downstop assemblies, which could result in a fuel leak and consequent fire."
3. The primary instrument for detecting toxic gases in this test is a Fourier transform infrared spectrometer analysis system.