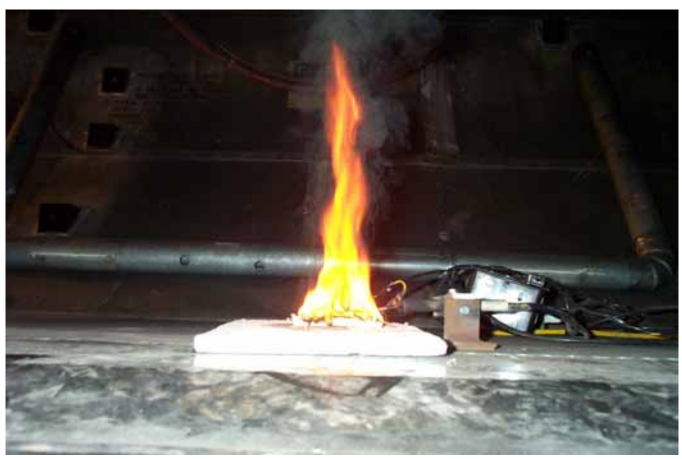
Fire Safety



Minimum Performance Standard for Halon Replacement Agents for Aircraft Cargo Compartment Fires

The Fire Safety Branch, AAR-440, of the FAA William J. Hughes Technical Center published a technical note titled "Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems," DOT/FAA/AR-TN03/6, Reinhardt, J., April 2003. This technical note establishes the minimum performance standard (MPS) that a Halon 1301 replacement aircraft cargo compartment fire suppression system must meet. It describes the tests that shall be performed to demonstrate that the performance of the replacement agent and system provides the same level of safety as the currently used Halon 1301 system. This MPS was developed in conjunction with the International Aircraft Systems Fire Protection Working Group, formerly known as the International Halon Replacement Working Group. In the past, the aircraft industry selected Halon 1301 total flood fire suppression systems as the most effective means for complying with the FAA regulations. Because of the ban on the production of Halon 1301 due to its harmful effects to the ozone layer (effective January 1994, as mandated by the Montreal Protocol), new fire suppression systems will need to be certified when Halon 1301 is no longer available.

The tests described in this standard are one part of the total FAA and Joint Aviation Authority certification process for cargo compartment fire suppression systems. Compliance with other applicable regulations is also required. Supplemental Type Certificate applicants attempting to certify replacement systems are encouraged to discuss the required process with regulatory agencies prior to conducting tests. The results of these tests will be used to determine the required concentration levels to adequately protect an aircraft cargo compartment against fire and hydrocarbon explosions. Currently, the FAA Transport Airplane Directorate is developing a policy letter to address the certification of aircraft cargo compartment fire suppression systems employing halon replacement agents and recommend the use of this standard as part of the means of compliance.

There are four different MPS fire test scenarios that new cargo compartment fire suppression systems must meet: (1) bulk-load fire (Class A and C fire), (2) containerized fire (Class A and C fire), (3) flammable liquid fire (Class B fire), and (4) an aerosol can explosion (figure 1). The bulk- and containerized-load fires, which are deep-seated fire scenarios, use shredded paper loosely packed in cardboard boxes to simulate the combustible fire load. The difference between these two tests is that in the containerized fire load the boxes are stacked inside an LD-3 container, while in the bulk-load fire scenario the boxes are loaded directly into the cargo compartment. The flammable liquid test uses 0.5 U.S gallon (1.89 liters) of Jet A as fuel. The aerosol explosion tests are executed by using an aerosol can simulator containing a flammable and explosive mixture of propane, alcohol, and water. This mixture ignites and causes an explosion within an enclosure when it is exposed to an arc from sparking electrodes. At least five tests per MPS scenario must be conducted. These tests are performed in a 2000 ft^3 simulated aircraft cargo compartment.

The suppression performance of a new agent, once the data is collected and analyzed, is then compared with the standard acceptance criteria to determine if acceptance criteria values are based on the it

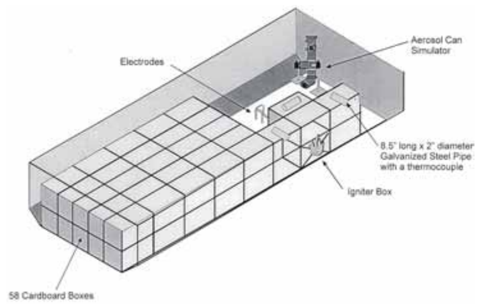


Figure 1. Example of an MPS Test Scenario—Aerosol Can Explosion Test

passes or fails the fire tests. The performance of Halon 1301. It is required that none of the peak temperatures and areas under the time-temperature curves exceed the values specified in the acceptance criteria table.

The MPS discussed above replaces the standard reported in the technical report titled "Development of a Minimum Performance Standard for Aircraft Cargo Compartment Gaseous Fire Suppression Systems," DOT/FAA/AR-00/28, Reinhardt, J., September 2000. In addition to gaseous replacement agents, the more recent MPS can be applied to nongaseous agents such as water or dry powder.

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Development of an Onboard Inert Gas Generation System to Prevent Fuel Tank Explosions

During FY03, significant progress was made in the development of a practical and cost-effective inerting system to prevent fuel tank explosions. An inerting system reduces the concentration of oxygen in a flammable fuel mixture to a level that will not support combustion. Engine bleed air is passed through an air separation module (ASM), a device that separates air into two streams—nitrogen-enriched air (NEA) and oxygen-enriched air (OEA). A system developed by the FAA inerts the fuel tank with the NEA generated by the ASM and discharges the OEA overboard.

The FAA was challenged by industry to develop a practical and reliable system that could be installed on commercial airliners within the next several years. Previous onboard designs, developed and used by the military, were relatively heavy and experienced poor dispatch reliability, something that could not be tolerated by the airlines. Ground-based inerting was an improvement, but required an airport infrastructure to supply nitrogen at each gate and a dedicated technician to transfer the nitrogen into the fuel tank, all at great expense. A simple concept was designed by FAA personnel. Fire Safety Branch personnel built a system from that design and ground tested it at the William J. Hughes Technical Center. The design incorporated a clever and relatively simple dual-flow design for generating NEA in flight. By using high-purity and low-flow NEA during ascent and cruise and lower-purity and high-flow NEA during descent, analytical modeling showed that most aircraft and flight regimes would render the fuel tank inert upon landing. Moreover, earlier experiments showed that the fuel tank would continue to remain inert while the aircraft was on the ground, negating the need for labor-intensive and costly ground operations. Industry was impressed by the relative simplicity of the design and the positive modeling results.

The Fire Safety Branch tested a small-scale fuel tank in a pressure vessel that could simulate the low pressures corresponding to various flight altitudes. The testing showed that the concentration of oxygen required to inert against a fuel tank explosion was higher than previously thought, reducing the amount of NEA needed to protect the tank, significantly reducing the size and weight of the inerting system. In addition, simulated flight tests in an altitude chamber, initially on the ASM and later with a 1/4-scale model of a B747 center wing tank, provided favorable data that were consistent with the analytical model predictions. The 1/4-scale modeling tests mapped the distribution of nitrogen (actually measured reduced oxygen level), with time, throughout the 6-bay center wing tank over entire flight regimes. The combination of analytical model predictions, the Fire Safety Branch's testing in the altitude chamber, and ground demonstration tests of the inerting system on the B747SP was enough to convince Boeing to pursue onboard inerting as a viable means of preventing fuel tank explosions.

On December 12, 2002, a major press conference was held for the national news and TV media at the FAA William J. Hughes Technical Center to highlight the recent significant progress in fuel tank inerting. The press was briefed by Nick Sabatini, AVR-1, and John Hickey, AIR-1, on the full scope of the FAA's program to protect fuel tanks. This was followed by a number of demonstrations. After viewing the installation of the inerting system in the pack bay area of the B747SP ground test aircraft, the media witnessed its operation from an instrumentation room containing a series of oxygen concentration analyzers that measure the state of the six center wing tank bays. Also, a small-scale fuel tank explosion was shown to the press in the pressure vessel facility, followed by an inerting test that prevented the explosion. Lastly, the altitude chamber tests with the 1/4-scale model of the B747 center wing tank were explained. The newspaper articles and TV coverage were generally positive, and Administrator Marion Blakey characterized the inerting system as a "major breakthrough."

In July 2003, Boeing began a flight test program to certify an onboard inert gas generating system (OBIGGS), which is based on the FAA design, on a B747 aircraft. The Boeing flight test program is being supported with instrumentation (as described in "A Description and Analysis of the FAA Onboard Oxygen Analysis System," DOT/FAA/AR-TN03/52, Mike Burns and William M. Cavage, July 2003) and personnel from the Fire Safety Branch. Boeing publicly announced their intent to begin installing OBIGGSs on B747 aircraft in FY05. The Fire Safety Branch also performed a joint flight test program with Airbus. Tests were conducted using a modified version of the FAA's B747SP system installed in the cargo bay of an A320 aircraft (figure 1). Fire Safety Branch personnel collected data using the specially designed instrumentation shown in figure 2. That data should lead to a greater understanding of OBIGGS and improvements in design.

Figure 1. OBIGGS A320 Flight Test System

Figure 2. FAA Fuel Tank Oxygen Monitoring System for the A320

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A Model for the Transport of Heat, Smoke, and Gases During a Cargo Compartment Fire

Current regulations require that aircraft cargo compartment smoke detectors alarm within 1 minute of the start of a fire and at a time before the fire has substantially decreased the structural integrity of the airplane. Presently, in-flight and ground tests, which can be costly and time consuming, are required to demonstrate compliance with the regulations. A physics-based computational fluid dynamics (CFD) tool, which couples heat, mass, and momentum transfer, has been developed to decrease the time and cost of the certification process by reducing the total number of in-flight and ground experiments. The model was developed by Sandia National Laboratories (SNL) with funding provided by NASA from their Aviation Safety Program. The tool would provide information on smoke transport in cargo compartments under various conditions, therefore allowing optimal certification tests to be designed.

The CFD-based smoke transport model will enhance the certification process by determining worst-case locations for fires, optimum placement of fire detector sensors within the cargo compartment, and sensor alarm levels needed to achieve detection within the required certification time. The model is fast-running to allow for simulation of numerous fire scenarios in a short period of time. In addition, the model is user-friendly since it will potentially be used by airframers and airlines that are not expected to be experts in CFD. The physics of the code have been verified by SNL and validation experiments are ongoing. The validation experiments are performed at the FAA William J. Hughes Technical Center in actual aircraft cargo compartments that are extensively instrumented to record smoke, temperature, heat flux, and gas species levels during the tests.

The fire source for the validation tests is a flaming block of a variety of plastic resin pellets that are heated and compressed. A length of nichrome wire is embedded with the resin block and is used to precisely control that rate of heat release from the burning resins. This flaming resin block is proposed as the standard fire for cargo compartment fire detection systems and has been submitted for a patent. Testing has shown the flaming resin block to be a very consistent and repeatable fire source. Initial validation tests show reasonably good agreement with the code predictions. The code has been slightly modified to account for heat transfer to the walls and ceiling of the cargo compartment, and more validation experiments are planned. Two technical reports documenting the results will be published next year. One report documents the properties of the smoke produced by the flaming resin block compared to the properties of artificial smoke previously used in certification tests. The second report describes the computational approach used in the code, the graphical user interface that was developed, and the initial validation test results. Figure 1 shows a flaming resin block, and figure 2 shows the inside of the B707 cargo compartment used for a validation experiment.

Figure 1. A Flaming Resin Block

Figure 2. The Inside of a B707 Cargo Compartment

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Fire and Flammability

The two stages of fire development are ignition and growth. If a fire ignites and grows quickly in an aircraft cabin, there may not be enough time for passengers to escape. The FAA and other government agencies have determined that the heat release rate of burning plastics is the best indicator of how fast the fire grows in compartments such as aircraft cabins, trains, and rooms. However, none of the tens of billions of pounds of flame-retardant plastic sold worldwide each year is tested for heat release rate. Instead, plastics are only tested for ignition resistance (flammability) by measuring the time it takes for material to self-extinguish after removal from a Bunsen burner flame. Consequently, nothing is known about whether, or how fast, a fire involving these plastics will grow to dangerous proportions.

The Fire Safety Branch, AAR-440, is studying the relationship between flame test performance and fire growth to better understand the fire hazard of plastics. In flame tests (figure 1), plastics are not forced to burn but may continue to do so after removal of the Bunsen burner if the sample's flame returns enough heat to the plastic surface to sustain the burning process. In contrast, plastics in fires or fire calorimeters (figure 2) are exposed to radiant heat that forces them to burn at a rate that increases with external heat flux.

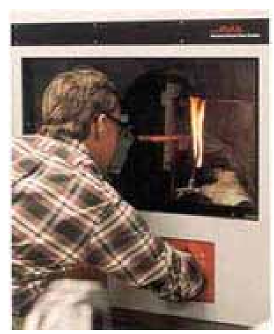

Figure 1. Bunsen Burner Test of Ignition Resistance

Figure 2. Fire Calorimetry Test of Heat Release Rate

FAA researchers hypothesized that—in the absence of external heating—a plastic will cease to burn if the rate at which heat is released by the flame at the tip of the sample is insufficient to continue the burning process. To test this hypothesis, the heat release rate of burning plastics needed to be measured without any external heating (i.e., the unforced heat release rate, HRR_0) and compared to the results of Bunsen burner tests of ignition resistance. The FAA used two strategies to measure the unforced heat release rate of plastics: direct measurement of HRR_0 in an isolated flame test and obtaining HRR_0 as the zero heat flux intercept in a plot of heat release rate versus external heat flux measured, as shown in figure 3.

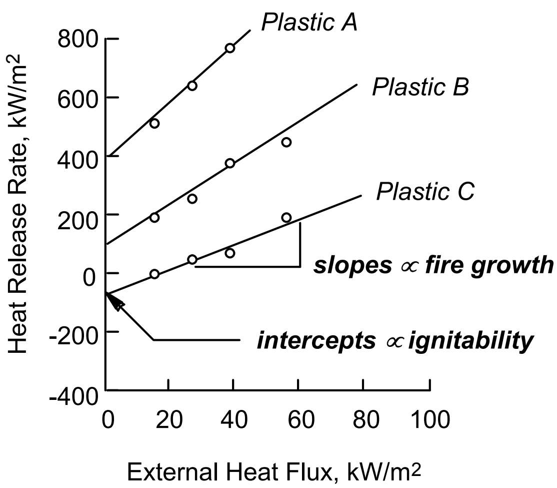

Figure 3. Typical Plot of Heat Release Rate Versus External Heat Flux Measured

Typical results for HRR_0 obtained by the extrapolation method are shown schematically in figure 3 for three different plastics. Both the direct and indirect (intercept) methods gave comparable results for HRR_0. Separate tests were conducted to measure the ignition resistance of plastics in a flame test (figure 1) using standard procedures. Data from dozens of commercial plastics and research materials were collected and analyzed.

The FAA found that plastics will self-extinguish when removed from a Bunsen burner flame if their release heat release rate in unforced flaming combustion HRR_0 is below a critical value of about 100 kW/m^2. Figure 4 shows data for flammability rating in the Underwriters Laboratories Test for Flammability of Plastics (UL 94) versus HRR_0 for over 40 different plastics. It is clear from figure 4 that self-extinguishing behavior (UL 94 V0 rating) is observed exclusively for plastics having HRR_0 less than about 100 kW/m^2. Thus, both stages of fire development, ignition and growth, depend on the heat release rate, a quantity that is easily measured in a fire calorimeter (kilogram samples) or in the FAA's microscale combustion calorimeter (milligram samples). This result allows fire protection engineers and FAA regulators to better estimate the fire hazard of a plastic in a particular environment from a few heat release rate tests.

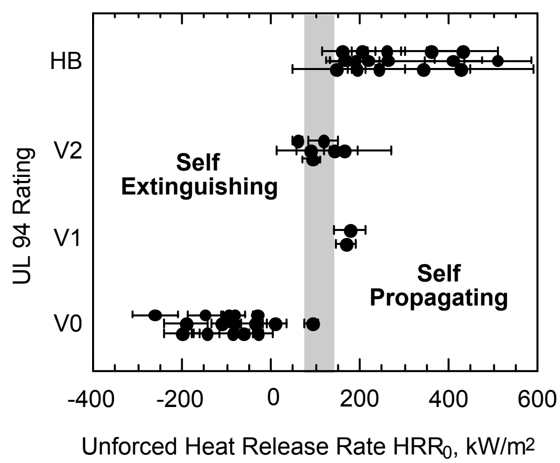

Figure 4. Ignition Resistance Measured in a Bunsen Burner Flame Test versus Heat Release Rate Intercept for 40 Plastics

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Ground Tests of Aircraft Flight Deck Smoke Penetration Resistance

A technical note was published titled "Ground Tests of Aircraft Flight Deck Smoke Penetration Resistance," DOT/FAA/AR-TN03/36, Blake, D., in April 2003. The report describes recent testing performed in support of an Aviation Rulemaking Advisory Committee harmonization working group using the Fire Safety Branch's B747SP and B727 aircraft. The group was tasked with developing draft regulations and advisory material to implement an International Civil Aviation Organization (IACO) agreement to include security considerations into the type certification of new aircraft.

One of the new requirements of the IACO agreement was to include specific design features to prevent smoke and gases from entering the flight deck following the activation of an explosive or incendiary device anywhere in the aircraft except the flight deck itself. The threat from this scenario would be the smoke and gases from the ensuing fire. Ground tests were conducted in both aircraft to either measure or demonstrate the positive pressure differential between the flight deck and surrounding areas needed to prevent smoke penetration into the flight deck. Bleed air from the aircraft's auxiliary power unit was used to run the air-conditioner packs, and every possible combination of each aircraft's ventilation system settings was tested. An actual pressure differential was not directly measurable using a differential pressure gauge (figure 1) with a resolution of 0.005 inch of water (0.00018 psi) at any ventilation system configuration in either aircraft.

Figure 1. Differential Pressure Gauge

To test the positive and negative pressure differential, a thin sheet of plastic covering was installed over the flight deck door opening (figure 2). Enough plastic was used to allow the plastic sheet to deflect either forward or aft based on the airflow direction. When airflow into the flight deck of the B727 was maximized and the cabin airflow was minimized, the plastic sheet clearly deflected into the cabin area, indicating a positive flight deck pressure differential.

Figure 2. Plastic Sheet Installed Over the Flight Deck Door Opening

A theatrical smoke generator was then used to determine if this positive flight deck pressure differential was sufficient to prevent smoke penetration. The smoke generator was placed in the cabin of the B727 with the output nozzle pointing at the closed flight deck door approximately 8 feet away. The generator was turned on at its maximum output, completely filling the forward cabin section of the B727 with smoke. No smoke penetrated into the flight deck for this ventilation condition. These tests were repeated at every other ventilation system setting that did not cause the plastic sheet to deflect into the cabin area, and smoke penetrated into the flight deck in every case. Similar tests were conducted in the B747SP aircraft. None of the ventilation settings caused a deflection of the plastic sheet into the cabin area in this aircraft, and smoke penetrated into the flight deck in every test regardless of the ventilation system settings.

The technique of using a plastic sheet to demonstrate the existence of a positive pressure differential and theatrical smoke generators to demonstrate the effectiveness of that pressure differential will be described in a new advisory circular as an acceptable method for complying with new regulations. The availability of functional test aircraft greatly enhances the Fire Safety Branch's ability to provide timely and realistic test results for FAA regulatory support.

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FAA Adopts Final Rule Requiring Improved Fire Tests for Thermal Acoustic Insulation

The FAA adopted improved and new flammability test standards for thermal acoustic insulation used in transport airplanes (see Federal Register, July 31, 2003, pp. 45046 to 45084). The standards include new flammability tests for in-flight fire ignition resistance and postcrash fire burnthrough resistance. Both test methods were developed by the Fire Safety Branch, AAR-440. Earlier fire tests and aircraft service experience had shown that the current standards did not adequately address situations in which current insulation materials contributed to the propagation of a fire. The new rule will improve aircraft safety "by reducing the incidence and severity of cabin fires, particularly those in inaccessible areas where thermal acoustic insulation is installed, and providing additional time for evacuation by delaying the entry of postcrash fires into the cabin" (Federal Register, July 31, 2003, p. 45046).

The new test method for in-flight fire resistance is called the radiant panel test since it subjects a material heated by a radiant panel to a pilot flame (see figure 1). It gave a good correlation with large-scale fire test data. The pass/fail criteria require that any flaming not extend beyond a 2-inch length from the point of flame application or continue flaming after removal of the pilot flame. Most insulation cover materials that are currently in use, which are thin films, will not meet the new fire test criteria. For example, based on past tests, most Mylar films, particularly the metallized types, fail the test, as do many of the Tedlars. Kapton films are good performers, as was one metallized Tedlar, and would be compliant with the new criteria. However, other factors affect the flammability of the insulation film materials, including weight or thickness, scrim (reinforcing lattice) type and pitch, scrim adhesive, and use of flame retardants. Thus, it is expected that new film formulations will be developed now that the rule has been adopted.

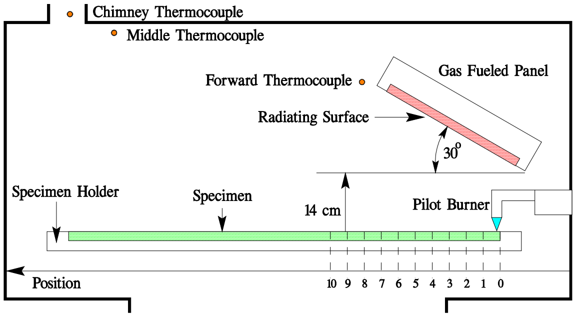

Figure 1. Schematic of Radiant Panel Test Apparatus

The test method for postcrash fire burnthrough resistance is a new test requirement since fuselage burnthrough resistance was not explicitly addressed in previous FAA regulations. It is comprised of two main components: a large burner that simulates a jet fuel fire and a sample holder representative of the fuselage structural framing (see figure 2).

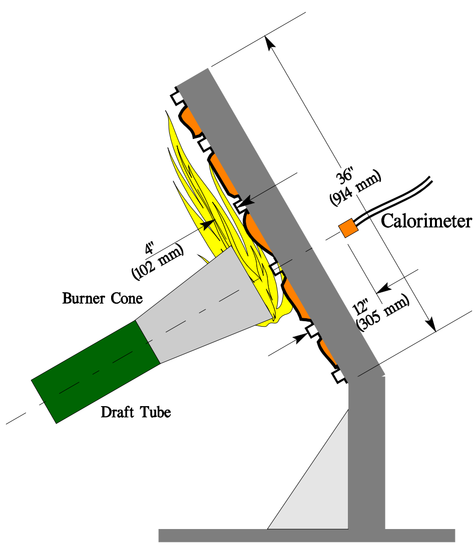

Figure 2. Proposed Burnthrough Test Apparatus

The burner flame conditions were set so that the melting time of aluminum sheeting would coincide with full-scale test results. By analyzing past accidents, the required pass/fail criteria for the insulation specimen were set at 4 minutes because there would be very limited benefit beyond this period (i.e., approximately 5 minutes, factoring in the skin melting time). The burnthrough time is based on visual observation and measured heat flux through the specimen back face. The FAA has tested numerous samples submitted by industry, and many have passed the required criteria. Compliant specimens fall into three broad categories: advanced fibrous material (fiberglass replacement), fire barrier with existing fiberglass, and hardened film material.

Work is near completion for a planned advisory circular to support implementation of the new flammability requirements for thermal acoustic insulation. A standardized radiant panel test methodology is being finalized for the evaluation of tape and hook and loop (Velcro). Both are used extensively in the installation of insulation blankets, and torn blankets are repaired with tape. It has been found that both components can contribute significantly to insulation blanket flammability. In addition, the method of installing the blanket onto the fuselage framing has a critical effect on the degree of burnthrough resistance. Insulation blanket overlapping and using proper fasteners are required to gain full potential burnthrough protection. Factors affecting the effectiveness of fasteners (fixing methods) include composition (metal or plastic), through-insulation pins versus clamps, the pitch or spacing of the fasteners, and the proper attachment to a stringer or former.

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