FAA's Cabin Fire Safety Program: Status and Recent Findings

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ABSTRACT

The purpose of this paper is to review the Federal Aviation Administration's (FAA's) research, engineering, and development (R, E, & D) program for aircraft systems fire safety. This review will include a brief introduction, a summary of regulatory products developed by the program, a description of current activities and recent findings, and a summary of new activities initiated in fiscal year 1990.

INTRODUCTION

The FAA's aircraft systems fire safety program focuses primarily on fire safety design improvements in transport aircraft. It addresses a broad range of fire safety design considerations; viz., fire test methods for interior materials, fire detection and suppression systems, portable fire extinguishers, fire containment, smoke venting, fire management, evacuation aids, and occupant protection. Emphasis is placed on both in-flight and postcrash fire scenarios. This program is complemented by the separate FAA programs to improve transport aircraft fire safety by safety fuels (e.g., antimisting kerosene) and crashworthy fuel systems.

Although the FAA has always had an ongoing aircraft fire safety program, additional resources were committed to the program in the late 1970's. A significant part of this enhanced FAA commitment was the establishment of new facilities at the FAA Technical Center devoted to fire safety R, E, & D. Perhaps most notable was a facility large enough to accommodate full-scale aircraft fire tests and also withstand the heat generated by a large fuel fire. Because of the unique test facilities at the Technical Center, many of the activities are accomplished in-house, although contractual studies are also supported, to a lesser degree, when special capabilities are required.

REGULATORY PRODUCTS

Over the past 5 years, the FAA has adopted an unprecedented series of new standards designed to improve transport aircraft fire safety (see table 1). In most cases, these standards were products of FAA's aircraft systems fire safety program. The following paragraphs highlight and update each of these regulatory products, and is based primarily on a recent technical paper (reference 1) which also references supportive technical documentation.

Seat Fire Blocking Layers. Today, the entire United States airline fleet, consisting of approximately 600,000 seats, is protected with seat cushion fire blocking layers (FBL). The FBL encapsulate the urethane foam cushions in order to retard the burning of the relatively flammable foam material during an intense cabin fire. Full-scale fire tests demonstrated that FBL may provide 40-60 seconds of additional time to escape during a postcrash fire. Most United States airliners employ FBL constructed of either aramid quilt or polybenzimidazole felt/fabric. It is believed that FBL saved many lives during the postcrash fire accident at Dallas/Fort Worth Airport on August 31, 1988, which was the first accident involving a United States airliner protected with fire blocked seats (reference 2).

Floor Proximity Lighting. All United States airliners also have floor proximity lighting to enable passengers to visually identify the cabin aisle escape path and exit locations when smoke generated by an aircraft fire obscures conventional overhead emergency lighting. For example, evacuation trials in a cabin simulator filled with stratified theatrical smoke demonstrated a 20 percent reduction in evacuation time due to main aisle illumination by low level lighting.

Burnthrough Resistant Cargo Liners. A critical function of sidewall and ceiling liners in lower cargo compartments is to prevent a cargo fire from spreading into other parts of the aircraft, particularly the cockpit and passenger cabin. A new fire test method that measures the burnthrough resistance of cargo liners under severe fire exposure conditions is now required by FAA for newly certified aircraft and will become effective for in-service aircraft on March 20, 1991. The more stringent burnthrough test requirements will ensure greater fire containment capability in both Class D compartments, where fire control is by oxygen starvation, and Class C compartments requiring a detection/suppression system.

Halon 1211 Extinguishers. A minimum of two Halon 1211 (bromochlorodifluoromethane), or equivalent, hand fire extinguishers is required by FAA in large transports. This requirement is based on the superiority of Halon 1211 in the knockdown and extinguishment of fuel-drenched seat fires in comparison to water, dry chemical, and carbon dioxide extinguishers. Additional FAA tests also demonstrated the safety of Halon 1211 in a transport cabin fire environment by showing that the concentrations of virgin agent and agent decomposition products near an extinguished seat fire were far below threshold values considered harmful.

Heat Resistant Evacuation Slides. Technical Standard Order (TSO) C69a contains a test requirement for pressure retention capability of slide fabrics subjected to radiant heat. It was demonstrated, again by full-scale tests, that aluminized, radiant heat resistant evacuation slides, for example, will remain inflated for more than twice as long as unprotected slides at a distance of 15 feet from the edge of a large fuel fire.

Low Heat/Smoke Release Interior Panels. A relatively recent and high-impact rulemaking action is the low heat and smoke release test requirement for interior panels. Most cabin surfaces, including sidewalls, ceilings, stowage bins, and partitions, are affected by this rule. The more critical requirements are effective on August 20, 1990. Full-scale postcrash fire tests were employed to develop the test methodology and acceptance criteria, and also to demonstrate the potential safety benefits (reference 3). As shown in figure 1, a phenolic glass (PH/GL) panel interior, which was a benchmark for setting acceptance criteria, provided as much as 3 minutes of additional time for escape for the fire scenario used. Moreover, the inverse relationship between heat release measured by the Ohio State University (OSU) test apparatus, specified by FAA, and the computed survival time demonstrated the appropriateness of a heat release test for hazard assessment.

FAA has supported round-robin test programs to establish and improve the reproducibility of test results between laboratories from the heat and smoke release test methods specified in the rule. This has been a difficult and time-consuming task due to the complexity of the test methods (especially when compared to the Bunsen burner test being superseded) and the sensitive relationship between heat release and panel design (relatively small changes in heat output may have a major impact on material usage). FAA has attempted to strive for consistent test results on an international basis. For example, the smoke round robin involves 18 laboratories in the United States, Europe, Canada, and Japan. Two other recent accomplishments will further support the new low heat and smoke emissions rule. First, a training video was recently prepared by the Technical Center which details the critical design, calibration, and operational features of the OSU apparatus. Second, per request and support of FAA, the National Institute of Standards and Technology has established a calorimeter calibration facility and now offers this service. A calorimeter is used to set the incident heat flux upon the sample to the value specified by the rule, which has a significant effect on material burn performance.

STATUS OF CURRENT PROJECTS

1 View Graph

Hidden Fire Protection. The use of highly fire resistant materials and the responsiveness of cabin crewmembers virtually guarantees that a small in-flight fire originating in an open or accessible location will be quickly extinguished before developing into a problem. However, several cases have occurred of fires originating in hidden or inaccessible areas that have become out of control, leading to large losses of life; e.g., Varig (1973), Saudia (1980), and Air Canada (1983). The purpose of this project is to experimentally study the characteristics of hidden in-flight fires under full-scale test conditions with the aim of examining any improved measures that may be warranted. To date, a large number of tests have been conducted in a wide body test article, employing various types of electrical problem ignition sources in hidden locations, such as behind sidewall panels, in the lower cheek area, and between the lavatory wall and fuselage skin. In all cases, the fires self-extinguished, although with varying degrees of damage to the exposed materials, demonstrating the fire resistance qualities of the thermal-acoustical insulation, insulation covers, and sidewalls panels. When combustion products passed into the cabin, visible smoke was quite evident but toxic gases were not measured. An interesting finding when the test fires were in proximity to the outflow valve was that the fires remained undetected within the passenger cabin because of the dominant airflow patterns toward the outflow valve. This demonstrated that some hidden fires, depending on location, may burn for long periods of time without being detected in the cabin. Currently, tests are being conducted to study the suppression of hidden lavatory fires originating in the waste paper compartment.

Recently, this project was redirected to examine the fire hazards of aerosol can toiletries carried on board aircraft by many passengers. Of concern is the use now of hydrocarbon propellants, such as butane, iso-butane, and propane, as replacements for the environmentally unacceptable, although inert, chlorinated fluorocarbons (CFC). The tests showed that aerosol cans will explode into a fireball when overheated (figure 2), and sometimes become projectiles. When luggage containing aerosol cans was set on fire in a Class D cargo compartment, the resultant explosion caused overpressures as high as 0.5 pounds per square inch, damaging cargo liners, dislodging passenger cabin floor boards, and creating an uncontrollable fire. Conversely, similar fires set in a Class C cargo compartment, protected with a detection/Halon 1301 total flooding system, were effectively suppressed. This was demonstrated for two circumstances: (1) when the agent was purposely discharged immediately following the explosion (3-4 minutes), although the fire was first detected in about 45 seconds, and (2) when the agent was discharged immediately following detection of the fire (the explosion was prevented). Follow up tests with a heating gun confirmed that an environment inerted with Halon 1301 will prevent ignition of hydrocarbon propellants released from a ruptured aerosol can. A technical report documenting the aerosol can test results has recently been drafted. The FAA is analyzing these test findings to determine if it is justifiable to require upgrading Class D cargo compartments (oxygen starvation/low leakage rate/small volume) to a Class C design (detection/suppression system).

1 slide

Aircraft Command in Emergency Situations (ACES). The purpose of this project is to develop and evaluate a prototype hardware/software module to advise the crew as to the best course of action during an in-flight fire. This project is prompted by three considerations: (1) finding appropriate emergency procedures in the flight manual can be time consuming and confusing to the crew; (2) the evolution towards the two-man cockpit crew creates additional workloads during an emergency; and (3) precious time can be spent in verifying that aircraft conditions definitely warrant declaration of an emergency. ACES is an approach that would link aircraft fire sensors to the cockpit computers to advise the crew on the status of the aircraft and prompt them on the course of action to take.

A feasibility study conducted by Dunlap and Associates, Inc., concluded that an ACES as conceptualized is well within the current (and very near future) state of technology of sensors, computers, and displays (reference 4). In September 1989, as a consequence of the positive feasibility study findings, a contract was awarded to Boeing Commercial Airplanes to develop design requirements, delineate components and interfaces, analyze costs, estimate performance, and project benefits for two promising ACES system approaches. Based on the results of this study, a phase II effort may be activated by FAA to build a working prototype of one of the systems for installation and fire test evaluation by FAA in a ground-based fuselage. The product of this work will be a demonstration of a prototype ACES system to aid a flight deck crew in a more rapid and proper response to in-flight fire emergencies.

3 slides

In-Flight Smoke Venting. FAA is winding down a multiyear effort to evaluate improved smoke venting measures during an in-flight fire. Briefly, the effort was an outgrowth of several past accidents, wherein accumulation of smoke in the cabin and cockpit was a factor in the survivability of the accident, that raised concerns with regard to the adequacy of current smoke ventilation procedures. Although a number of activities were undertaken during the overall effort, the following is a summary of what was perhaps the most significant work; i.e., flight tests of improved procedures and improved systems for evacuating smoke from an airplane.

The Technical Center teamed with the United States Air Force Military Airlift Command (MAC) on flight tests to explore the possibility of improving emergency smoke evacuation procedures. Most of the models in the MAC fleet, including the B-707, B-727, and DC-9, were subjected to approximately 10 hours of in-flight smoke evacuation tests. To support this effort, the Technical Center developed a unique portable smoke measurement and data acquisition system. The most significant finding from the flight tests was that modified flight procedures that improve smoke evacuation in one aircraft model may not be effective in other models. In fact, it was determined that opening windows and/or doors in flight, which for civil transports is highly controversial to being with, may not always improve smoke elimination. It was also found that on some aircraft, smoke evacuation procedures were ineffective, especially during descent or low engine power conditions.

To realistically evaluate improved smoke venting systems, a series of ground and flight tests were conducted in a Boeing 757 airplane modified with an additional upper lobe outflow valve (figure 3) and increased environmental control system (ECS) airflow capability. In principle, the higher ECS airflow would serve to vent smoke faster and the additional upper lobe outflow valve would provide for both better containment of smoke near the source and faster ventilation because of its ceiling location. Conventional outflow valves are mounted in the belly of an airplane and are less efficient in removing smoke because the hot, buoyant smoke tends to accumulate at the ceiling.

The flight tests essentially consisted of introducing artificial smoke into the passenger cabin and comparing the smoke venting capabilities provided by the new system with the results obtained by conventional smoke venting procedures. In some tests, an artificial smoke generator utilizing helium to create a buoyant smoke, developed by FAA personnel (patent request submitted), allowed for an objective comparison of roof-mounted and belly-mounted outflow valves. The results indicated that the higher (30 percent) ECS airflow did not significantly increase smoke venting capability. When buoyant artificial smoke was introduced in the vicinity of either the upper lobe or belly outflow valves, smoke control was far superior with the upper valve. The general conclusion is that potential improvements in smoke evacuation can be realized by making design changes on how the smoke is exhausted rather than by increasing the flow rate of fresh air into the cabin (reference 5).

1 slide

Fuselage Burnthrough. The purpose of this project is to study the characteristics of fuselage burnthrough by a postcrash external fuel fire and to evaluate design improvements, if warranted. This project arose from past accidents in which fuselage burnthrough is believed to have ignited the cabin interior (Malaga, 1982, and Manchester, 1985) and also from the recognition that the mechanisms and time framework for fire penetration and ignition of interior materials are not clearly understood. The latter is due to the limitations of past work that only addressed segments of the burnthrough problem (windows, fuselage skin, or sidewalls).

To characterize the fuselage burnthrough process, a total of six full-scale tests were completed using surplus aircraft (reference 6). Basically, a large fuel fire was set adjacent to or beneath an intact fuselage section that was instrumented with thermocouples, heat flux transducers, and cameras to attempt to determine penetration locations, times, and firepaths. The test results indicated that the aluminum skin provided protection from a fully developed fuel fire for 30-90 seconds. Furthermore, the thermal-acoustical insulation was an effective fire barrier once the aluminum skin melted away. In most cases, it appeared that initial flame penetration into the cabin was by way of air return grills or floor edge areas, following fuel fire penetration into the cheek area below the floor. Smoke obscuration inside the cabin, apparently due to pyrolysis of materials adjacent to the heated fuselage, preceded significant flame penetration into the cabin. It was also found that an aircraft with its gear extended was more vulnerable to burnthrough by an external fuel fire than an aircraft resting on its belly. This is illustrated by the photograph shown in figure 4, taken during the fourth test which had a pool fire centered beneath the aft section and 3-7 knot wind blowing from right to left. Due to aerodynamic effects created by the flow of wind over the fuselage and vertical stabilizer, the fuel fire stabilized on the downstream side of the airplane. The fuel fire was also more intense than experienced during the tests with the fuselage on the ground (collapsed land gear), as evidenced by fire swirling (firewhirls), high velocity updrafts, and shorter burnthrough times.

Another example of the test results are the temperature histories shown in figure 5. In this test (#5), a large pool fire was centered beneath the forward section of the test aircraft. Although an initial increase in cabin air temperature occurred within 1 minute of the time of maximum fire intensity, possibly because of fire penetration into the uninsulated electronics bay and up through the crew access tunnel, the results show that the main fuselage cross section is an effective fire barrier. Note that the aluminum skin did not melt until approximately 1 minute after full fire development. This was followed by about 2 1/2 minutes before the sidewall surface temperature increased significantly, demonstrating the burnthrough resistance of the thermal-acoustical insulation and sidewall. Tests results seem to indicate that the fuselage shell is relatively resistant to fire burnthrough, but that certain areas lacking insulation or being more accessible to the fuel fire will provide the initial pathway for fire penetration into the cabin.

The full-scale test results demonstrated that the position of the fire relative to the aircraft and wind direction, and whether the landing gear is deployed or collapsed, are important factors effecting the time of flame penetration into the cabin. During the Manchester accident (1985), it was concluded that initial fire penetration of the fuselage occurred within 20 seconds, followed by fire entry into the cabin within an estimated 60 seconds (reference 7). To study the possible criticality of the Manchester scenario, FAA plans to reenact this scenario, to a degree, using a C-880 airplane. Of particular interest will be the role of the downstream open aft right door on smoke/fire entry and the locations and accompanying times for fire penetration into the cabin.

1 slide
2 View GRAPHS

Electrical Wiring. The purpose of this project is to examine the arc tracking, flammability, and smoke emission characteristics of Kapton^{TM} and other types of aircraft wire insulation materials. This work stems from the controversy surrounding Kapton wiring insulation, which is primarily related to its poor arc tracking behavior, leading to its prohibition by the United States Navy in new generation aircraft. Kapton has been the material of choice in commercial and military aircraft because of its high temperature rating, ruggedness, low weight, and low volume. In spite of the Navy experience, after almost 20 years of use in commercial airplanes, the number of documented incidents of Kapton arc tracking failures in airliners is very small. This project attempts to assess the fire safety characteristics of aircraft wiring on a broader basis than arc tracking behavior by including flammability and smoke emissions performance.

FAA findings are documented in two technical reports (references 8 and 9). The results confirm that Kapton wiring exhibits wet or dry arc tracking failures that are more severe and occur earlier than with others types of wiring insulation. However, it was also shown that a thin Teflon^{TM} coating would prevent Kapton from arc tracking. One so-called "hybrid" wiring insulation of this nature has been developed to the point of initial evaluation in production airplanes. It was also found that extensive damage to wiring bundles from arc tracking was largely due to the resetting of circuit breakers; i.e., damage from the initial arc was usually confined to the two wires causing the problem. For this reason, FAA has recommended in a proposed advisory circular that the crew should make only one attempt to reset an automatically-disconnected circuit breaker that affects flight operations or safety, and that no attempt should be made if the disconnection does not affect flight operations or safety (reference 10). It was also determined that the flammability and, even more so, smoke emission data for Kapton and Teflon-coated Kapton wiring were better than for other types of electrical wiring tested.

1 slide

Aircraft Material Fire Test Handbook. The FAA requires a variety of fire test methods and performance criteria for aircraft materials in order to assure prescribed levels of fire safety in commercial airplanes. Some test methods were developed recently, while others have origins in research and development completed many years ago. Because of the span of time during which the various test requirements were developed, there is an inevitable wide variation in the accessibility of primary technical documents, in currency of test description details, and in style and clarity of technical content. Therefore, FAA is supporting the development of an Aircraft Material Fire Test Handbook that will describe all required fire test methods in a consistent and detailed format.

The handbook is being prepared by Boeing, with McDonnell Douglas as a subcontractor. The contents will include a description of the 14 FAA-required fire test methods, as well as separate sections pertaining to FAA fire safety regulations, the approval process, aircraft materials, industry test methods, European and other countries' test methods, suppliers of test equipment, and test laboratories. At the time this paper was being written, Boeing was making the final revisions to the handbook, following review of the first draft by FAA. It is expected that the handbook will be published in early 1990. Some consideration is being given to using the test method sections as a proposed advisory circular.

1 slide
4 View graphs

Cabin Water Spray Fire Suppression. At the request of the FAA Aircraft Certification Service, a new high priority project was initiated in FY 1989 to evaluate the effectiveness of an onboard cabin water spray fire suppression system. The FAA evaluation tests are part of a joint program with the United Kingdom (UK) Civil Aviation Authority (CAA), and Transport Canada (TC), to determine the feasibility of a water spray system. The CAA and TC are supporting planned studies by two major airframe manufacturers of the potential disbenefits of a cabin water spray system and the means of overcoming them. Of greatest concern is the consequences of an inadvertent discharge of water spray while an airplane is in-flight. The results of the joint FAA/CAA/TC studies will be factored into a benefit analysis to determine the potential for lives saved. The joint program is expected to take 12 months. Presuming that the benefits outweigh the disbenefits, the next steps will be to optimize the system for installation in an airplane and to develop design requirements and specifications.

The first evaluation tests on the water spray system were conducted in the summer of 1989. The system being evaluated was developed in the UK by Safety Aircraft and Vehicles Equipment Limited (SAVE). It consists of an array of spray nozzles that operate at relatively low flow rates and are mounted at the ceiling throughout the cabin. The tests are being conducted in a standard body fuselage with follow-on tests planned for a wide body fuselage if the initial test results are promising. A photograph of the standard body interior is shown in figure 6. The spray nozzles are mounted at intervals in the upper cabin, at the center of the ceiling, at the top of the sidewalls, and at the ceiling-stowage bin junction. Figure 7 shows the standard and wide body fuselages.

An extensive range of test conditions are being employed, governed by the following independent variables: type of postcrash fire scenario (large fuel fire adjacent to fuselage opening or beneath fuselage with burnthrough of the floor); interior with or without interior materials (fire hazards dominated by burning fuel, burning materials or a combination thereof); manual or thermal activation of water spray; and simulated wind speed. For each fire test condition, a test is conducted with and without water spray discharge in order to determine the additional time available for escape. The escape time is computed from cabin measurements of temperature, oxygen, carbon dioxide, and various toxic gases, such as carbon monoxide and hydrogen cyanide. Earlier, tests of the SAVE system in the UK indicated that the fine water spray pattern could lower cabin temperatures, improve visibility by removing smoke particulates, and wash out water-soluble toxic gases.

The cabin water spray concept is designed to suppress an aircraft fire by discharging a fine water mist at low flow rates. The weight penalty is far smaller than when associated with a water sprinkler system used in buildings. For example, the system weight for a 737 is roughly estimated to be 500 pounds, based on a discharge rate of 18 gallons per minute over a 3 minute period. A separate supply of water is devoted to the water spray system in order to provide immediate and continuous suppression and passenger protection during evacuation. Moreover, the water distribution system could be provided with external couplings accessible to firefighters that would allow high flow rates of water from rescue vehicles to knock down and possibly extinguish the internal fire.

1 veiw graph

Seat Component Fireworthiness. The incorporation of fire blocking layers on polyurethane seat cushions reduces the burning rate of aircraft seats when exposed to fire. This required improvement does not address the flammability of other components, such as trays, structure, and arm rests. However improved cabin materials have been developed and evaluated for compliance with the more recent low heat/smoke release standards contained in FAR Amendments 25-61 and 25-66. This rule is advancing the state-of-the-art for thermoplastics and composites, making it plausible to now extend this technology to aircraft seat components. The FAA is conducting fire tests to see if improvements in seat components are warranted.

1 slide Regulatory Support:

NEW PROJECTS

The following are brief descriptions of projects started in FY 1990:

2 view graphs

Cargo Compartment Fire Safety. In FY 1990, the cargo compartment project will focus on Class B cargo compartments to support the airworthiness directive (AD) recently issued in this area (reference 11). Class B compartments are typically main deck rather than below-floor compartments found in "combi" aircraft. This work will involve full-scale tests in the Technical Center's 130-foot-long wide body test article to evaluate procedures which will be proposed by manufacturers and to examine lighting conditions. These tests will be used with the systems required by the new AD.

1 view graphs

Auxiliary Fuel Tank Protection. Auxiliary fuel tanks installed in the pressurized hull of the aircraft have become more widely used. These installations give an aircraft added flexibility for use on routes of varying ranges. In FY 1990, full-scale fire tests will be performed to determine the vulnerability of these installations to both in-flight and postcrash fires, and the effect of their involvement in fire on survivability in the passenger cabin. This work complements dynamic crash tests on auxiliary fuel tanks under FAA's aircraft crashworthiness/structural airworthiness program. In FY 1991, the testing will be directed at reducing the entry of smoke and flames through passenger floor vents and examining the need for improved fire resistance of floor materials.

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Halon Replacement Guidelines. The primary agents for aircraft portable and fixed fire extinguishers are Halon 1211 and 1301. Both are to be limited in or removed from production based on an international treaty to protect the stratospheric ozone layer. These agents attained their present aviation status through over 30 years of tests and evaluations on safety and effectiveness by the FAA. In FY 1990, a multiyear effort will be initiated to develop Halon replacement guidelines. A study will be initiated to scope the impact of decreased Halon availability on civil aviation. Additionally, existing test facilities will be modified so that the effectiveness of alternate agents can be compared with Halon capabilities. These tests will include hand extinguishers, cargo compartment fixed systems, and engine nacelle installations.

1 Veiw gRAph

Oxygen Systems Safety. In FY 1990, an evaluation of in-service incidents will be conducted to define the potential fire hazards of cabin onboard oxygen systems, both as to their participation in the onset of a fire and to their vulnerability to existing fires. This study will provide a basis for the development of full-scale test scenarios. The overall effort will address fixed gaseous and solid chemical systems, as well as portable equipment.

Low-Pressure Flammability. Low-pressure flammability addresses the question as to whether an in-flight fire can be managed, to any degree, through control of the cabin pressure. Tests are planned in an altitude chamber to develop correlations for the effects of pressure at varying altitudes above sea level on burning rates of various cabin furnishing materials, as well as typical materials found in luggage.

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TABLE 1. Transport Aircraft Fire Safety Rulemaking

RULE	FINAL RULE PUBLISHED	COMPLIANCE DATE	PARTS EFFECTED	AM'D'T NO.
1. Seat Fire Blocking Layers	10/26/84	11/26/87	25, 29, 121	25-59
2. Floor Proximity Lighting	10/26/84	11/26/86	25, 121	25-58
3. Cabin Fire Protection	3/29/85		121	121-185
A. Lavatory Smoke Detectors		10/29/86		
B. Lavatory Auto. Fire Extinguishers		4/29/87		
C. Halon 1211 Hand Extinguishers		4/29/86		
D. Hand Extinguishers		4/29/85		
4. Cargo Compartment Fire Protection	5/16/86	6/16/86	25	25-60
5. Cabin Material Flammability	7/21/86 & 8/25/88		25, 121	25-61 & 25-66
A. 100/100 Heat		8/20/88		
B. 65/65 Heat, 200 Smoke		8/20/90		
6. Crew Protective Breathing	6/3/87	7/6/89	121	121-193
7. Cargo Compartment Fire Protection	2/17/89	3/20/91	121, 135	121-202

TABLE 1. TRANSPORT AIRCRAFT FIRE SAFETY RULEMAKING

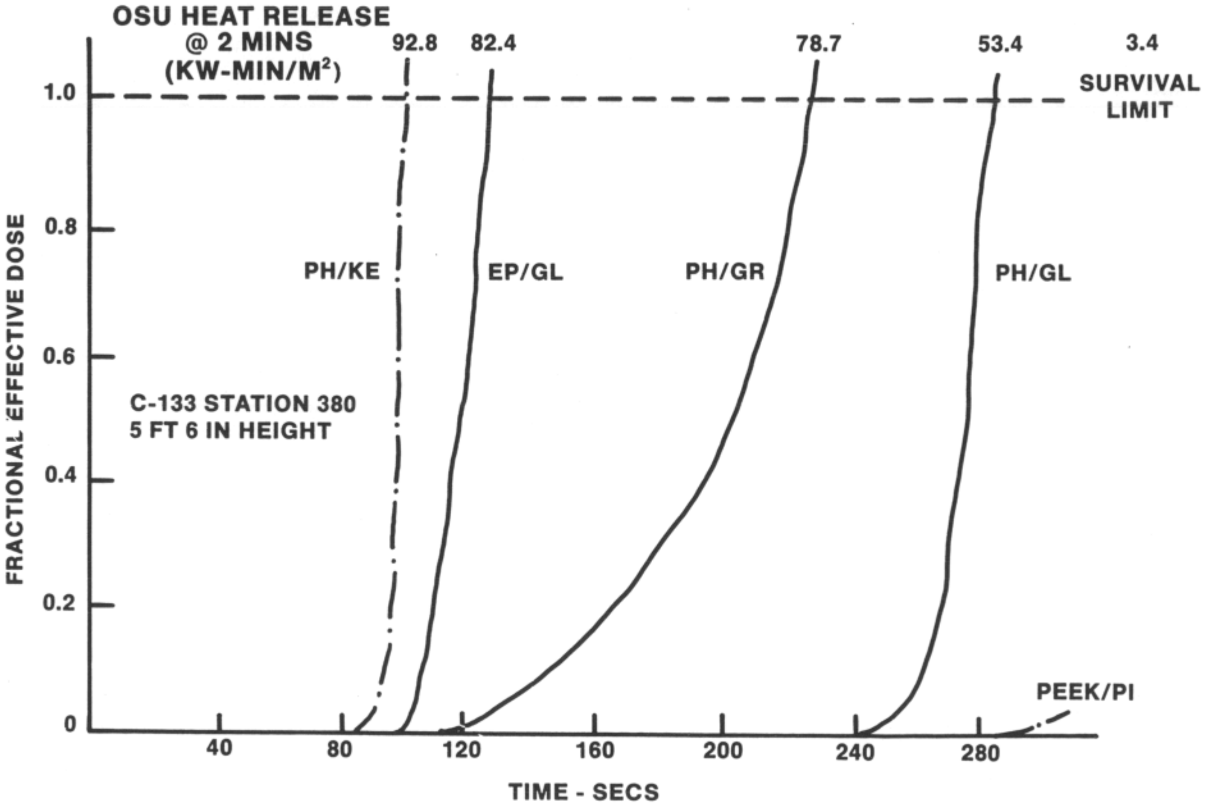

FIGURE 1. INTERIOR PANEL FULL-SCALE TEST RESULTS

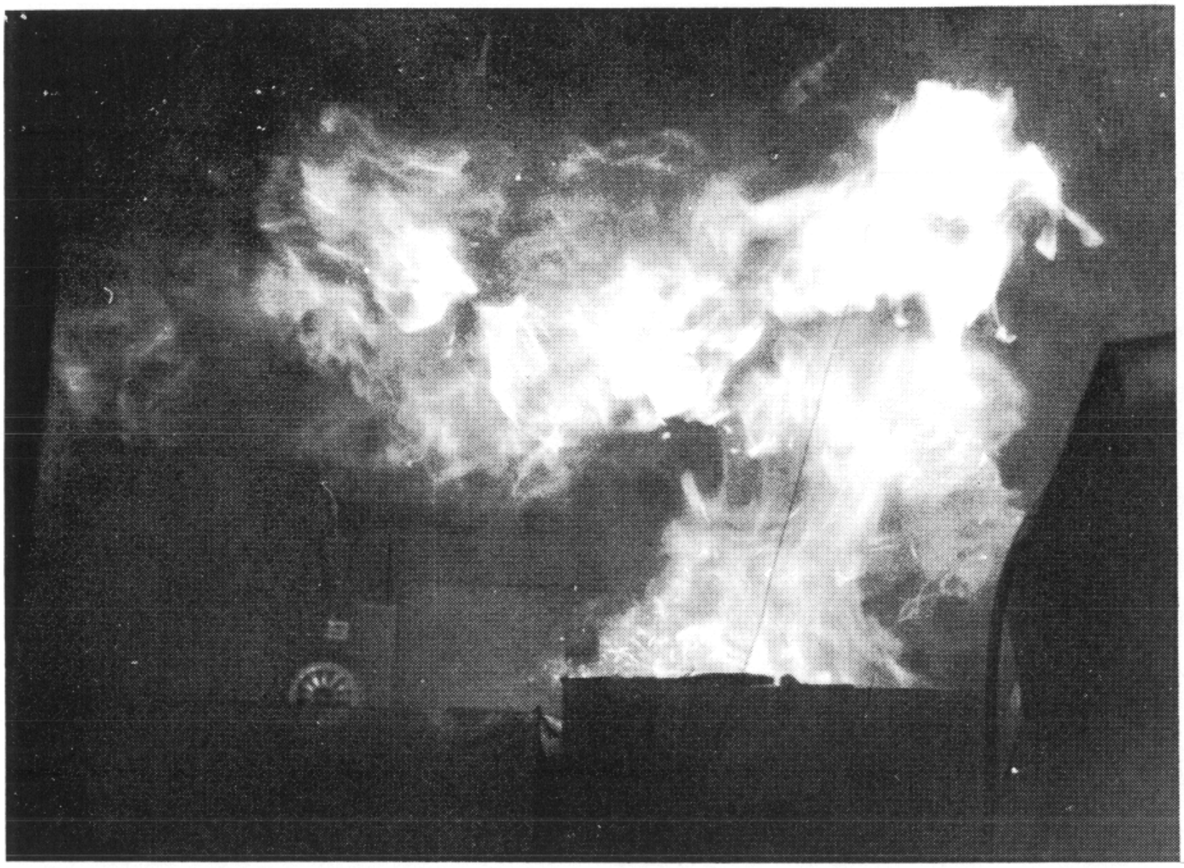

FIGURE 2. AEROSOL CAN TEST

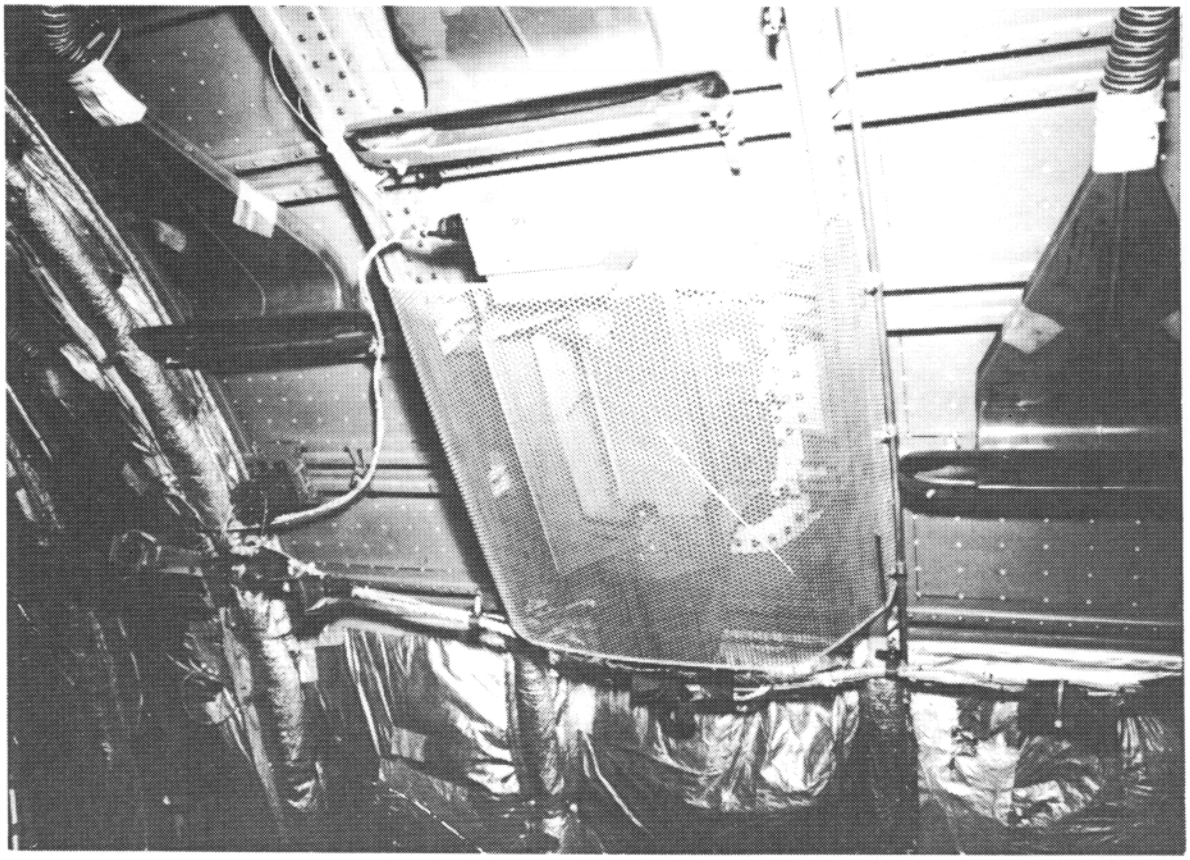

FIGURE 3. OUTFLOW VALVE INSTALLED IN 757 UPPER LOBE

FIGURE 4. BURNTHROUGH TEST NUMBER FOUR

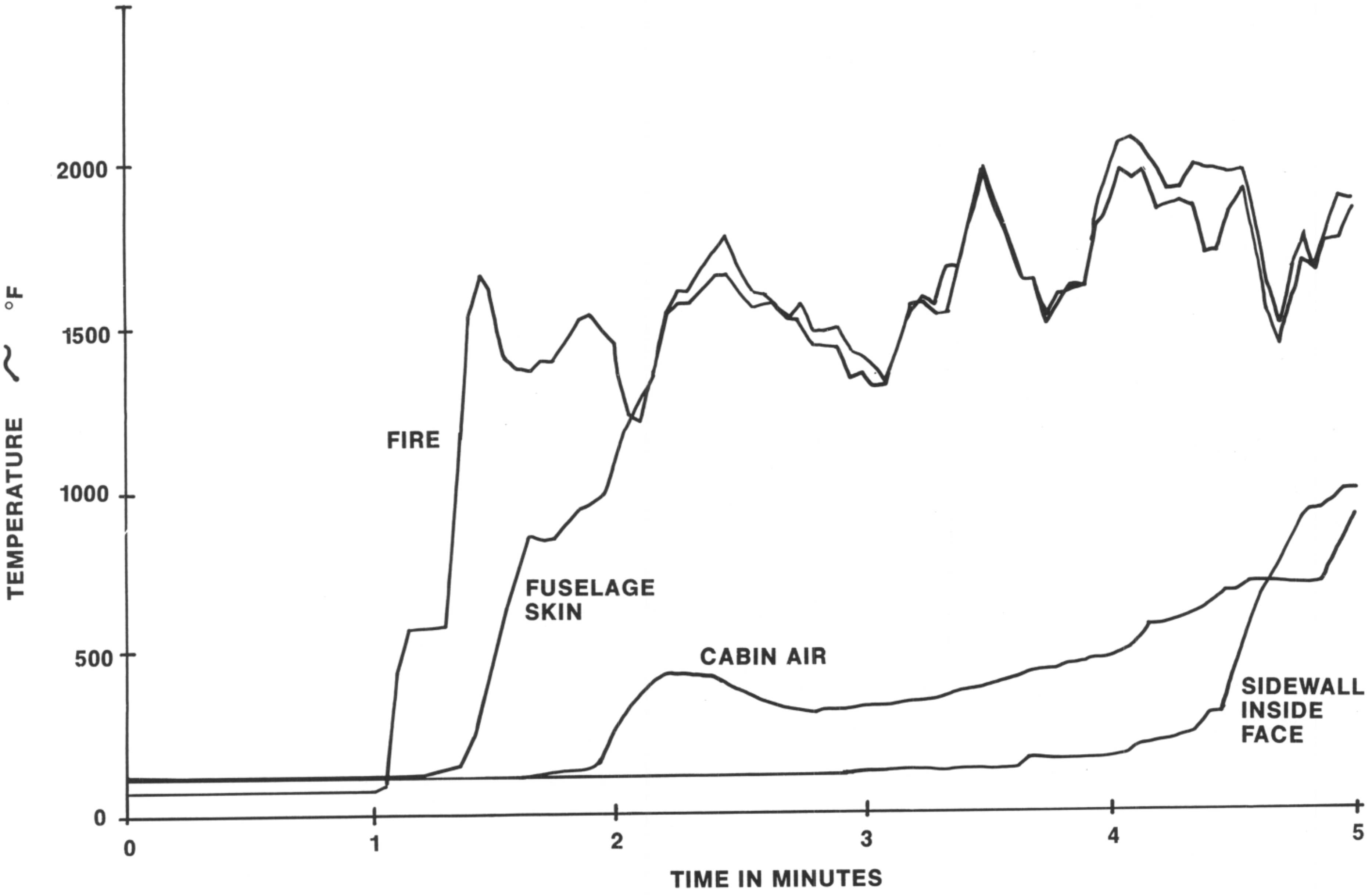

FIGURE 5. BURNTHROUGH TEST TEMPERATURE PROFILES

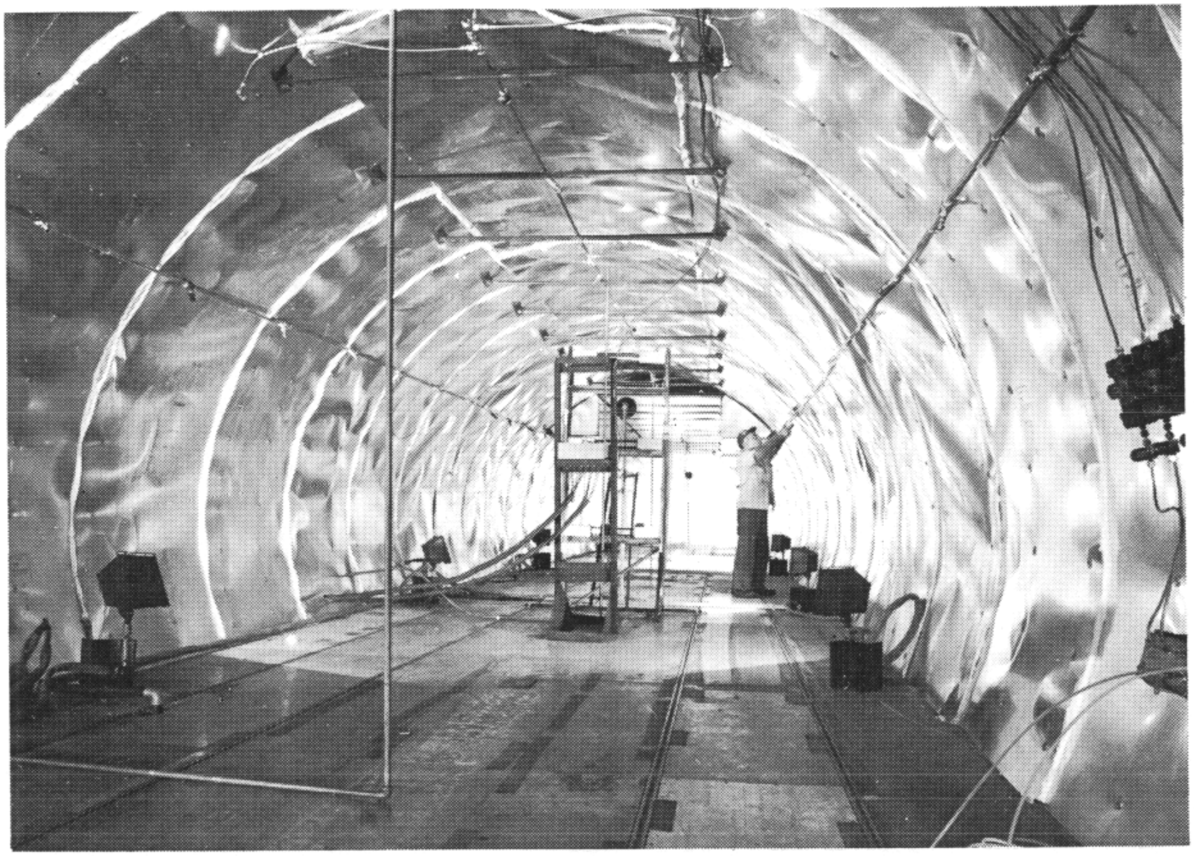

FIGURE 6. NARROW BODY TEST ARTICLE WITH WATER SPRAY SYSTEM

FIGURE 7. NARROW AND WIDE BODY TEST ARTICLE