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INTERRELATIONSHIP OF FAA-DOT-NASA PROGRAMS RELATING TO AIRCRAFT CABIN MATERIALS FIRE

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16. Abstract

Aircraft cabin materials fire hazards consisting of flammability, smoke emission, toxic gas emission and flash fire are discussed together with the work ongoing pertinent to these hazards by the FAA and other DOT Administrations and the NASA. The relationships among these efforts are considered together with funding estimates for FY 1974.

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INTRODUCTION

Post crash fires in transport aircraft are a major cause of fatalities in the air carrier segment of civil aviation. This report surveys the various hazards presented by such fires including the fire itself, smoke emission and toxic gas emission and their effect on cabin emergency evacuation.

The FAA and more recently the NASA both have E&D programs directed towards greater safety in the post crash fire environment. These efforts are presented to illuminate their complementary nature.

Future courses of action are outlined together with their probable impact on reducing cabin fire fatalities.

HAZARDS OF CABIN FIRES

A recent survey of transport accidents over the 1952-1972 period shows that there were at least 182 accidents where post crash fire occurred.[15] In 60 of these, impact alone caused the 1953 fatalities. In the remaining 122, the 1015 fatalities are largely attributable to fire.

In a post crash situation the spilled fuel ignites with the flames entering the cabin by melting the aluminum skin, through breaks in the fuselage structure or through opened doors. These flames then ignite the cabin interior materials. The initial hazards are the fuel flames and the burning material flames. Mobile occupants will of course attempt to move away from these flames toward the exits.

Being fed by the external fuel fire, the burning cabin materials emit both smoke and toxic gases. The smoke presents two hazards; one, of reducing interior visibility making it difficult to see the exits and two, producing lachrymal effects and respiratory smoke poisoning.

Toxic gases are emitted in a wide variety including carbon monoxide, sulfur dioxide, hydrogen sulfide, hydrogen cyanide, hydrogen chloride, hydrogen fluoride and other hydrocarbons. These gases produce varied toxic effects with some causing incapacitation and death when inhaled in minute concentrations.

A later hazard that occurs sometimes is the phenomenon of flash fire. Although little explored to date, flash fires apparently occur when the mixture of gases and smoke filling the cabin are ignited and burn very rapidly thoughout the cabin. Temperatures quickly reach over 1500°F which can be considered non-survivable. Flash fires have occurred in full scale fire tests and are suspected to have occurred in aircraft.

These hazards of material fire, smoke, toxic gases and flash fire vary in severity along the cabin length and vary in the time interval after crash at which they become incapacitating and then lethal. The fatalities they cause relate to how effectively the passengers and crew can exit the aircraft. In the recent Varig B-707 crash in Paris, these hazards occurred in flight with no exit possible. Fortunately this type of inflight fire is rare. That this particular B-707 was a cargo aircraft recently retrofitted with cabin seats and materials emphasized the urgency to upgrade the regulations covering cabin fires.

References in this report grouped under a combined Reference and Bibliography listing beginning on Page 11. Asterisks denote references in report.

MATERIALS FLAMMABILITY

The initial approach to reducing the effects of cabin fire was to limit the flammability of cabin materials. Standards were established in 1947 limiting the horizontal burn rate of materials. Tests run at the National Aviation Facilities Experimental Center (NAFEC) in 1962 showed that many materials in use passed this standard but yet could cause fatal fires. [1] In 1967 these standards were made more stringent for some materials used in cabins and required these to be self extinguishing after the flame is removed. In 1972 these standards were applied to all cabin materials. These recent standards apply to newly certificated aircraft with the 1967 standards applying to older transports whenever they are refurbished by the airlines.

Further regulatory action planned by the Flight Standards Service, FAA, on cabin material flammability standards includes all older transports to meet these standards at some future date. The existing standards are considered adequate to control the rate at which cabin fires spread so that they can be extinguished by prompt action. Although self extinguishing in the small sample tests when the flame is removed, currently used materials can be burned when exposed to crash fuel fire or other fire sources.

The NASA has research underway for the development of more fire resistant cabin interior and cabin insulation materials. [46] In the past, such improved materials seldom met the airlines criteria of wear, maintenance, cost and weight to the extent that these materials would be adopted voluntarily by the manufacturers and the airlines. Such a state-of-the-art improvement would warrent consideration of increasingly stringent agency standards.

The National Highway Transportation Safety Administration has adopted vehicle cabin material flammability standards that are equivalent to the FAA's 1947 standards. These are felt to be adequate for ground vehicles. [51]

The United States Coast Guard has a modest annual program underway to specify non-flammable materials for floor coverings, etc., to prevent fire both from a personnel hazard standpoint and for protection of ship structural integrity. [57]

BURNING MATERIALS SMOKE EMISSION

That smoke inhibits cabin emergency evacuation has long been recognized by industry and the agency. Testing at NAFEC in the early sixties showed these smoke hazards.[2] As the stringent flammability standards became adopted, however, it was found that the flame retardant additives used increased smoke emissions.[52]

Serious agency effort on smoke began with a funded National Bureau of Standards study of the smoke and gas emission from 141 aircraft interior materials. This work also developed the NBS Smoke Chamber for testing small samples of material and which is planned to be used as the means of compliance in agency rulemaking on smoke standards.[4] Further review of smoke emission and known toxicological effects was done by Dr. Einhorn for the agency at the University of Utah.[17, 18]

Small sample smoke tests in an NBS Smoke Chamber only permit the development of standards that eliminate those materials that smoke badly. To inject some degree of relevance to actual cabin fires into the standards, a contract was let to the Lockheed Corporation to correlate the NBS Smoke Chamber data with full scale fire tests in a L-1011 fuselage section. The final report on this work is in preparation and is expected to support the standards being promulgated as an NPRM by the agency.[19]

The NASA is actively investigating new classes of polymers whice are non-flammable and produce little or no smoke or toxic gas when exposed to fire. Currently these are very expensive and difficult to process by conventional methods, but as work progresses, these obstacles to commercial use should diminish.

BURNING MATERIALS TOXIC GAS EMISSION

The aviation community became more aware recently that toxic gas emissions from burning cabin interior materials constituted a hazard in transport crashes. Such awareness arose from the recent inclusion of tests for these toxic substances in autopsies of transport crash victims and their subsequent detection in significant quantities. This occurred during the accidents of Anchorage in 1970, New Haven in 1971 and Chicago O'Hare and Midway in 1972.

The first directed agency effort towards toxic gas analysis was the study by the National Bureau of Standards in 1968 [8] in which both smoke and toxic gas emissions were measured for 141 samples of cabin materials. Massive industry full scale tests also were run in 1968 [53] in which toxic gas concentrations were measured. A primary interest of these industry tests, however, was to evaluate both fire control and suppression techniques and smoke hoods, etc., for passenger protection. Little emphasis was placed on the reduction of toxic gas emissions by means of improved materials. The results of these agency and industry tests were insufficient to provide a basis for toxic gas regulatory standards.

A high priority project is in process at NAFEC to measure the toxic gas emissions from 60 currently used cabin materials. These data will enable issuance of a Notice of Proposed Rulemaking setting standards that eliminate the worst toxic gas producers. Full scale tests then will be conducted to measure toxic gas concentrations and distributions throughout the cabin and to relate these to the toxicological limits being developed by the Office of Aviation Medicine. These full scale tests then will be correlated to NBS Smoke Chamber gas emissions.

Recently both the NASA Johnson Space Center at Houston and Ames Research Center at Mountain View have been conducting material studies and full scale tests with the objective of developing improved cabin materials which possess flammability, smoke and toxic gas emission characteristics that should minimize the fire hazard potential in aircraft and spacecraft cabins. This work has been reasonably successful in terms of flammability but far from complete in terms of smoke, toxicity and practical use considerations. These new classes of polymers promise improvement, but much research remains to be done to bring them to the point of in-service use.

A new industry effort is underway by the Society of the Plastics Industry to study plastic material toxic gas emission. They are funding the National Bureau of Standards and the Southwest Research Institute to conduct tests which will be coordinated with the agency's work at NAFEC.

FLASH FIRE

Not much is known yet about flash fires but they occur apparently when the combined mixture of smoke, gases and oxygen in the burning cabin environment reaches a temperature at which they ignite and burn throughout the entire cabin. Temperatures reach 1500^{o} in less than a second and ignite the entire cabin. All the oxygen in the cabin is consumed. Survival in a flash fire is not considered possible.

Clearly, the flash fire phenomenon is related to material flammability and material smoke and gas emissions. The nature of this relationship is yet to be determined. The agency funded a laboratory study recently by the National Bureau of Standards to study flash fires specifically in relation to burning polyurethane foam cushions, a major smoke and gas emitter.[16] These tests indicated that smoke particles were essential to produce a flashover. Further work is planned at NBS on the physics of flash fires as part of a NAFEC project for FY 1973 and FY 1974 to investigate the relationship of flash fires to the flammability, smoke and toxic gas standards.

No NASA work is currently underway specifically related to aircraft flash fires.

CABIN FIRE CONTROL AND EXTINGUISHMENT

The only new effort underway in this area is at NAFEC. The project on establishing the feasibility and effectiveness of an extinguishing agent distribution system throughout the cabin is scheduled for completion of testing against internal cabin fires by December 1974. Testing for effectivity against external fuel fires and preparation of a final report are due for completion by October 1975.

The project to examine the feasibility of cabin compartmentation as a means of isolating flash fires has been delayed by lack of funding and personnel until FY 1975. Completion of this work and provisions of data for rulemaking is scheduled for September 1975.

TOTAL CABIN ENVIRONMENT PROTECTION

The existing agency standards on material flammability, the proposed standards on smoke emission and the future standards on toxic gas emission all are intended to contribute to a more survivable cabin environment that would permit safe egress. The agency proceeded to develop these standards in this order as a matter of relative priority and because funding did not permit simultaneous projects. A high priority effort has been assigned to NAFEC to develop a plan and carry-out full scale fire testing to determine which of these hazards is most critical to passenger safety and to determine the interaction among the hazards. This is a complex task because flame, smoke and toxic gases are unevenly distributed throughout the cabin, but ideally no one of them should be the dominant hazard.

When this information is known, the small scale NBS Chamber standards can be upgraded to match a full scale environment where all hazards are of equal but minimum severity. Cabin protection can then be increased to permit a longer egress period. This work will make an invaluable contribution to aviation safety.

The agency's effort described above is now being and will continue to be fully coordinated with the NASA efforts and industry efforts so that the respective goals of these groups can be met with maximum efficiency.

To summarize, the DOT goal and especially the FAA goal, is to perform E&D work on the various hazards associated with cabin fire to provide data that will support the issuance of airworthiness standards. Aircraft designed and constructed to these standards should provide a survivable environment during cabin fires. The NASA goal is to conduct basic research on improved cabin materials technology so that industry can develop and apply these materials to aircraft designs. Cooperation between the FAA and NASA personnel results in mutual use of all data generated to assist each agency to attain its goal.

FUNDING ESTIMATES

	FY 1974 $000
Department of Transportation	
Federal Aviation Administration	
Systems Research & Development Service	260
Office of Aviation Medicine	44
United States Coast Guard	30
National Aeronautics & Space Administration	250

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