FSS 000711 R

This report is Issue Number 21 of 300.

CRASHWORTHINESS DEVELOPMENT PROGRAM
JULY 1968

RECOMMENDED RESEARCH AND DEVELOPMENT

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.
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AIA

This report has been prepared by participants in the Aerospace Industries Association of America, Inc., Crashworthiness Development Program.

REPORT NUMBER AIA CDP-R&D

FOREWORD

This report is one of seven prepared by the Aerospace Industries Association of America, Inc. (AIA), to report the Association's Crashworthiness Development Program. These seven reports are as follows:

Technical Summary, Crashworthiness Development Program, Aerospace Industries of America, Inc.	AIA CDP-S
Materials Technical Group Report	AIA CDP-1
Fire Suppression and Smoke and Fume Protection Technical Group Report	AIA CDP-2
Lighting and Exit Awareness Technical Group Report	AIA CDP-3
Evacuation Technical Group Report	AIA CDP-4
Recommended Regulation Changes	AIA CDP-RC
Recommended Research and Development	AIA CDP-R&D

The Crashworthiness Development Program was formulated as part of the Aerospace Industries Association's response to the FAA Notice of Proposed Rule Making (NPRM) 66-26, "Crashworthiness and Passenger Evacuation," in mid-1966. The program began with a letter of encouragement from the FAA, dated February 7, 1967. Program progress has been presented periodically to assigned FAA liaison team members. Figure 1 shows the relationship of the AIA members in management of the program.

The objective of the program has been to find ways to increase passenger survivability following an aircraft accident involving a large air-carrier-type transport airplane through improvements in (1) interior materials, (2) fire suppression and smoke and fume protection systems, (3) emergency lighting and exit awareness, and (4) evacuation systems. Extensive studies and tests have been conducted in these four areas; however, the program did not include studies to develop methods of crash avoidance or to modify fuel to limit fuel spillage or flame propagation in the fuel following an accident. Duration of the program was approximately 1 year.

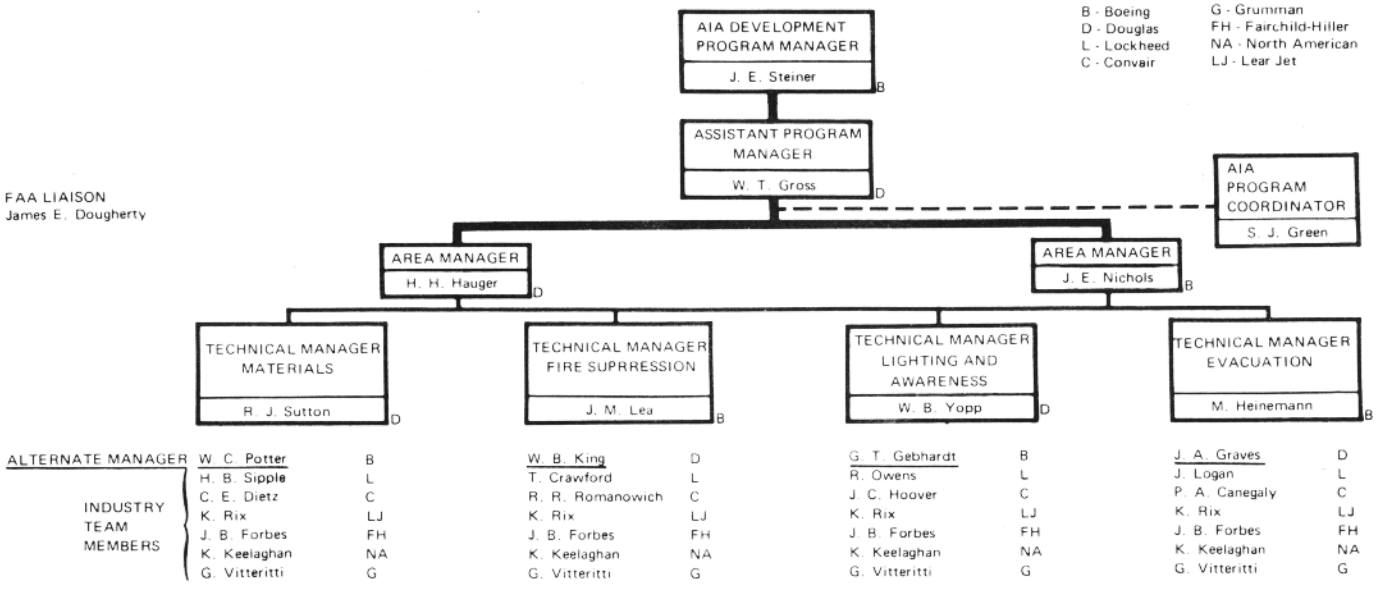

Figure 1. Program Management

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1.0 INTRODUCTION

The Crashworthiness Development Program studied ways of increasing a passenger's chance of survival after an airplane accident. The technical areas studied were (1) interior materials, (2) fire suppression and smoke and fume protection, (3) emergency lighting and exit awareness, and (4) evacuation systems. Those study items found to improve a passenger's chance of survival are recommended as rule changes in report AIA CDP-RC.

The 1-year development program proved to be too short to accomplish the testing necessary to determine whether or not certain study items were beneficial. This report contains recommendations for further work on items that appear to have merit but that require additional testing and data to determine if they will increase a passenger's chance of survival following an accident.

The AIA does not propose to continue its formal Crashworthiness Development Program to accomplish this additional work in research and development. These research and development items should be coordinated and funded by a central Government agency, because the results of the work would be beneficial to several facets of the transportation industry as well as to other industries and to the military services. A central Government agency would also have ready access to any supplementary work presently being funded by the Federal Government.

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2.0 SUMMARY

The Crashworthiness Development Program did not include work in the areas of accident prevention and control of burning fuel. Continued development work in these areas should be ranked as being more beneficial in increasing accident survivability than the additional research and development work recommended in this report.

Prevention of the aircraft accident is of prime importance. The accidents that occur during takeoff and landing that are survivable after initial impact are the accidents associated with the objective of the Crashworthiness Development Program. It is recommended that work be continued in the development of automatic takeoff and landing control systems that will reduce human error and, therefore, reduce the number of accidents.

The problems of survivability after initial impact are related to the burning of fuel in or around the airplane. Postcrash fires involving only interior materials of the type in service today allow ample evacuation time. If a large amount of fuel is burning, improved self-extiguishing materials provide little additional protection compared to in-service materials. Studies of ways and means that will eliminate the hazards of burning fuel, which is the critical condition affecting passenger survivability, should be continued and accelerated.

The recommended research and development items are summarized in Table 1.

Results of these research and development programs should be made available for review by the AIA. Those crashworthiness concepts that the AIA and FAA agree are beneficial and that result in a new FAR will require time for incorporation into production airplanes. Immediate incorporation would not be possible.

Table 1. Summary of Recommended Research and Development

TECHNICAL AREA	RECOMMENDED RESEARCH AND DEVELOPMENT	BASIS FOR RECOMMENDATION	TECHNICAL REPORT REFERENCE
Crash prevention	Develop automatic takeoff and landing systems	Most accidents occur on takeoff and landing; reduce or eliminate human errors that cause accidents.	AIA CDP-4, Par. 3.2.2
Fuel control	Continue and accelerate work on preventing fuel spillage and burning in or around the airplane	Loss of life in an accident that is survivable after initial impact is primarily caused by burning fuel; improved fire-resistant materials do not reduce the hazards of burning fuel.	AIA CDP-4, Par. 3.2.2, AIA CDP-1, Par. 3.2.16
Materials	Materials structure research	Provide knowledge for materials development	AIA CDP-1, Sec. 4.0
	Smoke-density and noxious-gas studies	Smoke reduces visibility; effect of noxious gas on survivability limits is not known.	AIA CDP-1 and CDP-4
	Fire-resistant and low-smoke- and noxious-gas-producing thermoplastics and seat cushions	State-of-the-art fire-resistant thermoplastics and foams produce considerable smoke.	AIA CDP-1, Pars. 2.1, 3.2.15, and 3.3.2
Fire suppression	Smoke hoods	Evaluations and Tests indicate effective devices might be developed	AIA CDP-2, Par. 3.2.6
	Compartmentation (fire curtains)	Curtains are effective in containing fire, heat, and noxious gases in test conditions.	AIA CDP-2, Par. 3.2.7
	Reporting and postmortem criteria for accidents involving fire	Specific accident-report data would be helpful in analyzing fire conditions	AIA CDP-2, Par. 3.1.3
Lighting and exit awareness	Auditory localization of emergency exits in an adverse visual environment	Tests showed auditory cues get people to exits in dark; several problems are still unresolved.	AIA CDP-3, Pars. 3.1.8 and 3.2.3
	Passenger warning and crew communication systems	Analysis revealed need and usefulness of this type of system.	AIA CDP-3, Par. 3.1.9
Evacuation	Mechanical escape devices	Provide system with greater durability.	AIA CDP-4, Par. 4.5.1
	Inflatable slide fabrication and materials	Provide escape devices that are more compact, more durable, and require less inflatable volume	AIA CDP-4, Par. 4.5.1

3.0 RECOMMENDED RESEARCH AND DEVELOPMENT

This section describes research programs recommended by the AIA. These programs are those that have shown promise but for which data obtained in the AIA Crashworthiness Development Program are not yet sufficient as bases for concluding that the concepts studied are feasible. This report presents work statements that identify the recommended research, the reason for the recommendation, current status as a result of AIA studies, a description of the work required to obtain further data upon which firm conclusions might be based, and estimated program duration. Supporting data are provided as required to describe current status based on work of the AIA Crashworthiness Development Program.

3.1 Materials

Recommendations for development work in the materials technical area are given in the following paragraphs.

3.1.1 Materials Structure Research

A research program should be conducted to determine how the molecular structure of organic materials relates to the mechanics of combustion and associated combustion products. The objective of the research would be to obtain information on how to build polymers that are fire resistant and that produce little or no smoke and noxious gases.

Materials structure research is needed in three areas:

- Flammability Studies on the Combustion of Solids—This program could start with the vaporization of materials and ways to increase the temperature of vapor formation or to prevent ignition.
- Smoke Production While in a Flame or Heated in Air—Studies of the rupture of the polymer chain and perhaps the oxidation reaction might be starting points that would result in elimination of the particle size and weight range that limit visibility.
- Low Noxious-Gas Production While in a Flame or Heated in Air—Ways may be sought to prevent decomposition of materials under probable temperature and atmospheric conditions so that the resulting products are harmless.

The program is outlined in Work Statement 1.

Work Statement 1: Materials Structure Research

OBJECTIVE: Research on the molecular structure of materials to simultaneously reduce the flammability and smoke and noxious-gas emission of aircraft materials.

REASON FOR RECOMMENDATION: To provide the knowledge required for development of new materials and test methods.

CURRENT STATUS: Flammability of aircraft materials has been reduced considerably, but all the additives used to accomplish this increase smoke emission. No work was done on heat of vaporization.

PROGRAM DESCRIPTION: Research is needed in three areas: (1) flammability studies on the mechanism of combustion; (2) smoke production while in a flame or heated in air; and (3) low noxious-gas production while in a flame or heated in air.

SHCEDULE: This program would require approximately 2 years.

REFERENCE: Report AIA CDP-1, Pars. 4.1.2, 4.2.2, and 4.4.1.

3.1.2 Smoke Density and Noxious-Gas Studies

A comparison of two smoke test chambers is given in report AIA CDP-1, Par. 3.3. The two chambers differ in one basic design concept. In the open XP2 chamber, it is assumed that the percent of light absorption equals the percent of smoke density. In the closed NBS chamber, the Bouguer Law of Extinction makes the percent optical transmission logarithmically related to optical density. A precise mathematical correlation between the chambers is unlikely. An attempt was made to determine if the two chambers placed materials in the same sequence under similar test conditions. Although the individual materials are usually juxtaposed, they are not in the same sequence and an occasional material is rated entirely differently.

An approach would be to rate material for smoke based on reference materials tested by any of several selected methods.

Noxious-gas analyses would be desirable to accompany the smoke test, since the ultimate objective is to rate individual materials and constructions.

To determine whether noxious-gas tests on individual materials are valid, more study is needed in mockups to define the extent to which combustible gases will burn or interact. This might be determined by studying the order, composition, and intensity in which the flame, the hot air, the smoke, and the noxious-gas fronts occur. A parallel study on individual materials pyrolized under similar conditions, possibly in a selected smoke chamber, would quantitatively identify the various gas emissions of each for comparison with mockup tests.

If this comparison or available material selection shows that noxious gases such as HCN, HCl, etc., are replaced with lethal amounts of carbon monoxide or increased temperature, no improvement can be made.

Concurrently, a study would be proposed to determine the need for obtaining data on the exposure effects of multiple hot gases on humans, particularly on subjects acting under conditions of excitement and panic. It may also be possible to rate an entire aircraft installation by exposing animals to combustion products from individual materials, as is required of the building industry by some cities.

The smoke density and noxious-gas study program is outlined in Work Statement 2.

Work Statement 2: Materials Smoke Density and Noxious-Gas Studies

OBJECTIVE: Establish standard procedures for evaluating materials for smoke and noxious-gas emission and to determine if noxious gases are limiting to survivability in an aircraft fire.

REASON FOR RECOMMENDATION: Smoke emission from burning materials reduces visibility inside the airplane. A need exists for establishing methods for selecting materials that minimize smoke and gas emission. The effect of noxious gases from burning materials on passenger survivability is not known.

CURRENT STATUS: The AIA program has developed data from testing individual materials and constructions in the XP2 and NBS smoke test chambers and the radiant-panel and tunnel tests. It has not been possible to correlate these chambers and often even tests within the same chamber. Gas emission has been measured from individual materials and from mockup tests, but a more basic understanding of smoke and noxious-gas evolution and the propagation of these gas clouds and isotherms with time is needed before test methods can be developed and analyses made.

PROGRAM DESCRIPTION: Determine the order, composition, and intensity in which the flame, hot air, smoke, and noxious-gas fronts occur in a typical aircraft fire. Develop tests for smoke and noxious gas that can be done rapidly and that are simple in equipment requirements and in technical skill required for operation. Determine the effects of combined gases on humans. Other approaches are to establish limits for smoke based on referee materials tested by any of several selected methods. Noxious gases may be limited by exposing animals to a specified weight of representative materials similar to tests used by various cities for the building industry. With such approaches, it should not be necessary to determine heated combined-gas effects on humans.

SCHEDULE: The program would require approximately 1.5 years.

REFERENCE: Report AIA CDP-1, Pars. 2.3, 3.3.1, 3.3.4, 4.3.1, and 4.3.2

3.1.3 Development of Self-Extinguishing Low-Smoke- and Low-Noxious-Gas-Producing Materials

Report AIA CDP-1, Par. 2.1, lists materials that require development to improve their fire resistance and to decrease their smoke and noxious-gas generation. Of these materials, the thermoplastics and seat cushioning are considered most important because of their extensive use in aircraft.

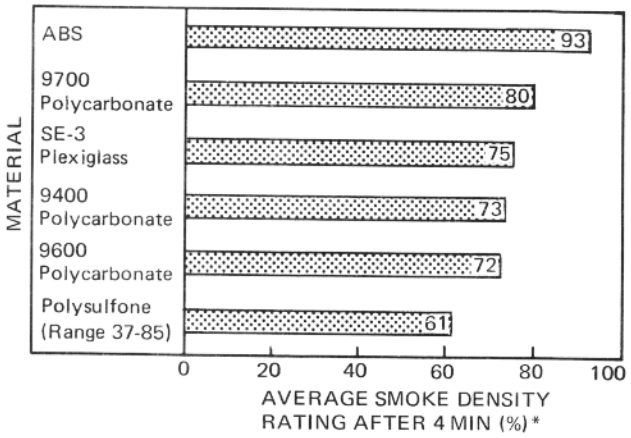
The AIA Crashworthiness Development Program showed that improved self-extinguishing thermoplastic and seat cushioning or padding materials are available but that they produce considerable smoke. (See Fig. 2 for thermoplastic smoke-generation data.)

The use of self-extinguishing seat foam did not reduce the amount of noxious gases emitted in the 15-ft-mockup test discussed in report AIA CDP-1, Par. 3.4.3. The seat cushioning material could also be improved from the standpoint of BTU's given off when burned. Figure 3 shows the difference in temperature in the 15-ft-mockup limited materials test when fiberglass seat cushioning (improved materials C) is used instead of fire-resistant urethane foam (improved materials B). Seat cushioning materials must be functionally satisfactory, which fiberglass is not, in addition to exhibiting improved fire resistance.

The program to develop fire-resistant low-smoke- and low-noxious-gas-producing thermoplastics and cushioning materials is outlined in Work Statement 3.

3.2 Fire Suppression and Smoke and Fume Protection

Development work on fire suppression and smoke and fume protection is recommended in three areas: (1) passenger smoke hoods, (2) the use of fire curtains for compartmentation, and (3) study of additional reporting requirements specifically directed toward accidents involving fire. These programs are outlined in Work Statements 4, 5, and 6. Figures 4, 5, and 6 provide supporting data for the programs described in Work Statements 4 and 5.



NOTE: Material varies in smoke production from vendor to vendor.

* $\frac{\text{Area under Light-Absorption-Time Curve}}{\text{Total Area under Graph}} \times 100$

Figure 2. XP2 Smoke Data for Thermoplastics

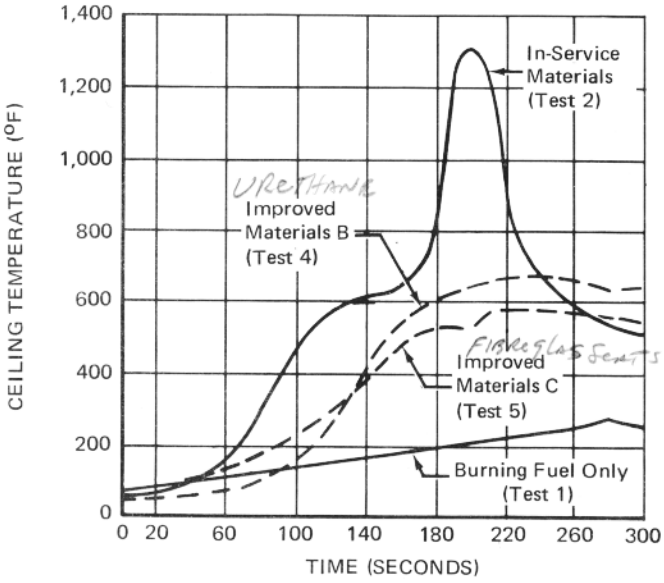


Figure 3. Comparison of Burning Characteristics of Selected Materials

The recommendation for a study to establish additional criteria for fire accident reporting was prompted by the accident study conducted by the AIA Fire Suppression and Smoke and Fume Protection Technical Group. This study would have benefitted from certain facts needed for thorough analysis of accidents involving fire. Items that would aid in future analyses might be entered into records of future accident investigations. Work

Statement 6 describes a study to determine what information might be required in a checklist for future accident investigations and to determine requirements for postmortem medical examinations. Although it may not be possible to obtain all the information noted, even by analysis, much more information might be gained if appropriate guidelines are established.

Work Statement 3: Development of Self-Extinguishing Low-Smoke- and Low-Noxious-Gas-Producing Thermoplastic and Seat Cushioning Materials

OBJECTIVE: Develop aircraft materials that when at a temperature of 800°F will be immediately self-extinguishing after being removed from a 2,200°F flame and that will not give off smoke nor harmful fumes either when heated or in the flame.

REASON FOR RECOMMENDATION: Commercially available self-extinguishing thermoplastics and cushioning materials generate considerable smoke.

CURRENT STATUS: The report AIA CDP-1 presents the status of the current state-of-the-art materials. The greatest needs are for a self-extinguishing low-smoke- and low-noxious-gas-producing (1) thermoplastic sheet that can be economically formed to double contours and that can contain a decorative surface finish and (2) seat cushioning materials.

PROGRAM DESCRIPTION: Work with the material suppliers to develop new materials that retain all needed properties for aircraft usage and that have increased resistance to heat flux so that they will resist decomposition when submitted to the test stated in the objective.

SCHEDULE: This program would require approximately 2 years.

REFERENCE: Report CDP-1, Pars. 2.1, 3.2.15, and 3.3.2.

Work Statement 4: Development of Hoods for Individual Passenger Protection in a Smoke-Filled Environment

OBJECTIVE: Investigate devices to protect individual passengers from smoke beyond the point investigated in the AIA Crashworthiness Development Program so that it may be concluded (1) whether adequate individual protection devices can be developed and (2) whether they will be used properly by passengers under conditions of heat and smoke without significantly delaying evacuation or endangering passengers after evacuation.

REASON FOR RECOMMENDATION: Evaluation and test of prototype smoke hoods in the AIA Crashworthiness Development Program indicated that devices to protect individuals from smoke in a hot environment might yet be developed.

CURRENT STATUS: Several prototype smoke hoods were evaluated and tested. Figures 4(a), (b), and (c) illustrate three of these prototypes. All three models were tested in simulated airplane evacuation tests using human subjects in dark and in light smoke conditions. Such tests indicated that fewer than 60 percent of the subjects used hoods in dark conditions simulating smoke, that subjects used hoods improperly, and that approximately 30-percent slower evacuation rates resulted. The hood in Fig. 4(c) was tested in a hot, burning jet-fuel fire environment. The test subject lost consciousness—apparently from lack of oxygen—after an exposure of about 130 to 140 sec.

PROGRAM DESCRIPTION: A program to develop smoke hoods would involve facilities for individual testing of adequacy of protection in a high-temperature and nontoxic but irritational smoke environment and a group evacuation test facility with a dense irritational smoke environment. Design deficiencies requiring correction exist in the following areas: (1) donning time (must not delay movement toward exits); (2) sealing and fit (all smoke must be excluded from entering device); (3) visibility degradation (actual and psychological; during tests, devices were removed in low light levels "to see better"); (4) duration of respiratory support; (5) accessibility and simplicity in use; (6) fail-safe nature; and (7) group use of the devices in a realistic smoke environment.

SCHEDULE: A program duration of about 12 months would be required to establish whether adequate smoke hoods could be developed.

REFERENCE: (1) Report AIA CDP-2, Par. 3.2.6, and (2) Report AIA CDP-3, Par. 3.2.3.

Work Statement 5: Compartmentation (Fire Curtains)

OBJECTIVE: Determine more thoroughly the effects of fire curtains on the development of a fire in the involved compartment and evaluate the effect of these curtains on evacuation time from the involved compartment. Develop fire curtains that will meet airplane service requirements.

REASON FOR RECOMMENDATION: Tests have shown the ability of transparent, lightweight curtains to contain fire, heat, and noxious gases within the compartment involved.

CURRENT STATUS: Several fire tests have been conducted using lightweight curtains of fire-resistant materials with transparent polyimide film panels. Containment was effective; see Figs. 4 and 5. The effect of the curtains on the survivability in the compartment involved has not been evaluated. The ability of curtains to prevent chimney effects was not determined. It also has not been determined what effect transparent curtains have on evacuation time or time to escape to a safe compartment. A configuration that is compatible with airplane service requirements has not been developed.

PROGRAM DESCRIPTION: The proposed program would be conducted in a large-fire mockup to obtain more information on survivability in compartments and effect of curtains on flow of fire gases into a punctured compartment. A furnished airplane interior mockup could be used to determine evacuation restraints and time differentials encountered when escaping to another compartment through fire curtains. If these tests are successful, information developed from them could be used for designing curtains that would meet service requirements.

SCHEDULE: About 12 months would be required to carry out this program.

REFERENCE: Report AIA CDP-2, Par. 3.2.7

Work Statement 6: Reporting Criteria and Postmortem Requirements for Aircraft Accidents Involving Fire

OBJECTIVE: Establish a specific reporting checklist and procedure for aircraft accidents involving fire.

REASON FOR RECOMMENDATIONS: AIA fire accident studies could have benefitted from specific facts in reports of accidents involving fire. Further study should be done to determine what additional information should be obtained and could be required in each accident investigation.

CURRENT STATUS: AIA Crashworthiness Development Program studies revealed specific areas where accident report information could be useful in establishing ground rules for future studies to combat accident fires or determine their causes.

PROGRAM DESCRIPTION: Conduct studies to determine checklists and requirements for postmortems and investigations of aircraft accidents involving fire. *Subjects to be studied would include:* (1) Methods of establishing the sequence of the fire, from its ignition to extinguishment considering (a) time history, approximated by analyses, (b) temperature and smoke profiles in the cabin, (c) involved portions of the airplane and materials consumed, (d) entry point to cabin, (e) original fuel source, and (f) original ignition source. (2) Methods of establishing the precise cause of fatalities wherever possible wherein (a) requirements for a complete autopsy should be considered that should include blood and tissue analyses for any combustion products that could cause death, (b) the respiratory system and eyes should be examined for effects of combustion products and hot gases on the passengers' ability to evacuate, and (c) attempt to determine if death was actually due to fire rather than other causes. (3) Consideration of examination of hospitalized injured as follows: (a) as soon as possible, blood samples should be analyzed for combustion products which enter the bloodstream, and (b) the injured should be examined to correlate the circumstances of the fire and to determine its effects upon the body (This information would be useful in defining important factors that would aid in designing for a survivable environment.) (4) The possibility of making this same information available on accidents occurring outside the United States by international agreement.

SCHEDULE: Approximately 12 months would be required for an adequate study.

REFERENCE: Report AIA CDP-2.

(a) Schjeldahl

(b) John Hand

(c) Boeing

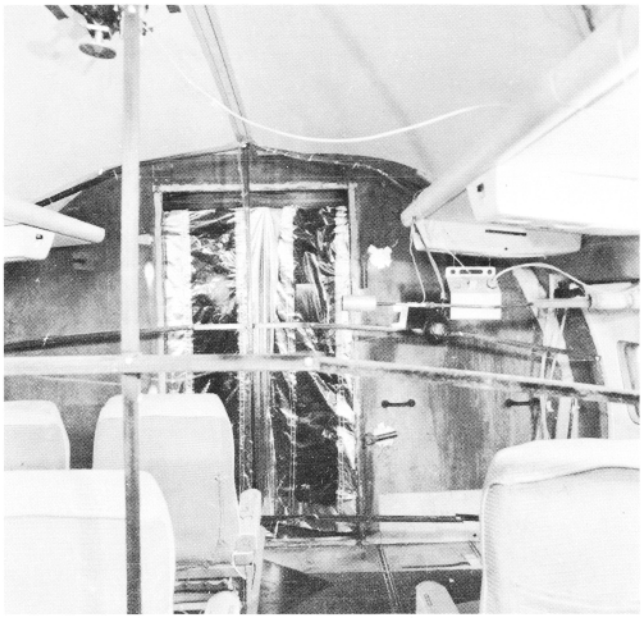
Figure 4. Three of Several Individual Smoke-Protection Hood Prototypes Evaluated

3.3 Emergency Lighting and Exit Awareness

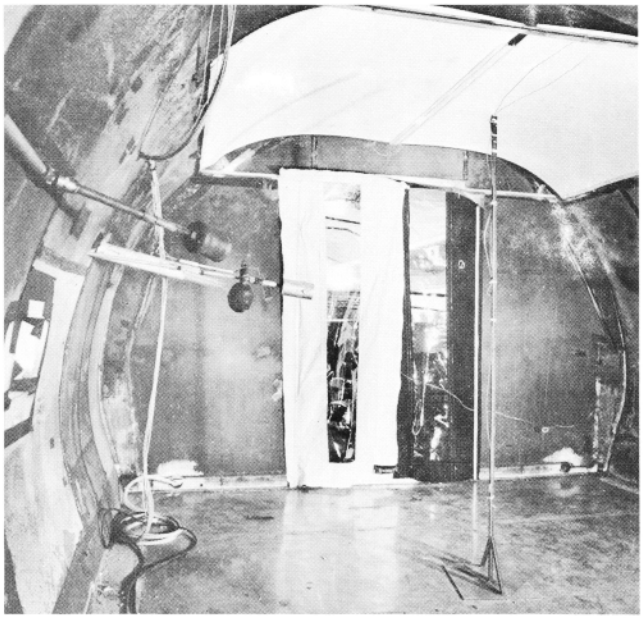
Development work in the emergency-lighting technical area is recommended in the two areas of passenger warning systems and auditory localization of emergency exits. The programs are outlined in Work Statements 7 and 8.

3.4 Evacuation

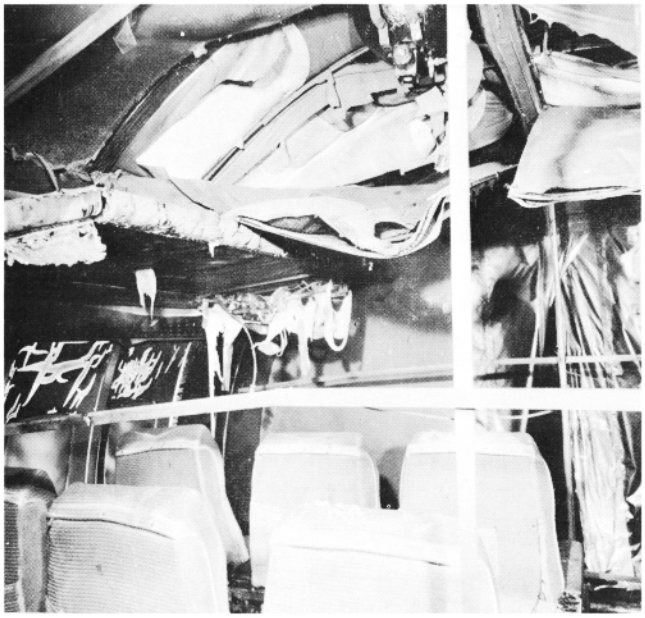
The development work in the evacuation technical area primarily involves system designs particular to a specific model airplane and will, therefore, be conducted by the individual airplane manufacturers. Two research and development items that should be conducted by a central Government agency are shown in proposed Work Statements 9 and 10.



Before Fire

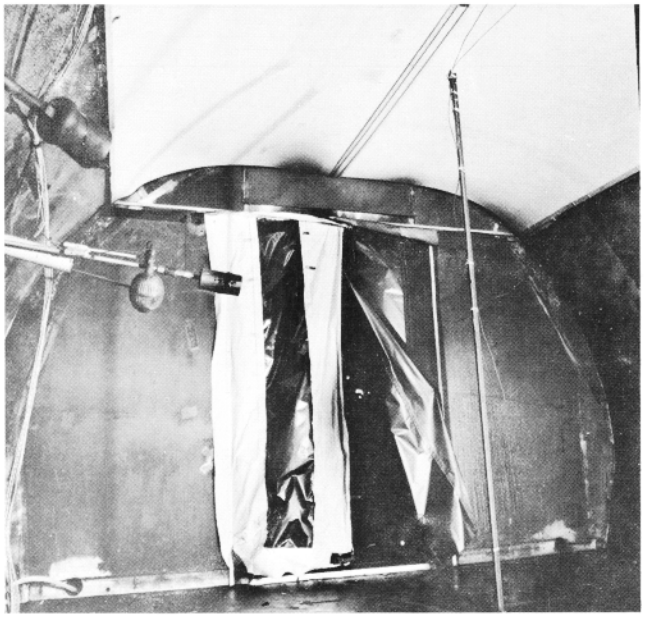


Before Fire



After Fire

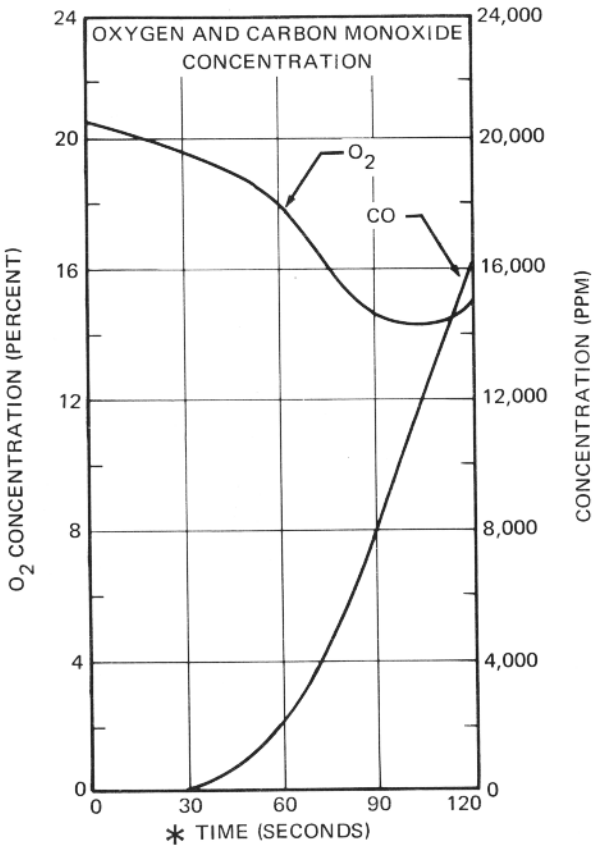
(a) Aft (Burned) Compartment (Furnished)

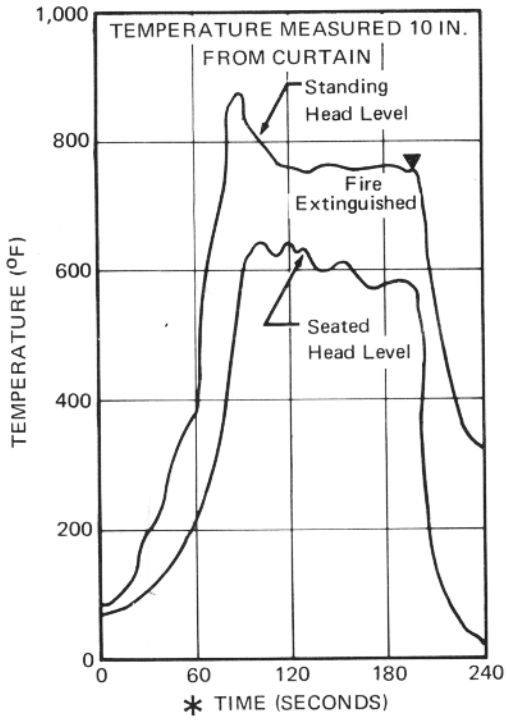


After Fire

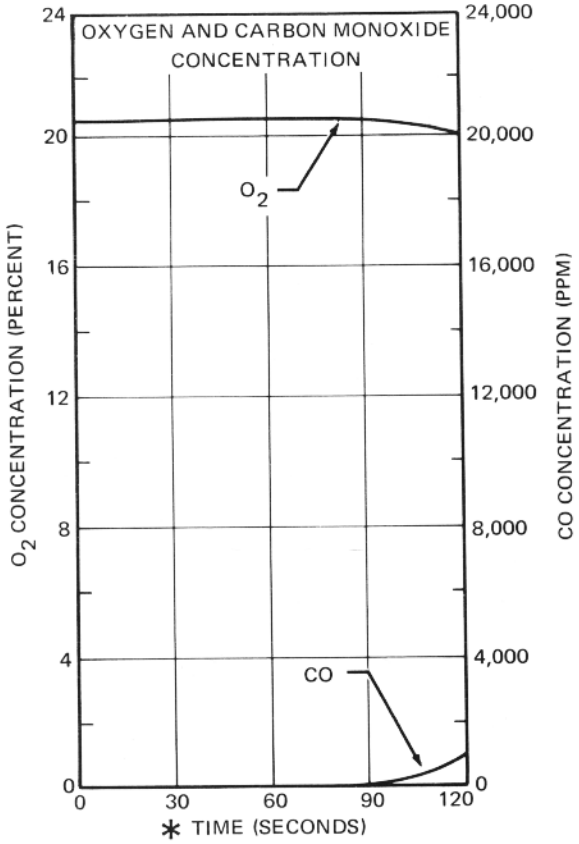
(b) Forward Compartment (Unfurnished)

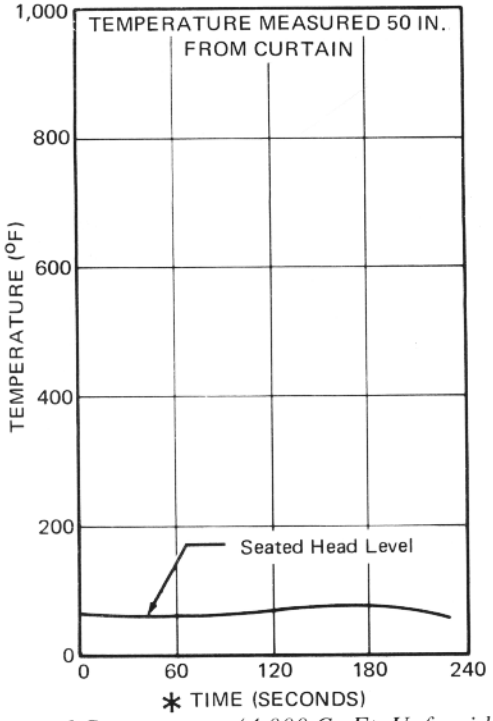
Figure 5. Full-Scale-Mockup Fire Test Using Fire Curtains





(a) *Aft (Burned) Compartment (2,000 Cu Ft)*





(b) *Forward Compartment (4,000 Cu Ft, Unfurnished)*

* Time After Fire Entered Fuselage Through Simulated Rupture

Figure 6. Effectiveness of Fire Curtains in Full-Scale-Mockup Fire Test

Work Statement 7: Auditory Localization of Emergency Exits in an Adverse Visual Environment

OBJECTIVE: Investigate auditory exit location variables that were not tested as part of the AIA Crashworthiness Development Program to the point necessary to conclude whether an auditory cue system should be required.

REASON FOR RECOMMENDATION: The AIA Lighting and Exit Awareness Program established that auditory cues were effective in getting people to exits in the dark.

CURRENT STATUS: Individual and group tests in the AIA Crashworthiness Development Program indicated that audible cues were effective in getting passengers to exits in the dark and that a human voice cue was more effective than signal horns. Problems yet unresolved are (1) how to mechanize such a system, (2) how to reduce the reinforcing qualities of an audible cue that tend to delay an evacuating passenger at a nonfunctional exit, and (3) how to avoid stereophonic effects that cause confusion near doors that are close together or at opposite sides of the cabin.

PROGRAM DESCRIPTION: Human factors laboratory and airplane interior mockup facilities would be required. Variables to be tested using human subjects would include activation of audible cues at all exits versus cues only at functioning exits; "off-phasing" auditory cues at various exits; pitch and sound intensity variation at various exits; time of activation of the auditory signals (before or after the door is open); the type of system hardware, including electrical and mechanical considerations.

SCHEDULE: Approximately 8 to 12 months would be required to conduct such investigations.

REFERENCE: Report AIA CDP-3, Pars. 3.1.8 and 3.2.3.

Work Statement 8: Passenger Warning System and Emergency Crew Communication System

OBJECTIVE: Investigate a flight station-to-passenger cabin emergency communication system and auditory aids for alerting passengers to evacuate an aircraft beyond the point studied in the AIA Crashworthiness Development Program so that it may be concluded whether or not such systems and aids would be feasible.

REASON FOR RECOMMENDATION: Evaluation of accident reports and evacuation studies indicates that the postimpact physiological and psychological conditions of passengers are such that it appears desirable to conduct further study of a warning system to supplement crew instructions or to activate and direct passengers in the event of crew incapacitation. These same accident reports also show incidents where an intercrew communication system could have been used.

CURRENT STATUS: A literature search and analysis were accomplished as part of the AIA Crashworthiness Development Program. These studies identified possible design criteria and indicated that a warning system should combine the detection and attention-holding attributes of nonverbal sounds (fire bell) with the identification and retainability attributes of the spoken word. Yet unresolved are the individual and combined effects that such variables as verbal messages, auditory localization concepts, and alarms have on an actual aircraft emergency evacuation. At least one airline is installing an emergency crew communications system on its aircraft at the present time.

PROGRAM DESCRIPTION: Both laboratory and mockup facilities would be needed. The laboratory tests should include type of signal, sound pressure level, wording, and locations of the signal—all to be tested in an integrated manner using an airplane interior mockup. The communication system would involve laboratory investigations of types of signals, visual and auditory displays, and locations and verbal communication methods. These combined concepts would constitute the mockup investigations.

SCHEDULE: A study of 8- to 12-months duration would be required.

REFERENCE: Report AIA CDP-3, Pars. 3.1.9.

Work Statement 9: Development of Mechanical Escape Devices

OBJECTIVE: Development of mechanical escape devices such as the folding-metal-stair concept, ramps, or slides.

REASON FOR RECOMMENDATION: A system that has greater durability as well as resistance to puncture and fire damage needs to be fully investigated to achieve maximum potential of this type of device.

CURRENT STATUS: Knowledge at present is limited to a few prototype models of these devices.

PROGRAM DESCRIPTION: Manufacturers to develop new concepts and techniques.

SCHEDULE: This program would require approximately 1 year.

REFERENCE: Report AIA CDP-4, Par. 4.5.1.

Work Statement 10: Investigation of Fabrication Technology for Application to Inflatable Escape Slides and New Materials for Use in Construction

OBJECTIVE: Development of escape slides that have greater resistance to puncture, abrasion, and ground fires, and that are more compact and require less inflatable volume.

REASON FOR RECOMMENDATION: New internally supported techniques could yield an improved device requiring less inflation capacity. Improved materials for evacuation slides are desirable to prevent failure from ground fires and resistance to abrasion, puncture, etc.

CURRENT STATUS: Knowledge at present is limited to present materials and techniques.

PROGRAM DESCRIPTION: Material and slide manufacturers and suppliers to develop new materials and techniques.

SCHEDULE: This program would require approximately 1 year.

REFERENCE: Report AIA CDP-4, Par. 4.5.1.