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Rescue and Firefighting Research Program

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Final Report

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16. Abstract

The Federal Aviation Administration (FAA) is dedicated to improving rescue and firefighting services at commercial airports. The FAA's goal is to increase passenger survivability when involved in a postcrash fire. The FAA, through its Research and Development (R&D) program, seeks cost-effective alternative methods to improve the efficiencies of Rescue and Firefighting (RFF) services provided by airports. One of the primary areas of focus for this research program will be firefighting requirements related to new large aircraft (NLA) such as the B-747X and the A380. Another key focus area will be the development of environmentally cleaner firefighting agents.

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) is dedicated to improving rescue and firefighting services at commercial airports. The FAA's goal is to increase passenger survivability when involved in a postcrash fire. The FAA, through the Airport Improvement Program (AIP), provides financial assistance to airports to purchase heavy rescue firefighting equipment at FAA certified airports in the United States. The FAA, through its Research and Development (R&D) program, seek cost-effective alternative methods to improve the efficiencies of RFF services provided by airports.

The FAA's regulatory obligation includes operation of the massive airport system which includes equipment, training facility, and fire station cost offsets for providing RFF services. The FAA has primary responsibility to develop standards, criteria, and guidelines on how RFF services shall be performed.

Improved firefighting training, techniques, and equipment are needed to support our airport safety and certification programs. Firefighting equipment requirements for new large aircraft (NLA) (specifically the B-747X and A380 models) must be developed and incorporated into supporting Advisory Circulars.

The analysis of recent aircraft accidents involving external fuel fires has shown that, although external fires are effectively extinguished, secondary fires within the aircraft fuselage are difficult to control with existing equipment and procedures. Firefighters, in general, lack specialized equipment to gain rapid entrance and receive little training to perform this task beyond the annual live fire training requirement.

INTRODUCTION

The Federal Aviation Administration (FAA) is dedicated to improving rescue and firefighting services at commercial airports. The FAA's goal is to increase passenger survivability when involved in a postcrash fire. The FAA, through the Airport Improvement Program (AIP), provides financial assistance to airports to purchase heavy rescue firefighting equipment at FAA certified airports in the United States (U.S.). The FAA, through its Research and Development (R&D) program, seek cost-effective alternative methods to improve the efficiencies of RFF services provided by airports.

The FAA's regulatory obligation includes operation of the massive airport system which includes equipment, training facility, and fire station cost offsets for providing RFF services. The FAA has primary responsibility to develop standards, criteria, and guidelines on how RFF services shall be performed. Industry representatives such as (American Pacific) Halotron; Crash Rescue Equipment Services (elevated boom), through Cooperative Research and Development Agreement (CRDA's); and the United States Air Force (USAF) (Tyndall AFB), through Interagency Agreements (IA), have all shared in financial partnerships to develop cost-effective alternative RFF.

Improved firefighting training, techniques, and equipment are needed to support our airport safety and certification programs. Research in equipment such as elevated booms, cabin skin penetrating nozzles, and systems used for locating accident scenes in low visibility, as well as evaluations of various chemical agents is required to keep abreast of developments. These advances will be incorporated into the various federal grant and regulatory programs that the FAA administers.

Firefighting equipment requirements for new large aircraft (NLA) (specifically the B-747X and A380 models) must be developed and incorporated into supporting Advisory Circulars. In addition to overall dimensions, any special requirements introduced because of double-deck seating, location of fuel tanks in tail and lower fuselage areas, and special materials used in construction must be considered.

The analysis of recent aircraft accidents involving external fuel fires has shown that although external fires are effectively extinguished, secondary fires within the aircraft fuselage are difficult to control with existing equipment and procedures. Large amounts of smoke-laden toxic gases and high temperature levels in the passenger cabin can cause delays in evacuation and pose a severe safety hazard to fleeing passengers. Firefighters put themselves at great personal risk when attempting to extinguish any interior fire using hand-held attack lines. Firefighters, in general, lack specialized equipment to gain rapid entrance and receive little training to perform this task beyond the annual live fire training requirement.

THE FAA'S AIRPORT RESCUE AND FIREFIGHTING PROGRAM.

The central themes in this research and development effort are improvements in techniques and equipment within the context of a search for improved cost-effectiveness. Sensitivity to costs is very important, especially at small airports where manpower is low and fire protection can be a very large part of the airport's operating costs. The policy is to maintain or improve current levels of service and improve firefighting effectiveness while stabilizing or reducing costs of that service and its associated equipment.

One of the principal components of the program's efforts are early recognition of a fire potential. This requires prompt notification of the RFF services. To be successful, a rapid fire service response to the accident site is needed, including the efficient, effective use of RFF personnel, equipment, and fire-extinguishing agents.

These research efforts concentrate on the development of technologies which will enhance occupant postcrash fire survivability. They evaluate advances in state-of-the-art technologies involving fire-extinguishing agents, dispensing rescue apparatus, operating techniques, and strategies of the fire services.

INTERIOR FIREFIGHTING TECHNIQUES. The focus of this program is to advance state-of-the-art technology in firefighting strategies and to provide an increase in passenger survivability under the extreme harsh conditions of a postcrash interior fire. In addition, it will provide a less harsh environment for firefighters to enter when the need arises.

1. Research helps to gain important information and understanding of the complex aircraft cabin interior fire suppression requirements.

2. This research can contribute a means to extend further survivability time and provide a risk-free environment for firefighters entering a distressed aircraft to rescue trapped passengers.

The FAA William J. Hughes Technical Center's Airport Technology Research and Development Branch recently conducted very successful research programs in several technology areas. These efforts included (1) the evaluation of elevated waterway and cabin skin penetration technology, (2) the testing of Halon 1211 alternative fire-extinguishing agents for airport firefighting, and (3) Driver's Enhanced Vision System (DEVS) was developed to assist rescue response under adverse weather conditions of fog, rain, sleet, and snow.

A full-scale research program was conducted to determine the effectiveness of elevated waterway devices along with its aircraft cabin skin penetration system. To date, many different models of existing commercial aircraft designs have been easily penetrated with the boom-mounted cabin skin penetration system. In addition, a demonstration program was conducted that validated the effectiveness of the fine mist spray when injected into the burning interior of a Boeing 707 aircraft. An intense fire that was taken to severe flashover conditions was brought back under control in 2 minutes with approximately 500 gallons of injected water.

Fire suppression techniques are currently being validated for the most effective application of a valuable fire-extinguishing agent used for combating large postcrash fuel pool fires. The most effective application appears to be a fire attacking technique, which deploys the boom in an initial low angle attack mode, first sweeping across the selected fuel pool fire area, then raising the elevated device to a high angle position for far-reaching fire areas. This can usually be accomplished without moving the rescue vehicle very far from its initial attack setup point.

NEW LARGE AIRCRAFT RESEARCH. There is a need to extend current elevated boom research evaluations to the NLA. These aircraft are larger in size, have more escape slides, and a larger number of passengers to provide protection for. There is a need to develop a new generation of rescue vehicles. The Interior Intervention Vehicle (IIV) would provide rapid access for firefighters needing to gain access to the aircraft. This concept vehicle could also provide passenger evacuation assistance should escape slides fail due to postcrash heat exposure. NLA research should have five primary objectives:

1. To establish the analytical and experimental basis for improving the accuracy and validity of the FAA methodology that is used to determine airport minimum extinguishing agent quantities, agent discharge rates, and Aircraft Rescue and Firefighting (ARFF) vehicle and equipment configurations for NLA firefighting and rescue operations.

2. To establish the analytical and experimental validity of airport minimum extinguishing agent quantities and agent discharge rates when involved in double-decked interior firefighting.

3. To determine critical NLA crash site conditions and aircraft configurations that might impact the success of future ARFF operations.

4. To identify NLA-specific test parameters that can be incorporated into a live fire test program to experimentally validate fire-extinguishing agents and delivery system performance under realistic NLA conditions.

5. Develop/investigate the use of advanced rescue tools capable of providing access to the aircraft cabin or access for passengers.

Figure 1 shows an artist concept of IIV. Firefighters can use a large ramp to gain rapid access to the second level to conduct interior fire attack or medical rescues while carrying heavy equipment. Passengers could use the ramp mechanism should existing escape slides fail due to heat exposure.

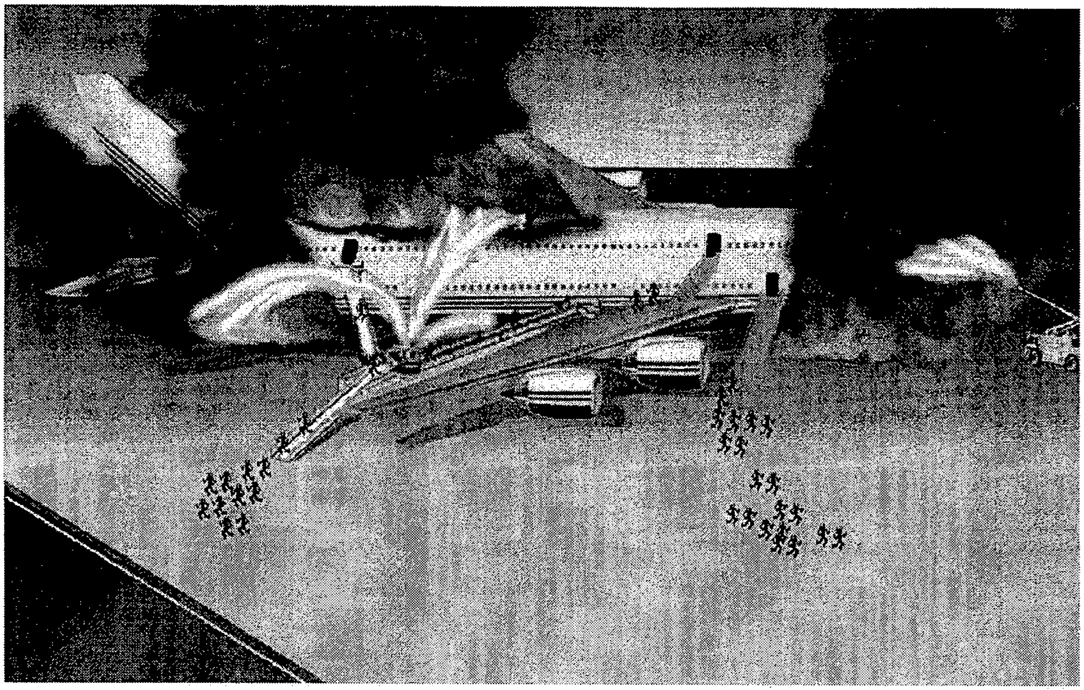

FIGURE 1. INTERIOR INTERVENTION VEHICLE CONCEPT

LARGE-SCALE FIREFIGHTING REQUIREMENTS. Research needs to validate the Theoretical and Practical Critical Area (TCA/PCA) methodology. It needs to calculate minimum extinguishing agent quantities and flow rates required to establish and maintain fire control inside a "critical fire area" within an acceptable period of time. Research and development conducted by the Air Force and the FAA in the 1960s and 1970s was the technical basis for this methodology.

The TCA/PCA methodology calculations were proposed by the International Civil Aviation Organization's (ICAO) Rescue and Firefighting Panels I and II (RFFP-I/II) in 1970 to 1972. Subsequently, this technical approach was adopted and enhanced by the FAA.

Since 1972, few changes have been made to refine the TCA/PCA equation to account for increasing large frame aircraft (LFA), fuel loads, new fire-extinguishing agents, increased passenger capacities, and fire-extinguishing agent requirements for interior firefighting.

The TCA/PCA formula is based on the limited fire-extinguishing agent performance experimental data and the airport firefighting operational experience that were available in 1972 to the RFFP-II and did not include current wide-body LFA fleet crash response statistics. Additionally, the methodology was developed without regard to actual incident site fire surface conditions and did not account for the three-dimensionality of aircraft crash-fire dynamics. Finally, the TCA/PCA calculations did not account for fuel being carried in lower fuselage areas nor in the vertical stabilizers of current aircraft designs.

The TCA/PCA equation and the TCA/PCA methodology, as a whole, have never been experimentally validated. More importantly, no comprehensive live fire tests using realistic crash site conditions, a full range of currently available agents and delivery equipment, or the crash worthiness of current LFA have been conducted to determine if a 1960's technical approach still applies to year 2000 LFA crash conditions and fire service capabilities.

These deficiencies underscore the inconsistencies of the TCA/PCA methodology to accurately predict recent LFA crash on-scene fire-extinguishing agent requirements. Therefore, there needs to be a full-scale evaluation of relevant factors to validate TCA/PCA for LFA as well as NLA. This work will be a continuation of LFA research accomplished under an interagency research program with the USAF at Tyndall AFB, Florida.

Figure 2 depicts the escalating fuselage surface area expected to be cooled by the TCA/PCA fire-extinguishing agent quantity. Since 1972, there has been no increases in the amount of fire-extinguishing agents allocated for the larger surface area. There has been no increases for protection of second-level aircraft such as the Boeing 747 series.

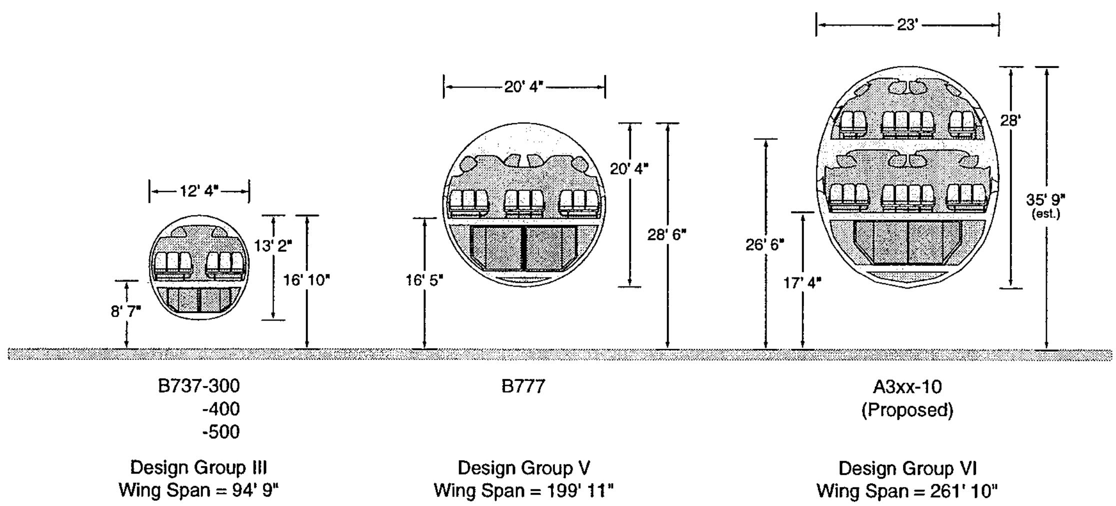

FIGURE 2. FUSELAGE SIZE COMPARISON

FUNDAMENTAL AGENT RESEARCH. The Airport Technology R&D Branch, ARFF R&D Program is currently expanding the capabilities of the National Airport Fire Extinguishing Agent Performance Test Facility located at the FAA William J. Hughes Technical Center. The ground-spill fire facility measures 200 by 120 feet and will be used to assess the performance of unique fire-extinguishing agents used for specialized airport fire protection needs. This facility will be used to develop new performance standards for all classes of extinguishing agents including dry chemical and halon alternative clean agents. The facility is concrete protected with a 5000-gallon collection containment vault to retain waste and spent fuel without endangering the environment.

Basic research needs to be accomplished to evaluate proposed new environmentally safe primary extinguishing agent replacements for the toxic Aqueous Film Forming Foams (AFFF) currently being used by our nation's airports.

Research will be performed to test, evaluate, and rank firefighting foam agents (protein, AFFF, fluoroprotein foam (FPF), film-forming fluoroprotein foam (FFFP), multipurpose film-forming foam, special purpose low-temperature foams, and ultra-high expansion foams) as may be indicated by proposed changes/advances in aircraft structural materials and propulsion systems. Research will include:

1. Evaluate the fire-extinguishing effectiveness of complementary agents (dry chemicals and halocarbons) and establish their equivalency with primary foam agents on advanced fuels and composite structures.

2. Evaluate "special purpose" fire-extinguishing agents for combustible metals, polar solvents, and other advanced fuel fires.

3. Determine the critical fire area of postcrash fuel spill fire associated with aircraft constructed of advanced materials.

4. Improve the effectiveness of foams when discharged from RFF vehicles to secure unburned aviation-type fuels.

5. Develop cost-effective operational criteria for emulsifying and wetting-type foam concentrates as applicable.

Figure 3 shows dry chemical agents undergoing tests using the FAA's new complementary agent test procedures.

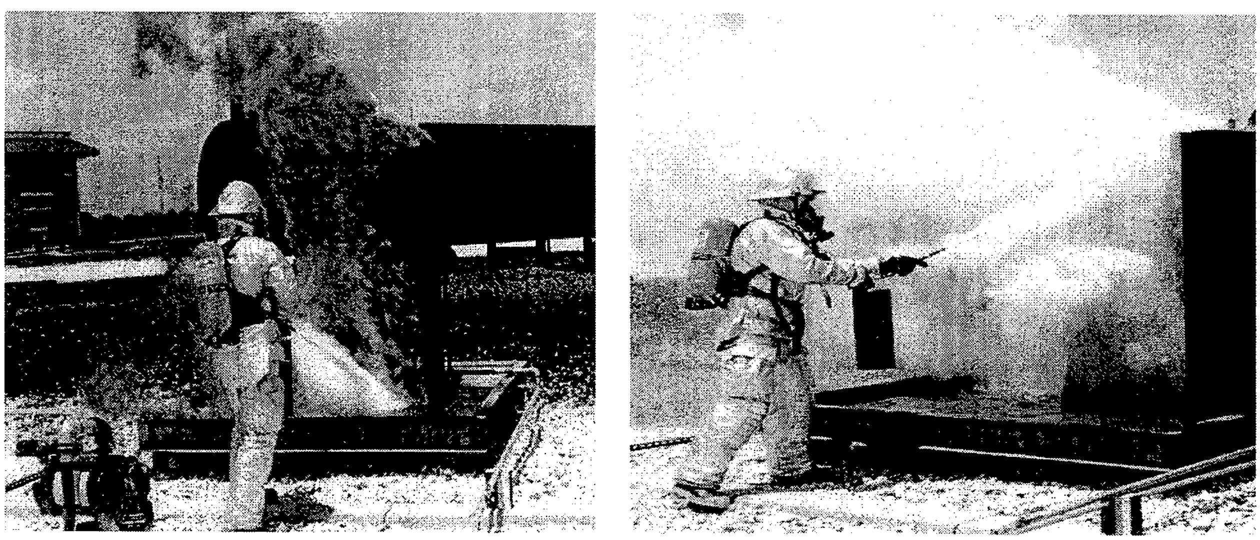

FIGURE 3. NEW COMPLEMENTARY AGENT TEST PROCEDURES

Continuing programs will examine fire-extinguishing technologies such as compressed air foam delivery systems, environmentally sensitive replacements and improvements to AFFF, dry chemical, clean extinguishing agents, and development of testing protocols for secondary or complementary agents used at airports.

Past trends in the U.S. at the larger airports has been to procure high-capacity foam-dispensing vehicles to provide for an effective foam discharge range equal to the fuselage length of the largest aircraft in use at the airport. Loss of operator visibility when dispensing agents and the reduced effectiveness of these high-flow rate applications has caused recent concerns in the industry. Research needs to continue on new methods of application of agents below operator window sight planes (low ground attack).

1. An evaluation should be conducted to determine the most cost-effective means to provide both quality application and extreme reach of foam agents needed to provide fuselage protection for aircraft that are now approaching 300 feet in length.

2. Determine the fire-extinguishing effectiveness of foam-dispensing devices, specifically the high-capacity turret nozzles in both the air aspirating, compressed air and nonair aspirating modes to provide airports with cost-effectiveness baseline data.

VEHICLE DYNAMIC STABILITY. This is an investigation and study into the recent occurrences of airport heavy rescue vehicle rollover/turnover. The vehicles involved in these rollover incidents were manufactured in the U.S. and certified to be in compliance with meeting FAA minimum specification designs for airport rescue vehicles, AC 150/5220-10B. This will be a dynamic moving rollover study of performance-specific requirements of the heavy rescue airport emergency vehicle and their dynamic stability requirements.

Since 1977, there have been approximately 41 reported heavy rescue vehicles involved in rollover accidents. Since 1995, there have been 20 vehicles reported to have been rolled over, four have occurred in the year 2000. This is an alarming number of occurrences considering the few miles and operational hours that the rescue and fire services use these vehicles each year. What is even more puzzling is the fact that most of these occurrences have occurred in nonemergency response situations. Most of the documented cases have occurred during training or in vehicles that were in transit for maintenance or other nonoperational reasons.

Because of the serious nature of the ARFF response and the potential for loss of life to both the operators of these vehicles as well as the safety of the flying public, this issue needs to be further investigated. Should rollover situations occur under actual emergency response situations, this would put the flying public at great risk. Though few of these accidents have occurred in actual response situations, the high response speeds necessary to maintain recommended response requirements dictates that rescue vehicle drivers have the utmost confidence in the vehicles that they are driving.

Considerations in undertaking this research include methods for reducing the danger to operators, eliminating potential sources of failure to actual ARFF responses, reducing the costs of vehicle repairs, and providing training guidance and documentation, such as video etc., to eliminate and/or reduce these rollover occurrences.

The FAA advisory circular for these vehicles is called "Guide Specification for Water-Foam Aircraft Fire Fighting and Rescue Vehicles," AC 150/5220-10B.

This document contains detailed performance parameters for fully loaded vehicles that include, but not limited to, the following:

1. Side slope stability
2. Dynamic balance
3. Minimum speed on a 100-foot radius circle in mph
4. Approach and departure angles
5. Wall-to-wall turning diameters
6. Maximum accelerations times from 0 to 50 mph
7. Service brake stopping distance

None of these specific requirements appear to address any of the fundamental requirements of operation of these heavy rescue vehicles, which is to determine the full turning/maximum braking limitations of these vehicles in actual high-speed dynamic movement situations.

The ultimate goal in civil airport firefighting vehicle safety is to provide vehicles that provide the operators with safety, operational efficiency, and ergonomics. This can be accomplished by recommendations and changes to the FAA AC 150/5220-10B document.

The main concern in a vehicle's construction should be safety. The vehicles which the FAA recommends for airport use should respond to the performance needs of the ARFF by providing rapid response, safe cornering at moderate speeds as well as high speeds, greater stability under braking conditions in a turn, and greater side slope stability. These vehicles need to display the same stability when fitted with elevated boom devices. In addition, their off-road, soft-field response should not be compromised.

An investigation into the large number of recent rollover accidents has pointed toward the need to improve vehicle stability and handling as well as driver education.

<u>HUMAN ELEMENTS</u>. Previously, there was no firefighting and rescue equipment available that would enable the RFF service to rapidly gain access to burning aircraft interiors or airframe voids. However, recent efforts conducted at the FAA William J. Hughes Technical Center have resulted in the evaluation of various equipment which could provide occupants increased protection while self-evacuating a burning aircraft. Such devices include a cabin skin penetrator nozzle, electronically controlled heat-seeking and/or thermally sensitive nozzles, and onboard fire-extinguishing agent dispensing systems. If applicable, the following operational criteria should be developed.

1. Evaluation of firefighting performance by the person participating in the fire suppression/extinguishment process should be accomplished. At issue, is annual live-fire training sufficient to keep firefighters proficient?

2. Evaluation of the quality of training facilities, new training techniques, environmental factors, firefighting strategies, and new computer interactive software and training systems should be accomplished. At issue, is the level of firefighting training consistent throughout the U.S.?

3. Establish the feasibility of providing aircraft cabin passenger protection using advanced concepts such as a skin penetration system to inject fire-extinguishing agents into the cabin without prolonging evacuation time. Additional research needs to be accomplished to further validate this strategy.

4. Study RFF vehicle response time criteria to potential accident sites based on the available database, addressing mobility on and off the pavement. Considerations should be accessed for different times of day and varying terrain, weather, and seasonal conditions.

5. Evaluation of personal protective clothing to protect the firefighter from exposures to new composite materials used in aircraft manufacturing.

Figure 4 shows firefighters training at a propane facility using hand lines.

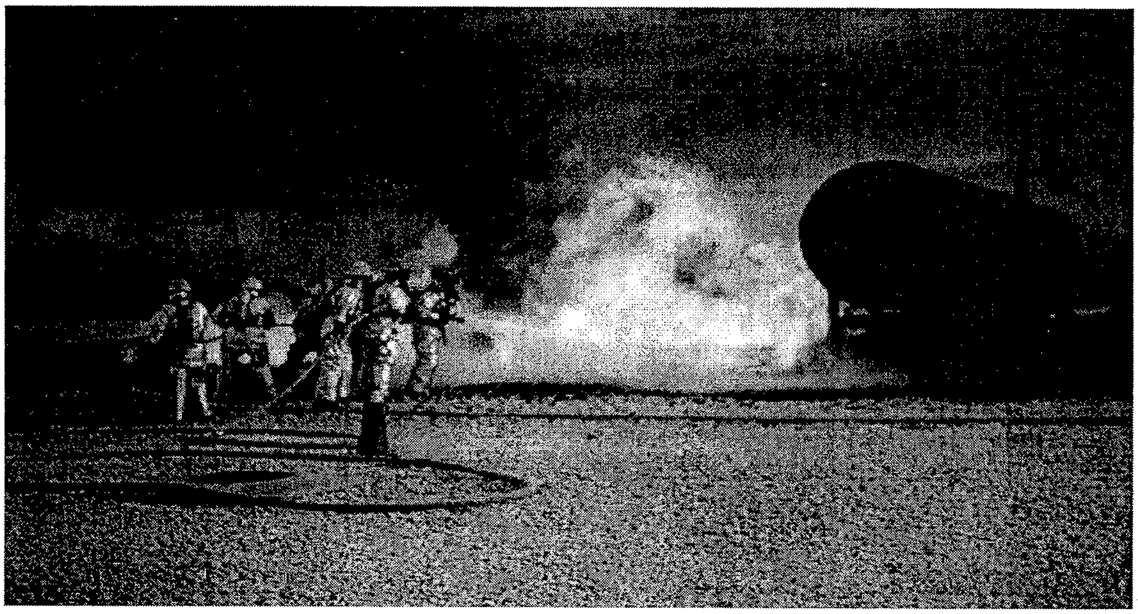

FIGURE 4. FIREFIGHTERS TRAINING AT A PROPANE FACILITY

<u>TRAINING FACILITIES</u>. The primary responsibility of the airport firefighting and rescue units in survivable aircraft accidents is to save lives by creating conditions under which survival is possible and permit rescue operations to proceed smoothly. This requires the efficient use of highly complex equipment by skilled personnel in a coordinated fire intervention effort. Because of the complexity of current equipment and agents, an acceptable level of performance will only be achieved through suitable and thorough training of responsible personnel. The training of airport firefighters is largely the responsibility of individual airports. Consequently, there is considerable variation between airports in the frequency of training and nature and quality of training.

Recent training policies have been directed towards development of regional training facilities, intermixed with somewhat smaller mobile simulators which can be transported to off-site locations and used by several different airport authorities. Most of the facilities the FAA funded in this program are computer-simulated, environmentally friendly propane facilities. The FAA needs to provide unified training curriculum and standards of performance at these training facilities.

A human factors study and a long-term tracking method of firefighters' performance is required. This will assure that firefighters who train on simulated, computer-generated facilities are in fact capable. Are they receiving the proper levels of firefighting training to maintain proficiency in firefighting the real world live, hydrocarbon-generated fires?

As new technologies such as elevated boom, cabin skin penetration, and DEVS technology reach airports, it is important that training methods reflect the use of these new assets.

Research should validate interactive computer training methods and video training aids to provide high-speed response and rescue vehicle operational training relating to reducing incidences of vehicle rollover.

Figures 5 and 6 show ARFF vehicles fighting a computer-controlled propane fire and a real aviation fuel fire.

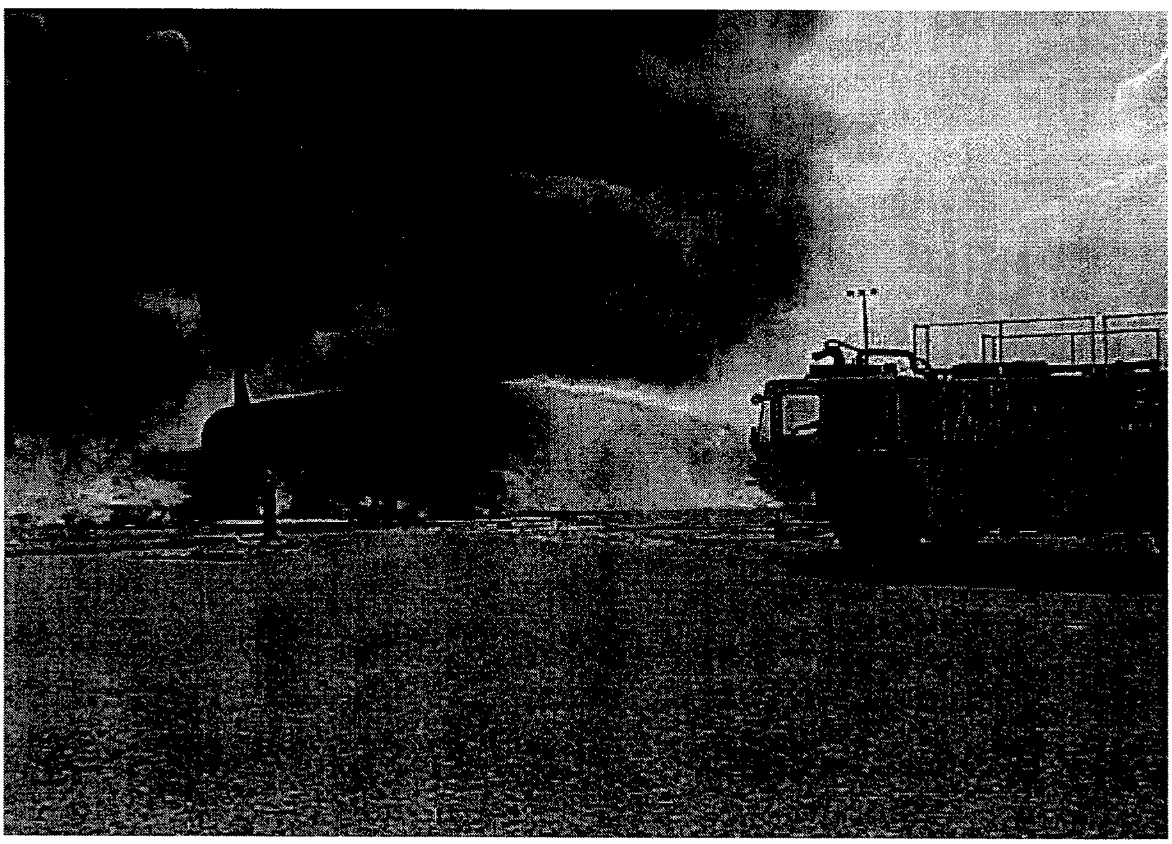

FIGURE 5. AIRCRAFT RESCUE AND FIREFIGHTING VEHICLE FIGHTING A PROPANE-SIMULATED FIRE

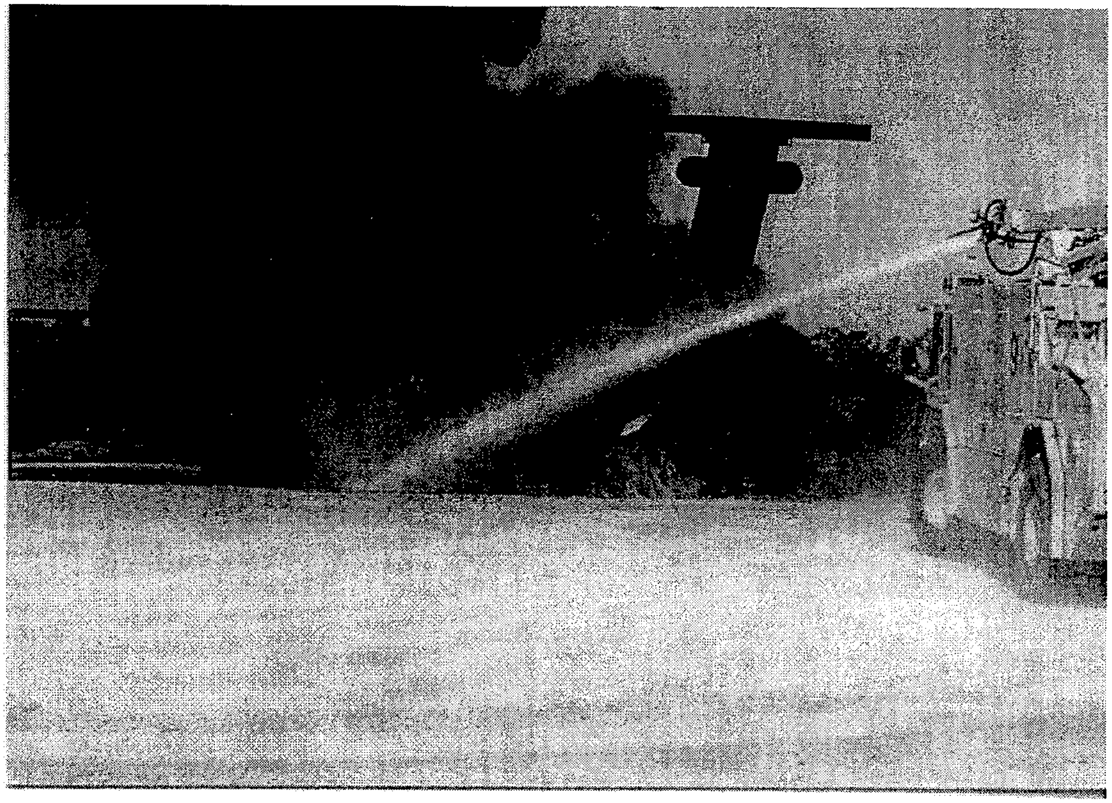

FIGURE 6. AIRCRAFT RESCUE AND FIREFIGHTING VEHICLE FIGHTING A REAL FUEL FIRE

INTERFACES. The FAA William J. Hughes Technical Center's airport rescue and firefighting personnel closely coordinate its research and development efforts with those of other Government agencies, such as the United States Navy (NAVSEA) and the USAF (Tyndall Air Force Base). A good working relationship has been established over the years with groups in the private sector, such as 3M, Angus Fire Armour Corporation, Chubb National Foam, Inc., Ansul Fire Protection, Emergency One, Oshkosh Truck Company, and Crash Rescue Equipment Services.

Other responsible organizations such as the ICAO and the NFPA use published FAA technical reports in developing their recommended standards and practices such as ICAO Annex 14 and standards and NFPA 403, "Aircraft Rescue and Firefighting Services at Airports." The FAA uses the William J. Hughes Technical Center's reports as a source of information in developing relative Advisory Circulars, such as AC 150-5210-6C, "Aircraft Fire and Rescue Facilities and Extinguishing Agents."

The William J. Hughes Technical Center's technical reports on crash fire rescue subjects are recognized as authoritative, both nationally and internationally.

CONCLUSION

The FAA has the primary responsibility to develop standards, criteria, and guidelines on how RFF services shall be performed. The FAA, through the AIP, provides financial assistance to airports to purchase heavy rescue firefighting equipment at FAA certified airports in the U.S. Uniform standards assist the FAA in assuring that federal funds are being judiciously employed and that the public investment in RFF services is prudently performed.

Policy is to maintain or improve current levels of service and improve firefighting effectiveness while stabilizing or reducing costs of that service and its associated equipment. The FAA, through its R&D program at the William J. Hughes Technical Center located at the Atlantic City International Airport, New Jersey, performs research, evaluation, and testing to seek out cost-effective alternative methods to improve the efficiencies of RFF services provided by airports.

Improved firefighting training, techniques, and equipment are needed to support airport safety and certification programs.