RESEARCH AND DEVELOPMENT

HIGHLIGHTS

1997

Airport and Aircraft Safety R&D
AAR-400
William J. Hughes Technical Center

Research and Development

R&D

Highlights 1997

Federal Aviation Administration

Airport and Aircraft Safety R&D Division
William J. Hughes Technical Center
Atlantic City International Airport, New Jersey 08405-0001

Foreword

As the nation's premier research organization for aviation technology, the Federal Aviation Administration's (FAA) aircraft research and development (R&D) program has made significant contributions to assure the safety, efficiency, and cost effectiveness of the national aviation system. Today that system is under heavy pressure to keep pace with rising traffic demand, needs for essential safety and security improvements, airspace user requirements for more flexible and efficient air traffic management operations, and demands for further mitigation of the environmental impacts of aircraft operations. To meet these future challenges, the FAA employs a comprehensive research, engineering, and development program that assures all available resources remain customer-focused and targeted on the highest priority activities.

The fundamental mission of the FAA is to foster a safe and efficient air transportation system. With respect to safety, the FAA's goal is to establish an operating environment that promotes an error free system that produces no accidents or fatalities. The mission of the Airport and Aircraft Safety R&D Program is:

> *To provide a safe global air transportation system by developing technology, technical information, tools, standards, and practices to promote the safe operation of the civil aircraft fleet.*

This report contains highlights of the major accomplishments and applications that have been made by Airport and Aircraft Safety researchers and by our university, industry, and government colleagues during the past year. The highlights illustrate both the broad range of research and development (R&D) activities supported by the FAA and the contributions of this work in maintaining the safety and efficiency of the national aerospace system. The report also describes some of the Division's most important research and testing facilities, considered to be some of the most scientifically advanced in the world. For further information regarding this report, contact Mr. Thomas J. O'Brien, Technical Assistant for Programs, AAR-400, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ 08405, (609) 485-4143, or Mr. Joseph Manning, Technical Assistant for Facilities, AAR-400, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ 08405, (609) 485-5397.

Chris C. Seher
Director

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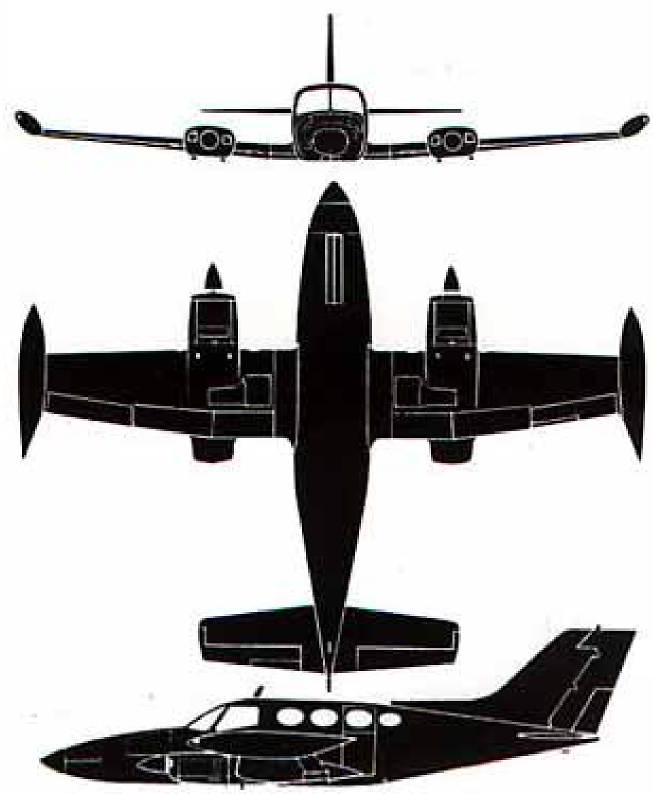
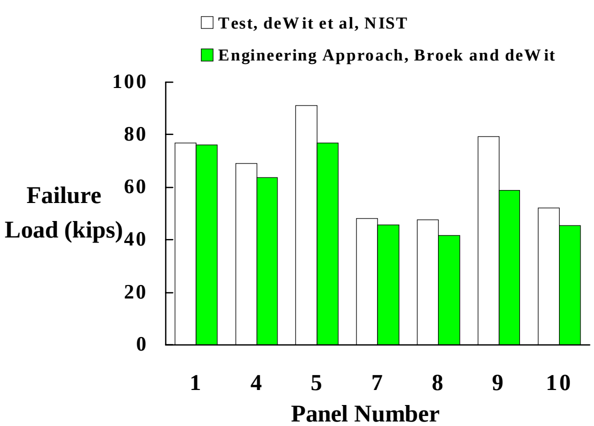


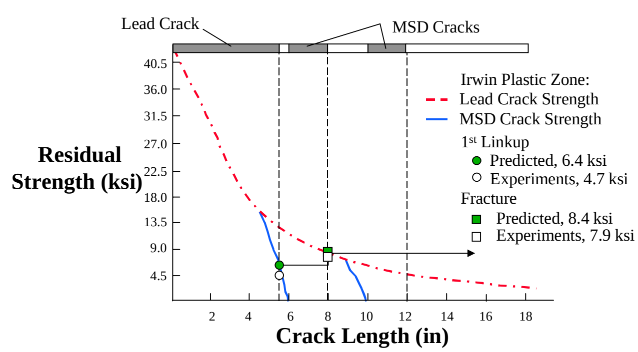
Engineering Approach to Predict Residual Strength of Fuselage Panels With WFD

Widespread fatigue damage (WFD) in the form of small cracks emanating from multiple rivet holes in the fuselage lap splice joint can degrade the load carrying capability of an aircraft below the original certification requirements. Tools and methodologies to evaluate the effect of WFD on the structural integrity of aircraft are under development. One of these tools, an engineering approach for evaluating the residual strength of fuselage panels with WFD, is being developed by the FAA. The approach, developed by Broek and Swift, assumes that the smaller crack will be absorbed by the main lead crack through plastic collapse of the net section ligament. Referred to as the plastic zone linkup criterion, this occurs when the plastic zones from the lead crack and smaller crack meet. The geometry of the plastic zones is determined from appropriate values of the stress-intensity factors (SIF).

The engineering approach has been successfully applied to predict the residual strength in flat panels containing various multiple crack configurations. The flat panels were tested by the FAA at the National Institute of Standards and Technology (NIST). On average, the difference between the experiments and the predictions of the fracture strength was 13%. The engineering approach is appealing since it can be used in numerous parametric studies to screen a large number of cases to identify critical configurations, which may then be analyzed in more detail.



To further develop the engineering approach to predict the residual strength of curved fuselage panels with WFD, the effect of bulging has been incorporated into analysis. Finite element results generated in a parametric study were used to derive an expression for the bulging factor for unstiffened shells using dimensional analysis. The shape of the bulging profile was modeled and used in an energy balance approach to derive an expression for the bulging factor, which was incorporated into the engineering approach. The resulting methodology was used to predict the residual strength of an unstiffened fuselage panel with multiple-site damage (MSD). The difference between the experimental and the prediction of the fracture strength was 7%.

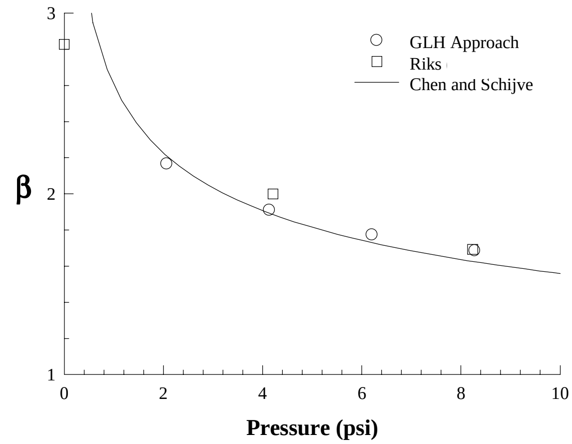


POC: Dr. John Bakuckas, AAR-431, (609) 485-4784.

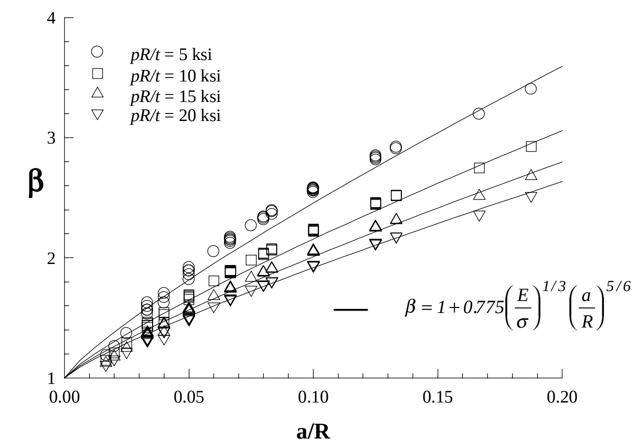
Bulging Factors for Predicting Residual Strength of Fuselage Panels With WFD

An engineering approach for evaluating the residual strength of fuselage panels with widespread fatigue damage (WFD) is being developed by the FAA. The approach, developed by Broek and Swift, uses the residual strength diagram modified to include multiple-site damage (MSD) cracks. It is assumed that the MSD crack will be absorbed by the main lead crack through plastic collapse of the net section ligament. Referred to as the plastic zone linkup criterion, this occurs when the plastic zones from the lead crack and MSD crack meet. The geometry of the plastic zones is determined from appropriate values of the stress-intensity factors (SIF).

A two-part investigation was conducted to generate bulging factors for pressurized unstiffened and stiffened fuselage structures. In the first part, bulging factors and crack profiles were calculated for a variety of configurations using a global-local hierarchical (GLH) approach using nonlinear finite element analyses. Comparisons with bulging factors β from the literature (Riks and Chen and Schijve) were used to validate the GLH approach. Once validated, results showed that, for the unstiffened cases, the bulging factor increases as the crack length increases and decreases as the applied pressure increases. For the stiffened cases, the effect of an intact and broken central strap on the bulging factor and strap stresses was studied. An intact central strap significantly reduces both the bulging effect and the stresses in the adjacent strap compared to a broken central strap.



In the second part, results from the GLH approach were used to derive a generalized expression for the bulging factor for unstiffened fuselage panels using a dimensional analysis. The shape of the bulging profile was accurately modeled and used in an energy balance approach to derive an expression for the bulging factor. For all cases, the derived expression was within a few percent of the results generated using the GLH approach.



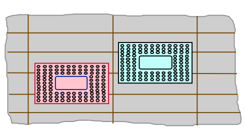
The reported solutions for the bulging factors will be used in future work to predict the residual strength of fuselage panels containing widespread fatigue damage.

POC: Dr. John Bakuckas, AAR-431, (609) 486-4784.

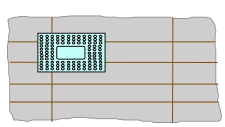
Enhanced Repair Assessment Procedure and Integrated Design (RAPID)

A critical issue identified by the aviation industry is the need to examine the effects of fuselage skin repairs on the structural integrity of the aircraft. The incorporation of damage tolerance methodologies in the maintenance and repair practices of aircraft is required in order to insure their continued airworthiness and operational safety. The resources needed for damage tolerance designs of repairs are lacking for small operators, independent repair facilities, and military repair depots. In an effort to address this need, a task was undertaken under the joint sponsorship of the United States Air Force and the FAA to develop a new user-friendly software tool, Repair Assessment Procedure and Integrated Design (RAPID), capable of static strength and damage tolerance analyses of fuselage skin repairs.

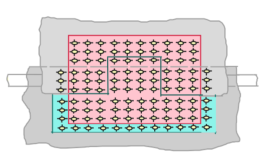
RAPID is a Windows-based, user-friendly repair analysis and design software tool that can run on a PC computer with minimal hardware and software requirements.



Repairs Near Other Repairs



Repairs Over Stiffeners

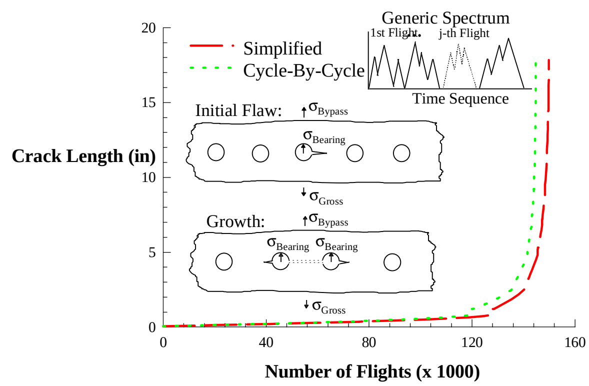


Repairs Over Joints

The development of RAPID has been undertaken in two phases. Phase 1, completed March 1996, considered simple fuselage skin repairs. In Phase 2, completed in November 1997, more common fuselage skin repairs found in industry are considered including repairs near other repairs, repairs of splice joints, and repairs over stiffeners. The analysis features include:

- Two-dimensional fastener loads
- Stress spectrum options:
  - Generic spectrum for the narrow- and wide-body aircraft
  - User-specified stress spectrum
  - Equivalent stress
- Two crack growth analysis options:
  - Simplified, based on Walker's Equation
  - Cycle-by-cycle
- Crack growth analysis in the longitudinal and circumferential directions

All aspects of the damage tolerance analysis methodology in RAPID were evaluated. A comparison of the results from the cycle-by-cycle and the simplified crack growth models using a generic stress spectrum is shown below. Due to the excellent agreement, the simplified approach can be used to obtain a quick and accurate solution when retardation effects can be neglected.

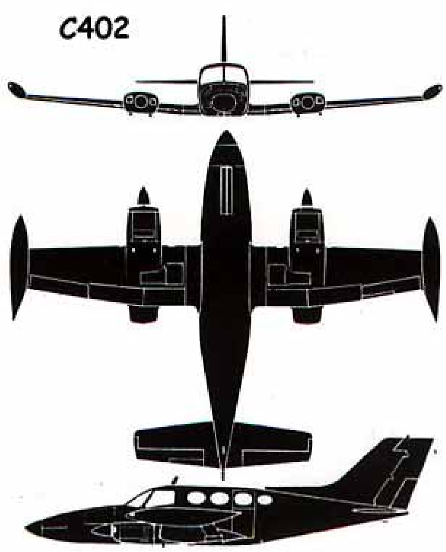


POC: Dr. John Bakuckas, AAR-431, (609) 485-4784.

Supplemental Inspection Documents for Commuters

Increased utilization, longer operational lives, and the high safety demands imposed on currently operating air carrier airplanes have indicated that there is a need for a program to provide for a high level of structural integrity for all airplanes in the commuter transport fleet. Supplemental Inspection Programs (SIP) have been used successfully to provide this level of safety in the large transport segment of the industry.

To extend this concept to commuter category airplanes, the FAA proposes changes to require all airplanes operated under CFR Part 121, all U.S.-registered multiengine airplanes operated under part 129, and all multiengine airplanes used in scheduled operations conducted under part 135 to undergo inspections after their 14th year in service to ensure their structural integrity. The proposed rule would also require that damage tolerance (DT) -based SIPs be developed for these airplanes



before specific deadlines. This proposal represents a critical step toward compliance with the Aging Aircraft Safety Act of 1991. It ensures the continuing airworthiness of aging airplanes by applying modern DT analysis and inspection techniques to older airplane structures that were certificated before such techniques were available.

Many commuter airplane manufacturers and operators do not have the large engineering staffs, budgets, or fleet sizes to support a program as extensive as the large transport program. To ease this burden, the FAA is assisting U.S. manufacturers of selected airplane models to develop Supplemental Inspection Documents (SIDs) which could then be used by operators to develop SIPs. In

addition, other manufacturers can also use these SIDs as guidance material as they develop the documents for their aircraft models. SIDs are under development for three models of aircraft representing a cross-section of the commuter fleet: Cessna 402, Fairchild Metro 227, and the Piper Navajo.

To date, Cessna has developed inspection thresholds and intervals for each of the principal structural elements (PSEs) for the Model 402 through the use of DT-based analyses. A PSE is an element of structure that carries a significant amount of load and is essential in maintaining the overall structural integrity of the aircraft. The inspection thresholds and intervals, as well as recommendations and descriptions of inspection techniques, will form the basis for the SID, which is to be completed early next year. Fairchild has identified a list of PSEs and determined the corresponding stress spectrum for use in the DT analysis of the Metro airplane. It is anticipated that Piper will begin developing a SID for the Navajo airplane early next year.

POC: Mr. Richard Micklos, AAR-432, (609) 485-6531.

FAA-NASA Fracture Testing of Stiffened Panels With Multiple-Site Damage (MSD)

A joint FAA-NASA experimental program has been conducted to evaluate the effect of multiple-site damage (MSD) cracking on the strength of stiffened, flat panels. MSD cracking is a scenario that has potentially catastrophic consequences for commercial airliners and military transport aircraft. Each time an aircraft flies, it undergoes a pressurization of the fuselage structure, exposing the aircraft skin and internal structure to a cyclic stress. These aircraft have been designed to withstand this cyclic operating stress even with a single large (10 inches or more in length) crack. Such a lead crack would be detected, using existing inspection technology, before it grew to a length (critical length) that threatened the structure. However, if in addition to the single long crack a number of small MSD cracks developed in a concentrated area (along a row of rivets for example), then the critical length of the lead crack would be sharply reduced. The shorter the critical length of the lead length, the less the chance that the crack would be detected by inspection. Moreover, the typical size of the MSD cracks (0.01-0.05 inch) are too small to be confidently found using existing inspection technology, so the operator may have no prior indication of impending fleet MSD problems.

The objective of this joint FAA-NASA experimental program was to conduct fracture tests to evaluate and quantify the effect of MSD cracking on stiffened panels. Ten, 40-inch-wide panels of 0.063-inch-thick 2024-T3 aluminum alloy were tested. Five of the panels had riveted stiffeners to simulate tear straps of an aircraft fuselage; the other five panels were unstiffened. The crack configurations tested were (1) a single 8-inch lead crack, (2) a single 8-inch lead crack in line with 24 open holes, (3) a single 8-inch lead crack with 24 open holes with a 0.01-inch-long crack on both sides of each hole, (4) a single 8-inch lead crack with 24 open holes with a 0.03-inch-long crack on both sides of each hole, and (5) a single 8-inch lead crack with 24 open holes with a 0.05-inch-long crack on both sides of each hole. During each test, applied load, crack growth, strain at 60 locations, and large area x, y, and z displacements were measured. The results indicate that the presence of the small

MSD cracks reduced the load required to fail the stiffened and unstiffened panels by more than 25%. The results of this study will provide experimental data to show that MSD cracking sharply reduces the critical load for stiffened structures and will be used to verify analytical fracture models. Once verified, these analytical fracture models can be used to predict when an aircraft would develop MSD cracking, determine inspection intervals to maintain safety in the presence of MSD, and evaluate repairs suggested to eliminate MSD problems.

The following figure is a photograph of a 40-inch-wide, flat, stiffened panel. The five vertical riveted tear straps are clearly visible. In the center of the panel is a single 8-inch-long crack that runs perpendicular to the tear straps. Also visible in the photograph are some of the 60 gages used for strain measurements and a black and white speckled region used for the large area x, y, and z displacement measurements.

POC: Dr. Paul Tan, AAR-431, (609) 485-6665.

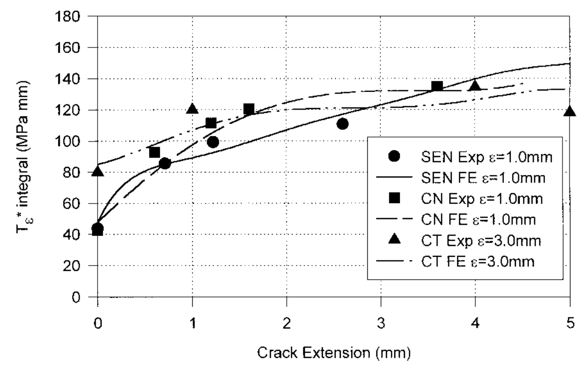
Experimental Verification of T* Theory

The FAA Center of Excellence for Computational Modeling of Aircraft Structures, Georgia Institute of Technology (GIT), has developed an elastic-plastic crack growth criteria which is based on strain energy at the crack tip, T*. This criteria has been successfully used to predict crack growth in stiffened and unstiffened flat panels. It has been proposed that T* is a material property and thus the objective of this work was to experimentally measure this quantity.

The specimens used consisted of fatigue precracked, thin, single-edged notched (SEN) and center notched (CN), 2024-T3 aluminum alloy specimens. The orthogonal displacement components surrounding the crack tip was measured by Moiré interferometry using a cross-diffraction grating of 40 lines/mm prior to and during stable crack growth. T* software, developed by the FAA Center of Excellence for Computational Modeling of Aircraft Structures was modified to evaluate T^*_ε integral using Moiré fringe data along a given part rectangular contour which moved with the moving crack tip. The T^*_ε integral and the crack opening angle (CTOA) were determined during successive increments of stable crack growth. Simultaneously, the SEN specimens were analyzed by GIT and the CN specimens were analyzed at the University of Washington (UW) using the ABAQUS finite element (FE) code. These results were then compared with the experimentally determined T^*_ε.

The following figure shows the results of the experimentally and numerically determined T^*_ε in the region closest to the crack tip where distinct Moiré fringes are observed.

Concurrent with these experimental and numerical efforts were efforts to extend the T^*_ε theory to mixed modes I and II loading as well as to the growth of a curved crack.



Experimental and Finite Element Analysis T^*_ε Integral Values. (2024-T3 Aluminum Alloy SEN, CN and CT Specimens)

POC: Dr. Paul Tan, AAR-431, (609) 485-6665.

Full-Scale Curved Panel Test System

A full-scale curved panel test system is being developed under contract with the Boeing Company, Long Beach, CA. It is a unique adaptation of mechanical, fluid, and electronic components, which will be capable of applying pressurization, longitudinal, hoop, and shear loads to a curved panel test specimen.

The internal pressure will be applied using water as media, eliminating the possibility of a catastrophic accident. The system will be capable of dynamically cycling the internal pressure as well as performing a static pressurization to levels above flight gradients.

The hoop and longitudinal stresses will be simulated by the controlled application of distributed loads around the perimeter of the test panel. Hoop forces will be distributed by individual loading linkages using a two-tier coaxial whiffle tree assembly, which generates four equal forces from each controlled load point. A total of seven load points are used on each side of the specimen, creating a total of 28 attachment points. Longitudinal forces are created using similar loading devices on each end of the panel, consisting of four load control points and 16 attachment points. Similar devices are available to apply bending and tension loads at each end of a frame.

An innovative shear loading system has been developed that uses two load distribution points in the longitudinal direction at the edges of the specimen. The force is applied as a couple and is reacted by a couple in the hoop direction. A unique feature of the shear loading system is the elastomeric coupling between the loading mechanisms and the test specimen. The elastomer, which has a soft shear modulus, creates a close approximation to uniform shear distribution in both the applied and reacted couples.

All forces are generated using water as the fluid medium. The external loads are generated by applying water pressure to bladder type actuators, which are controlled by pressure activated dome valves. The dome valves are automatically controlled by the use of pneumatic control valves. The valves are driven by a computer control system in a closed-loop configuration. A graphical interface allows the operator to control the loads, speed, and type of test desired. Data acquisition from strain transducers, load transducers, pressure transducers, etc., will be displayed on color monitors in real time, as well as stored for off-line analysis.

The system is scheduled to be installed at the FAA William J. Hughes Technical Center in June 1998. The photograph below shows the test rig being assembled.

POC: Dr. Paul Tan, AAR-431, (609) 485-6665.

Flight Loads Data Collection Program, Large Transport Airplanes

The Federal Aviation Administration has re-established a flight loads data collection program for large transport airplanes.

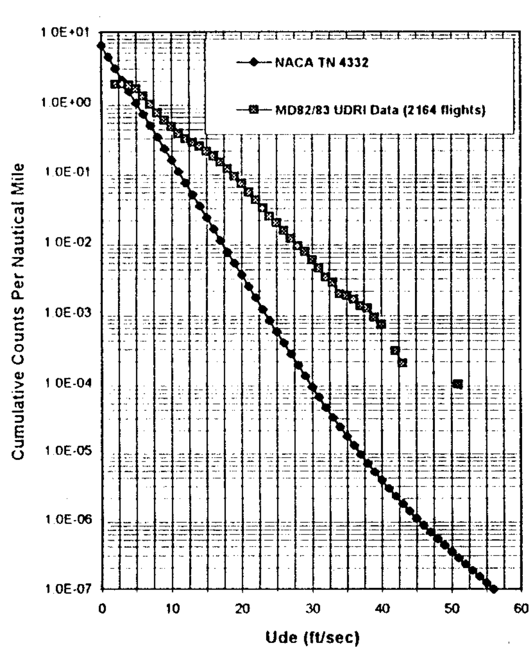
The FAA system is operational, and the data collection and analysis procedures have been established and verified by collecting and reporting on approximately 900 hours of operational data on a B-737 (DOT/FAA/AR-95/21, Flight Loads Data for a Boeing 737-400 in Commercial Operation, 1996). An additional 18,000 hours of B-737 data and 8000 hours of MD-82 data have been collected and are currently being reduced and analyzed. Another technical report summarizing the new data is expected later this year.

A number of initial results are already available. As an example, see figures below. At high altitude the gust exceedance is considerably less than that from the National Administration of Civil Aeronautics (NACA) reports, yet, conversely, at low altitudes the gust experience is considerably greater than previous NACA data.

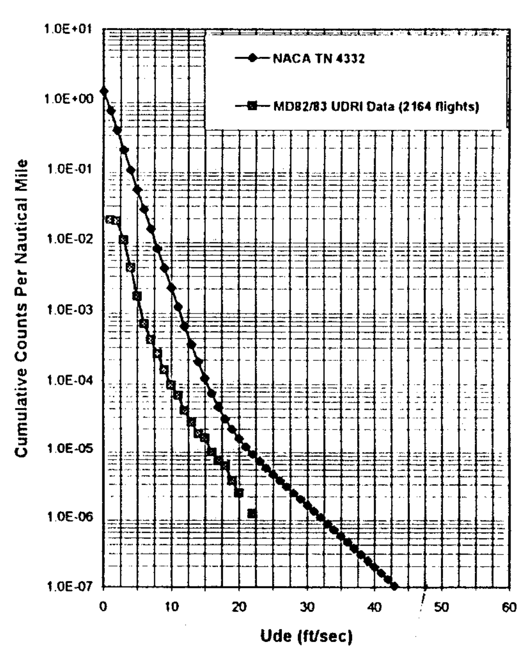
Equally important is the merging of three FAA programs for on-board data monitoring sources. Researchers from the subject program and the Flight Operational Quality Assurance and Automated Performance Measuring System have been sharing data from their respective systems. See figure on next page. For the Flight Loads Program, we purchased only 12 Optical Quick Access Recorders, yet are receiving data from 27 recorders with expectations of data from an additional 16 during the next fiscal year. Host airlines are gaining an interest in on-board data monitoring and are purchasing their own recorders and making these data available to the FAA for research.

Airframe manufactures strongly support this research effort and played a major role

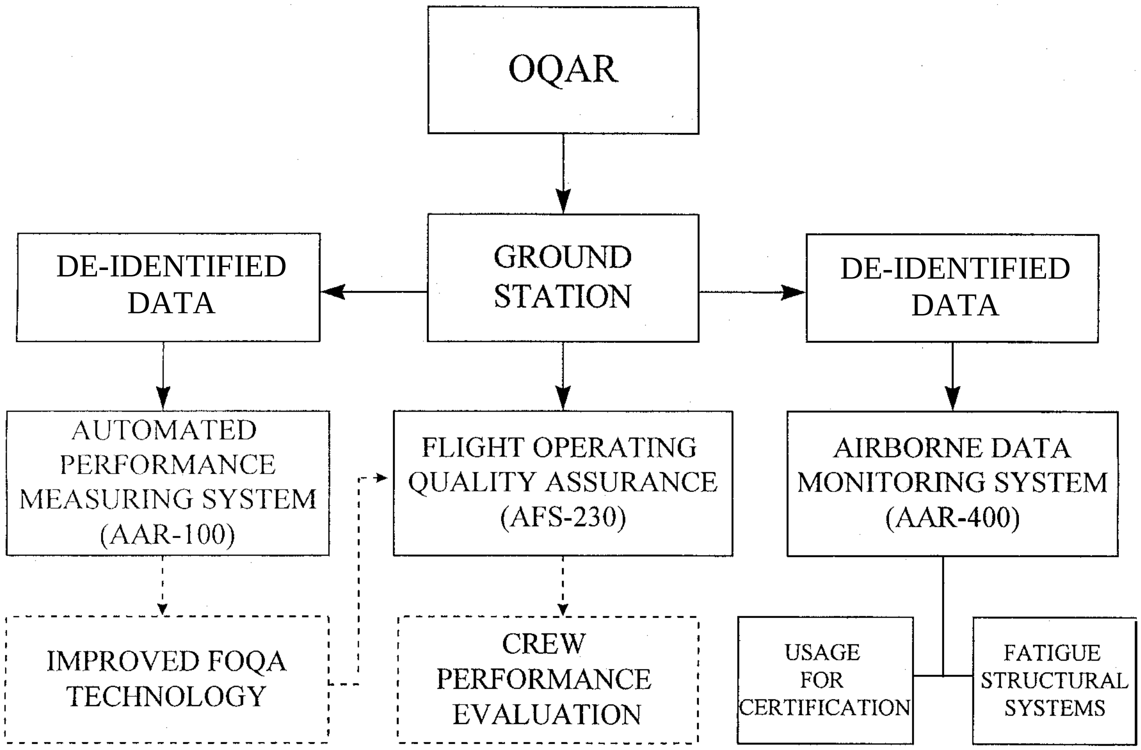
Upward Gusts, Hp< 2000 ft



Upward Gusts, Hp = 30,000-40,000 ft



Derived Gust Velocity Cumulative Peak Counts



OQAR- Optical Quick Access Recorder   FOQA-Flight Operational Quality Assurance

in defining the data reduction formats presented in the referenced FAA report. A second and yet more extensive set of statistical requirements has been jointly researched by the FAA and aircraft manufacturers.

As the program matures even further, additional recorders will be installed by the airlines in different type airplanes to develop a balanced database. The next installations are expected to be on B-767 airplanes.

POC: Mr. Thomas DeFiore, AAR-431, (609) 485-5009.

Video Landing Parameter Survey at London City Airport, United Kingdom

Personnel from the Propulsion and Systems Section AAR-432 lead a joint research team, from the FAA William J. Hughes Technical Center and the Naval Air Warfare Center, Patuxent River, MD, to conduct a extensive video landing parameter survey at London City Airport (LCY), United Kingdom. Landings at both Runways 10 and 28 were video taped. This was the fourth of a series of surveys conducted by the FAA to more fully characterize the landing contact conditions of transport aircraft in routine operations. Prior surveys were conducted at JFK International, Runway 13L, Washington National, Runway 36, and Honolulu International, Runway 8L.

LCY is a relatively new, commuter only, airport in East London, UK, near the dock lands. LCY has a single east-west runway, 3800 feet long which requires aircraft to descend with a minimum 5.5 degree glide slope (3.0 degrees is typical). The data acquisition system was expanded to monitor both ends of the LCY runway, and six cameras were used to collect the landing video images. Approximately 80% of the total daily operations at LCY were recorded. A total of 430 landings, mostly BA-146's and FK-50's, were digitally video taped at LCY during the two week period from June 23 to July 4.

UK Civil Aviation Authority (CAA) and British Aerospace (BAe) researchers have indicated that the foremost missing element in their usage performance data is a precise characterization from the time the airplane is over the runway threshold to landing impact. Another important missing element is a description of the dispersion of the actual touchdown locations. The landing parameter data acquisition survey conducted on this 5.5 degree glide slope airport is expected to provide the CAA and BAE researchers with much of the landing ground contact data needed for new future regulations regarding steep approaches.

POC: Mr. Thomas DeFiore, AAR-431, (609) 485-5009.

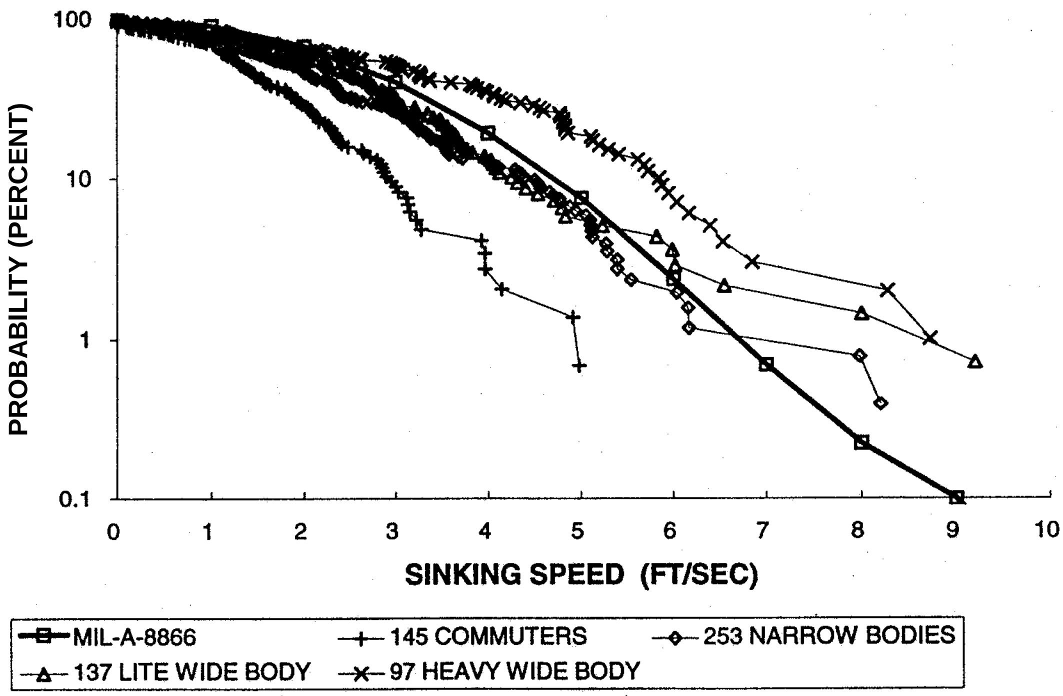
Video Landing Parameter Survey, John F. Kennedy International Airport

The Federal Aviation Administration William J. Hughes Technical Center is conducting a series of video landing parameter surveys at high-capacity commercial airports to acquire a better understanding of typical contact conditions for a wide variety of aircraft and airports as they relate to current aircraft design criteria and practices.

The initial survey was conducted at John F. Kennedy (JFK) International Airport in June 1994. Four video cameras were temporarily installed along the north apron of Runway 13L. Video images of 614 transport (242 wide-body, 264 narrow body, and 108 commuter) aircraft were captured, analyzed, and the results presented in FAA Technical Report DOT/FAA/AR-96/125 Video Landing Parameter Survey - John F. Kennedy International Airport, published this year. Landing parameters presented include sink rate; approach speed; touchdown pitch, roll, and yaw angles and rates; off-center distance; and the landing distance from the runway threshold. Wind and weather conditions were also recorded and the landing weights were available for most operations. Since this research is concerned with overall statistical usage information only, all data were processed and presented without reference to the airline or flight number.

The video landing data acquisition system has proved to be a practical, cost-effective technique for collecting large quantities of typical landing parameter data at major commercial airports.

While the initial indications are that the heavy wide-body aircraft (B-747, MD-11, DC-10, L-1011) land with a higher sink rate than other jet transports, the rather limited number of these large jets suggest that additional data on these aircraft need to be collected before any conclusions concerning their landing performance can be made. See figure below.



Probability of Distribution of JFK Survey Sinking Speeds

The commuter data collected during this survey may not reflect typical operations for this category aircraft since these aircraft landed on a 10,000-foot runway with heavy jets in the landing pattern.

POC: Mr. Thomas DeFiore, AAR-431, (609) 485-5009.

Variation in Load Factor Experience of Fokker F27 and F28 Operational Acceleration Exceedance Data

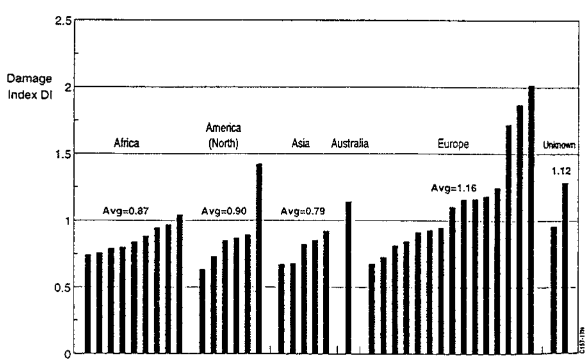
Fatigue meter data obtained during operational flights of Fokker F27 and F28 aircraft were reprocessed and analyzed to study the variation in load experience between different aircraft of the same model type.

The data covered about 470,000 flights which were made by 101 aircraft belonging to 51 different operators. A simple algorithm was developed to quantify the load factor experience in terms of fatigue damage per flight. The data were subjected to a statistical analysis where considerable variations in load experience were obtained. See accompanying figures for the F27 and F28. The results give an indication of the potential benefits which can be gained from individual aircraft load monitoring. Similar studies are planned on data for US carriers when sufficient flight data are obtained.

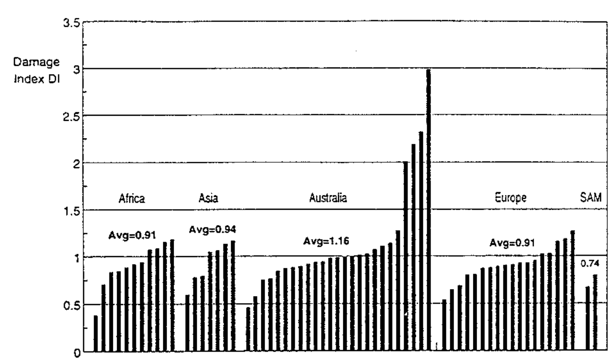
This research was performed under a memorandum of cooperation between the Federal Aviation Administration and the Netherlands Aviation Department. As part of this effort, the National Aerospace Laboratory was contracted to participate in this research effort.

A final technical report was published, DOT/FAA/AR-96/114, Variation in Load Factor Experience of Fokker F27 and F28 Operational Acceleration Exceedance Data, December 1996.

POC: Mr. Thomas DeFiore, AAR-431, (609) 485-5009.



F28 Database



F27 Database

FAR23 Loads Program - Computer Aided Engineering for Airplane Loads to the Code of Federal Regulations

The FAR23 Loads Program was developed to approximate loads on small airplanes from preliminary airplane geometry using methods acceptable to the FAA. The program includes 20 modules that are each self-contained sub-programs designed for specific application.

Most of the detailed flight loads are developed from the flight envelopes specified in 23 CFR Parts 333 and 345. At every point specified in the flight envelope, the airplane is balanced by a tail load reacting to the specific linear normal acceleration and the aerodynamic lift, drag, and moment about the center of gravity. The data needed to make these balancing calculations consists of (1) the weight at the center of gravity, (2) aerodynamic surface geometry, (3) structural speeds, and (4) aerodynamic coefficients. After the balanced loads are developed, the critical structural loads are determined for each component. For the critical conditions, the air, inertial, and net loads are calculated. Aileron, flap, tab, engine mount, landing, and one engine out loads are also calculated. Landing loads are calculated from the landing geometry, landing load factor, weight, and center of gravity data.

The FAR23 Loads Program provides a procedure for calculating the loads on an airplane according to the Code of Federal Regulations, Title 14 - Aeronautics and Space, Chapter I - Federal Aviation Administration, Subchapter C - Aircraft, Part 23 - Airworthiness Standards: Normal, Utility, Aerobatics, and Commuter Category Airplanes, Subpart C - Structures.

The FAR23 Loads Computer Program is documented in an FAA Technical Report, DOT/FAA/AR-96/46, User's Guide for FAR23 Loads Program. Computer Aided Engineering for Airplane Loads to Federal Air Regulations.

POC: Mr. Thomas DeFiore, AAR-431, (609) 485-5009 and Mr. Richard Micklos, AAR-432, (609) 485-6531.

Joint FAA-Air Force Corrosion Fatigue Interaction Research Program

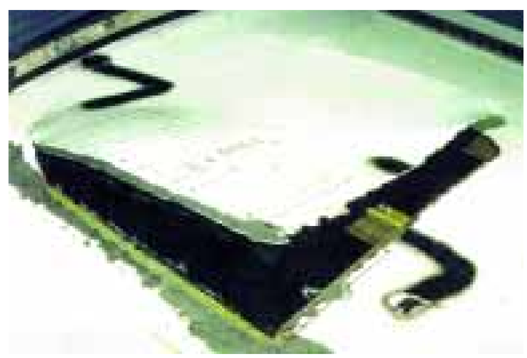
The problems of corrosion and fatigue associated with aging aircraft are common to both civilian and military aircraft. The interaction of pre-existing corrosion with fatigue is being examined by testing fuselage panels supplied by the US Air Force obtained from disassembly of retired Boeing 707 and C/KC-135 airplanes.

Both fatigue and static strength tests are being done on the FAA Aging Aircraft Test fixture located at and operated by Foster-Miller, Inc., under contract with the Volpe National Transportation Systems Center. The test fixture accommodates panels that are approximately 10 feet in length by 6 feet along the circumference with a 74-inch radius of curvature. Prior to the current test program, only laboratory panels had been tested in the fixture. The work in progress demonstrated that panels from actual aircraft can be tested in the fixture.

Various nondestructive inspection (NDI) techniques are being applied to the panels before testing to detect any hidden corrosion or fatigue cracking from in-service usage. These methods include thermal wave imaging, magneto-optic imaging, D-sight, pulsed eddy current, and ultrasonics. These NDI methods will be validated by panel teardowns after the test program is completed.

To date fatigue testing has been completed on two Boeing 707 panels taken from the same airplane. The airplane had been in service for 23 years and accumulated 22,071 flight cycles and 77,742 flight hours. One panel was taken from a location forward of the wing and had a nominal skin thickness of 0.040 inch. The other panel was taken at a location aft of the wing and had a skin thickness of 0.062 inch. Both panels were tested in fatigue with pressures varying from 1 to 9.5 psi.

The first panel tested, the panel with the thinner skin, was characterized as having light corrosion by the NDI techniques. The first fatigue crack was found after 36,000 fatigue cycles. Linkup of two adjacent cracks occurred after 47,500 cycles. Linkup of several adjacent cracks occurred after 48,616 cycles resulting in a single crack length of over 14 inches in length. At this point, fatigue cycling was stopped and a static residual strength test was performed. The internal pressure was increased at a rate of 0.2 psi per second from 0.5 psi until panel failure occurred at 13 psi. The residual strength test revealed that the tear straps provided sufficient crack arrest capability to create a safe decompression during failure as shown in the photograph.



The remaining panels will be inspected using the NDI techniques to detect any corrosion or cracks prior to testing and then tested in a similar manner to the first panel. The fatigue and residual strength tests on all the panels will be completed by the end of 1998.

POC: Dr. Thomas Flournoy, AAR-433, (609) 485-5327.

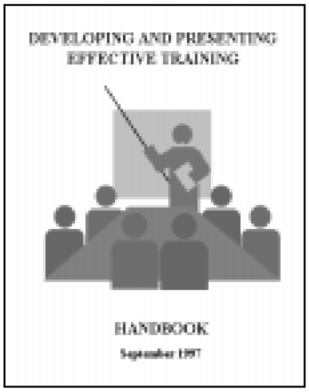
Aviation Safety Program Managers for Airworthiness

FAA field unit Aviation Safety Program Managers for Airworthiness (ASPM/A) have many job functions. A major one is their ongoing development and delivery of technical safety training sessions to components of the aviation community. The safety training covers a broad spectrum of content areas ranging from new CFRs and Airworthiness Directives (ADs) to the newest concepts in aviation maintenance technician (AMT) preparation and training.

In 1996, a video tape, with a workbook, on how to develop and deliver effective training was developed at the request of the FAA Aviation Safety Program Manager. It was felt that the ASPM/A force would be able to better perform their safety training function if there was a standard training tape (train-the-trainer type) available with an accompanying workbook. The workbook would capture the essentials of the training tape and provide sets of checklists covering all aspects of the training development and delivery.

By using the video and the workbook, the ASPM/As would develop and deliver training in accordance with the best principles and practices available. The video and workbook would enable the ASPM/As to translate their safety expertise into a format where it could be effectively shared with and used by the aviation community. Thus, consistent, high-quality safety training would be available across a gamut of categories of operation from general aviation (GA) to corporate and even the USAF.

The format and content for the video script and the workbook were developed. The FAA's Imaging Video Lab did the filming, with FAA and professional personnel used as both actors and off-screen voices. The video and workbook, along with a tutorial on the products, were made available to the FAA ASPM/As during 1997.

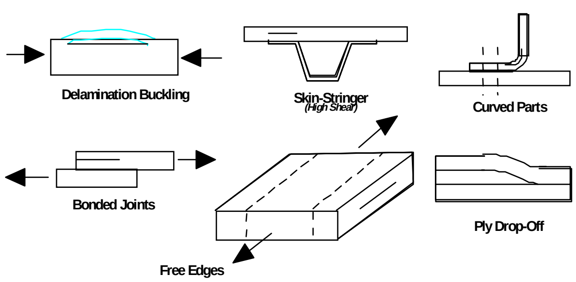


The training tape and workbook are somewhat generic; i.e., they are not specific to the development and delivery of a specific type of training, but rather to any training. As a result, aviation industry personnel can make good use of the video and workbook in their efforts to develop and deliver quality technical training that improves and enhances aviation safety.

POC: Dr. Ronald Lofaro, AAR-433, (609) 485-4501.

Methodology for Delamination Growth Assessment in Composite Material Aircraft Structures

Delamination growth is a common failure mode in laminated composite aircraft structures. Delaminations occur in critical areas of the structure, as shown below, and need to be addressed to satisfy damage tolerance requirements during certification and in-service to guide inspection and repair activities. Presently, the criticality of the delaminations, by size and location, is determined by tests. An efficient analytical methodology to reduce testing will also reduce the costs of certification and aircraft maintenance.



Such a methodology has been developed for the prediction of delamination growth in laminated composites at Syracuse University under FAA grant sponsorship. To predict delamination growth, the available energy to create a new surface area through delamination, defined as strain-energy-release rate, *G*, is compared to a critical value of that energy or toughness. If *G* at a particular delamination tip exceeds the material toughness, the delamination will grow. The developed methodology addresses both the computational difficulties and complexities of determining *G* and the experimental determination of material toughness for practical structural details (as shown above) found in composite aircraft structures.

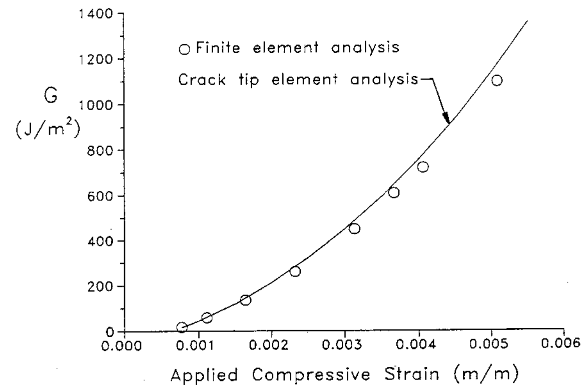
The developed methodology uses a crack-tip element (CTE) analysis based on classical plate theory. The CTE analysis provides closed-form expressions for *G* and for its components, G_I (crack opening mode) and G_{II} (sliding mode), respectively, in terms of force and moment resultants in the vicinity of delamination tip. Such quantities are usually available from a global finite element analysis (FEA) of the structural component. As this procedure is computationally efficient it can be used at a large number of interfaces where delamination growth is likely. Once *G* is calculated it is compared to material toughness at the appropriate mode mix ratio (G_I/G_{II}) to determine delamination growth initiation. In addition, the CTE approach allows non-classical definitions of the individual *G* components. This is useful for many laminated composites when classical linear elastic fracture mechanics (LEFM) is inapplicable. For those cases where the near-tip damage zone is small and the classical definitions of *G* apply, solutions by the CTE approach have been compared to FEA showing excellent correlation and computing efficiency. See comparisons on the next page for a laminate with a delamination under compressive loading. The predictions match not only the total *G* but also the mode mix as shown by the G_{II}/G plot.

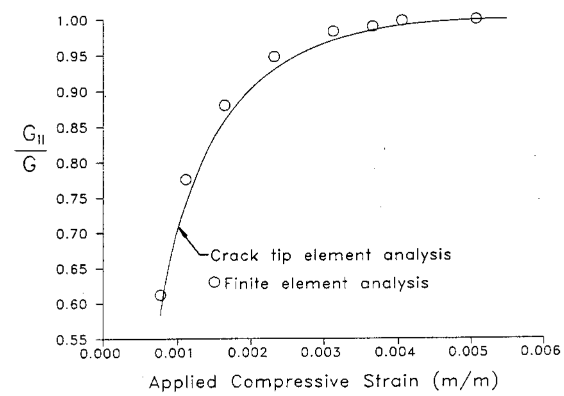
The experimental part of the methodology has established testing requirements to characterize fracture properties or toughness for various mode mix ratios of the composite material. Standard ASTM tests and newer methods were used to determine number of tests required and the specimen configurations. Data reduction of these tests was studied extensively and it was found that the CTE method provides a robust procedure to obtain a single value of toughness for the full range of mixed mode ratios.

Although the developed methodology has been demonstrated to work for unidirectional laminates of one material system, for the method to be accepted by the aircraft industry it must be shown to work for other material systems and other lay-ups and must be compared to test results of more complex structural details. This work and the extension to repeated load environments are underway.

The developed methodology has the potential of profoundly affecting design, analysis, and certification procedures for composite aircraft structures. First, it will allow a relatively rapid assessment at a large number of possible locations, under a wide range of loadings, as to whether delamination growth is likely. This will provide an early identification of possible failure sites that may not be found by the current selective testing approach resulting in improved flight safety. Second, knowledge of the critical size and location of delaminations will reduce maintenance activity as it will serve as a guide for repair actions. Finally, this methodology may allow the implementation of a more economic certification procedure based on a mix of analysis and testing to assure a damage tolerant structure, similar to that presently in-use for metallic structure.

POC: Mr. Peter Shyprykevich, AAR-431, (609) 485-4967.





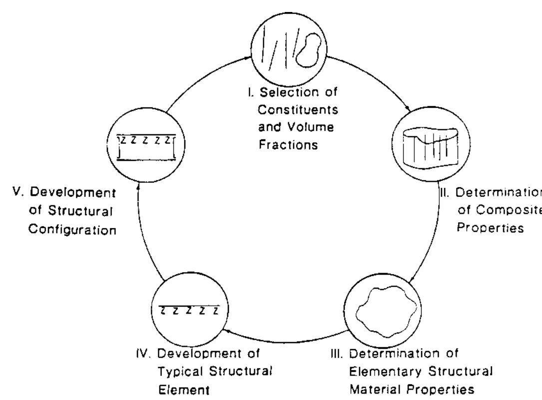
Handbooks for Advanced Composites

With the increased use of advanced composite materials in fabrication of commercial aircraft parts, there is a need to have readily available pertinent information on composites for use by the regional FAA offices. The information would be used to aid engineers and manufacturing inspectors in their certification and continued airworthiness activities.

Two handbooks "Fiber Composite Analysis and Design: Composite Materials and Laminates, Volume I" DOT/FAA/AR-95/29,I and "Handbook: Manufacturing Advanced Composite Components for Airframes" DOT/FAA/AR-96/75 have been published to provide this needed information. Both were complete revisions of texts that were first published in the nineteen-eighties.

The "Fiber Composite Analysis and Design: Composite Materials and Laminates, Volume I" provides an extensive background on the characteristics and mechanics of fiber reinforced composites which permits engineers experienced in the evaluation of structures involving conventional materials, especially metals, to extend their competence to the assessment of fibrous composite structures. The emphasis is on the definition of the nature and magnitude of the differences associated with the use of composites compared to conventional metallic materials and particularly on explaining the reasons for the differences and their implications for design evaluation. Accordingly, a broad spectrum of technologies is involved, ranging from detailed methods of analysis to more qualitative discussions on methods of analysis and design. The material is divided into two major categories: (1) composite materials and laminates, treated in Volume I; and (2) structures covered in a separate FAA technical report (DOT/FAA/CT-88/18, Volume II), which is currently undergoing similar revisions and should be available in early 1998. Volume I has been revised to include significant advancements in the design of composite structures as well as in the analysis mechanics of composites.

The design process for composites is essentially the same as for conventional metals. With composites, however, there is an additional requirement that the material be designed along with the structure. There are more steps required in the design cycle than heretofore with metallic structures, as illustrated in the following figure.



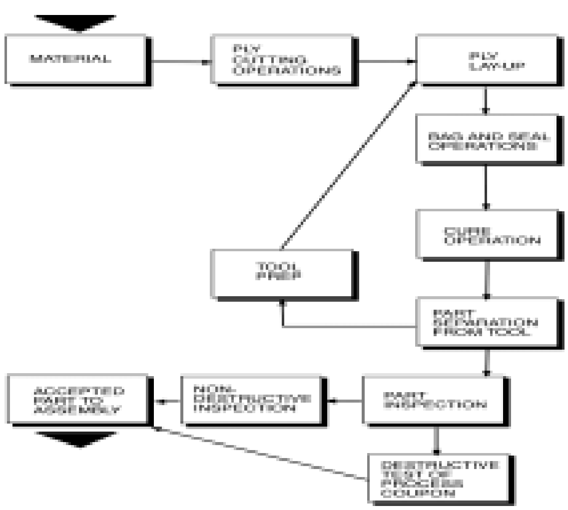
Thus, with composites, the possibilities of improvement in the design by reiteration of the design cycle are increased by the added steps in the design cycle. In other words, the structural efficiency of a design may be improved by changes in constituent properties and laminate configurations.

The "Handbook: Manufacturing Advanced Composite Components for

Airframes" is a compendium of information on methods of manufacture of advanced composite components for airframes. It is aimed at familiarizing the reader with the common industry standards and aspects of using composites in aircraft applications. The contents are drawn from various sources and are condensed into an easy-to-read, comprehensive format.

The contents of the handbook include introductory background on composite materials describing fiber reinforcements, matrix systems, core types and styles, handling, related practices found in the manufacturing and fabrication as well as the use of these materials, the concepts of producing parts using tooling, various manufacturing methodologies, processing, machining, quality assurance, assembly, repair, and related safety and environmental issues.

The organization and flow of the handbook are arranged to mirror that of the conventional processing of a composite part as shown below.



First, as with any material, an understanding of the basic materials with details on their unique properties are covered. Next, the steps required in the fabrication of a composite, beginning with the lay-up and orientation of the material in the mold, are described. From there, bagging, processing (cure), trimming, and installation of the composite parts are covered. Other topics include inspection, damage identification, repair, and safe handling requirements.

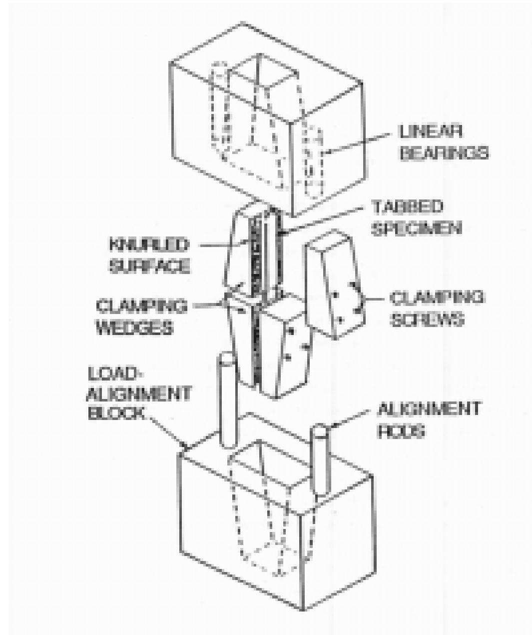
The handbooks will provide FAA personnel with a better understanding of composites. The topics addressed in these handbooks are considered essential for proper assessment of the engineering, design, and manufacturing qualities of composite parts used in civil aviation today and in the future. The handbooks are also distributed to the aerospace community who have found them to be useful.

POC: Mr. Donald Oplinger, AAR-431, (609) 485-4914, and Mr. Peter Shyprykevich, AAR-431, (609) 485-4967.

Compression Testing of Composite Materials

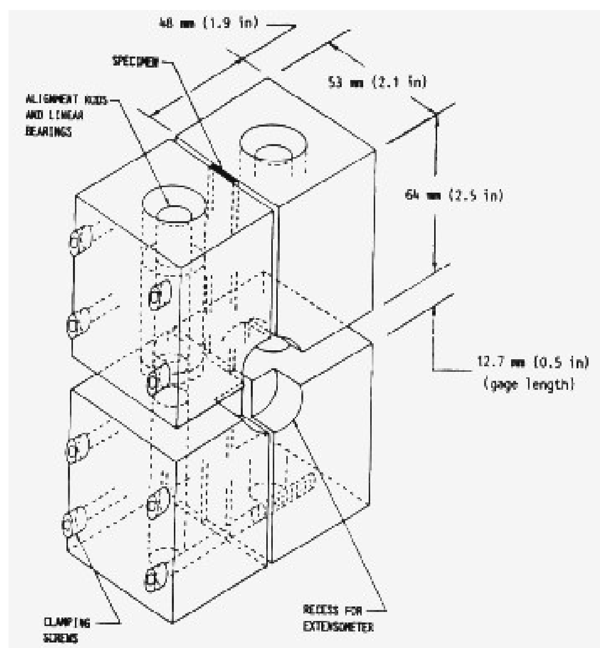
In contrast to metallic structures made with materials that are well characterized, certification of composite airframe structures requires a variety of structural property tests because of the influence of processing and resulting variability. Of the various properties (tension, compression, shear etc.) of composite laminates that must be determined, satisfactory measurement of compression strength values (related primarily to upper wing skin, lower fuselage, and various control surface applications) has been a major stumbling block to composite airframe manufacturers. Difficulty with compression testing can lead to high development costs of composite structures because of the need for repeating questionable test values, as well as inefficient use of these materials because of the extra conservatism which must be accepted in the presence of large scatter in test results. The Composite Materials Research Group (CMRG) at the University of Wyoming has made significant progress in overcoming the problems of compression testing of composites by developing an improved test method.

Existing test methods, such as the American Society of Testing and Materials (ASTM) Standard D 3410 IITRI compression test method seen above right, were first thoroughly examined to establish their limitations. Finite element analyses suggesting that a combination of shear and end loading would provide better test results by reducing detrimental stress concentration effects. This lead to the Combined Loading Compression (CLC) fixture shown below on the right.



IITRI Compression Test Fixture

The CLC test method has been received with considerable interest by the composites community. Members of the MIL-HDBK-17 Composite Materials Handbook Guidelines Committee,



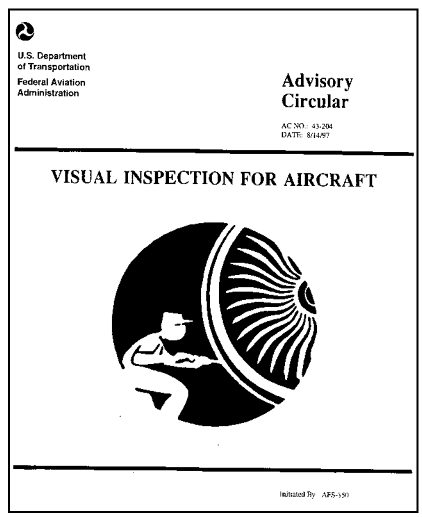
CLC Test Fixture

including representatives of Boeing, McDonnell Douglas, Lockheed Martin, Sikorsky, and the FAA, together with members of ASTM D30, have recently met to discuss the status of compression testing and the issue of adopting the approach developed by Wyoming CMRG as an industry standard. Adoption of the CLC test method as an ASTM standard is being given serious consideration. A program for making such a decision is being formulated and will be carried out within the next year.

POC: Donald Oplinger, AAR-431, (609) 485-4914.

Advisory Circular - Visual Inspection for Aircraft

Visual inspection is an essential part of airplane maintenance. Over 80 percent of the inspections on large transport category aircraft are visual inspections and the percentage is even greater on small transport and general aviation aircraft. Visual inspection is defined as the process of using the eye, alone or in conjunction with various aids, as the sensing mechanism from which judgments may be made about the condition of the object being inspected. Visual inspection is usually the most economical and fastest way to obtain an early assessment of the condition of an aircraft and its components. Many of the defects found on aircraft are found by visual inspections, and airframe manufacturers and users depend on regular visual inspections to ensure the continued airworthiness of their aircraft. It is important that visual inspection methods be understood and properly applied by those responsible for the continued airworthiness of aircraft. Proficiency in visual inspection is crucial to the safe operation of aircraft. Such proficiency is obtained through experience, but also by learning the methods developed by others. This advisory circular describes the methods of visual inspection and the ways they are used in the various inspections carried out on aircraft.


U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

AC NO.: 43-204
DATE: 8/14/97

VISUAL INSPECTION FOR AIRCRAFT

Initiated By AFS-350

Advisory Circular 43-204, “Visual Inspection For Aircraft” was completed and signed on 8/14/97 after an extensive FAA and industry review. The Advisory Circular was sponsored by the FAA Flight Standards Service, AFS-300.

POC: Mr. James Newcomb, AAR-433, (609) 485-5720.

Installation of Composite Doubler on L-1011 Aircraft in Delta Airlines Fleet

A boron epoxy doubler was applied as a door corner reinforcement on an operational Delta Airline, L-1011 on February 18 and 19, 1997. The installation occurred while the airplane was undergoing a heavy maintenance visit (D-check). The installed doubler passed all the planned inspections and was in service as of February 28. The FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) performed additional inspections of the doubler in order to accumulate history regarding the long-term doubler endurance under actual flight conditions. This activity represents the completion of the FAA-sponsored project which involved the services of the following organizational participants:

(1) FAA provided oversight and regulatory format approval.
(2) AANC provided project management, NDI development, validation, and structural testing.
(3) Lockheed provided doubler design analysis and OEM approval documents.
(4) Delta installed the doubler, issued process specifications, and provided engineering oversight.
(5) Textron provided doubler materials and installation training.

The bonded composite doubler has numerous advantages over the mechanical fastened repair. They are:

(1) adhesive bonding eliminates the stress concentrations caused by additional fastener holes,
(2) the composite laminate was easily formed to fit the contour of the fuselage section,
(3) corrosion resistance,
(4) a high strength-to-weight ratio, and
(5) economic advantages.

Delta's maintenance program indicates that the installation of the conventional metallic repair requires approximately 600 man-hours. The composite doubler installation and inspection required approximately 250 man-hours.

From an engineering view, the door corner application, shown below, provided a good showcase for composite doubler capabilities. The design, fabrication, and

installation challenges included large heat sinks, severe bending loads (shear stresses), a cutout in the center of the doubler, a complex geometry, multiple taper directions and an extremely thick (72 ply/0.040 inch) doubler.

The data resulting from this study serves as a comprehensive evaluation of a bonded composite doubler for general use. The associated documentation package provides guidance regarding the design, analysis, installation, damage tolerance, and nondestructive inspection of the doubler. The documentation package for this validation effort resides in the public domain. The FAA Atlanta ACO maintains the documents under the FAA project number SP1798T-Q. The engineering data and process specifications will also be published in a series of FAA DOT reports.

Currently, a composite doubler project with Boeing (Long Beach) and Federal Express is underway. Activities include the selection of candidate composite doubler repairs on Federal Express aircraft and identifying the specific tasks necessary to produce a composite repair installation on a DC-10 aircraft.

The main goals of the current composite repair program is to move the technology and associated validation into the repair regime, expand composite doubler sponsorship to another original equipment manufacturer, and complete the technology transfer to another carrier. A major emphasis is to streamline the design-to-installation process in order to make composite doubler technology more attractive for wide-scale use.

POC: Mr. James Newcomb, AAR-433, 609-485-5720.

Eddy-Current Methods for Crack Detection

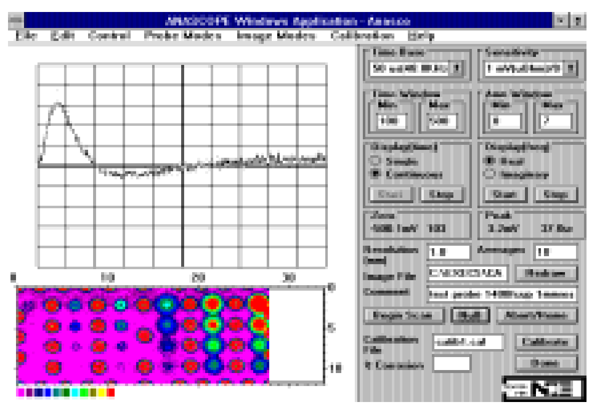
A novel pulsed eddy-current instrument (originally developed for use in detection of hidden corrosion in lap splices) has been adapted to detect small fatigue cracks in layered aircraft structures by researchers at the FAA Center for Aviation Systems Reliability–Iowa State University. The advantages of pulsed eddy-current techniques include the wide bandwidth attainable, which permits a single probe and a single measurement to provide information over a broad frequency range. Pulsed eddy-current signals can be used to characterize cracks and locate them in the depth of the material. Time gating of the pulsed eddy-current signals provides a means to discriminate against interfering signals from lift off, air gaps, and fasteners.

Pulsed-Eddy Current (PEC) Device

The principal advantage of the instrument developed in this program, as compared to the commercially available pulsed eddy-current instrument, is that this instrument can be adapted for use with any commercial probe and used in any type of geometry normally inspected with eddy currents. The commercial instrument employs a rotating Hall-effect sensor and is designed specifically for fastener inspection. The ability to scan and image areas up to 8 x 20 inches in size is a considerable advantage. The time-gating feature included in this instrument is a unique capability that has no parallel in commercial instrumentation.

Samples of laboratory-produced fatigue cracks are being obtained from Prof. Morris Fine and Ms. Zayna Connor of Northwestern University for further development of the technique. Work is continuing on optimizing probe design for flaw detection and increasing the scanner resolution to improve the detection of very small cracks. A constant current probe drive has been constructed and will be tested in the coming year. Demonstrations of the instrument at the FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC), Northwest Airlines, and Foster-Miller, Inc. are anticipated next year.

The instrument has been licensed to Sierra-Matrix, a California-based company, for commercialization.

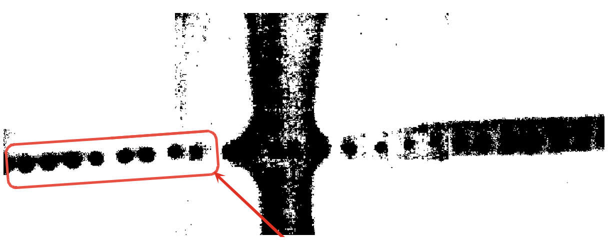


PEC Output Display

POC: Dr. Christopher Smith, AAR-433, (609) 485-5221.

Thermal Wave Imaging of Disbonding and Corrosion in Aircraft Structures

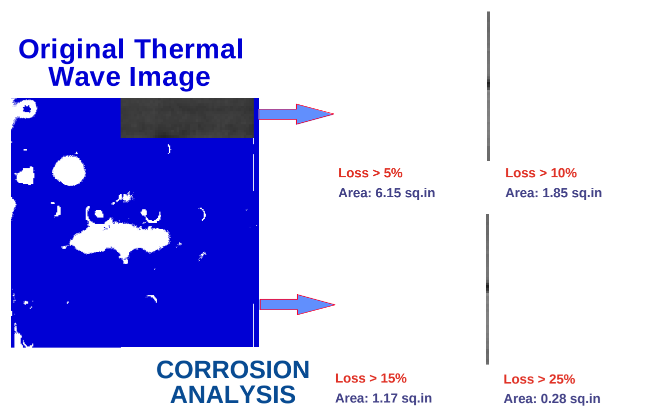
Infrared (IR) thermal wave imaging, developed by R. L Thomas and his team at the Center for Aviation Systems Reliability–Wayne State University, is a new technology with applications to aging aircraft. The technique uses pulsed surface heating (with flashlamps) and fast, synchronous IR video imaging of the surface temperature to form rapid (two or three second), wide-area (more than a square foot) images of subsurface structure, such as skin corrosion and disbonded doublers or tear straps. Images of doublers resemble x-ray images, with the disbonds showing as bright contrast on a dark background. On typical aircraft skins, thermal wave imaging is capable of measuring corrosion thinning with a sensitivity of better than 2 percent material loss.



Example of Disbonded (Left) and Bonded Doubler Regions on a B747 Aircraft.

During two 1997 visits to Northwest Airlines (NWA) and one to Boeing-Wichita the Thermal Wave Imaging (TWI) System demonstrated the capability to inspect painted aircraft without applying water soluble paint. In earlier versions of the TWI system, it was necessary to temporarily apply a water soluble paint to the area of the fuselage to be inspected. The inspection results were as good or better than results from the same area when paint was applied and were in agreement with independent inspections by NWA and Boeing personnel. This new capability significantly reduces the inspection preparation and cleanup time and should relieve recurring industry concerns regarding the application of paint to inspection areas.

Based on these demonstrations, Northwest Airlines has asked Boeing to authorize the use of thermal wave imaging for both the repetitive inspections and the terminating actions called for in service bulletins. United Airlines has also asked Boeing to authorize the use of thermal wave imaging for similar authorization for a separate inspection application. Boeing intends to pursue activities required to add thermal wave imaging to their nondestructive testing (NDT) manual.



Example of Corrosion Analysis of a Two-Layer Corrosion Test Specimen.

Intergranular Corrosion Creeping out From Under the Countersunk Fastener Heads (Bright Areas) on 3 of the 4 KC-135 Wing Fasteners Displayed.

POC: Dr. Christopher Smith, AAR-433, (609) 485-5221.

Visual Inspection Reliability

The FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) has completed benchmark experiments on the reliability of visual inspection. The experiments are part of a coordinated effort to examine a broad range of visual inspection tasks. The experiments used professional aircraft inspectors, inspecting real aircraft, and were designed to be broadly applicable to a large class of visual inspection tasks.

The primary test beds consisted of a Boeing 737 and a Fairchild Metro II commuter aircraft. Both aircraft are part of the AANC's collection of test specimens. Simulated lap splice specimens with well-characterized cracks were also used in the experiments.

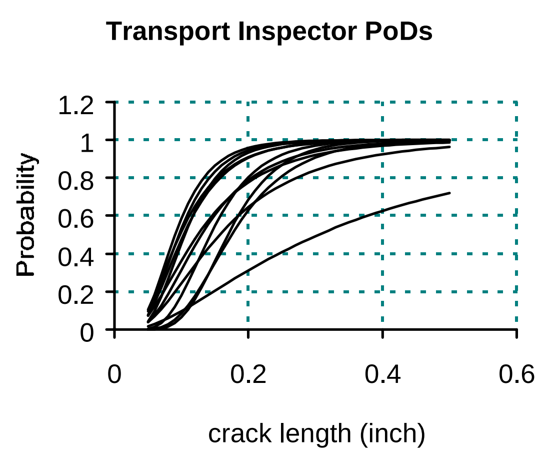
The experimental program consisted of two different phases. The first phase used the Boeing 737 as a test bed and included 12 inspectors from four different major airlines who have the Boeing 737 in their fleets. The second phase used the Fairchild Metro II and included 11 inspectors from North American commuter and cargo operators with the Fairchild Metro in their fleets. Each of the inspectors spent two days at AANC performing different inspection tasks specific to their background. Both groups also inspected the simulated lap splice specimens.

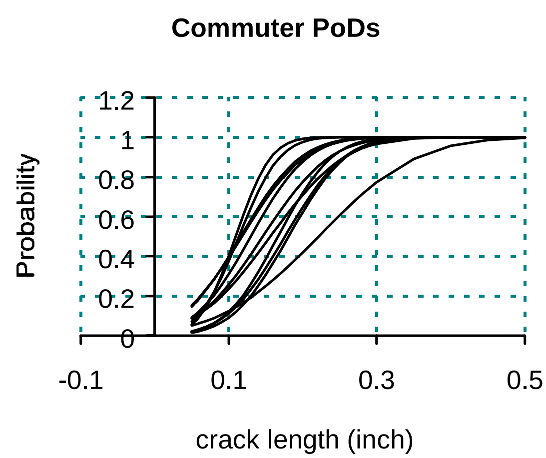
Following are some significant observations coming from these experiments.

1. Substantial inspector-to-inspector variation in performance existed. The two figures on the right (Transport and Commuter PoDs) show probability of detection curves fit to results of the simulated lap splice inspection for cracks from beneath rivets. Comparable inspector-to-inspector variation, as well as an overall level of detection, is exhibited in each of the population of inspectors. The commuter inspectors spent more time on the task and produced more false calls. This is as expected since the specific task was more familiar to the transport inspectors.

2. Performance levels were task specific. An inspector's good performance (relative to other inspectors) on one task did not necessarily indicate a relatively good performance on other tasks.

3. The AANC investigators were able to distinguish inspector failures of detection specific to the searching for cracks from a decision failure in





calling an indication a crack. The search component of the process was the larger factor in determining performance levels, although the decision process accounted for much of the worst performance. The implications here are that most, if not all, inspectors can benefit from training interventions that address search procedures.

4. Both test-beds contain several cracks that were found by only one or two of the inspectors, and not the same inspectors. The lengths of these test-bed cracks did not significantly contribute in predicting the number of inspectors that would detect them. The implication of these results is that probability of detection curves as a function of crack length are meaningful only within specific inspection tasks and conditions of inspection.

POC: Dr. Chrisotpher Smith AAR-433, (609) 485-5221.

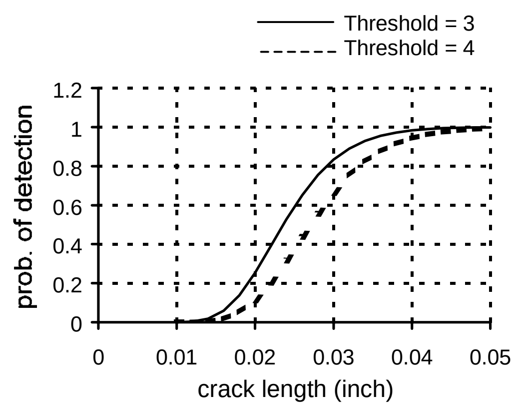
Eddy-Current Detection of Small Cracks

Over the past few years the FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) has conducted numerous experiments using a variety of eddy-current inspection equipment to inspect for small cracks from beneath rivets. All of the experiments were performed as blind experiments. That is, the person or persons performing the inspections did not know whether any specific inspection site contained cracks or not. In this way the inspections mimicked conditions of actual inspections that would take place in normal use conditions.

Equipment included in the study were the following off-the-shelf equipment: Nortec 30 Eddyscan, Krautkramer Branson Crackfinder, Hocking FastScan, Nortec 19e with sliding probe procedure, and MIZ22 with pencil probe and template procedure. Also included were instruments or probes recently developed that are not readily available to the public. These include the Northrop-developed low-frequency eddy-current array (LFECA), the NASA-developed rotating self-nulling probe, and a McDonnell Douglas Aerospace/GK Engineering surface scanning probe used with an Elotest B1 minirotor.

Eddy-current procedures commonly employed in aircraft inspection are capable of reliably detecting cracks as small as 0.050 inch while maintaining false calls below 1 percent. However to achieve such detection rates requires careful settings of threshold levels and appropriate standards for setup.

There are newly developed techniques and instruments that are capable of doing better. The NASA self-nulling rotating probe demonstrated that it could reliably be used to find cracks as small as 0.032 inch and the Northrop LFECA demonstrated a capability of reliably detecting cracks as small as 0.040 inch. These rates were achieved without an increase in false calls. (Illustrative probability of detection curves for the NASA probe are shown in the figure.)



Other experimenters have reported that the Hocking FastScan, Nortec-30 Eddyscan, Northrop LFECA, and GK Engineering/Elotest are capable of detecting surface cracks 1.0 mm (0.040 inch) in length under flush-head aluminum rivets. The AANC study extends these results and indicates that although capable of detecting this size crack, the probability associated with routinely detecting them (at false call rates < 0.01) are approximately 0.23 (FastScan), 0.74 (Eddyscan), 0.88 (LFECA), and 0.67 (GK).

The effect of inspecting through paint (0.003 to 0.005 inch) is often a decrease in the probability of detection. However, this effect seems to be due primarily to the difficulty in properly centering the probe over the rivets rather than because of the paint layer. Techniques that give the operator signal feedback that can be used to assure proper centering were shown to be effective in removing this level of paint as a major reliability factor.

The AANC also addressed methodology issues for estimating probability of detection curves from signal data. Specifically, they have shown that the traditional "*a*-hat versus *a*" analysis that looks at NDI signal strength versus flaw size can be generalized by considering an analysis performed on crack flaw predictions based on the signal strength. The predicted values are treated as the dependent variable with the flaw characteristics as the independent variables in the traditional "*a*-hat versus *a*" analysis to estimate the probability of detection curve. This proposed methodology was shown to be equivalent to the "*a*-hat versus *a*" analysis when there is a single dimensional signal, but offers the capability of extending the analysis to multiple dimensions of a signal.

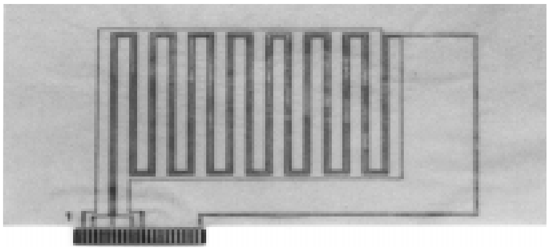
POC: Dr. Chrisotpher Smith, AAR-433, (609) 485-5221.

Early Fatigue Detection and Characterization Using the Meandering Winding Magnetometers

A thin, conformable eddy-current sensor and associated grid measurement algorithms invented at the MIT Laboratory for Electromagnetic and Electronic Systems was further developed under FAA and DoD sponsorship by JENTEK Sensors, Inc. The Meandering Winding Magnetometer (MWM™) measures electrical conductivity profiles as a function of depth from the outer skin surface. The sensor has the capability to:

- provide manufacturing quality control and fatigue and thermal degradation monitoring for coated and uncoated engine components (e.g., thermal degradation of thermal barrier coatings, overtemperature for 718 alloy blades, and degradation of diffused aluminide coatings for turbine blades)
- detect signs of unusual material distress in aircraft skins and structural members prior to the formation of detectable cracks, which may provide evidence of the onset (or absence) of widespread fatigue damage

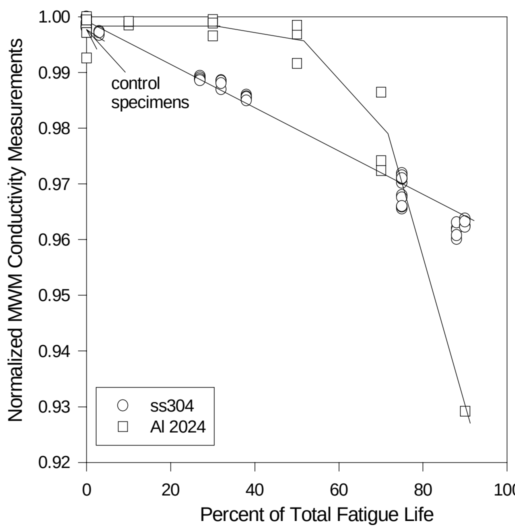
The patented MWM sensor shown below has demonstrated the capability to measure the thickness variation of thermally grown oxide layers under thermal barrier coatings with a precision of better than 1 micron.



MWM Sensor

The MWM sensor is essentially a transformer confined to a single plane. The impedance (secondary voltage/primary current) magnitude and phase is converted to electrical properties at each applied frequency using a patented measurement approach. The measurement grids (look-up tables) are generated off-line (in advance) using a model of the MWM interactions with multiple-layered media, such as an aircraft skin lapjoint. These grids are then stored in a grid library. The grids and GridStation™ software provide real-time electrical property profile measurement as a function of depth from the exposed surface. The MWM is thin and flexible permitting inspection of complex geometries such as the leading edge of an airfoil/root transition region for a turbine blade.

The figure below shows the results of single frequency MWM measurements on aluminum and stainless steel bending fatigue specimens. Photomicrographs of sectioned aluminum specimens show microcrack clusters approximately 1-3 mills deep near the surface for specimens at 70% of the estimated fatigue life. These microcracks could not be detected with focused liquid penetrant testing. The stainless steel specimens showed no microcracking at 75% of the estimated fatigue life. JENTEK is working on similar curves for titanium and nickel alloys used in engine components.



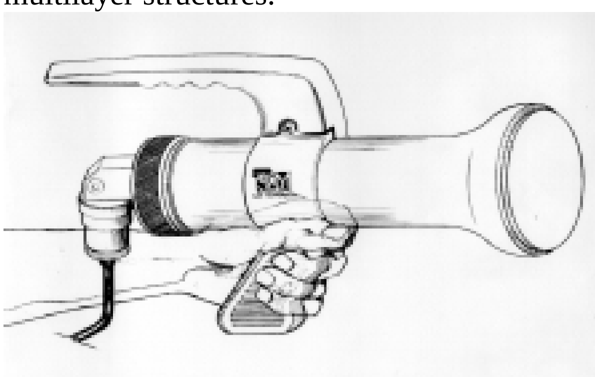
MWM Single Frequency Measurements on Four Point Bending Fatigue Specimens.

JENTEK Sensors, Inc. has continued this technology development under an FAA Phase I Small Business Innovative Research (SBIR) for commercial aircraft applications, and under a Navy Phase II SBIR for military aircraft. JENTEK plans to continue the testing and validation of this technology on the Boeing 737 test bed and engine test specimens at the FAA AANC. The MWM and portable GridStation™ system are now commercially available from JENTEK Sensors, Inc. For more information contact Dr. Neil Goldfine at (617) 926-8422.

POC: Dr. Chrisotpher Smith, AAR-433, (609) 485-5221.

Superconducting Quantum Interference Devices for Detection of Hidden Cracks

Pulse-excited superconductive quantum interference devices (SQUIDs) are a new technology for eddy current evaluation of aircraft structures. Their high sensitivity at extremely low frequencies enables penetration of 15 mm of aluminum (0.6 inch) through multiple layers to identify submillimeter fatigue cracks and material loss of less than 5 percent. In combination with emerging eddy-current scanning techniques, this technology is capable of a three-dimensional view of defects in sublayers and tomographic imaging of multilayer structures.



Hand-held scanning head

In recent years the price and capability of superconducting technology have arrived at a point where near-term (2-3 year) implementation in airframe manufacturing environments, and subsequently in airframe maintenance facilities, is possible. This and the FAA's increasing interest in thicker structure motivated the FAA to fund a Phase I Small Business Innovative Research proposal submitted by SQM Technology in late 1995.

Results of the Phase I work include:

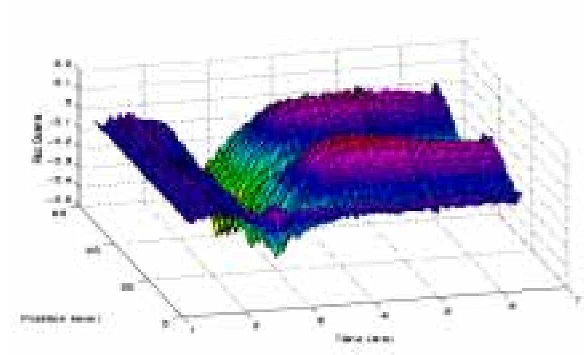
- Detection of a 1 mm change in thickness through 5, 10, and 15 mm of aluminum plate to demonstrate deep penetration of pulsed eddy currents with SQUIDs.

- Resolution of the lengths of millimeter size cracks through 10 mm of aluminum plate with SQUID pick-up loops of 1 mm diameter.

- Time discrimination of pulsed eddy currents that separates surface effects, like lift-off and tilt, from signatures of deep cracks.

- Submillimeter sampling at scan rates of 1mm/sec or more over a 25 mm swath.

- Demonstration of the feasibility of a small hand-held unit suitable for a field environment.



25 mm Crack Under 10 mm Al

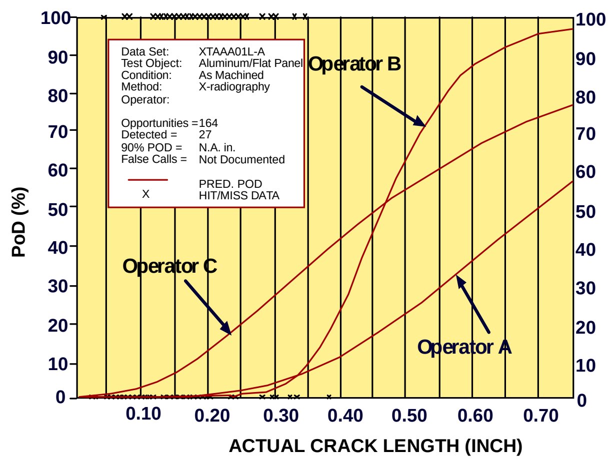
POC: Dr. Christopher Smith, AAR-433, (609) 485-5221.

NDE Capabilities Data Book

An FAA program, conducted by the Nondestructive Testing Information Analysis Center (NTIAC), is in progress to collect, analyze, and organize documented probability of detection (PoD) data and information for a variety of nondestructive evaluation (NDE) methods, procedures, materials, and applications related to aircraft inspection. PoD has been used as a quantitative measure of NDE reliability and capability for a number of years. Originally developed as a data presentation approach to meet functional engineering analysis needs, the concept has grown into a recognized approach for comparison of the performance capabilities of various NDE procedures, for quantification of improvements in NDE procedures, for validation and management of NDE system performance, and for personnel skill development and qualification. Compilation of this information into an *NDE Capabilities Data Book* provides an engineering reference for use in NDE engineering analyses and for development and validation of new NDE procedures. PoD reference data in the Data Book can be used in selecting an NDE procedure for a specific application and for assessing the potential equivalency of an alternate NDE procedure.

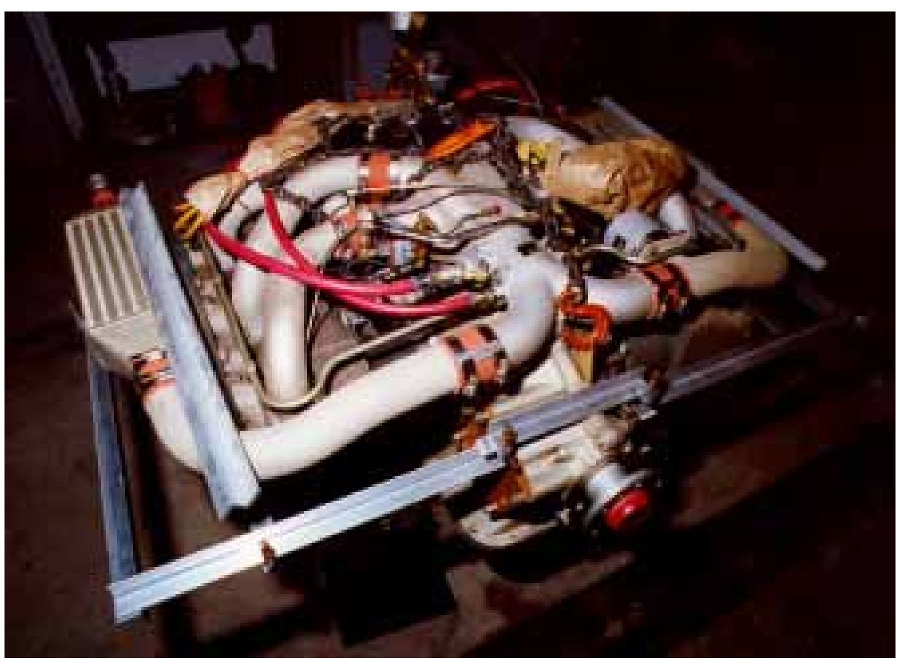
The current edition of the *NDE Capabilities Data Book*, available in both hard copy and on compact disk, contains 284 PoD curves presented and organized by NDE method. A documentation page precedes each PoD data set and provides a condensed description of the test object, test artifacts, NDE procedures, and results summary. The PoD curves for varying test object, test artifact, and data collection conditions are presented as a function of crack length and as a function of crack depth and crack depth-to-thickness ratio for selected datasets. Original reference source information is provided for each data set. Work is continuing on upgrading the Data Book with additional PoD information, such as the visual inspection reliability data developed by the FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC).

POC: Dr. Chrisotpher Smith, AAR-433, (609) 485-5221.



Example PoD Curves From the NDE Capabilities Data Book

Propulsion Systems



Economical Eddy-Current for Engine Components

In an effort to eliminate potential service inspection problems before they result in serious consequences, the FAA Engine Titanium Consortium (ETC) is working with the airlines to identify common servicing needs of the most popular engine models. As a result of their efforts, there now exists a suite of eddy-current tools which allows controlled scanning and digital data acquisition for a variety of applications.

A portable scanner and data acquisition system have been developed for use in airline overhaul and maintenance shops. The portable scanner consists of a generic mechanical scanning system with application specific tooling for probe positioning and manipulation. Adapter plates are used to mate the mechanical scanning system to a variety of engine disks by using the bolt hole patterns to align the system to specific disks. A lunch box computer has been used for data acquisition and analysis. The system has been interfaced with a variety of commercially available instruments as well as conventional and wide field probes, including the ETC-developed probe.

A series of onsite meetings at airline maintenance and overhaul facilities and a survey of over 50 national and international engines were used to determine the features of the final product. The ETC scanning tools have been demonstrated at the ATA NDT Forums annually since 1994. This continues to provide valuable input to the application of the tools. In addition to the commercial aviation community, the portable scanner concept has been discussed with potential military users including demonstrations at several Air Force sponsored meetings. Key inspection personnel from the Tinker AFB Air Logistics Command, Oklahoma City, and the Wright Patterson R&D staff will participate in the upcoming demonstration at American Airlines.

To date, bore scans (axial motion), web scans (radial motion), and slot scans have been demonstrated on engine hardware from all three engine manufactuers involved in ETC: Pratt & Whitney, General Electric Aircraft Engines, and AlliedSignal. Validation testing has been completed at United Airlines and Northwest Airlines where efforts focused on inspection of the 14^{th} and 15^{th} stages of the JT9D compressor disks. Additional validation testing is under way with AlliedSignal and is planned with American Airlines. Signal processing tools are being developed at Iowa State University for use in the AlliedSignal applications.

ETC Portable Scanner Applied to AlliedSignal Engine Component.

The Northwest Airlines Atlanta facility has expressed interest in conducting validation testing in late 1997 or early 1998. To date the scanner and data acquisition system have been successfully adapted for use with six instruments at various airline facilities. In addition to the intended jet engine applications, minimal adaptation has enabled the system to be applied to inspection of propeller blades, reportedly saving the industry over $10 million.

Commercialization discussions began with applicable vendors in 1996 and led to the recent partnership with Uniwest. The first commercial version of the scanner is expected to be on the market in early 1998. Several airlines and OEMs have expressed interest in purchasing the scanner for future inspection initiatives.

POC: Dr. Christopher Smith, AAR-433, (609) 485-5221.

Enhanced Turbine Rotor Material Design and Life Methodology

A major, ongoing, multiyear program managed by the FAA Airworthiness Assurance R&D Branch through a cooperative grant to Southwest Research Institute (SwRI) with engine company partners General Electric, Pratt & Whitney, Allied Signal, and Allison features the development of a probabilistic code to improve the structural integrity of failure critical turbine rotor disks used in commercial aircraft engines. The research team led by SwRI produced a major deliverable in the summer of 1997. The first functional version of the code was completed, called DARWIN (Design Assessment of Rotors with Inspection) incorporating the most sophisticated risk assessment methods into design procedures. The deliverable featured a user manual with executable source code and example problems. A successful evaluation and verification was completed by AlliedSignal using a company impeller design example. The figure on the next page shows the framework for this integrated rotor design code.

When completed, the code will be the basis for an approved FAA advisory standard that engine companies can incorporate into their design systems. The anticipated outcome when fully implemented will have the potential to reduce the uncontained rotor disk failure rate while providing more realistic inspection schedules.

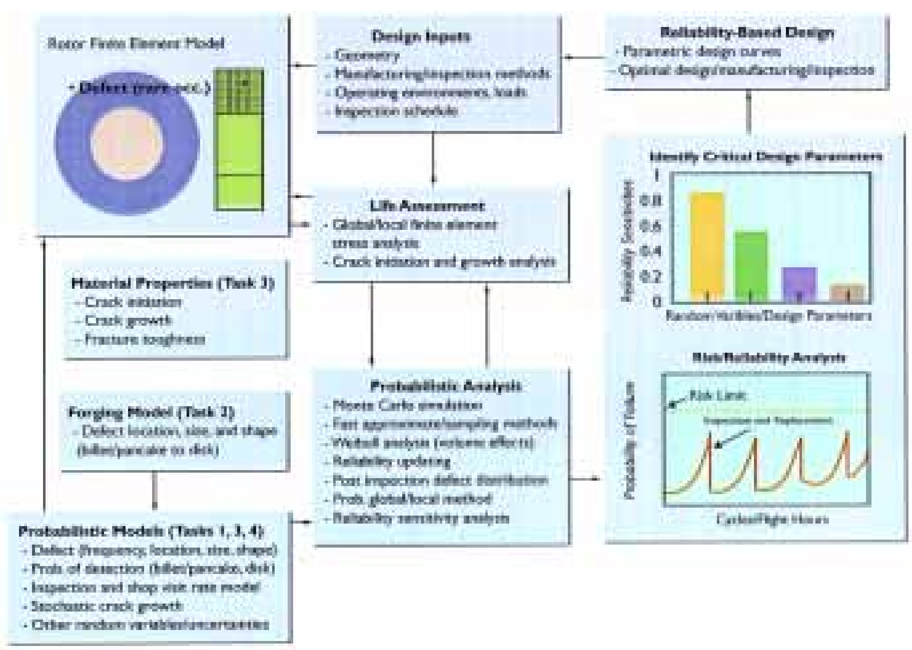
Current design practice for these critical engine parts uses a safe-life approach. This method assumes that any material or manufacturing condition that could affect the life of a part, such as a material flaw, is addressed by the rigorous standard testing procedures carried out in manufacturers' laboratories as well as by conservative estimates of mechanical properties.

However, service experience by the aircraft turbine engine industry has shown that despite this rigorous approach, material and manufacturing flaws that can reduce structural integrity may remain undetected. As an example, the loss of a DC-10 at Sioux City, Iowa, in 1989 which was caused by an uncontained disk failure was eventually traced to just such an undetected defect. The chance of these flaws being detected by standard nondestructive testing procedures is very small.

In response to this issue, the FAA, working closely with the engine industry through the Rotor Integrity Subcommittee of the Aerospace Industries Association, has developed supplemental design and lifing methods that formed the basis for this research program. The probabilistic design code standard developed by this program does not replace the current safe-life methods but provides an additional tool to minimize the risk of failure.

The first phase of the program is focusing on the presence of melt-related defects, known as hard alpha, found in titanium alloys. Hard alpha refers to small zones in the material microstructure stabilized by the presence of nitrogen, which can be introduced at various stages in the melting history of the alloy. The zones often have cracks or voids associated with them and can initiate the low-cycle fatigue cracks that contribute to disk failure. Future phases of the program may apply the methodology to other types of titanium flaws and to other widely used rotor metals such as nickel alloys.

POC: Mr. Bruce Fenton, AAR-432, (609) 485-5158.



Fleet Octane Requirement for Unleaded Fuels

The 1990 Clean Air Act Amendments passed by the US Congress called for the elimination of the use of tetraethyl lead in all fuels. Since that time the FAA has been encouraging a partnership between government and industry to oversee the development of an unleaded fuel to replace the primary fuel used by the general aviation industry, 100 low lead (100LL).

In February of 1995, a Coordinating Research Council (CRC) committee was formed with members from the FAA and private industry to oversee the development of a replacement fuel for 100LL. This forum has served as a mechanism for the competitive interests of individual segments of the general aviation industry to share information and help foster the development of a new unleaded aviation gasoline.

Soon after its formation, the CRC committee agreed that determining the octane requirement of the general aviation fleet was the most important parameter demanding immediate attention. The lead in the fuel provides the octane rating necessary for the safe operation of high-performance general aviation piston engines. Data generated by the FAA William J. Hughes Technical Center on test engines, shown on the right, has yielded data to develop and validate a ground-based procedure to determine an engine's octane requirement. That procedure has been documented in a draft report that will be submitted at the next semiannual American Society of Testing and Materials (ASTM) meeting for approval as an ASTM standard procedure.

Octane rating tests conducted in FY97 determined that to date no engines have performed with 100% satisfaction on the primary reference fuels. This result has forced the generation of new formulations, from the participating oil companies, of unleaded primary reference fuels that will have octane ratings higher than 100. Prior to this development, primary reference fuels needed lead to get a rating higher than 100. FY98 promises more developments in this area that should yield the first submission of industry-supplied replacement candidate fuels.

POC: Mr. Stewart Byrnes, AAR-432, (609) 485-4499.

Uncontained Turbine Engine Debris Characterization and Vulnerability Analysis

Uncontained turbine engine events have caused catastrophic results to aircraft. The FAA saw a need to update advisory material relative to uncontained turbine engine failures. An Aviation Rulemaking Advisory Committee (ARAC) was tasked to update Advisory Circular (AC) 20-128, "Design Considerations for Minimizing Hazards Caused By Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Failure." This group determined that there was a need to better characterize the types of failures, number of fragments, velocity of fragments, and damage caused by these fragments. However, engine and airframe manufacturers, who considered this data to be proprietary, had collected much of the data needed to do this. Therefore, in 1995, the FAA Technical Center entered into an interagency agreement with the Naval Air Warfare Center, Weapons Division (NAWCWD), China Lake, CA , to gather this data and conduct an analysis of the data which could then be used to update AC 20-128. Data was given freely to NAWCWD because this organization had pre-existing nondisclosure agreements with most engine and airframe manufacturers and could therefore respect the proprietary nature of this data. This data has now been analyzed and the results have been made available to members of the ARAC to use for the update of AC 20-128. The results of this characterization of uncontained debris will also be published shortly in an FAA report to be prepared by NAWCWD. Additionally, this characterization will also be used to prepare stochastic models of uncontainment events of various types to be used in conjunction with vulnerability assessment tools. These tools (FASTGEN 3 and COVART 4.0) have been used by the military to assess the vulnerability of their aircraft to hostile threats. By modifying this code for use by civilian airframe manufacturers, the vulnerability analysis of a commercial airframe to the threat from uncontained engine debris can be conducted. NAWCWD and their support contractor, The Service Engineering Company, have already identified certain modifications to this code. These modifications will begin shortly. In addition, initial testing of these vulnerability assessment tools by airframe manufacturers will begin shortly. Both Boeing and McDonnell Douglas will conduct initial evaluations of the vulnerability assessment tools under contract from NAWCWD. Both contractors shall provide recommendations, which will improve the tools' ability to assess aircraft safety to the uncontained engine debris threat. NAWCWD will then prepare a vulnerability assessment tool improvement plan. The resulting vulnerability assessment tools will enhance the safety of commercial aircraft by providing the means to critically examine the threat posed by uncontained engine debris and allow steps to be taken to mitigate the threat.

POC: Mr. Robert Pursel, AAR-431, (609) 485-6343.

Crashworthiness

Overhead Stowage Bin Research

Recent aircraft accidents have shown that a serious threat to the safety of aircraft passengers in an accident is the contents of the overhead stowage bins or the bins themselves. One test series has been conducted and another test series is currently underway which seek to quantify the threat posed to the passengers. Ten-foot sections of narrow-body fuselages (accompanying photograph) have been configured with in-service overhead bins from various manufacturers. These fuselage sections are then subject to both nondestructive horizontal accelerations and destructive vertical drop tests to simulate actual severe but survivable accidents. The bins are highly instrumented. Test results to date indicate that the failure mechanism of the bins may be highly dependent on bin design and attachment to the fuselage.

POC: Mr. Gary Frings, AAR-431, (609) 485-5781.

Commuter Airplane Dynamic Drop Testing

Dynamic seat testing requirements had been adopted for all categories of aircraft except small commuters. To define the loads and structural deformations which this type of airplane might experience, a series of destructive dynamic drop tests (accompanying photograph) have been conducted which simulate a severe but survivable crash environment. Results to date indicate that these fuselages are very stiff. Consequently, the loads experienced by the passengers are relatively high. Dynamic seat testing requirements should reflect the results of this research.

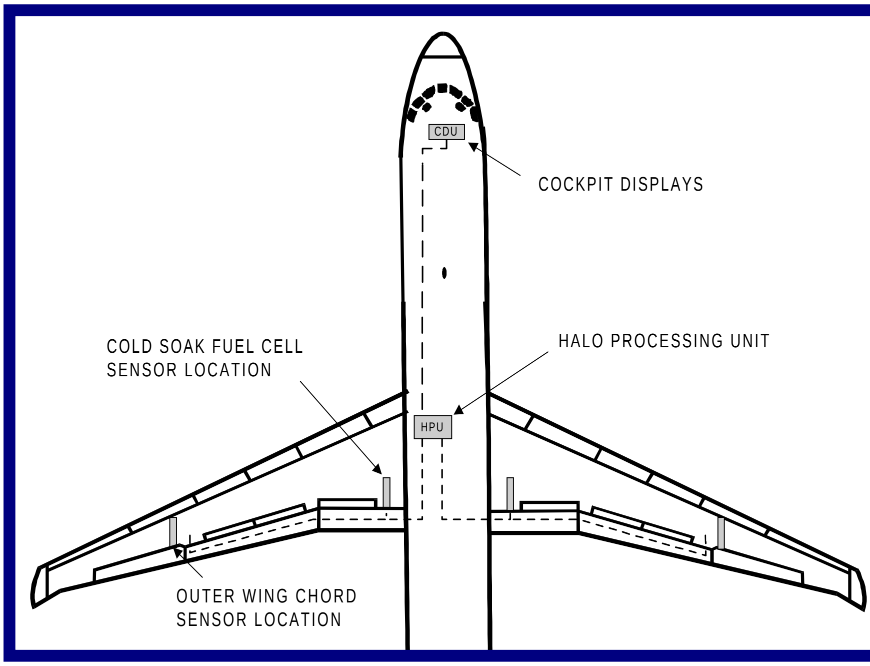
POC: Mr. Gary Frings, AAR-431, (609) 485-5781.

Head Injury Criterion Research

A unique pass/fail certification requirement exists in the seat dynamic performance standard relative to passenger head injury criteria (HIC). To determine if a manufacturer's seat installation passes this requirement, dynamic sled testing of the seat installation must be conducted. This testing is expensive and time consuming. A HIC component tester (shown in the photograph), used in lieu of actual sled testing during the developmental stage, would be an invaluable aid. Research conducted to date holds out the promise that such a component tester might be available for seat installation developmental purposes.

POC: Mr. Gary Frings, AAR-431, (609) 485-5781.

Safety of Flight



Aviation Risk Analysis Rapid Prototyping Facility

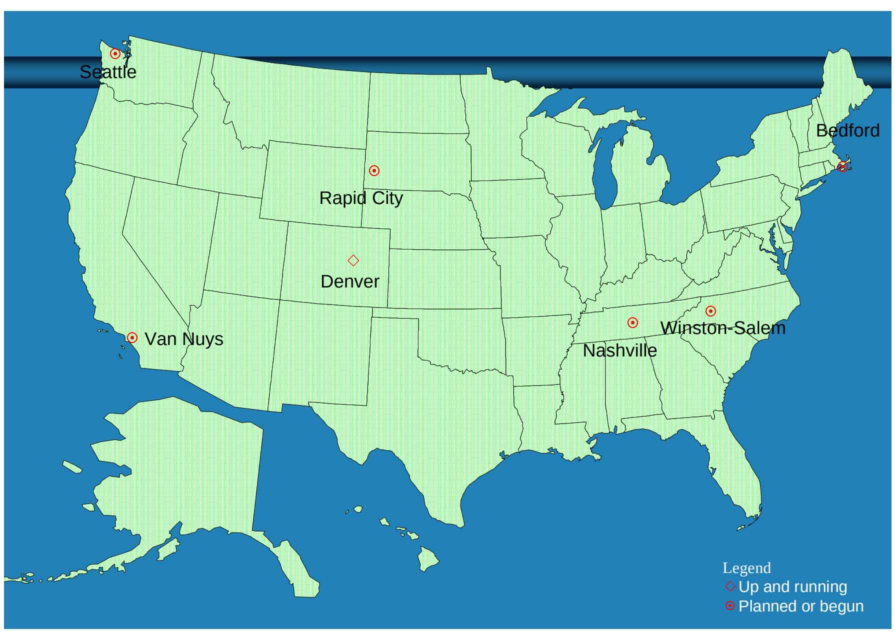
In 1997 the Aviation Risk Analysis Section established a rapid prototyping facility at the FAA William J. Hughes Technical Center. The mission of this facility is to develop sophisticated analytical techniques using data from the various data sources to support decision making regarding the safety of commercial aviation operations. Response is quick since the extensive coordination necessary to develop out-of-house requirements is bypassed. The prototype software is installed in the field and evaluated to determine the operational efficacy of the analysis results.

The core of this facility is a 180 MHz Pentium processor server with 132 MB RAM and 32 GB of hard drive space. This server is running Microsoft Windows NT Server 4.0 and Microsoft SQL Server 6.5. Periodically the data base is refreshed with data from various data sources uploaded via the FAA Wide Area Network (WAN). Two full-time mathematical analysts with extensive experience in engineering data analysis comprise the development team.

The development team participates in several expert panel meetings chartered to publish the requirements of the safety analysis program. From observations at these meetings and review of the proceedings, the team develops prototype algorithms and data presentation methods to assist the users, aviation safety inspectors, in uncovering potentially hazardous situations involving commercial civilian aviation operations.

To date, several field facilities have been targeted to receive the prototype software for evaluation purposes (see map below). The program is installed by downloading the software from the file transfer protocol (FTP) site housed within the same NT Server.

POC: Mr. Carmen Munafo, AAR-424, (609) 485-5907.



SPAS Performance Measures Components

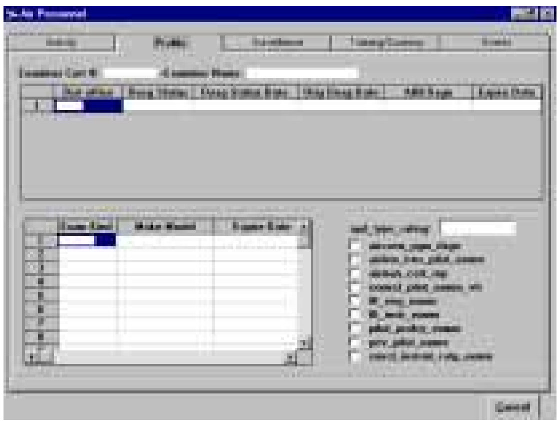
The performance measures of Safety Performance Analysis System (SPAS) are under development by the Risk Analysis Section (AAR-424) at the FAA William J. Hughes Technical Center. Early in the development, it became apparent that performance measures in the format that was used for large air carriers would be difficult to implement and would not, in general, result in useful performance measures. The purpose of the work at the William J. Hughes Technical Center is to integrate the information, display background information, perform computations of parameters required for surveillance, investigation, and certification activities, and to provide continuous monitoring of critical parameters. The objectives are to provide a means of informing Aviation Safety Inspectors of potentially important situations and to expedite the inspector's activities in the areas of certification, re-certification, surveillance, and investigation by providing readily accessible information from a variety of data sources.

The Risk Analysis Section produced a set of working models to support development of integrated performance measurement and information profile software for the Air Personnel and the Air Agency component of SPAS. These measures will include flags to advise the inspector of the need for closer analysis, numeric data resulting from computations that generated the flag, and raw data in tabulated query form that support the computations. These working models use the Microsoft Visual Basic language and data from a variety of data sources. The working models were used for prototype analysis and interaction with SPAS expert panels during development of SPAS components.

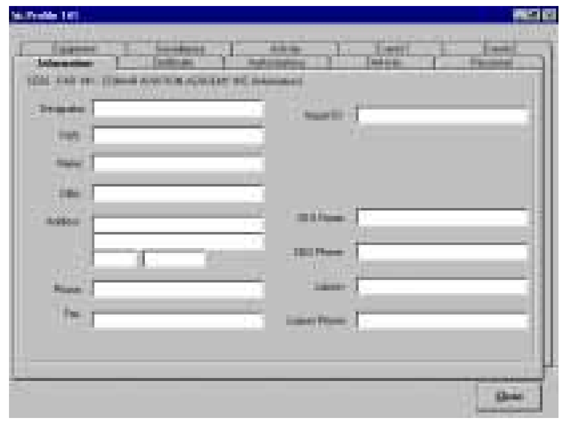
For the Air Personnel component, a wide variety of air personnel further complicated the issue. The resulting concept became a blend of context-sensitive, rule-based performance measures and an expanded personnel information profile. A set of general areas of interest (personnel dimension) has been specified which may have more than one parameter, depending on the specific type of personnel concerned. Specific performance measure parameters will be based on computations concerning activity, events, dates of required actions, etc. Specifications for Designated Pilot Examiners, Designated Mechanic Examiners, Certificated Flight Instructors, and Mechanic with Authorization have been completed and was submitted to the Volpe Center on September 30, 1997, for production. Research and development will continue on other types of Air Personnel that were specified by the Air Personnel Expert Panel. The figures on the next page show some of the typical screen layouts for SPAS.

The proposed Air Agency component used an extensive agency profile and a set of rule-based performance measures. Certain data was highlighted to provide inspectors with information regarding required actions or other information which might influence their decisions. This highlighted data is displayed in the same manner as performance measures but will usually not involve computations and may not directly reflect a problem of the agency's performance. For the Air Agency component, specifications for Certificated Repair Stations were completed and submitted to the Volpe Center on April 29, 1997, for production. The development of the Repair Stations profile and its imbedded performance measures were released in SPAS II in mid-September 1997. The draft Schools and Training Centers Software Requirements Specifications was submitted to Volpe Center on August 8, 1997, for production. Research and development will continue on other performance measures that were specified by the Air Agency Expert Panel.

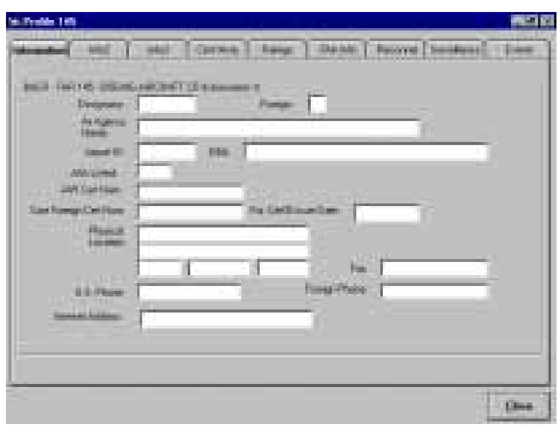
POC: Ms. Cristina Tan, AAR-424, (609) 485-8168.



Qualification/Profile Section Screen Layout



School Profile Information Section Screen Layout



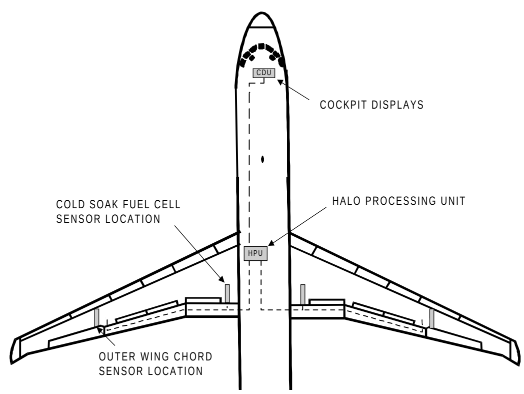
Repair Station Profile Information Section Screen Layout

HALO™ Ice Detection System

In response to a number of aircraft accidents attributed to frozen precipitation and/or ice on critical aircraft aerodynamic surfaces, the FAA mandated the “Clean Wing” concept. The Clean Wing concept prescribes that no aircraft may take off with frozen precipitation adhering to its critical aerodynamic surfaces. In order to assure that their aircraft have clean wings during takeoff, airlines commonly employ glycol-based deicing and anti-icing fluids.

Both deicing and anti-icing fluids have holdover timetables (HOTs) that provide a range of times that a particular fluid will remain effective under various weather conditions. Use of HOTs requires the pilot to make judgments on the remaining effectiveness of the deicing or anti-icing fluid applied to his aircraft based on often rapidly changing meteorological conditions. Pilots will often attempt to ascertain the condition of the wings and/or the anti-icing fluid by examining them through a cockpit or cabin window. Unfortunately, this must often be done in poor visibility conditions, at night, or both.

A system that would continually and accurately monitor the condition of the wing and the applied deicing and anti-icing fluids could potentially make the pilot’s job much easier and operations in freezing precipitation much safer. Further, a monitoring system that could prevent the needless reapplication of deicing and anti-icing fluids would reduce the impact of glycol runoff on the environment and would reduce costs to the airlines. The US Air Force, facing similar problems with their transport aircraft, decided to sponsor research and development (R&D) for a wing mounted ice detection system through the Department of Defense (DOD) Advanced Research Projects Agency (DARPA) Joint Use Program. Due to its extensive expertise in this area, the Flight Safety Research Section, AAR-421, was asked by DARPA to direct and manage this R&D program. A consortium consisting of McDonnell Douglas, Northwest Airlines, FBS Inc. (a Pennsylvania State University-based technology business), and led by Rosemount Aerospace, were chosen by DARPA to perform this research. DARPA and the consortium contributed financial and material resources in equal amounts. The result of this government and industry cooperative effort is the HALO™ ice detection system. The system consists of four ultrasonic sensors, a single HALO processing unit (HPU), and a cockpit display. Two ultrasonic sensors are installed on each wing, one each in an inboard and outboard location. In addition to determining the effectiveness of the glycol, the two inboard sensors also provide foreign object damage (FOD) ice detection capability for rear mounted engine aircraft.



The formal R&D effort was completed in February 1997. Rosemount Aerospace is now evaluating the HALO system for operational use.

POC: Mr. Edward J. Pugacz, AAR-421, 609-485-5707.

Electromagnetic Environment for Aircraft

A survey was conducted of all electromagnetic transmitters in the United States. It included transmitters such as television stations, radio stations, radars, cellular telephone transmitters, ship and aircraft transmitters, etc. The purpose of the survey was to define the high intensity radiated fields (HIRF) environment that civil aircraft are exposed to during flight. The data is needed to develop, design, and test criteria for the flight controls and avionics systems onboard the aircraft to insure that they will not be susceptible to the electromagnetic transmitters. New aircraft, and retrofit aircraft, are incorporating more and more advanced digital technology which can be sensitive to electromagnetic interference. Additionally, some new aircraft are replacing aluminum skin and structure with composite materials which, though very strong, do not have the same shielding effectiveness against electromagnetic interference. A similar survey was conducted in Europe and the data was combined with the U.S. data. The result is a set of tables which define the worldwide HIRF environment for all types of civil aircraft. A table for the HIRF Certification Environment is shown below.

The table contains peak and average signal measurements, in volts per meter, for the US, Europe, and Combined. The measurements are displayed in frequency bands which start at 10 KHz and go up to 40 GHz. Other data collected were used to define the HIRF Normal, Severe, and Rotorcraft environments as well. This is a significant accomplishment since the US and European aviation communities have been working on a worldwide environment for many years and, up until now, were not able to come to an agreement on the signal levels. This meant that aircraft would have to be tested and certificated twice, once in the US and then again in Europe. The development of an agreed upon worldwide HIRF environment permits one set of tests and one certification for each aircraft while ensuring aircraft safety.

POC: Mr. Peter Saraceni, AAR-421, (609) 485-5577.

	1997 HIRF Certification Environment					
	US Certification		European Certification		Combined Certification	
Range	Peak	Average	Peak	Average	Peak	Average
10 kHz to 100 kHz	13	13	40	40	40	40
100 kHz to 500 kHz	36	25	40	40	40	40
500 kHz to 2 MHz	13	13	40	40	40	40
2 MHz to 30 MHz	113	113	100	100	110	110
30 MHz to 70 MHz	8	8	20	20	20	20
70 MHz to 100 MHz	9	9	20	20	20	20
100 MHz to 200 MHz	14	14	50	20	50	20
200 MHz to 400 MHz	14	14	70	70	70	70
400 MHz to 700 MHz	40	40	730	30	730	40
700 MHz to 1 GHZ	143	51	690	70	690	70
1 GHz to 2 GHz	514	53	2200	160	2200	160
2 GHz to 4 GHz	1003	187	3500	240	3500	240
4 GHz to 6 GHz	3875	160	3200	130	3900	160
6 GHz to 8 GHz	125	76	800	330	800	330
8 GHz to 12 GHz	1231	76	3500	330	3500	330
12 GHz to 18 GHz	496	188	1700	210	1700	210

Based on November 1996 US environment definition and March 1997 European environment definition

1997 HIRF Certification Environment

Icing Information Notes

Several informal technical notes have been written to provide practitioners in the field of aircraft icing with clear, ready references on some of the fundamentals. These write-ups were prepared in response to requests from the field or to clarify known areas of confusion in the interpretation and application of icing data and technical literature. The information notes available at this time are described below.

"**Looking for Large MVD's?**" Tells what to look for and what to expect when searching for icing clouds with droplet MVD's in the range of 30 to 50 microns during test flights.

"**Terminology for Droplet Size Measurements**" There are often questions, errors, or confusion about droplet size measurements, computations, and terminology. Topics include: Cloud Droplet Basics, Water Content of Clouds, Engineering Significance of Droplet Sizes, Substitutes for Dropsize Distributions (Mean or Average Diameter, Median-Volume Diameter (MVD), Mean-Volume Diameter, and Mean Effective Diameter), and Cautions in Reading Icing Literature and Interpreting Dropsize Tables.

"**Answers to Questions about Low-Level Icing Conditions**" Answers the questions "Are low-level icing conditions above a high-elevation airport any different from low-level icing conditions near sea level?" and "Is the Continuous Maximum Envelope (Fig. 1 of FAR 25, Appendix C) really valid all the way down to ground level or sea level?"

"**Legitimate (and Illegitimate!) Uses of the LWC Adjustment Curves in Appendix C of FARs 25 and 29**" There are often questions, errors, or confusion about the legitimate use of the LWC adjustment (F-factor) curves in Appendix C. Topics include: Proper Use of the F-factor Curves; Converting Available LWC Averages to Equivalent Values Over 17.4 nmi or 2.6 nmi; Judging the Adequacy of an Icing Exposure for Test or Certification Purposes; and Acceptable Methods for Documenting, Comparing, and Extrapolating Test Exposures.

"**Method for Computing Condensable Water due to Expansion (Suction) Cooling in Turbine Engine Air Inlets**" When air is drawn into turbine engine inlets during low-speed (ground) operations, the air can be cooled by as much as 15°F (8°C) due to the air pressure drop inside the inlet. If the outside air is moist and the temperature drops below its dew point during ingestion, then moisture (and possibly ice) will condense in the inlet. This note describes a method for computing the mass (grams) of condensable water per unit mass (kilograms) of ingested outside air.

"**Summary of Some Current Practices in Selecting Design Values from the Icing Envelopes in Appendix C of FARs 25 and 29**" Questions arise periodically on the significance, proper usage, and interpretation of horizontal extent of icing conditions represented by the design envelopes in Appendix C of FARs 25 and 29. Topics include: Selecting Exposure Distances, Selecting Values of MVD, and Special Considerations.

POC: Dr. Richard Jeck, AAR-421, (609) 485-4462.

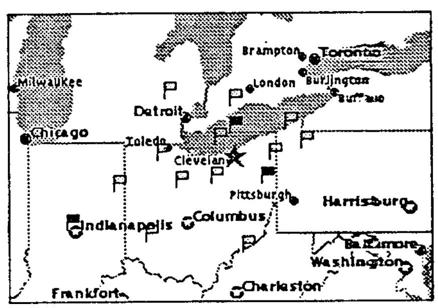
Data Acquisition to Characterize a Hazardous Icing Environment

In October 1994, a turbopropeller aircraft crashed near Roselawn, Indiana, after the aircraft had been holding in icing conditions awaiting clearance to land in Chicago. The accident claimed the lives of all sixty-four people aboard. The National Transportation Board found that the accident occurred in a form of freezing drizzle which researchers refer to as supercooled large droplets (SLD) aloft. At that time, and still today, droplets this large are not included in the icing certification envelopes in Part 25, Appendix C, and no aircraft are certified for such conditions. The FAA William J. Hughes Technical Center was given the chief responsibility for organizing the FAA International Conference on Aircraft In-flight Icing (attended by more than four hundred participants from twenty countries) for the purpose of joining with industry, research organizations, pilot organizations, and other parts of the international aviation community to determine the most appropriate course of action. It was determined at the conference that North American data on SLD aloft is mainly limited to mountainous regions of the western U.S. and the maritime provinces of Canada. This resulted in a recommendation urging the acquisition of more data in other geographic areas of North America, such as the Great Lakes region, in order to better to characterize the SLD aloft environment. Such information was seen as valuable for guidance on operations, simulation, and design and as a necessary prerequisite to modifying or supplementing the Appendix C certification envelopes to include SLD aloft. Following the conference, the FAA issued an Inflight Aircraft Icing Plan endorsing this recommendation.

The FAA William J. Hughes Technical Center joined with NASA Lewis Research Center and the National Center for Atmospheric Research in a flight research program aimed at the acquisition of SLD aloft data. The project was based in Cleveland, Ohio, and researchers conducted many successful flights in the Great Lakes region, a geographic area where severe icing conditions occur with greater frequency than in most other areas of North America.

In addition, the FAA William J. Hughes Technical Center has initiated a research effort at the Mount Washington Observatory in New Hampshire to acquire freezing drizzle data. Because of its height above sea level, this location offers an appropriate and cost-effective location to acquire data in conditions representative of SLD aloft.

Data from these and other efforts will be entered into the FAA SLD database, and detailed analyses of the data will be used by the FAA to determine appropriate guidance material and regulatory action.



POC: Mr. James T. Riley, AAR-421, (609) 485-4144.

Fire Safety

A New Flammability Test for Airline Blankets

In 1993, a fire erupted in a stowage bin aboard a Northwest Airlines Boeing 727-200 aircraft. The fire was noticed just as the aircraft was being pushed back from the loading gate at Dorval International Airport in Canada. Upon completion of their investigation, the Transportation Safety Board (TSB) of Canada determined that the original source of the fire was the 100% polyester airline blankets. Prior to this incident, there was no Federal Aviation Administration (FAA) regulation that required flammability testing of airline blankets. Because of this incident, the U.S. National Transportation Safety Board asked the FAA to develop a fire performance test method and performance criterion for blankets supplied to commercial airline operators.

At the time, many airlines only used blankets that met the FAA vertical Bunsen burner test specified in FAR 25.853-Appendix F. This test, however, was inappropriate as a measurement of ignitability for certain types of blankets since the polyester blankets involved in the Northwest 727 fire met the test criteria. For example, some polyester blankets compliant with the Bunsen burner test could be ignited with a match.

The FAA William J. Hughes Technical Center Fire Safety Section conducted a test program to evaluate a number of different flammability tests for airline blankets. This program led to the development of a 4-ply horizontal test method that produced consistent test results, correlated well with full-scale testing, and was more realistic since the blankets are folded and stored horizontally in the aircraft stowage bin.

A full report and test method was issued in March 1996. In August 1996, a Flight Standards Information Bulletin for Air Transportation (FSIB) went into effect, specifying the FAA recommendation that air carriers replace old blankets at the end of their service life with blankets that meet the 4-ply horizontal test. During 1997, the 4-ply horizontal test fixture was redesigned in order to simplify the test procedure for the operator. New drawings

Blanket Flammability Test

were also sent out to laboratories that perform this test to assure that the test results are reproducible among laboratories. Additionally, the test method will be included in the Materials Fire Test Handbook that is scheduled for release in early 1998. The handbook will be the most comprehensive, detailed description of aircraft material fire test methods and criteria available as guidance material for FAA certification engineers, designated engineering representatives, and test method operators.

Although not mandated, the majority of airlines require that replacement blankets be compliant with the new flammability test method. The addition of this test method is another step in the improvement of fire safety for the flying public.

POC: Ms. Patricia Cahill, AAR 422, (609) 485-6571.

A Microscale Combustion Calorimeter for Determining Flammability Parameters of Research Materials

A microscale combustion calorimeter has been developed to measure flammability parameters of milligram polymer (plastic) samples under test conditions which approximate aircraft cabin fires. The test provides a quantitative measure of the fire hazard of new materials in an aircraft cabin fire when only research quantities are available for testing.

Figure 1 is the microscale combustion calorimeter showing, from left to right, the sample pyrolysis stage, the heated oxygen mixing manifold, and the combustion furnace and oxygen analyzer.

Figure 1. Microscale Combustion Calorimeter.

Figure 2 is a composite plot of microcalorimeter data for different plastics, some of which are used in aircraft interiors. A sharp, quantitative, and reproducible heat release rate peak is obtained in the test. After normalizing the curves for the sample size the results are independent of the physical form of the material (e.g., powder, film, fiber, etc.). The microscale heat release rate data are expressed in kilowatts per gram of original material. The best and worst samples tested differ by a factor of 100 in peak heat release rate.

Figure 3 compares the peak heat release rate (HRR) measured on milligram samples in the microcalorimeter to the heat release rate measured for 100 gram samples in a fire calorimeter. The heat release rate plotted along the vertical axis in figure 3 is the steady-state or average value obtained in a fire (cone) calorimeter at 50 kW/m^2 incident heat flux according to standard procedures.

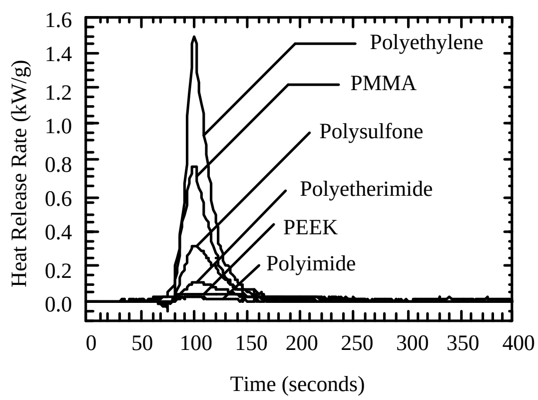


Figure 2. Heat Release Rate Curves for Various Polymers in the Microcalorimeter.

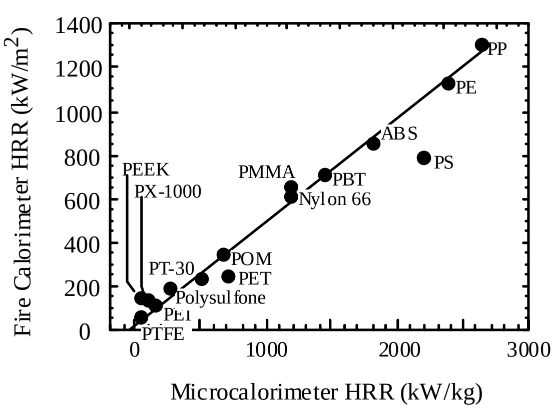


Figure 3. Correlation Between Microscale and Fire Calorimeter Results.

Full-scale fire tests at the FAA have shown that the heat release rate of interior materials measured in a fire calorimeter correlates with passenger escape time in a simulated postcrash fuel fire. The good correlation between fire and micro-calorimeter results in figure 3 shows that the microcalorimeter is also a good predictor of passenger escape time and, therefor, of full-scale fire hazard. A DOT/FAA patent has been filed on this invention.

POC: Dr. Richard E. Lyon, AAR-422, (609) 485-6076.

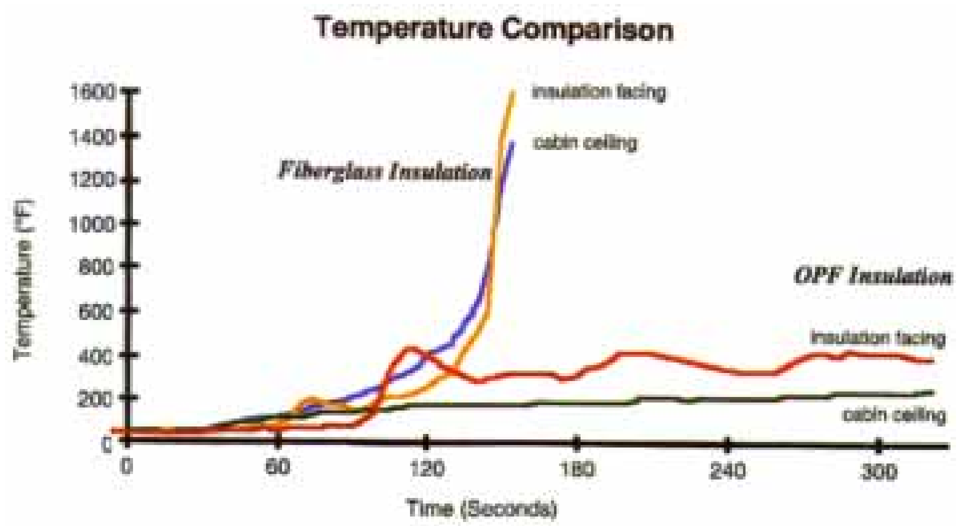
Fuel Fire Burnthrough Resistance Improvements

Fuselage burnthrough refers to the penetration of an external jet fuel fire into the interior of an aircraft. The time to burnthrough is critical because in a majority of survivable aircraft accidents accompanied by fire, ignition of the interior of the aircraft is caused by burning jet fuel external to the aircraft. Therefore, the integrity of the aircraft and its ability to provide a barrier against fuel fire penetration is an important factor related to the survival of aircraft occupants. Fuselage burnthrough resistance becomes particularly important when the fuselage remains intact following a crash. The best example of an accident where fuselage burnthrough was determined to be critical to the outcome was the Boeing 737 accident in Manchester, England, in 1985. In this accident, the investigators concluded that burnthrough occurred within 60 seconds and did not allow sufficient time for all occupants to escape (55 people died from the effects of the fire).

Fuselage burnthrough resistance may be simplistically viewed as the time interval for a fuel fire to penetrate three fuselage shell members: aluminum skin, thermal acoustical insulation, and sidewall panel/cabin flooring. Flame penetration may occur in other areas as well, such as windows, air return grilles, and seams or joints. The burnthrough resistance of the aluminum skin is well known. It takes only about 20 to 60 seconds for the skin to melt, depending on its thickness. The thermal acoustical insulation is the next impediment to burnthrough following the melting of the aluminum skin. In past FAA outdoor fuel fire burn tests on surplus fuselages, it was determined that the fiberglass insulation provided an additional 1 to 2 minutes of protection, if it completely covered the fire area and remained in place. Thus, the method of securing the insulation to the fuselage structural members is important. The sidewall panels and flooring offer the final barrier to fire penetration. Sandwich panels comprised of honeycomb cores and fiberglass facings are effective barriers; however, full-scale fire tests also show that the fire can penetrate into the cabin through air return grilles, seams, joints, or window reveals. Moreover, some airplanes use aluminum sidewall panels, which offer minimal burnthrough resistance. FAA researchers are focusing on the thermal acoustical insulation as the most potentially effective and practical means of achieving a burnthrough barrier.

A full-scale test article is used to accurately evaluate improved materials and concepts when installed realistically inside a fuselage and subjected to an external fuel fire. The test article is a 20-foot-long barrel section, constructed of steel framing members, inserted in the aft end of a Boeing 707 fuselage. A 10-foot-long by 8-foot-wide fuel pan subjects the test article to an intense fuel fire.

Aircraft thermal acoustical insulation batting is typically comprised of lightweight fiberglass encapsulated in a thin film moisture barrier, usually polyester or polyvinyl fluoride. Several materials have been tested which exhibit marked burnthrough resistance compared to the baseline thermal acoustical batting. The effective materials include a heat stabilized, oxidized polyacrylonitrile fiber (OPF) as a replacement for the fiberglass, a lightweight ceramic fiber mat used in conjunction with the present fiberglass, polyimide foam encased in quartz fiber



mat, and a polyimide film as a replacement for the polyester or polyvinyl fluoride films. A comparison of full-scale test temperature readings taken at the inside of the insulation and near the ceiling illustrate the burnthrough protection provided by the OPF insulation. Both the OPF and fiberglass insulation materials were securely attached to the framing members. It takes about 1.5 to 2 minutes for the fuel fire flames to penetrate the aluminum skin and fiberglass batting, whereas the OPF insulation did not burn when subjected to a fuel fire for over 5 minutes. A 5-minute window for passenger evacuation should cover most, if not all, crash accident scenarios.

Burn Test with Ineffective Insulation

Burn Test with Effective Insulation

In summary, full-scale fire tests have identified a number of promising materials that can significantly improve fuselage burnthrough resistance. The next step is to develop burnthrough design guidelines, including a small-scale fire test to evaluate materials and methods of attachment.

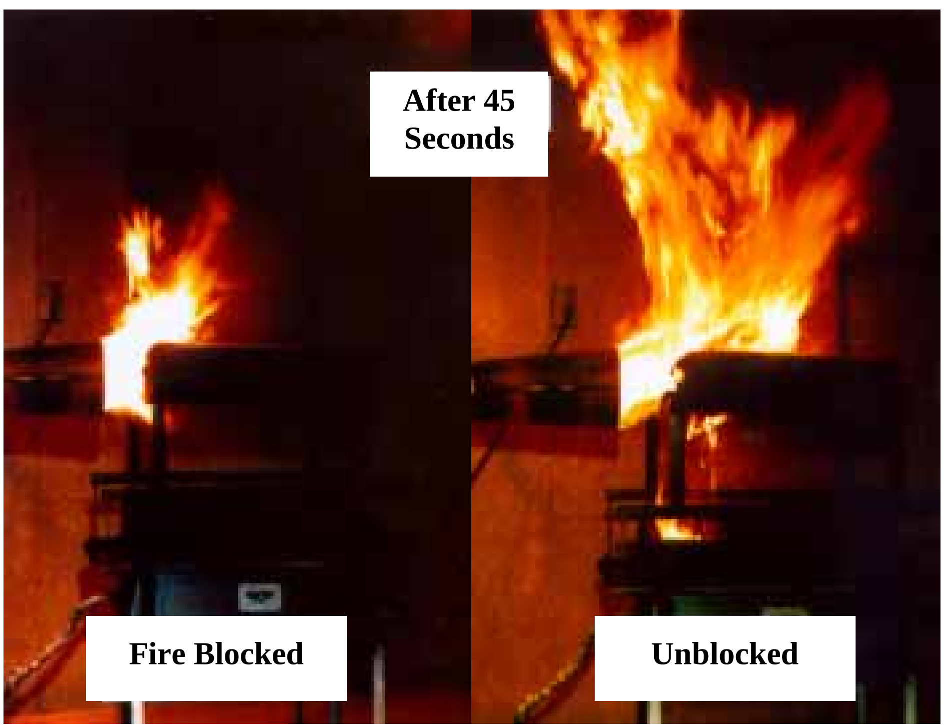
POC: Mr. Timothy Marker, AAR-422, (609) 485-6469.

Continued Fire Worthiness of Seat Fire-Blocking Layers

On April 6, 1993, a China Eastern Airline MD-11 diverted to Shemya, Alaska, due to flight control problems. The aircraft was able to land without loss of life but suffered severe interior structural damage. During the subsequent investigation, the National Transportation Safety Board (NTSB) noticed interior cabin seat cushions with worn fire-blocking layers exposing the polyurethane foam. Typically, a fire-blocking layer encapsulates the passenger and crew seat cushions to minimize the fire hazard of the foam itself in the event of a cabin fire. As a result of the NTSB accident report, the Federal Aviation Administration (FAA) was charged with evaluating the continued fire worthiness of various cabin materials as they aged. The material particularly highlighted was the fire-blocking layer required on aircraft seat cushions. The fire performance for aircraft seat cushions is regulated through 14 CFR and FAR 25, §25.853; a fire test method for demonstrating compliance is given in Appendix II of that document.

The fire-blocking layers aboard the China Eastern Airline aircraft that was involved in the accident that lead to the FAA investigation were graphite-based fibers not commonly used by U.S. air carriers. To address the NTSB charge, the FAA investigation was shifted to focus on the U.S. civil fleet. Observations were made on in-service aircraft seat cushions to determine the level of degradation, and used materials were donated by cooperative U.S. air carriers.

On aircraft in-service seat cushions were examined at three airports: Newark International Airport (Newark, NJ), Stewart International Airport (Newburg, NY), and the Atlantic City International Airport (Pomona, NJ). The in-service conditions of the fire blocking layers in seat cushions on Shorts 360, ATR 42, Embraer EMB-120RT, McDonnell



Douglas DC9/MD80, Boeing 727, and Airbus A300 aircraft were evaluated. A total of 176 seats were examined. Evaluations of the in-service seat cushions indicated the materials were in satisfactory condition and were not the same materials found by the NTSB on the China Eastern MD11. U.S. air carriers also donated 38 seat cushion sets for destructive testing. The condition of the donated cushions was compared to the materials observed during the on aircraft in-service investigations. The donated materials possessed similar degradation characteristics. The donated materials were destructively tested to determine their compliance with Federal Regulations. The FAA specified test was used to evaluate the worn seat cushion materials. Although the test conditions were not precisely applicable, the test results provided a credible indication of whether or not the worn materials were within compliance intent. All the donated materials demonstrated an acceptable level of fire endurance even though materials on average were 7 years old. From these results, it was concluded that the seat fire-blocking materials commonly used by U.S. air carriers retain their fire endurance effectiveness during service. These results eliminated the need to add additional tests to determine the material degradation with age, which would have resulted in costly, periodic inspection of seat cushions, as recommended by the NTSB. This project was done in cooperation with participants from industry and government in the International Aircraft Material Fire Tests Working Group sponsored by the Fire Safety Section, AAR-422. A detailed report has been issued describing the work, "A Study of Continued Fire Worthiness of Aircraft Seat Cushion Fire-Blocking Layers," DOT/FAA/AR-95/49, published in March 1997.

POC: Mr. Douglas Ingerson, AAR-422, (609) 485-4945.

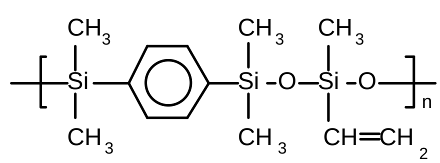
Fire-Resistant Elastomers for Aircraft Seat Cushions

Commercial transport aircraft contain between 1000 and 2500 pounds of flammable elastomers (rubber) as seat cushions, pillows, and sealants. Polyurethane rubber seat cushions are favored for their durability and recovery but they are among the primary contributors to the fire hazard in aircraft interiors.

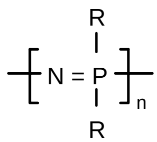
In 1987 the FAA imposed regulations on the flammability of aircraft seat cushions to delay their involvement in cabin fires. Manufacturers responded to these regulations by wrapping the polyurethane seat cushion in a fire-resistant barrier fabric. Seat fire blocking allowed manufacturers to pass the FAA certification test but the cushions burn vigorously when the fire-blocking layer is consumed after minutes of exposure to a fire.

The flammability of foamed rubber depends on the chemical composition of the polymer from which it is made. Rubbers made from carbon-hydrogen-based (organic) polymers are the most flammable because of their high fuel value. Replacing carbon and hydrogen atoms in the polymer with inorganic atoms such as chlorine, silicon, nitrogen, sulfur, or phosphorus results in a semiorganic polymer with reduced flammability because of the lower fuel value or increased heat resistance.

In the Fire-Resistant Materials research program we are focusing on semiorganic rubbers for seat cushions. Phenyl-silicon-oxygen backbone (silphenylene) elastomers which are crosslinkable and extremely heat resistant have been synthesized. The silphenylene whose chemical structure is shown below contains only 30% combustible material and can withstand temperatures of 600ºC (1100ºF).



Polyphosphazenes are semiorganic rubbers based on a phosphorus-nitrogen backbone as shown below



where R is an organic group which allows the material to be dissolved or crosslinked. Commercial production of polyphosphazene was recently discontinued despite the extremely low toxicity and ultra fire resistance of these foams because the process for making them was prohibitively expensive.

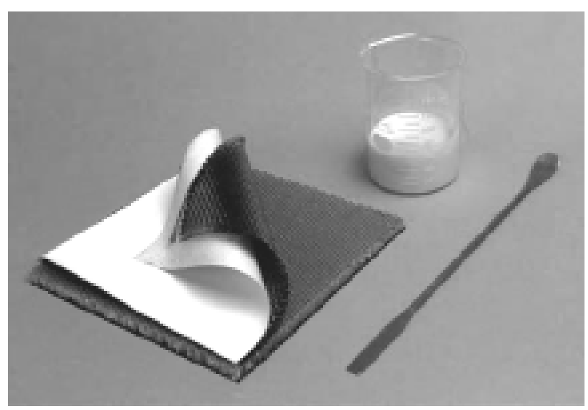
We are pursuing a new low-cost, low-temperature synthetic route to polyphosphazenes which eliminates a costly intermediate from the process and allows control over the molecular weight of the polymer. This new direct synthetic route has provided the first phosphazene copolymers including an 80-20 urethane-phosphazene copolymer which does not ignite in a flame.

POC: Dr. Richard E. Lyon, AAR-422, (609) 485-6076.

Fireproof Composites

The flammability of organic polymer matrix, fiber-reinforced composites limits the use of these materials in commercial aircraft where fire hazards are important design considerations because of restricted egress. At the present time, affordable, processable resins for fire-resistant aircraft interiors are unavailable since most organic polymers used for this purpose ignite and burn readily under fuel fire exposure conditions.

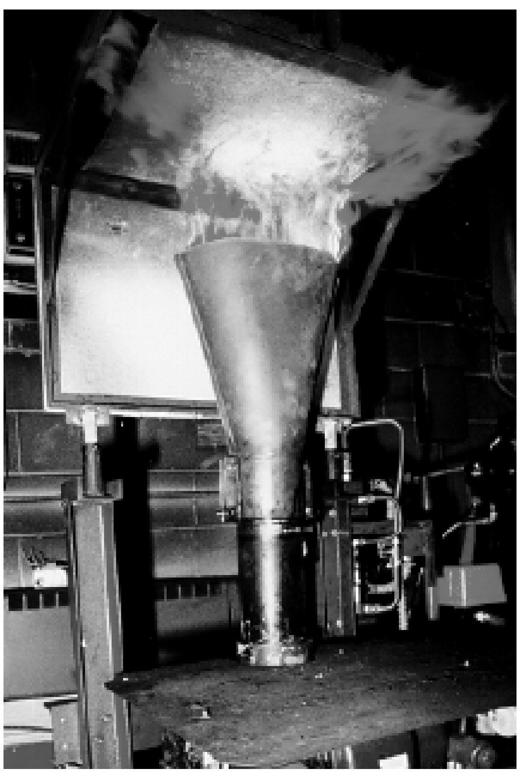
The Aircraft Safety R&D Branch, Fire Safety Section of the Federal Aviation Administration is conducting a research program to develop aircraft cabin materials with an order-of-magnitude reduction in fire hazard when compared to plastics and composites currently used as interior materials. The goal of the program is to eliminate cabin fire as a cause of postcrash death in aircraft accidents.



The Geopolymer resin in the beaker above is being evaluated as a resin for use in fireproof aircraft cabin interior panels and cargo liners (see test at right). Geopolymer is a two-part, water based, liquid potassium aluminosilicate resin which cures at 80°C (176°F) to a fireproof solid having twice the density of water.

Geopolymer has the empirical formula $Si_{32}O_{99}H_{24}K_7Al$. The fire response and mechanical properties of Geopolymer composites were measured and compared to lightweight organic matrix composites and aluminum used in aircraft.

Carbon fabric reinforced Geopolymer crossply laminates were found to have comparable initial strength to phenolic resin composites currently used in aircraft interiors. Unlike the phenolic laminates however, the Geopolymer composites did not ignite, burn, or release any heat or smoke even after extended exposure to high heat flux. Geopolymer composites retained 67 percent of their original flexural strength after fire exposure while organic (e.g., phenolic) composites and aluminum had no residual strength after the test. Geopolymer composites have higher strength and stiffness per unit weight, higher temperature capability, and better fatigue resistance than steel or aluminum.



Future work will focus on understanding how Geopolymer resin protects the carbon fibers from oxidative degradation at 800ºC (1500ºF) in air, optimizing processing to obtain maximum strength, and improving the toughness of laminated composites.

POC: Dr. Richard E. Lyon, AAR-422, (609) 485-6076.

Lavatory Fire Extinguisher Test Standard

The requirement for an automatic fire extinguisher which discharges into a lavatory trash container was proposed in FAA Notice 84-5 as a consequence of two aircraft accidents. The first involved an aircraft cabin fire (Air Canada, Cincinnati 1983) in which 23 people perished. The second occurred at Tampa International Airport in Florida on June 25, 1983, where passengers and crew evacuated the aircraft with no injuries or loss of life. Following these accidents, an inspection survey of the U.S. carrier fleet by the FAA revealed that the fire containment capabilities of trash containers may be compromised by the wear and tear typical of service. Considering the seriousness of inflight cabin fires, enhanced fire protection was considered necessary. As a result, rulemaking was implemented on April 29, 1987, that required each lavatory trash container be equipped with a built-in fire extinguisher which discharges automatically into the container when there is a fire.

Currently, all aircraft lavatory disposal receptacle fire extinguishers use Halon 1301 as the fire extinguishing agent. Due to environmental concerns, a total ban on the production of Halon 1301 was issued on January 1, 1994. Halons, and Halon 1301 in particular, are the mainstay of aircraft fire protection systems and thus environmentally acceptable replacements must be identified, as well as the means for their approval.

A standard test method is needed to establish that a replacement will provide a level of safety equal to Halon 1301. The FAA established the International Halon Replacement Working Group to address the development of performance standards for aircraft fire extinguishing systems employing halons. A specific task group was formed to develop a minimum performance standard for the lavatory trash receptacle fire extinguishing system. The minimum performance standard development process started with the test article, shown in the photograph below, based on input from the Boeing Commercial Airplane Group. The test article is representative of the largest trash receptacle currently in service. To provide sufficient air circulation combustion to start and continue until the lavatory extinguisher (Lavex) is discharged, ventilation was provided at both the top and bottom of the test article. The ventilation holes could be closed with damper flaps so that the agent wouldn't leak from the bottom of the test article after discharging.

Initial tests found that crumpled paper hand towels were the most appropriate material to represent lavatory trash. A pair of nichrome coils located close to the bottom of the trash receptacle provided the ignition source. This simulated a glowing cigarette buried in the trash, providing a deep-seated, smoldering combustion. To cover the range of aircraft operational conditions, a minimum test temperature was set to ensure the Lavex would function properly in cold environments, such as can result when an aircraft is parked for extended periods. Several other requirements were implemented into the minimum performance standard in order to obtain a repeatable test condition. These include standardization of the ignition source temperature, towel specification, a minimum number of required successful tests for acceptance, and tolerances on the actual "crumpling" tightness of the paper towels. The minimum performance standard for lavatory trash receptacle fire extinguishers is documented in FAA Report, "Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers," DOT/FAA/AR-96/122, dated February 1997. The test standard may be used in certification testing of halon alternatives for lavatory trash receptacles. Policy Letter TAD-97-003, March 31, 1997, generated by the FAA Transport Airplane Directorate was circulated to the various Aircraft Certification Offices to serve notice that this new standard is now in place.

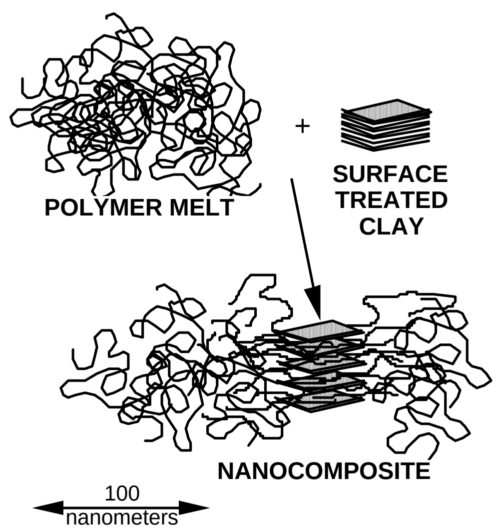
POC: Mr. Timothy Marker, AAR-422, (609) 485-6469.

Nanocomposite Fire-Retardant Technology for Aircraft Interiors

Commercial transport aircraft contain between 1500 and 2500 pounds of flammable plastics as seat trim, windows, window shades, wire insulation, and miscellaneous parts. At present these molded parts are not required to meet the heat release rate regulations imposed on large area interior panels, stowage bins, ceilings, and partitions. The lower flammability requirement for molded parts is due to the fact that they are not considered to be a significant fuel load. High-temperature plastics that do pass the heat release rate test do not have the requisite toughness, durability, environmental resistance, and aesthetics to function effectively in aircraft interiors.

The Federal Aviation Administration is committed to developing the enabling materials technology for a totally fireproof cabin. The goal of the program is to eliminate cabin fire as a cause of death in aircraft accidents. To achieve this goal we will need interior plastics with an order-of-magnitude reduction in their fire hazard compared to that of current materials.

Nanocomposite technology is an entirely new generic approach to reducing the flammability of polymeric (plastic) materials using environmentally friendly, chemical-free additives. The fire-retardant effect of nanometer sized clay particles in plastics was discovered by the FAA through a research grant to Cornell University. The National Institute of Standards and Technology (NIST) subsequently confirmed the effect in fire calorimeter testing. The approach is to disperse individual, nanometer-sized, layered silicates in a molten polymer to create a clay-plastic "nanocomposite." The clay particles are about the same size as the polymer molecules themselves (less than one millionth of an inch in diameter) so they become intimately mixed and chemically bonded. This has the overall effect of increasing the thermal stability and viscosity of the plastic while reducing the transmission of fuel gases generated during burning.



The result is a 60% reduction in the rate of heat released from a burning nylon nanocomposite containing only 5% clay. This extraordinarily high degree of fire retardant efficiency comes with reduced smoke and toxic gas emissions and at no sacrifice in mechanical properties. The nylon nanocomposite has twice the stiffness and strength of the original nylon and a 150ºF higher softening temperature.

POC: Dr. Richard E. Lyon, AAR-422, (609) 485-6076.

Chemical Oxygen Generator Fire Testing

Fire Safety Section personnel at the FAA William J. Hughes Technical Center participated in the National Transportation Safety Board (NTSB) investigation of the crash of a ValuJet DC-9 near Miami on May 11, 1996. During the initial investigation, it was determined that up to 140 unexpended and improperly packaged sodium chlorate oxygen generators were in the forward cargo compartment of the airplane. As the investigation proceeded, burned pieces of oxygen generators were recovered at the accident site and the reconstruction of the forward cargo compartment showed increasing evidence of a severe inflight cargo fire. Although these types of generators were previously involved in aircraft fires, there was very little test data on the likelihood of an inadvertently activated generator starting a fire or the magnitude of a fire possible involving up to 140 generators.

The Fire Safety Section began tests to provide some of this data. Initial tests measured the temperature of the steel case of a variety of types of generators after activating the firing mechanism. The photograph shows the size of one of the generators. The temperatures were in the 300 to 400°F range, well below the manufacturers specification of a maximum temperature of 500°F.

The next series of tests involved activating the generators in a variety of packaging materials. In the majority of tests, the packaging materials ignited due to the temperature of the generators and the higher than normal oxygen concentrations within the packages. When multiple generators were packaged in the same box, the heat of the burning package was sufficient to initiate the chemical reaction in adjacent generators which produced even more heat and oxygen. The resulting fire quickly consumed all the generators and packaging materials present. The temperatures generated were high enough to melt steel which has a melting point of approximately 2500°F.

A series of three tests were then conducted in an instrumented DC-10 cargo compartment for the NTSB. The three tests were run as follows: (1) one box containing 24 generators, (2) five boxes each containing 24 generators, and (3) five boxes each containing 24 generators and suitcases and an aircraft tire inflated to 50 psi with nitrogen adjacent to the generators. The last test, shown below, was designed to be similar to the way the forward cargo compartment of the accident airplane was loaded. In all of the tests, all of the generators were consumed in the test fires, and, in the last test, the aircraft tire burst from the heat. The instrumentation in the cargo compartment was able to measure up to 3400°F; the temperature exceeded that value for a short period of time. The video recording of the last test was played at the NTSB public hearing for the accident in November 1996 and was released to the press by the NTSB. It was replayed nationwide by all the major networks. The tests corroborated the on-site accident investigation findings and demonstrated the unusual severity and rapid development of the fire. It provided

NTSB with additional evidence to support their conclusion that the probable cause of the accident was the activation of an oxygen generator in the forward cargo compartment.

A last series of tests was conducted in two different volumes of cargo compartments using a Halon 1301 fire suppression system. Various quantities of oxygen generators were used for the tests. These tests had mixed results. Temperatures were kept under control when relatively small quantities of generators were involved in fires in the large compartment but the Halon had minimal impact when larger quantities of generators were used in the smaller compartment. The accompanying photos show a sodium chlorate oxygen generator and the fire test conducted for the NTSB in the DC-10 cargo compartment in the FAA Full-Scale Fire Test Facility.

POC: Mr. David Blake, AAR-422, 609-485-4525.

Fuel Fire Penetration Test and Destruction of a Transport Aircraft

In 1985, a British Airtours B737 experienced an engine failure while taking off from Manchester International Airport in Manchester, England. The left wing tank was punctured releasing fuel into the fire plume trailing from the damaged engine. The plane was safely brought to a halt on the runway, where fuel continued to spill from the wing tank creating a pool fire upwind of the aircraft. The wind carried the fire onto the left rear part of the aircraft where it penetrated the hull and ignited the interior. Fifty-five people lost their lives in spite of prompt airport fire-fighter response.

Survivors and accident investigators initially reported that the fire entered the aircraft in as little as 15 seconds after the aircraft was brought to a stop. This rapid burnthrough was inconsistent with previous accidents and FAA-conducted burnthrough tests. The aircraft should have resisted fire penetration into the cabin for up to 2 minutes.

In an effort to better understand the rapid burnthrough of the aircraft and resultant high loss of life, a test was designed and conducted at the FAA William J. Hughes Technical Center that incorporated many of the key elements of the Manchester accident. A Convair 880 was selected for use as the test article with modifications designed to emulate the Boeing 737 involved in the accident. The aircraft was equipped with instrumentation that provided temperature, heat flux, and toxic gas data designed to track the progress of the fire and the resultant cabin environmental conditions. Extensive video and motion picture camera coverage was provided to document both the external and internal fires. The photograph below shows that final stages of the test conducted at the Technical Center.

The test scenario was derived from the accident report and included sequenced

door openings, external pool fire size and location, and wind speed and direction. The external pool fire was lit and the fire was allowed to progress, eventually penetrating the aircraft and igniting the interior. The aircraft was allowed to burn until it was completely consumed by the fire.

This test provided what may be the most realistic accident reenactment conducted to date. Fire penetration points, cabin smoke patterns, and fire propagation within the cabin closely matched survivor and eyewitness accounts of the Manchester accident.

The data collected in this test has provided insight into the dynamics of external fuel fire penetration and propagation into an aircraft fuselage. The three factors that had the greatest bearing on survivability were clearly the resistance to burnthrough, the flammability of cabin materials, and the buildup of toxic gases. The forward part of the aircraft remained survivable, despite a raging fire in the rear, until a phenomenon called flashover occurred. Flashover is the sudden combustion of built up gases that occurs during an interior fire. When flashover occurs, the available oxygen is reduced and lethal levels of toxic gases are produced. The importance of reducing the incidence of flashover through the development of fire-resistant materials was clearly demonstrated. The toxic gases became the driving factor determining survivability in the forward cabin, reaching lethal levels minutes before the smoke and temperature levels become unsurvivable.

This test was used as the basis for an ongoing effort to improve the resistance of an aircraft to resist burnthrough from an exterior fuel fire through the development of improved insulation materials.

The data and conclusions derived from this test significantly increased our understanding of the mechanism of burnthrough and the factors that affect survivability in a postcrash fuel fire environment. For additional information regarding this test, please refer to the final report, DOT/FAA/AR-96/48, published in December 1996.

POC: Mr. Harry Webster, AAR-422, (609) 485-4183.

Airport Technology

National Airport Pavement Test Machine

…a joint FAA/Boeing partnership project

The Federal Aviation Administration and the Boeing Company have joined in a Cooperative Research and Development Agreement (CRDA) to construct and operate an airport pavement test machine capable of testing full-scale airport pavements to destruction with simulated full-scale traffic loading. The purpose is two-fold: first, to validate new methodologies for designing, constructing, and evaluating airport pavements; and second, to develop a basis for petitioning International Civil Aviation Organization (ICAO) to modify the international convention for describing aircraft and airport compatibility. Current methodologies for both of these activities are inadequate when applied to the advanced landing gears proposed for future heavy aircraft.

he facility is under construction at the FAA William J. Hughes Technical Center at the Atlantic City International Airport, New Jersey. The test machine will be located in a fully enclosed building. Overall dimensions of the structure are approximately 1200 feet long, 100 feet wide, and 40 feet high. Pavement test sections will be constructed using conventional construction equipment and techniques; thus representing actual field construction. Testing will be conducted 24 hours a day, year round, and in a fully automated mode.

The pavement test section area is approximately 900 feet long and 60 feet wide. This size permits simultaneous testing of 9 different pavement cross sections. Simulated aircraft loading will be applied with an electrically driven vehicle operating on railroad rails. The vehicle will be roughly 75 feet long and 80 feet wide and weigh approximately 1.1 million pounds. Hydraulic actuators reacting against the dead weight of the vehicle will provide the desired wheel loads. Loads on the pavement test sections will be variable up to a maximum total load of 900,000 pounds. Movable wheel module assemblies permit wheel groups to be moved up to 20 feet laterally and longitudinally to simulate a variety of wheel base configurations.

The facility will be operational in late 1998. The total cost to design, construct, and conduct the first series of tests is $21 million. Under the terms of the CRDA the Boeing Company has provided a total of $7 million towards the project; the FAA is providing the remaining $14 million.

POC: Dr. Satish Agrawal, AAR-410, (609) 485-6686.

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Evaluation of Airfield Lighting Circuit Performance

New requirements for airfield guidance signs have necessitated replacement and purchase of a large number of airfield signs throughout the United States. In the process, manufacturers have developed new designs for airfield signs using current technology for illumination and control. However, as the new signs are placed into service, airports have experienced problems with the performance of the signs. In order to determine the scope and to investigate these problems, the Federal Aviation Administration (FAA) conducted an evaluation at several different airports. An FAA Technical Report DOT/FAA/AR-96/120 was issued July 1997 detailing this evaluation.

For the evaluation, a test program was developed which consisted of both photometric and electrical performance testing. Crucial to this program was the need to obtain data on several different types of airfield guidance signs, constant-current regulators, and the different configurations of airfield circuits. Furthermore, it was essential to obtain this data during real-life airfield applications in normal operating conditions. Toward this end, data was obtained at six different airports.

During the course of the evaluation it became evident that the signage problems encountered were not airport specific, i.e., the problems were characteristic of new airfield signs. Results showed that the source of the electrical problems was the incompatibility between the signs and constant-current regulators (CCRs). Contributing to this incompatibility were the harmonics present in the signs and the regulators during normal operating

conditions. It was also concluded that the photometric output of the sign was impacted by the electrical characteristics and sign performance. In particular, the light output was a function of the shape of the CCR output voltage waveform. The more distortion that exists in the waveform the less the photometric output of the sign, i.e., the sign is less bright.

The study lead to recommendations for improvements to both the signs and the regulators. To minimize the effects of harmonics and the nonlinear characteristics of the CCR and to improve the photometric performance of the signs as well as the compatibility of the signs and regulators, it was recommended that criteria be established to limit the time which the regulator is not conducting within one complete cycle (dead time) exhibited in the output waveforms at all ranges of connected load. A practical solution for improving the harmonics is the addition of a tap-setting mechanism in the regulator. Two suggested methods include an automatic tap setting and a tap setting that will work in conjunction with the regulator output step setting to accommodate load changes.

It was also necessary that the photometric performance of the signs comply with FAA requirements. To better define the photometric performance parameters of the signs, it was recommended that the FAA standards be revised to include (1) luminance requirements for the red background on mandatory signs, (2) contrast requirement for mandatory signs, and (3) field test procedures to periodically measure the photometric output of the signs.

POC: Mr. Paul Jones, AAR-410, (609) 485-6713.

Soft Ground Arresting System for Airports

On February 28, 1984, a jet transport aircraft overran runway 4 Right at JFK International Airport and plunged into the Thurston Basin. The aircraft was extensively damaged and required $20 million in repairs. A similar overrun accident occurred 2 years prior at Boston Logan Airport on January 23, 1982. The aircraft was destroyed and two people were killed in that accident.

To eliminate such accidents, the FAA now requires a safety overrun zone of 1000 feet in length beyond the end of a runway. However, many older runways, built before the 1000 feet became a standard, do not have sufficient space available to comply with this requirement. For such locations, the FAA's solution is to install what is known as a soft ground arresting system.

Through extensive research and testing at the FAA William J. Hughes Technical Center, the FAA developed preliminary design specifications for a soft ground arresting system. Under a Cooperative Research and Development Agreement with Engineered Systems Company, the FAA demonstrated that a Boeing 727 aircraft could be stopped in less than 300 feet from a speed of about 63 mph. The photograph below shows the B-727 in the soft ground arresting system.

Following the successful demonstration, the Port Authority of New York and New Jersey signed a contract with the Engineered Systems Company to install a full-scale arrestor bed at runway 4R at JFK—the scene of the 1984 accident. The installation was completed in December 1996. The FAA is monitoring its performance over the next two years to collect data for a Soft Ground Arrestor Standard. Such as standard will provide advanced modeling, materials, and methods for safely arresting aircraft that overrun the ends of runways.

POC: Mr. James White, AAR-410, (609) 485-5138.

Runway Instrumentation at DIA - Development of Database

A better understanding of in situ behavior of airport pavements under operational conditions is one of the critical elements in the development of improved design methodologies, new pavement materials, advanced construction techniques, and better maintenance procedures.

The Federal Aviation Administration (FAA) initiated a major research effort to study the in situ response and performance of Portland cement concrete (PCC) pavements. A comprehensive instrumentation system with a total of 462 sensors was installed within the pavement structures in the takeoff area of Runway 34L at the Denver International Airport (DIA). An elaborate data acquisition system was put in place to control these sensors and collect data. Remote access was established in 1994, providing the FAA with on-line access to the data acquisition system.

In 1997, the response data was made available on-line through the Internet. All sensor responses are recorded and stored as data files by a data acquisition system located at the site; transmitted to the FAA William J. Hughes Technical Center in Atlantic City International Airport, New Jersey; processed by PC-based computer programs; and the reduced data stored in an on-line Oracle database.

The instrumented section of pavement is 80 feet long and is located 400 feet from the threshold of the runway. There are 135 H-Bar strain gages, 23 Carlson elastic-wire strain meters, 60 LVDT's in 10 multidepth deflectometers (MDDs) and 20 single-depth deflectometers (SDDs), and 15 geophones. Six infrared LED emitter/detector pairs are located on opposite sides of the runway to sense aircraft position. Each aircraft event lasts approximately 10 seconds, depending on the speed the aircraft passes over the pavement. Data processing is by means of a Windows-based computer program written in Visual Basic. The program (1) reads the binary data file containing all sensor data for a single aircraft event, (2) filters (where necessary) and converts the data to engineering units, (3) displays relevant sensor data in a tabular format, (4) provides a graphical display of the data record for individual sensors, (5) calculates aircraft speed and position as a function of time, (6) identifies the aircraft type, (7) calculates peak responses, and (8) generates a standard-query-language (SQL) file for transfer of the processed data to the Oracle database. This data processing procedure can also be executed in an automatic batch mode for a large number of aircraft events.

The speed and longitudinal and lateral position of the nose wheel of the aircraft are computed from Infrared (IR) sensor trigger signals. Additional information on wheel base and main gear geometry is calculated from the response of vertical strain sensors positioned at 1-foot intervals across the pavement at the beginning and end of the test section. Aircraft type is determined by comparing computed gear geometry with gear geometry of common aircraft types stored in a library. Maximum peak values are found automatically, with the peak defined relative to the offset of the leading part of the data record. Up to two additional peaks can be selected manually and their values retained for storage in the database. The offset of the trailing portion of the data exceeding a predetermined threshold are retained for storage in the database.

For the 10 percent of the records in each sensor category which have the largest maximum peak values, each of the data records is converted to a text string for storage in the database.

The resulting SQL files containing the processed information are then transferred into the on-line Oracle database residing in a UNIX workstation in the Airport Technology Branch. With on-line Internet access to the database, it provides worldwide users with the most convenient means to obtain the collected data and allows the FAA to disseminate valuable research information as soon as it becomes available. The Internet address for the DIA database is http://www.airtech.tc.faa.gov/dbase/.

POC: Dr. Xiaogong Lee, AAR-410, (609) 485-6967.

Infrared Aircraft Deicing

The Code of Federal Regulations (CFR) prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, control surfaces, engine outlets, and other critical surfaces of the aircraft. This rule is the basis for the clean aircraft concept.

The clean aircraft concept is essential to safe flight operations. Common practice is to deice and, if necessary to anti-ice an aircraft before takeoff. In most cases this is done using glycol.

Glycol runoff from deicing/anti-icing operations can impose a significant impact on adjacent water systems. Glycol contaminated storm water runoff can deplete dissolved oxygen levels and threaten aquatic life. Additionally, the deicing fluids contain corrosion and rust inhibitors which are considered toxic to biological systems.

The escalating environmental and economic cost of chemical deicers has prompted the development of alternative ways to deice an aircraft. Process Technologies, Inc., (PTI) has developed a gas-fired, radiant heat unit which is capable of melting ice and snow from the surfaces of an aircraft.

In April 1995 (under the terms of a Cooperative Research and Development Agreement), the FAA’s instrumented Convair 580 was deiced with infrared energy inside a temporary hangar in Buffalo, NY. PTI erected the structure, fabricated and installed 96 EPU’s, and conducted the tests in the presence of FAA personnel. Observable results showed that the aircraft, with ≈3/16" ice coating, was deiced in approximately 5 minutes. The test report for these activities is available from Process Technologies, Inc.

A series of deicing demonstrations were conducted with the FAA’s Boeing 727 test aircraft in March 1996 within a larger hangar that spanned Taxiway C1 at Greater Rochester International Airport, shown in the photograph below. Deicing times ranged from 5 to 9 minutes depending on power settings. Hourly fuel cost for the deicing was estimated at less than $100/hour.

In April 1997, PTI and Prior Aviation, the fixed base operator (FBO) at Buffalo Airport, jointly designed, built, and operated the first infrared deicing facility. AIP/PFC funding eligibility for this type system was granted by the FAA in July 1997.

POC: Mr. James White, AAR-410, (609) 485-5138.

Rescue and Fire Fighting

Phase I of the Large Frame Fire Fighting Evaluation Program has been completed. Under a joint interagency agreement the Airports Technology Research and Development Branch and the United States Air Force, Tyndall AFB, Florida, completed the first phase of a multiyear task to evaluate improved rescue and fire fighting equipment, advance technologies, extinguishing agents, and airport requirements for fire fighting.

The central theme in this research and development effort is improvement in techniques and equipment with improved cost-effectiveness. Sensitivity to costs is very important, especially at small airports where fire protection can be a very large part of the airport's operating costs. FAA policy is to maintain or improve current levels of service and fire fighting effectiveness while stabilizing or reducing costs of that service and its associated equipment.

The focus of this program is to advance the state of the art in fire fighting strategies and to provide an increase in passenger survivability under the extreme, harsh conditions of a postcrash interior fire. This technology program, the most comprehensive look at airport fire fighting in the last 30 years, includes evaluation of such equipment as airport emergency response equipment such as GPS moving map and infrared vision enhancement devices. It also includes evaluations of the effectiveness of elevated boom and cabin skin penetration systems, hydra-chemical nozzle applications, and advanced airport fire fighting extinguishing agents which are more environmentally acceptable to the ground water and air quality.

Phase II of this research effort will look at providing fire protection needs for new generation aircraft including multilevel second floor passenger aircraft and their unique fire protection requirements.

POC: Mr. Joseph Wright, AAR-410, (609) 485-5131.

Research Facilities

Materials Fire Test Facility
Building 203

The Materials Fire Test Facility, Building 203, located in the Safety Research and Development area of the Federal Aviation Administration (FAA) William J. Hughes Technical Center, is dedicated to small-scale fire testing of aircraft materials. All of the test equipment required to conduct all of the regulatory tests for aircraft interior materials specified in Code of Federal Regulations 25.853 is part of the Materials Fire Test Facility. This includes the Ohio State University (OSU) rate of heat release apparatus, the National Bureau of Standards (NBS) smoke chamber, oil burners for the seat cushion and cargo liner tests, and Bunsen burners for the vertical, horizontal, 45-, and 60-degree flammability tests. The facility provides technical support to the Northwest Mountain Region-Transport Airplane Directorate, Aircraft Certification offices, Designated Engineering Representatives, testing laboratories, and aircraft materials manufacturers.

The facility is also the site for the development of new small-scale flammability tests such as the wet and dry arc propagation tests for aircraft wiring, as shown on the left. While other test methods are used in some laboratories, a number of the NASA labs have adopted the dry arc propagation test developed in the Materials Fire Test Facility with a few minor modifications. A more realistic smoke test for aircraft wiring using the NBS smoke chamber was also developed in this facility. This test duplicates the behavior of overheated wires and smoking insulation in an in-flight hidden-fire scenario.

As a result of a fire in a stowage bin aboard an aircraft and a recommendation from the National Transportation Safety Board, a new flammability test for aircraft blankets was developed in the Materials Fire Test Facility. The new test procedure was released as a Flight Standards Information Bulletin in 1996.

Round-robin testing by interested parties in the United States and Europe is monitored and the test data is collected and evaluated by FAA personnel at the Materials Fire Test Facility. This has led to improved flammability tests for aircraft materials. One example is the “cotton swab” test method for thermal/acoustical insulation films. This test method will be incorporated into the Aircraft Materials Fire Test Handbook which is scheduled for release in early 1998. The FAA is also working with industry and regulatory personnel on an international scale to encourage use of the cotton swab test method for selection of thermal/acoustical insulation film coverings.

The Materials Fire Test Facility personnel also participate in aircraft accident investigations by testing and evaluating materials removed from the aircraft. Other projects, such as burn-through, electrical wiring, and seat component programs are also supported in this facility.

To find out more about the Materials Fire Test Facility, contact:

Ms. Patricia Cahill, AAR-422, (609) 485-6571.

Airflow Induction Test Facility
Building 204

The Airflow Induction Test Facility, Building 204, is located in the Safety Research and Development area of the Federal Aviation Administration (FAA) William J. Hughes Technical Center. The facility contains a 5 ½-foot-diameter subsonic wind tunnel and a low-turbulence, low-speed wind tunnel as described below.

5 ½-Foot-Diameter Subsonic Wind Tunnel

The 5 ½-foot wind tunnel is an induction type nonreturn design. The induction drive is provided by two Pratt and Whitney J-57 turbine engines exhausting into the diffuser cone. The high-speed

exhaust from the two engines provides the primary flow that induces a secondary flow through the test section(s). The nonreturn design allows a continuous supply of fresh air to the facility essential for combustion type work. This design is very rugged and unaffected by debris passing through the drive section. Tunnels of this design simulate an increase in altitude as the airspeed is increased.

Test Section (high speed): The test section (shown on the right) is 5 ½ feet in diameter and 16 feet in length. Maximum airspeed in this section is limited to approximately 0.9 Mach. The entire lower lobe of the section swings away to allow for the installation of the test article. A 5- x 16-foot elevator deck makes raising the test article into position simple and safe.

Test Section (low speed): This test section (shown on the left) is 9 feet in diameter and 20 feet in length and is located upstream of the high-speed section and operates at a lower speed. Maximum airspeed in this section is limited to approximately 150 miles per hour.

The 5 ½-foot wind tunnel has been used for a variety of research applications including testing of airport runway signs to determine the design requirements needed to withstand turbine engine jet blasts and simulated in-flight testing of hand-held fire extinguishers used in general aviation aircraft.

Low-Turbulence, Low-Speed Wind Tunnel

This wind tunnel was originally designed to provide an environment to calibrate wind speed instruments. The highly accurate airspeed measurement capability, in conjunction with the six component force balance system, make this facility ideal for model testing. The facility also contains a model shop and a data acquisition system.

The low-turbulence, low-speed wind tunnel consists of an Aerolab low-speed open circuit type wind tunnel and force balance. The dimensions of the test section are 20 x 28 x 48 inches. The electrically driven wind tunnel can achieve speeds ranging from 0 to 160 mph in the test section. The six component balance system can accurately measure lift, yaw, pitch, drag, side force, and rolling moment.

The low-speed wind tunnel has been used to accurately calibrate air flow and velocity devices and is now configured to conduct model testing.

Environmental Test Chamber

The environmental test chamber is designed to simulate preset temperature, humidity, and air pressure (altitude) conditions. Chamber controllers can be programmed to simulate an entire flight from takeoff to climb-out, cruise, approach, and landing. The test chamber measures 72 x 71 x 93 inches. The environmental chamber has been used to study the behavior of in-flight fires at altitude, to evaluate the performance of wing ice detectors, and to calibrate various environmental sensors.

To find out more about the Airflow Induction Test Facility, contact Mr. Harry Webster, AAR-422, (609) 485-4183.

FAA Engine Nacelle Fire Simulator

Building 205

The Engine Nacelle Fire Simulator, Building 205, located in the Safety Research and Development area of the Federal Aviation Administration (FAA) William J. Hughes Technical Center, is designed to mimic the environment found in today's modern high-bypass ratio turbofan engines. The simulator is used by the Fire Safety engineers at the Technical Center to evaluate substitutes for halon as fire suppressants.

Currently, halon replacement is an important issue for aviation. As a result of work sponsored by the Fire Safety Section, in the Airport and Aircraft Safety Research and Development Division, a document titled "The Minimum Performance Standard for the Engine and APU Compartments" (MPSE) was drafted. This document describes the geometry of an engine nacelle simulator, operational parameters, and testing requirements required to evaluate a material or technology being considered as a halon replacement within the engine or auxiliary power unit (APU) compartment. In support of this mission, a basic engine nacelle simulator was fabricated in Building 205. The simulator will simulate the proper engine environment, meeting the intent of the MPSE.

The total fire suppression simulation requires an engine nacelle geometry, an air flow, a fire scenario, and a fire suppressant delivery. To address each element of the simulation, various systems are used. All systems are housed in a test bay having a volume approaching 12,000 cubic feet and a floor area of 4,000 square feet. The control room is adjacent to the test bay and houses support personnel and control and data gathering equipment necessary to operate the simulator.

The simulator is an 80-foot-long duct containing the air supply equipment, approach and exhaust ducts, and a test section. Three additional components are required; the first provides different aviation-specific liquids, such as fuels, at the desired temperature and quantity to the simulator interior. The second component provides a gaseous fire suppressant to the simulator interior, and the third component provides the simulator control and data gathering functions for the entire process.

The air supply equipment is capable of 0.9-3.0 lbm/s air flows heated as high as 500°F. The approach ducting contains the air flow and is 3 feet in diameter and approximately 40 feet long. The approach houses airflow sensors and stream flow correcting mechanisms. The test section, measuring 18 feet long and 4 feet in diameter, follows and is the heart of the simulator. The test section contains geometry representing an engine compartment, hardware to produce two different fire scenarios, sensors to record the environmental data, and portals to visually record fire behavior. Two fire scenarios, either pool- or spray-based, are possible. The fires are fed by the external fuel supply system which is capable of delivering fuel at 150°F and up to 1 gallon per minute. The gaseous fire suppressants are delivered by piping from the agent extinguisher into the diffuser cone entrance of the test section. These fire suppressants can be stored in various quantities at differing pressures and temperatures. Four gaseous fire suppressants (Halon 1301, HFC125, HFC227ea, and CF_3I) are on-site for near-term work.

Rounding out the capabilities of this facility is the ability to record the testing. For each test, a record is established describing the fire suppression event. The record will contain a concentration profile within the test section recorded by a Halonyzer gas analyzer for gaseous fire suppressant events; a computer file containing sensor activity measuring temperatures, pressures, air flows, and ambient relative humidity; and finally, a visual recording of the fire zone and its activity during the event.

The FAA Engine Nacelle Simulator was completed in 1997 and the test program to evaluate materials or technologies being considered as a halon replacement within the engine/APU compartments will be completed by December 1998. By using a simulator and not a true aircraft engine for the bulk of the halon replacement work, maintenance costs will be reduced. Additionally, the generic geometry of the simulator can be used to develop a better understanding of the fire suppression environment. The specific geometry of an existing engine nacelle may present a unique case which might cloud general understanding and inhibit widespread application of the generated data.

To find out more about the FAA Engine Nacelle Fire Simulator, contact Mr. Douglas Ingerson, AAR-422, (609) 485-4945.

Dynamic Vertical Drop Test Facility

Building 214

The Federal Aviation Administration (FAA) is responsible for airplane crashworthiness standards. These standards increase the possibility of occupant survival in case of an accident and were established empirically using the results of prior airplane crash test programs. In development of those standards it was noted that the full-scale airplane impact test database did not include airplanes representative in size of commuter category airplanes. To provide data for those size airplanes, the FAA initiated a full-scale vertical impact test program of 14 CFR 23 commuter category airplanes. As part of this program a test of a Metro III aircraft was conducted in April 1992 and a Beechcraft aircraft was tested in October 1995. The tests were structured to assess the impact response characteristics of airframe structures, seats, and the potential for occupant impact injury.

In addition, the Aircraft Safety Research Plan calls for the vertical impact test on a series of transport category fuselage sections. These tests are conducted to determine the impact response characteristics of some typical items of mass installed on board a transport airplane to assess the adequacy of the design standards and regulatory requirement for those components. Items of mass include overhead stowage bins, auxiliary fuel tanks, and seats/occupants.

The FAA's Dynamic Vertical Drop Test Facility, located in the Safety Research and Development area at the FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey, is used to obtain the empirical data needed to set crashworthiness standards and to obtain other crashworthiness data as described above. The data from tests conducted at this facility will enable a quantitative evaluation of the effects of crash events on occupant survivability.

The Technical Center drop test facility, shown in the photograph below, is comprised of two 50-foot vertical steel towers connected at the top by a horizontal platform. An electrically powered winch, mounted on the platform, is used to raise or lower the test article and is controlled from the base of one of the tower legs. The current lifting capacity of the winch is 13,600 pounds. Attached to the winch is a cable used to raise or lower the test article. A sheave block assembly hanging from the free end of the reeved cable is engaged to a solenoid operated release hook. A cable/turnbuckle assembly connects the release hook to the airframe with hooks bolted to the fuselage section. A 15- by 36-foot wooden platform is located below the winch cable assembly and between the tower legs. The platform rests on I-beams and is supported by 12 independent load cells. The load cells are used

to measure the fuselage impact on the platform.

The data collected in future tests will be added existing databases. Scheduled vertical drop tests include testing a commuter Shorts330 aircraft and two transport narrow body fuselage sections, one with overhead stowage bins and one with an auxiliary fuel tank. The data obtained in these tests will be used to improve standards for seats, overhead stowage bins, and auxiliary fuel tanks.

To find out more about the Dynamic Vertical Drop Test Facility, contact Mr. Gary Frings, AAR-431, (609) 485-5781.

Full-Scale Fire Test Facility
Building 275

Completed in 1980, the Full-Scale Fire Test Facility, Building 275, located in the Safety Research and Development area at the FAA William J. Hughes Technical Center, is the largest U.S. Government operated facility of its kind. A 40-foot-high fire-hardened ceiling allows testing with large pool fires under controlled conditions. There are currently two aircraft fuselages inside the facility which can be set up to simulate a variety of test conditions. The narrow-body Boeing 707 test article can be configured for cabin water mist, seat comparison, and burnthrough tests, while the 132-foot-long hybrid DC-10 test article has the added capability of supporting cargo compartment fire simulations in three fully instrumented sections. Continuous gas sampling, temperature measurements, smoke levels, heat flux, and acid gases can be monitored in each of the test sections. The data obtained from the fire tests can be transferred into hazard models designed to generate estimated survival times at particular cabin locations. All testing is conducted from a remote area that contains state-of-the-art video monitoring equipment for continuous observation. Both in-flight and postcrash fire scenarios have been studied, which has led to the development of vastly improved fire safety standards for aircraft cabin interiors and cargo compartments.

In addition to the two test articles, there are small test chambers located within the facility that are capable of supporting existing and new laboratory-scale tests, as well as quick mock-up work often required during accident investigations. A full-length attached warehouse serves as an enclosure for the many aircraft components and equipment required to support the full-scale tests.

Currently, there are two major research programs underway at this facility: halon replacement and fuselage burnthrough.

Halon Replacement. Halon, a gaseous extinguishing agent used in aircraft cargo compartments, engine nacelles, lavatory trash receptacles, and hand-held extinguishers, is the most effective fire extinguishing agent on a weight basis. Although effective, halon depletes stratospheric ozone.

Halon manufacturing was banned under the 1994 Montreal Protocol, a treaty signed by countries around the world. The FAA is in the process of developing minimum performance standards by which replacement agents' effectiveness can be measured. Candidate fire protection systems for the cargo compartment areas include gaseous agents, pyrotechnically generated aerosols, and water mist. The photograph on the left depicts the initial stages of a cargo compartment fire scenario against which the various agents will be evaluated.

Fuselage Burnthrough. After an accident, fuel fire flames can enter the cabin through an inadvertently open escape exit or, in a more severe impact, through a break in the fuselage. Fire can also enter the cabin by penetrating the fuselage structure, which is the focus of this research project. In an accident in Manchester, England, in 1985, 55 fatalities occurred due to the rapid burnthrough from an external fire. As a result of this accident, fire tests were conducted to determine the burnthrough paths and the time frame involved in order to better understand the accident scenario. The emphasis of the current test program is on evaluating improvements to delay the burnthrough time and thereby increase the escape time and to validate test work being performed on a medium-scale burnthrough rig. To date, several technologies have emerged that have the capability of delaying burnthrough for several additional minutes. The photograph below shows the external pool fire used during these experiments.

To find out more about the Full-Scale Fire Test Facility, contact Mr. David Blake, AAR-422, (609) 485-4525.

Chemistry and Materials Sciences Laboratory

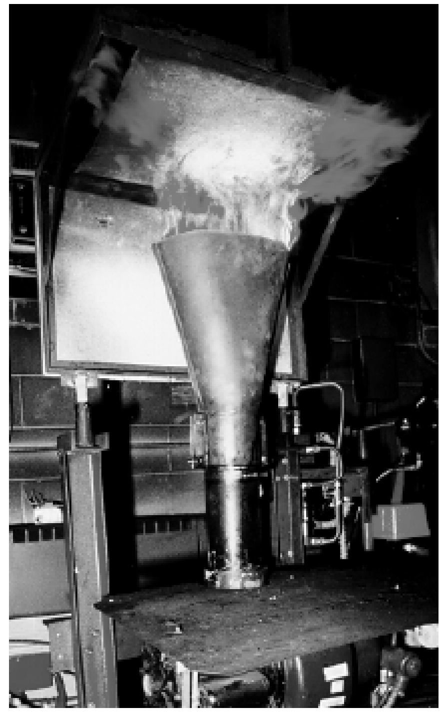
Building 277

The Chemistry and Materials Sciences (C&MS) Laboratory located in Building 277 in the Safety Research and Development area at the FAA William J. Hughes Technical Center provides FAA chemists, fire scientists, and materials engineers the facilities and equipment to quantify the amount of toxic gas produced during full-scale aircraft cabin fire tests. The FAA is committed to developing the enabling materials technology for a totally fireproof cabin. The goal of the program is to eliminate cabin fire as a cause of death in aircraft accidents. To achieve this goal we will need interior plastics with an order-of-magnitude reduction in fire hazard compared to current materials. In the C&MS Laboratory, research and development of new, more fire-resistant materials is conducted using state-of-the-art laboratory equipment for thermal analysis, calorimetry, spectroscopy, rheology, surface chemistry, microscopy, and multiaxial mechanical testing. Flammability and combustion parameters of cabin materials are determined in bench-scale fire calorimeters. Prototype components up to 1/2 meter square can be fabricated. C&MS Laboratory equipment includes:

- Netzsch High-Speed Thermogravimetric Analyzer (TGA) for evolved gas analysis
- Perkin Elmer System 7 TGA and Differential Scanning Calorimeter
- Nicolet Magna 550 Fourier Transform Infrared (FTIR) Spectrometer
- Parr Oxygen Bomb Calorimeter for heat of combustion determinations
- FAA Microscale Combustion Flow Calorimeter (patent pending)
- Dionex DX 500 Ion Chromatograph with Thermo-Separations AS 3500 Autosampler
- Rheometrics RDA-II Dynamic Analyzer for rheological testing of fluids and solids
- Instron Model 1125 Universal Mechanical Testing Machine
- Rame-Hart Contact Angle Goniometer for surface chemistry measurements
- PHI Heated Laminating Press–50 Ton/1000°F capability
- Gruenberg Curing Oven–800°F (426°C) capability
- Atas Scientific Cone Calorimeter–measures flaming combustion parameters of materials

A unique instrument, the microscale combustion calorimeter which was developed by FAA researchers, is located in the C&MS Laboratory. The calorimeter is used to measure flammability parameters of milligram polymer (plastic) samples under conditions which approximate aircraft cabin fires. The tests performed using the calorimeter provide a quantitative measure of the fire hazard of new materials in an aircraft cabin fire when only research quantities are available, thus saving the expense of manufacturing and testing large quantities of new materials. The photograph on the right shows the microscale combustion calorimeter, showing, from left to right, the sample pyrolysis stage, the heated oxygen mixing manifold, and the combustion furnace and oxygen analyzer.

A new, potentially fire-resistant material being tested in the C&MS Laboratory is the Geopolymer resin. This material is being evaluated as a resin for use in fireproof aircraft cabin interior panels and cargo liners (see test at right). Geopolymer is a two-part, water based, liquid potassium aluminosilicate resin which cures at 80°C (176°F) to a fireproof solid having twice the density of water. Geopolymer has the empirical formula: $Si_{32}O_{99}H_{24}K_7Al$. The fire response and mechanical properties of Geopolymer composites were measured and compared to lightweight organic matrix composites and aluminum used in aircraft.



Carbon fabric reinforced Geopolymer crossply laminates were found to have comparable initial strength to phenolic resin composites currently used in aircraft interiors. Unlike the phenolic laminates however, the Geopolymer composites did not ignite, burn, or release any heat or smoke even after extended exposure to high heat flux. Geopolymer composites retained 67 percent of their original flexural strength after fire exposure while organic (e.g., phenolic) composites and aluminum had no residual strength after the test. Geopolymer composites have higher strength and stiffness per unit weight, higher temperature capability, and better fatigue resistance than steel or aluminum.

Work in the C&MS Laboratory is continuing on understanding how the Geopolymer resin protects the carbon fibers from oxidative degradation at 800ºC (1500ºF) in air, on optimizing the processing of materials made with the Geopolymer resin to obtain maximum strength, and on improving the toughness of laminated composites made with the Geopolymer resin.

To find out more about the Chemistry and Materials Sciences Laboratory, contact Dr. Richard Lyon, AAR-422, (609) 485-6076.

Aircraft Components Fire Test Facility

Building 287

The Aircraft Components Fire Test Facility, located in the Safety Research and Development area at the FAA William J. Hughes Technical Center, houses two test bays designed and used for component or intermediate-scale fire tests. The larger of the test bays is 2000 sq. ft. and the smaller is 1600 sq. ft. Both bays are 20 feet high and have access through a large roll up door. Both bays are constructed of fireproof materials and contain large blowout panels for explosion protection. A centrally located instrumentation and control room contains test monitoring and data collection equipment and is connected to the bays via under floor conduits. In addition to the test bays, the building includes a small work and buildup area, a conference room, a computer lab, and office space for six fire safety personnel.

Recent testing in the building has included the development of new fire test standards for flight data recorders. The testing included propane burner tests, shown on the left, as well as long-term elevated temperature tests, using a high-temperature programmable oven. The results were used in the development of a new Technical Standard Order (TSO) for flight recorders.

The testing of solid oxygen generators was conducted under various scenarios. This included the testing of a single canister (see photo on right) under various conditions up to full-scale tests of over 100 generators in a Boeing 727 cargo compartment. The results were used as part of the Valujet investigation and as part of the justification for rulemaking to eliminate class "D" cargo compartments.

Testing was conducted to develop a methodology to use HFC 125 as a substitute for Halon 1301 in certification testing of fire suppressant/extinguishing systems. By substituting HFC 125 for Halon 1301, less Halon 1301, an ozone depleting gas, is expended during the certification tests of new systems.

The testing of thermal/acoustic insulation materials included the standardization of a small-scale flammability test method. This method has been included in the Aircraft Materials Fire Test Handbook and has been adopted by major airframe manufacturers. Additionally, larger scale mockup tests were conducted (photo on right) in sections of an aircraft fuselage. The results of those tests have lead to the modification of the specification for thermal/acoustic insulation by at least one major airframe manufacturer.

The cargo compartment fire suppression testing included comparisons of class "D" and class "C" compartments for various fire threats and suppression systems. The test article used was a Boeing 727 cargo compartment. Fire scenarios included exploding aerosol cans (photo on left) and suppression systems ranging from the presently used Halon 1301 to nonconventional water mist systems. Work was in support of ongoing rulemaking.

To find out more about the Aircraft Components Fire Test Facility, contact Mr. Richard Hill, AAR-422, (609) 485-5997.

Runway Friction Laboratory

Building 288

The FAA's regulatory obligation (49 USC Sec 47105(b)3) includes operation and maintenance of the massive airport system. Surface traction is a fundamental element in this respect. Loss of braking ability and directional control continues to be a problem for a small but significant number of aircraft operations. Previous research has led to the use of runway friction measuring equipment in maintaining airport pavements in proper condition. But additional work is needed in order to use this equipment to provide operational information to pilots. The following precision measuring equipment is housed in Building 288 located in the Safety Research and Development area at the William J. Hughes Technical Center and supports a variety of research programs where the measurement of micro-texture on a runway surface must be considered.

<u>Surface Friction Tester (SFT)</u>

The SFT is a front wheel drive, self-contained, continuous friction measurement device. Mounted inside the rear of a Saab 900 is a hydraulically controlled fifth wheel with a chain connection to the rear axle. A slip ratio of 10%-12% is produced. A torque measurement is used to compute friction values versus distance traveled. The calculated friction values are printed on a strip chart and can be downloaded to a laptop computer for further analysis.

<u>Runway Friction Tester (RFT)</u>

The RFT is a front wheel drive, self-contained, continuous friction measuring device. The friction equipment is mounted inside a Dodge Caravan and was manufactured by K. J. Law Engineers, Inc. This device uses a two-axis force transducer that measures vertical and drag loads. The friction measuring wheel is connected to the rear axle by a gear drive that produces a fixed 13% slip. The computer calculates friction coefficient values for each foot of distance traveled and can plot this data directly to a digital printer installed in the van. The data can also be downloaded to a laptop computer for further analysis.

<u>Mu-Meter</u>

The Mu-Meter is a side-force measuring trailer marketed by Bison Industries. Two of the three wheels on the trailer unit are positioned at 7.5° from the center axis of the trailer. This produces an apparent slip ratio of 13.5°. The third wheel is for distance measurement. The computer equipment produces a strip chart with continuous friction values versus distance traveled.

Skidometer BV-11

The Skidometer is a trailed vehicle, equipped with a friction measuring wheel designed to operate at a fixed slip rate between 15 and 17 percent. Airport Equipment Co. markets the trailer device. A torque measurement is processed by the computer and recorded on a strip chart as a continuous plot of friction values over the distance traveled.

Swenson Solid Chemical Spreader

This equipment mounts in the bed of a pickup truck and is used for dispersing solid chemicals at precise application rates. The solid chemicals are usually runway deicers and anti-icers, but sand and salt can also be dispersed. The advantage of this particular piece of equipment lies in the computer control and monitoring capabilities, which were specifically designed to produce minute applications of solid chemicals for research projects.

Batts Liquid Chemical Sprayers

This equipment also mounts in the bed of a pickup truck or on a trailer. It is a small-scale version of common chemical dispersal equipment used on highways as well as airports. The control box is specifically manufactured for the precise application of runway deicers and anti-icers but has also have been used for spraying aircraft deicing fluids as well as water.

To find out more about the Runway Friction Laboratory, contact Mr. Wayne Marsey, AAR-410, (609) 485-5297.

Propulsion and Fuel Systems Test Facilities
Buildings 292 and 211

Several individual laboratories which comprise the propulsion and fuels systems test facilities are located within the Safety Research and Development area at the FAA William J. Hughes Technical Center. The facilities provide research and testing to ensure the safety of all civil aircraft propulsion, fuel, and powerplant and fuel system installations. These facilities also provide the validation of data and technical bases for improvements to civil aircraft certification and operational standards, including procedural guidance and means of demonstrated compliance to these standards. The individual laboratories include (1) Large Turbine Engine Test Laboratory, (2) Small-Engine Test Laboratory, (3) Fuels Research Laboratory, and (4) Wing Fuel Spillage and Jettison Laboratory.

<u>Large Turbine Engine Test Laboratory</u>

The Large Turbine Engine Test Laboratory consists of two test cells (40 by 30 ft.), a control room, and supporting test and data acquisition equipment that can be used to assess the safety and performance of large turbine engines and related systems. The active test cell is equipped with a thrust stand rated at 20,000 lbs. and an eddy-current dynamometer that can accommodate aviation piston engines up to a maximum rating of 500 shaft horsepower. The second test cell is a multipurpose facility that is used for engine test or for other non-engine research program support. Research conducted within this test cell laboratory include full-scale tests and safety investigations associated with turbine engine fuels and fuel systems, water ingestion, emissions, and turbine engine failure prediction studies. One of these test cells is shown above.

<u>Small-Engine Test Laboratory</u>

The Small-Engine Test (SET) Laboratory is designed for full-scale testing and performance evaluation of small aircraft engines, including existing engine (i.e., turbine, piston, etc.) and future engine (i.e., diesel, rotary, etc.) designs. The building contains two test cells equipped with water brake (750 hp) and eddy-current (500 hp) dynamometers, control room, data acquisition system, and associated support equipment needed to perform engine combustion analysis, exhaust emission, detonation detection, and other safety and performance related assessments. The photograph on the right shows a piston engine-dyno test cell installation in the SET Laboratory.

Fuels Research Laboratory

The Fuels Research Laboratory (shown at left) consists of two main test areas, one for fuels analysis and another for fuel component system testing. The fuel analysis area is equipped for conducting tests in accordance with American Society for Testing and Materials (ASTM) test standards specified for aviation turbine fuels (ASTM 1655), aviation gasolines (ASTM D910), automotive gasolines (ASTM D439), and other alternate fuels. The fuel component systems test area includes bench test installations to perform research and testing associated with aircraft fuel transfer and other handling systems. The fuel component systems test area is set up to conduct tests on (1) engine fuel systems (i.e., tanks, pumps, valves, fittings, etc.), (2) engine controls and accessories, and (3) engine fire protection systems.

Wing Fuel Spillage and Jettison Laboratory

The Wing Fuel Spillage and Jettison Laboratory (see photograph at right) consists of a ram air (200 knots) wind tunnel and a wing test section and data acquisition control area that is used to assess the safety and performance characteristics of fuels and fuel transfer systems under simulated high air flow flight conditions. The laboratory has been used to evaluate postcrash effectiveness of safety fuel additives and can be used for procedures associated with the emergency jettison of aircraft fuel and other experiments involving fuel and fuel transfer system performance needs.

To find out more about the Propulsion and Fuels System Test Facilities, contact Mr. Stewart Byrnes, AAR-432, (609) 485-4499.

National Airport Fire Extinguishing Agent Performance Test Facility

Improved fire fighting training, techniques, and equipment are needed to support FAA airport safety and certification programs. It is FAA policy to maintain or improve current levels of service and fire fighting effectiveness while stabilizing or reducing the costs of that service and associated equipment. The central theme in this research and development effort is the improvement of fire fighting techniques and equipment while maintaining or improving cost-effectiveness. Sensitivity to cost is very important, especially at small airports where fire protection can be a very large part of the airport's operating costs.

This program is focused primarily on advancing the state of the art in fire fighting strategies and increasing passenger survivability under the extremely harsh conditions of an interior postcrash fire. A secondary focus includes evaluating the effectiveness of elevated boom and cabin skin penetration systems for interior fires, cargo fires, and composite material fires, as well as evaluating the effectiveness of advanced airport fire fighting extinguishing agents which are more environmentally acceptable so that ground water and air quality are protected.

Laboratory tests have not proved reliable to predict the performance of extinguishing agents in large postcrash fuel spill fires. Additionally, interior aircraft fire protection requirements can only be measured under actual full-scale interior fire conditions of flashover. Real-time fire fighting strategies and fire protection requirements need to be established for new generation aircraft having second-level seating passenger designs. In addition, aircraft constructed of advance composite materials pose unique and specialized requirements on firefighters which will be determined using this facility.

The test facility consists of three parts:

- A full-scale, environmentally protected ground facility to test new fire extinguishing agents and collect toxic waste and spent fuel without endangering the environment.

- A full-scale aircraft facility with second-level passenger configurations to test new equipment, fire fighting tactics, and strategies.

- The FAA's advanced high-performance rescue research vehicle (HPRV) with its 55-foot elevated boom and cabin skin penetration system.

A large military surplus C-133 cargo aircraft will be fire hardened and configured to test agent distribution and fire performance in several unique fire scenarios, including interior fires, cargo fires, and second-level fires.

The ground spill fire facility measures 200 x 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. The specialized two-level aircraft facility measures 190 feet in length, 12 feet in diameter, and 26 feet high. It will be the first full-scale second-level aircraft fire test facility in the world. The photograph below shows the advance high-performance rescue research vehicle (HPRV) with its 55-foot elevated boom and cabin skin penetration system conducting a fire test.

To find out more about the National Airport Fire Extinguishing Agent Performance Test Facility, contact Mr. Joseph Wright, AAR-410, (609) 485-5131.

Category I Reconfigurable Approach Lighting System Testbed
(RALST)

The Airport Technology Research and Development Branch, Airport Safety Technology Section, has a Category I Reconfigurable Approach Lighting System Testbed at the Atlantic City International Airport, New Jersey.

The testbed consists of seven 5-lamp barrettes spaced 200 feet apart starting 200 feet in front of the threshold of Runway 4. At the 1000-foot station two additional barrettes of 5 lamps are on either side to the 5-lamp barrette. From the 1600- to the 2400-foot station, 5 strobes are spaced 200 feet apart (1 strobe per station). The lamps on each barrette are individually controlled for maximum flexibility in approach lighting research and development. External power is provided at each station to provide for new technology research.

The testbed is currently being used in support of the Approach Lighting Research and Development project. This project will provide data to ensure safe and efficient airport ground operations, especially at night and under low-visibility conditions. Improvements in the visual aids will help to eliminate runway incursions. The goal of this program area is to eliminate deficiencies in visual guidance systems and procedures that may contribute to surface collision accidents.

To find out more about the Reconfigurable Approach Lighting System Testbed, contact Mr. Donald Gallagher, AAR-410, (609) 485-4583.