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NASA TECHNICAL ADVANCES IN

AIRCRAFT OCCUPANT SAFETY

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THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION'S AERONAUTICS PROGRAM is directed at improving performance, efficiency, and safety of aircraft and their operation. By far, the majority of NASA's $280+M annual aeronautics budget supports the development of advanced technologies for more efficient, higher performance aircraft designs with safe and reliable operation an implicit goal throughout the program structure. In a gross sense, the NASA aeronautical research philosophy seeks a safety norm through the development of advanced technologies which in themselves are "accident/incident avoidance" oriented. However, operational experience yields many examples of safety problems, and NASA spends annually about $12M of its aeronautical budget on programs undertaken specifically for safety assurance and improvement.

Safety can be defined as the absence or control of factors which can cause injury, loss of life, or loss of property. The complexities of aeronautical technologies, coupled with our incomplete understanding of the natural and operational environments, threaten a desirable level of control of these factors. Accidents occur, as they do in all human endeavors, because of our ignorances and our failure to completely understand and properly assess hazards. These ignorances and failures, coupled with subjective decisions, whether at the drafting board, in the dispatch office, at the radar console, or in the cockpit, or even at the top management levels, influence the sequence of events in which safety margins are critically affected. In the extreme, these sequences of events can lead to injury or death of the aircraft occupants. NASA's Aviation Safety Technology Program examines specific safety problems associated with atmospheric hazards, crash-fire survival, control of aircraft on runways, human factors, terminal area operations hazards, and accident factors simulation (1)*, with a view toward improving through research, our knowledge and understanding of the factors involved.

A complete review of the broad range of NASA's Aviation Safety research activity is beyond the scope of this paper. While aircraft occupants are ultimately affected by any of the hazards named above, their well-being is immediately impacted by three specific hazard events:

- o Unexpected Turbulence Encounters
- o Fire and its Effects
- o Crash Impact

NASA research effort in these three areas is the subject of this paper.

UNEXPECTED TURBULENCE ENCOUNTERS

Flight in the turbulent atmosphere has been a continuing concern to those involved in aircraft design and operation. NASA's record of turbulence research goes back to the earliest days of NACA (2), when the concerns centered mainly around the structural integrity of an aircraft subjected to gusts, and assuring the effectiveness of control systems in such environments.

These concerns were augmented by passenger discomfort during bumpy flight as well as the operational economic penalties incurred by diversions, delays, and aircraft repair due to turbulence. While experience has led us to expect and prepare for turbulence during flight through visible cloud and storm systems, the advent of high-flying jet aircraft exposed the aircraft and its occupants to a new hazard: Clear Air Turbulence, or CAT. CAT is not associated with visible convective activity and therefore sudden, unexpected encounters at high cruise speeds have resulted in injury to passengers and crew, damage to aircraft, and in rare instances fatal injuries. Research was undertaken by several government agencies and airlines on a coordinated basis to characterize and understand this new hazard and to examine the possibility of providing advance warning of CAT encounters.

CAT Characterization - CAT occurrence is associated with both mountain waves and shear layers attendant to the high altitude jet stream. NASA and others have worked for several years to characterize CAT in functional terms so that its occurrence and geographical extent could be reliably forecasted from analysis of measurable parameters (3). Many researchers support the conclusion that CAT is caused primarily by unstable shear-gravity inertia waves breaking into small eddies and transferring kinetic energy downstream (Figure 1). According to another widely-accepted theory, the motion becomes turbulent when the value of the Richardson number, (an expression of the ratio of bouyant force to the shearing stress), i.e.,

$$Ri = \frac{g}{\theta}\frac{\partial\theta/\partial z}{|(\partial V/\partial z)|^2}$$

become smaller than some critical value.

* Numbers in parentheses designate References at end of paper.

Present uncertainties in understanding place this critical value somewhere between 0.5 and 0.25.

The arrival of extensive data handling capability of computers has made possible more numerous and complex procedures to analyze and utilize standard meteorological data to forecast CAT. The improvements in this area have been evidenced in current U.S. airline turbulence encounter procedures which, through seat belt warnings and reductions in penetration speeds, have reduced injuries and aircraft damage from CAT.

CAT Detection - Several years ago, as part of the U.S. Federal Coordinator's Program for Meteorological Research, NASA undertook an investigation of laser technology as applied to the problem of CAT detection and encounter warning. The goal was to examine the feasibility of developing an airborne laser-Doppler system (LDS) for operational use, and to determine whether CAT could be measured far enough ahead of an airplane sufficiently well to be considered practical. Theoretical studies to determine feasibility and to define preliminary design requirements were conducted in 1968-69. The results of these studies led to the design and development of a breadboard pulsed CO_2 laser Doppler system during 1970 to 1972. This breadboard system was flight tested in 1972 and 1973 aboard NASA's CV-990. A special forward looking fairing was designed and built for the portside emergency door (Figure 2) of the aircraft, which permitted the laser beam to be transmitted forward along the heading of the aircraft. Receiving backscattered light from micron-sized aerosol particles in the atmosphere, the system measures this signal, comparing with the transmitted beam, processes the information, and relays it to the displays and recorders. Since the CAT warning must extend over many miles, the laser beam must be highly stable and have large coherence lengths. The system utilizes a small, very stable CW master laser operating as follows:

- Wave Length 10.6μ
- Pulsed Length 4-10 μsec.
- Pulsed Rate 140-160/sec.
- Peak Power 5KW
- Average Power 3W
- Optics Diameter 12 in. (28 cm)

The objectives of the flight tests were to:

- Determine if the complex electro-optical sensor could be operated successfully aboard an aircraft during most flying conditions, including heavy turbulence.
- Test experimentally whether a CO_2 laser Doppler system could measure CAT sufficiently far ahead of an airplane to potentially qualify as an operational onboard CAT detection and warning system.
- Determine if the aerosol content and the backscatter efficiency or transmittance of the upper atmosphere (2-14 Km) was sufficient to backscatter frequency-shifted laser radiation to the airborne transmitter from a range of about 12 n.mi. (20 Km).

Two series of flight tests were conducted. Some modifications were made to the hardware between the two tests that increased the signal-to-noise performance of the system by about 15dB.

Overall results of this series of test are as follows:

- No CAT sensor operating problems due to the airborne environment were encountered.
- Nonjet stream turbulence was identified and subsequently encountered:
  - Near a dust storm in Arizona
  - On the east side of the High Sierras, over the ishop Valley (wave turbulence was located and identified in a region that had many cumulus clouds)
  - In the Mojave Desert near Edwards, AFB, and near the Salton Sea where turbulence from thermals was located.
- A 30 knot (15 m/sec.) wind shear was detected, measured, and encountered near a storm at an aircraft altitude of about 7,000 feet (2130 m) above the ground.
- Clear air signals, where there was no turbulence, measured the true air speed during the tests showed that the concentration of aerosols in the atmosphere was significantly less than predicted by the AFCRL model, by 1.5 to 2.5 orders of magnitude.

The feasibility of laser Doppler technology for detection of CAT was demonstrated. While turbulence detection ranges were disappointingly short (5 to 6 n. mi. actual vs expected 16-20 n. mi.) in these tests, system sensitivities and signal-to-noise ratios are presently being improved to achieve near-theoretical performance. We are conducting a series of ground-based tests with the system incorporating hardware improvements made since the flight test series. These ground tests precede potential further flight tests in mid-1978.

A companion effort in CAT detection involves flight testing of another concept; a simple prototype infrared radiometer and signal microprocessor of the aircraft.

- There were many signals from cirrus clouds at 25,000 to 38,000 feet altitude, ranging from 3 to 11 nautical miles (5.5 to 20 Km).
- Doppler signals were measured from the ground at ranges up to 16 n. mi (30 Km), with signal intensities between 5 and 15 dB
- Three well-separated cumulus clouds aligned along the system line-of-sight were detected simultaneously demonstrating low signal attenuation through clouds.
- Severe turbulence was measured ahead of the aircraft and encountered as predicted during the flight through mountain wave turbulence. The velocity gradient on one encounter was 40 knots (20 m/sec) in less than 3,000 feet (914 m), with accelerometer reading over 0.5G.
- Aerosol sampling data collected system. This system detects water vapor anomalies which seem to be associated with CAT presence. Initial tests aboard the NASA C-141 Kuiper Airborne Observatory at tropopause levels have established this relationship fairly confidently. We have installed the system aboard a Lear Jet (Figure 3) for additional flight testing and concept validation. The system de-bugging was accomplished in January, and data acquisition is currently underway.

FIRE AND ITS EFFECTS

Successful egress from a crashed airplane can be hindered or made impossible by fire, while in-flight fires must be dealt with directly in order to survive. Studies of aircraft accidents (4,5) present evidence of aircraft occupants in some cases surviving crash impact, only to succumb to the associated fire or its effects (Figure 4). While three catastrophic in-flight fires have occurred in turbine-powered transport operations, by far the majority of in-flight fires have been of small magnitude, were detected early, and have usually been satisfactorily controlled. The potential for catastrophe remains, however, and continuing attention to preventing, detecting, and extinguishing these fires is essential.

NASA's interest in aircraft fires dates from early NACA research (6) and the well-known full-scale crash fire tests of the late 1940's and early 1950's (7). This work emphasized solutions to the more obvious fuel fire hazards present in the crash environment. At the time, we felt reasonably secure in the feeling that fire-retardant cabin materials would somewhat delay all but the most severe interior fires. In 1967, however, the tragic Apollo 204 spacecraft fire jolted us into an awareness of the hazards presented by the functional interior materials, whose safety levels we had previously often taken for granted. NASA subsequently examined several thousand candidate materials for spacecraft application which would offer improved fire resistance. About 100 or so eventually were judged to offer possible advances over those materials in use up to that time.

During the same time period, the FAA and industry concerns over involvement of cabin materials in aircraft fires prompted NASA to examine the applicability of these spacecraft candidate materials to aircraft interiors. As a first step, derivatives of the improved spacecraft materials yielded a dozen or so possible candidates for aircraft interiors based solely on flammability considerations. Factors of cost, availability, manufacturability, long-term stability, mechanical properties, etc., were less attractive. These material candidates consisted generally of inorganic materials, fire resistant polymers and fire retardant treatments. They were evaluated in a series of transport aircraft cabin tests (Figure 5) at Johnson Space Center in 1972. This test series included baseline fire tests of pre-1968 materials, state-of-the art materials, and so-called "space age" materials. While the tests showed substantially improved flammability resistance with the newer, "space age," materials, we found that these classes of materials, exposed to a relatively small heat source, yielded sufficient smoke and toxic gas levels to caution against their immediate adoption in cabin interiors.

During the same period, scientists at the Ames Research Center, drawing upon a decade or more of experience in spacecraft re-entry heat shield development had developed char-forming ablative chemistry to a very high level. This work suggested fire protection schemes in the form of intumescent protective coatings, insulative foams and base materials with fire resistance designed into the molecular structure itself. The char-forming foam costing concept was examined in 1969 in a test using a C-47 fuselage (Figure 6). Half of the fuselage was coated with a 3" layer of foam applied to the internal surface of the fuselage skin; the other untreated half served as a control, or baseline. A surrounding pool of about 4500 gallons of JP-4 was ignited. The results clearly demonstrated the concept of thermal protection by such foams. Derivatives of this technology have been successfully applied by the military for ammunition protection and in-flight ballistic threat protection in the form of intumescent coatings and isocyanurate foam void fillers. However, their effective application in crash situations where the structural integrity of the fuselage is not maintained remains unclear.

These two examples represent NASA's first directed attention to aircraft cabin fire protection. In themselves, they failed to provide immediate solutions. However, they were important in that they provided a basis of understanding and insight from which subsequent research has evolved. The general interest in fire research intensified during the late 60's and early 70's, due to a growing awareness of our society's total fire liability in ground structures and all transportation modes. Collectively we have become more aware of the fact that many fire retardants, while effective in preventing ignition from relatively low energy level heat sources, become less effective at higher heat loads and worse yet, are often the source of heavy smoke and incapacitating or toxic gases. The materials combustion process is a complex process with many variables. The scientific and engineering community doesn't yet understand some of the interrelationships involved, nor do we always know just how to proceed from what do we know to an effective, practical design for fireworthiness. Added to this problem is that of linking an eventual engineering understanding of the relationships between fire processes and design to human survivability in fire situations. Toxicologists are presently unable to agree on a rational toxicity ranking scheme or to provide a comprehensive "specification" for short-term acute exposure tolerance of the many toxic gases evolved in fire processes.

With the fire process in mind, let us now turn to considering how best one can effectively deal with fire. The fire logic tree (Figure 7), shows the two major choices: Prevent the fire, or manage the fire. Several options exist within these choices. At the heart of effective fire prevention or control, as any fire fighter knows, is the question of how best to intercede early enough in the fire development chain to limit the role of energy transfer to the fuel. As a first line of defense we should of course try to prevent ignition. Failing that, we must slow the rate of pyrolysis and fire build-up or preferably reverse the process to extinction. Lastly, we may try to isolate the occupant from exposure to the fire and its effects. Within this logic framework, many options suggest themselves. The question is one of how best to intercede. From an interior materials improvement standpoint, we seek rate-limiting mechanisms to extinguish or slow the rate of fire development. One can employ extinguishants as an externally-applied rate control; a retardant treatment which is a passive deterrant applied to an otherwise flammable material; employ fire resistant polymers or design fire retardant chemistry into the material at the molecular level which confers a degradation stability on the material system itself. Each of these methods has advantages for particular situations.

NASA reassessed its aircraft fire program in 1975, and considering inputs of industry and the FAA, defined a program augmentation which we named FIREMEN, for FIre REsistant Materials ENgineering. FIREMEN began in 1976 and is a 5-year \$4.2M augmentation of our R&T base program. FIREMEN is built upon the continuing broad-scoped fire research and technology effort. This R&T effort has averaged about \$600K/year since FIREMEN began. An important objective of FIREMEN is to stimulate an accelerated interest in examining advanced materials technology for possible applications to improvement of aircraft interior fire safety. This is being accomplished through contracting for directed development and test of structural assembly concepts, based upon application of advanced materials research and analysis. FIREMEN is dependent upon industry participation, since the acceptability of new materials and material systems is heavily dependent upon the availability, processability, fabrication and service life of the components, all of which determine relative costs. Applications of these basic materials included sandwich panels, thermoplastic moldings, transparencies, seat cushion materials and fabrics.

One of the early deficiencies we found was a lack of test methodologies which could reliably predict full scale effects. The development of better test methods and techniques to correlate results obtained in different test facilities and at different scales is a major joint objective of NASA, FAA, and the industry. Development of an ability to confidently model the fire process at all scales is also a vital objective of our program, in order to realistically guide materials development and to eventually reduce the present need for costly and time-consuming full-scale testing. We are augmenting the FAA's Cabin Fire Model program and supporting their Combined Hazard Index program with complementary thermochemical and large scale modeling efforts.

Since preventing ignition with total assurance is unlikely, we are currently concentrating on two approaches to controlling the fire (Figure 8). Fire retardant additives work to delay pyrolysis of the base material in several ways. Exposed to elevated heat levels, these additives either passively insulate the base material or actively yield inflammable gases. Halogens or phosphorus are the main ingredients. However, the retardants themselves may produce smoke and toxic gases when heated, even though the basic material may not be immediately involved. Exposed to an external heat source long enough, the retardants can be pyrolyzed complete, no longer affording protection, and the flammable base material is now exposed and burns. However for short time low heat flux situations, this class of materials may be entirely satisfactory.

In the synthesis, or modification approach, using char-forming polymers, protection is afforded by a different mechanism. This approach, perhaps more difficult, has yielded encouraging results in both laboratory and limited larger-scale tests. Phenolics and bismaleimides when exposed to fairly severe heat fluxes, produce little smoke and low levels of toxic gases, and can withstand very high heat levels without burning. When heat is applied to a char-forming polymer (Figure 9), the surface decomposes, forming a char layer. The convective portion of the applied heat is attacked and deflected by the gases formed from the decomposition of the constituent polymers. The radiant heat load is also rejected by thermal re-radiation from the hot char surface, which, due to its now expanding state, has a very low thermal conductivity, all of which effectively insulate the remaining base material.

Flammability properties (Figure 10) of these char-forming polymers (Flame, speed, smoke, thermal efficiency, ignition) generally improve with increasing char yield. However, the state-of-the-art is such that the availability of many basic monomers to make the polymers is limited. Furthermore, processing these thermally attractive polymers into manufacturable items is extremely difficult. Consequently, the cost becomes proportionately higher for the available better fire resistant materials. It is not enough just to identify new fire resistant materials in the laboratory, they must be obtainable, processable, and must be competitive in an engineering sense. Generally the best combination of properties and costs lie in the 40-60% char yield range where good flammability resistance is obtained. These values are approximate only, and will vary according to specific chemical makeup.

In order to rationally employ these concepts, the relationship between laboratory flammability tests of simple materials and the thermal performance of aircraft interior assemblies made up of combinations of materials must be determined. The FIREMEN program is examining the applicability of advanced materials to such sub-assemblies as floor panels, cargo liners, air conditioning ducts, cabin sidewall panels and seat cushions.

As an example of concept application, the reconstruction of aircraft light-weight load bearing panels (Figure 11) substitutes advanced material components. Each of these advanced substitutes have been chosen for char yields in excess of 40%; their limiting oxygen indexes (LOI) are approximately the same as char yield, so it is evident that none of these materials would in themselves support combustion. Comparison of typical present materials thermophysical performance with that of a small laboratory panel of advanced materials (Figure 12) shows the backface temperature-time-history for the two panels, both of which are exposed to the same front surface heat flux of 11 W/cm^2, typical of actual flashover heat levels. These results are significant when one considers the long-term potential for reducing fire spread and panel burn-through rates.

Simulated lavatory enclosure tests (Figure 13) have been run to obtain baseline data on containment capability and fire dynamics. These tests are providing new understanding of fire development in closed spaces and data by which potential applications of advanced materials can be evaluated. Most recent tests have demonstrated the capability of state-of-the-art lavatory designs to contain severe fires if the lavatory door is securely closed.

Similar tests have been conducted in a simulated large cargo bay to obtain baseline information of fire development and intensitites, with a view toward maximizing fire containment and control (Figure 14).

Tied to the testing program is an effort in thermochemical modeling. An analytical model has been developed which describes and predicts inter-relationships of flammability, smoke emission and ignition delay characteristics of materials as a function of the chemical constitutents of the materials themselves. Progress is being made in developing enclosure and external pool fire predictive models, complementing and supporting FAA's efforts in this area. NASA also participates in the Mathematical Fire Modeling Steering Committee of the National Bureau of Standards.

Toxicology efforts have been aimed at chemical characterization of toxic gases evolved during pyrolysis of advanced materials and at exchanging data with industry and FAA's Field laboratories on time-to-incapacitation tests. NASA has also sponsored a project in the National Research Council's Advisory Center on Toxicology to address the problem of establishing guidelines for toxicology testing which would eventually lead to a better appreciation of human survivability limits in fire situations. They are currently examining the various toxicology test protocols in use to identify preferable tests for aviation application purposes. We also participate in National Bureau of Standards' agency Committee on Toxicology.

Currently-used thermoplastics meet current regulatory requirements, but we have been working with the supplier industry and aircraft manufacturers to study and define materials that offer improved fire resistance, resistance to melting, and upon combustion, less smoke and gas yield. There are currently two or three of these higher char yield polymers which in laboratory samples exhibit improved properties. Difficult manufacturing processing problems must be overcome, however, before they can find practical application.

Aircraft seat cushions and fabrics provide a substantial source of solid fuel in interior fires, producing heavy, irritating smoke. A comparison of baseline textile and elastomeric cushion materials properties with some advanced material candidates (Figure 15) shows that even the advanced textiles tested so far which respond well to burning in terms of smoke and flash fire with high LOI's still exhibit middle to high toxicity on the average. There is more optimism as regards seat cushions; however, the advanced materials have yet to complete other necessary testing for manufacturability, mechanical properties, wear, resilience, stability, and so on.

As the material development efforts move into the testing phases in FY 78, fire modeling work will intensify. The establishment of a basis for specifications for using advanced materials must include consideration of the availability of materials,themselves, as well as processing, design, and fabrication feasibility and costs.

In summary, NASA is engaged in a vigorous program of advanced R&D directed at materials development, testing and modeling. This is a cooperative program involving industry and other government agencies which is already yielding useful results in the laying of groundwork for future improvements in aircraft fire safety, and the resulting improvement in occupant protection.

CRASHWORTHINESS RESEARCH

<u>Crashworthiness Design Technology</u> - A joint NASA-FAA program was begun five years ago to develop an upgraded reliable technology upon which crashworthiness design of aircraft can be based. The joint program has three objectives:

- Development of analytical methods
- Definition of a survivable crash envelope
- Improved seat and restraint systems.

The organization of this program divides the respective responsibilities of the two agencies, and NASA's portion of the joint program has three program elements (Figure 16)

- Full-scale crash simulation testing
- Non-linear crash impact analysis
- Crashworthy design concepts

These three program elements are brought together in the NASA Crash Dynamics program which has as its objective the development and demonstration of new concepts and design methods for crashworthy fuselages and seats. The goals of this program are:

- Establish small twin engine crashworthy design criteria
- Validate analytical crash response predictive methods
- Determine crash response behavior and energy absorption characteristics of composite structural components.
- Examine, by analysis and test, promising energy attenuating concepts and restraint systems for small aircraft seats.
- Develop and demonstrate energy absorption concepts for general aviation aircraft structures.

The full-scale crash simulation testing is being conducted at the Langley Research Center's Impact Dynamics Facility, the former Lunar Landing Research Facility. It has been modified for free-flight crash testing of full-scale aircraft structures and structural components under controlled test conditions (8). The test vehicles are suspended pendulum fashion from beneath the bridge of the facility, swung and released just prior to impact to simulate free-flight crash conditions at impact.

The objective of the analytical effort is to develop the capability to predict the non-linear geometric and material behavior of sheet stringer aircraft structures subject to large deformations and to demonstrate this capability by determining the plastic buckling and collapse response of these structures to impulsive loadings. Two specific finite-element computer programs are being developed with attention focused on modeling concepts applicable to large plastic deformations of realistic aircraft structures:

o Plastic and Large Deflection Analysis of Nonlinear Structures (PLANS): This computer program for static finite-element analysis is capable of treating problems which include bending and membrane stresses, thick and thin axisymmetric bodies, general three-dimensional bodies, and laminated composites. (9)

o Analysis of Crash Transients in Inelastic and Non-linear Range (ACTION): A non-linear dynamic finite element computer program is being extended at Langley to more realistic aircraft sheet stringer structures. Membrane elements have been added to the initial truss and frame simulation capability to predict the transient response of frames with and without sheet coverings.

Energy absorption seat concepts (Figure 17) using wire bending energy absorbers have been built into test units for subsequent evaluation at FAA's Civil Aeromedical Institute.

To date, over 20 light aircraft crash tests have been conducted. The latest of these incorporated small booster rockets installed on a light twin to increase impact velocity (Figure 18). The information from these tests has added to our understanding of fuselage structure failure modes and mechanisms and of the forces transmitted to the occupant through seat and restraint systems. Much of this information has been used to modify or enhance the analytical effort.

The capabilities of the analytical programs have been expanded and enhanced by through the addition of new algorithms and through scales to vector conversions. Static non-linear computer programs have been verified and transmitted to COSMIC for release to the industry.

The seat program objectives (Figure 19) are (a) to develop an energy absorbing seat, rail, and restraint system for general aviation aircraft, and (b) to support the development of FAA's computer program to model the energy absorbing seat designs, including occupant and restraint systems users an occupant lumped-mass model, and a restraint system model, in conjunction with a finite-element seat model to incrementally apply forces to the system and observe displacement, distortion, and failure modes.

CONCLUSION

In conclusion, NASA has underway three major research efforts whose results can be used by designers to directly improve aircraft occupant safety. Reliable warning of imminent turbulence encounters will enable flight crew members to alter flight level or route, or prepare for turbulence transit by reducing airspeed and ensuring passenger restraint by seat belt to prevent occupant injury.

Likewise, efforts to prevent the outbreak of fire, to promptly detect and extinguish fires, or to control the rate of fire development, should improve the likelihood of occupant survival in fire-threat situations. Finally, improved efficiency of energy absorbing fuselage structure, and seat and occupant restraint system designs should greatly improve the likelihood of surviving crash impact trauma.

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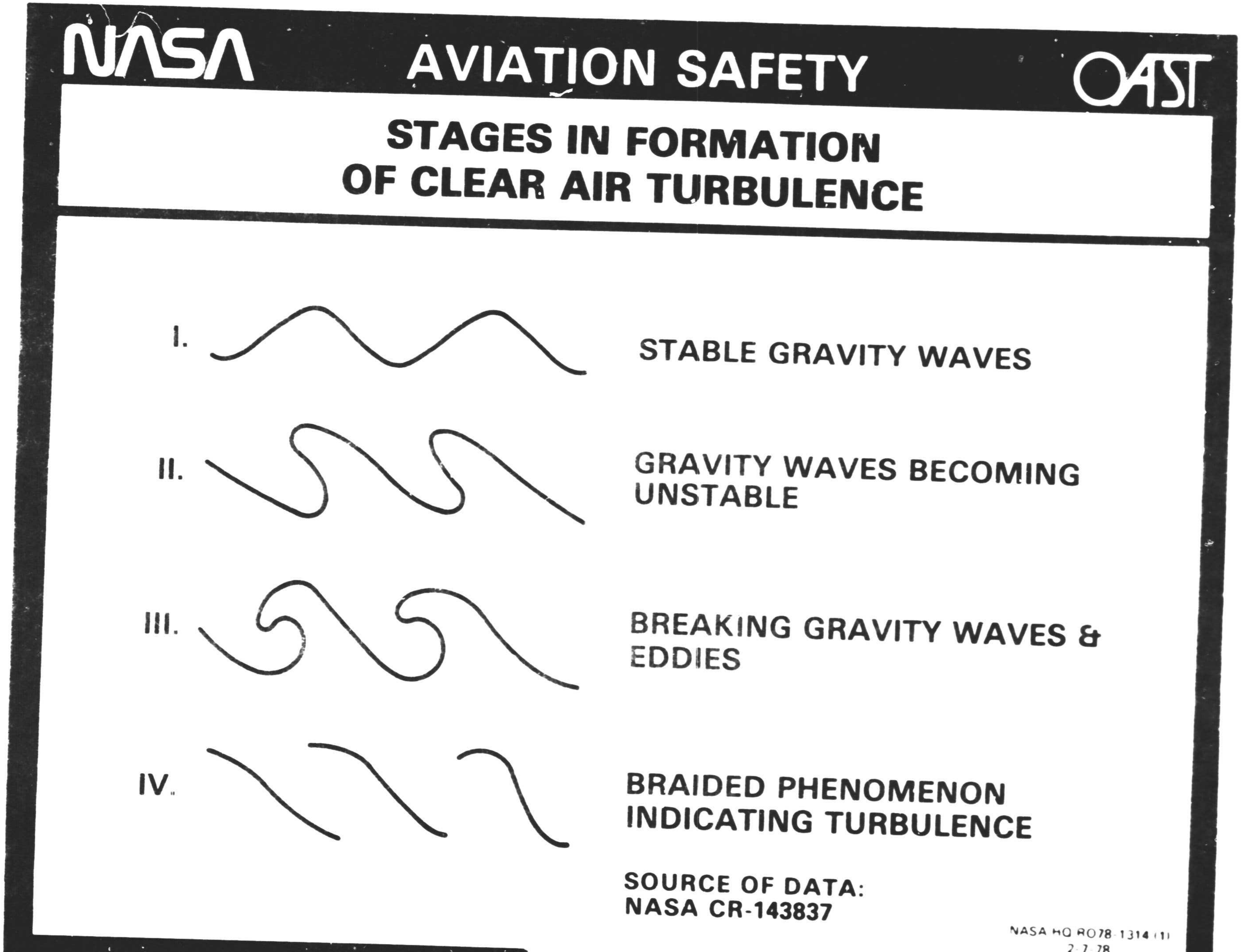

NASA
AVIATION SAFETY
OAST
STAGES IN FORMATION
OF CLEAR AIR TURBULENCE
I.
STABLE GRAVITY WAVES
II.
GRAVITY WAVES BECOMING UNSTABLE
III.
BREAKING GRAVITY WAVES & EDDIES
IV.
BRAIDED PHENOMENON INDICATING TURBULENCE
SOURCE OF DATA:
NASA CR-143837
NASA HQ RO78-1314 (1)
2-7-78

FIGURE 1

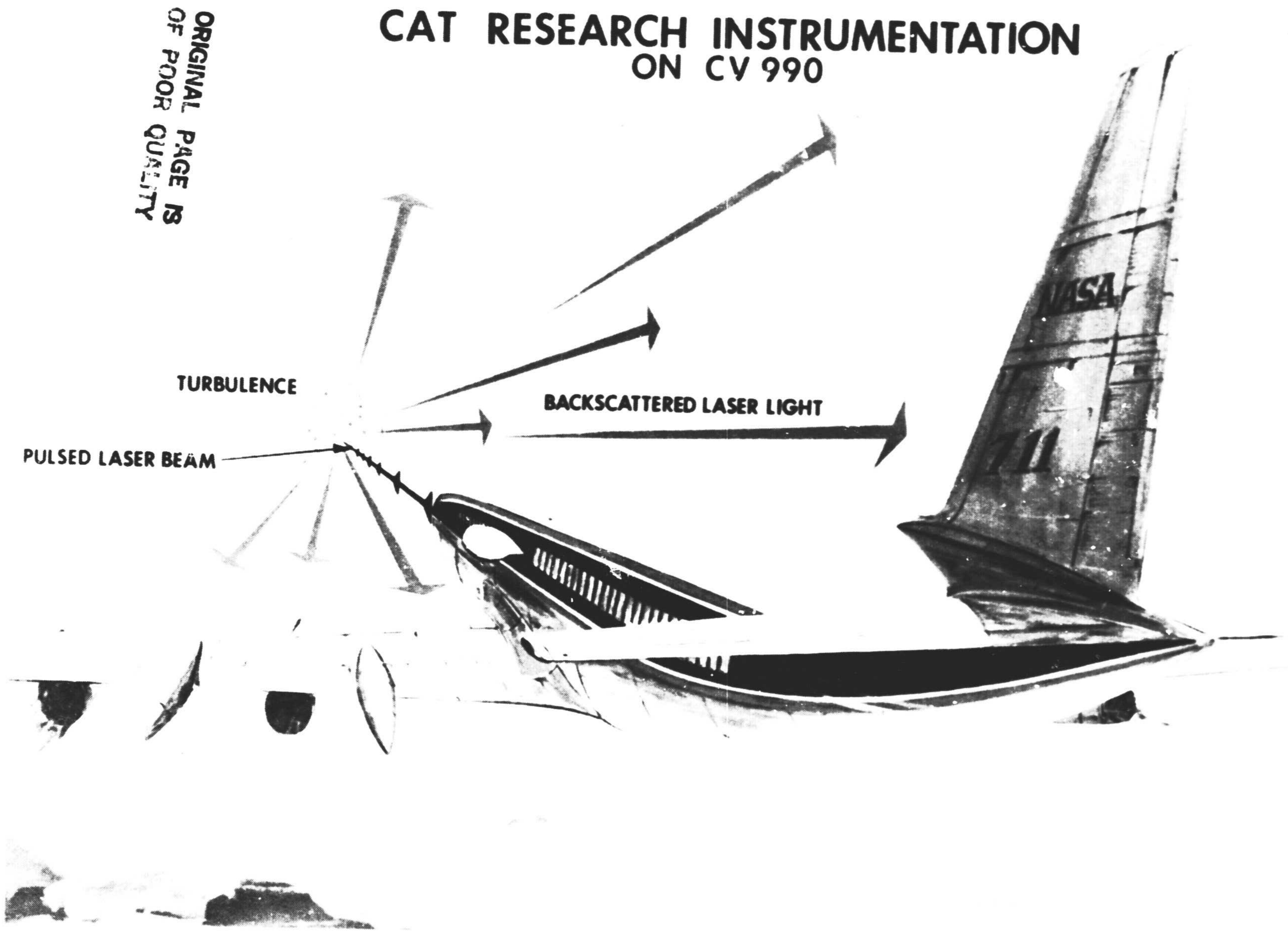

CAT RESEARCH INSTRUMENTATION
ON CV 990
TURBULENCE
PULSED LASER BEAM
BACKSCATTERED LASER LIGHT
NASA
711

FIGURE 2

NASA AVIATION SAFETY OAST

CLEAR AIR TURBULENCE RESEARCH
INFRARED RADIOMETER DETECTOR SYSTEM

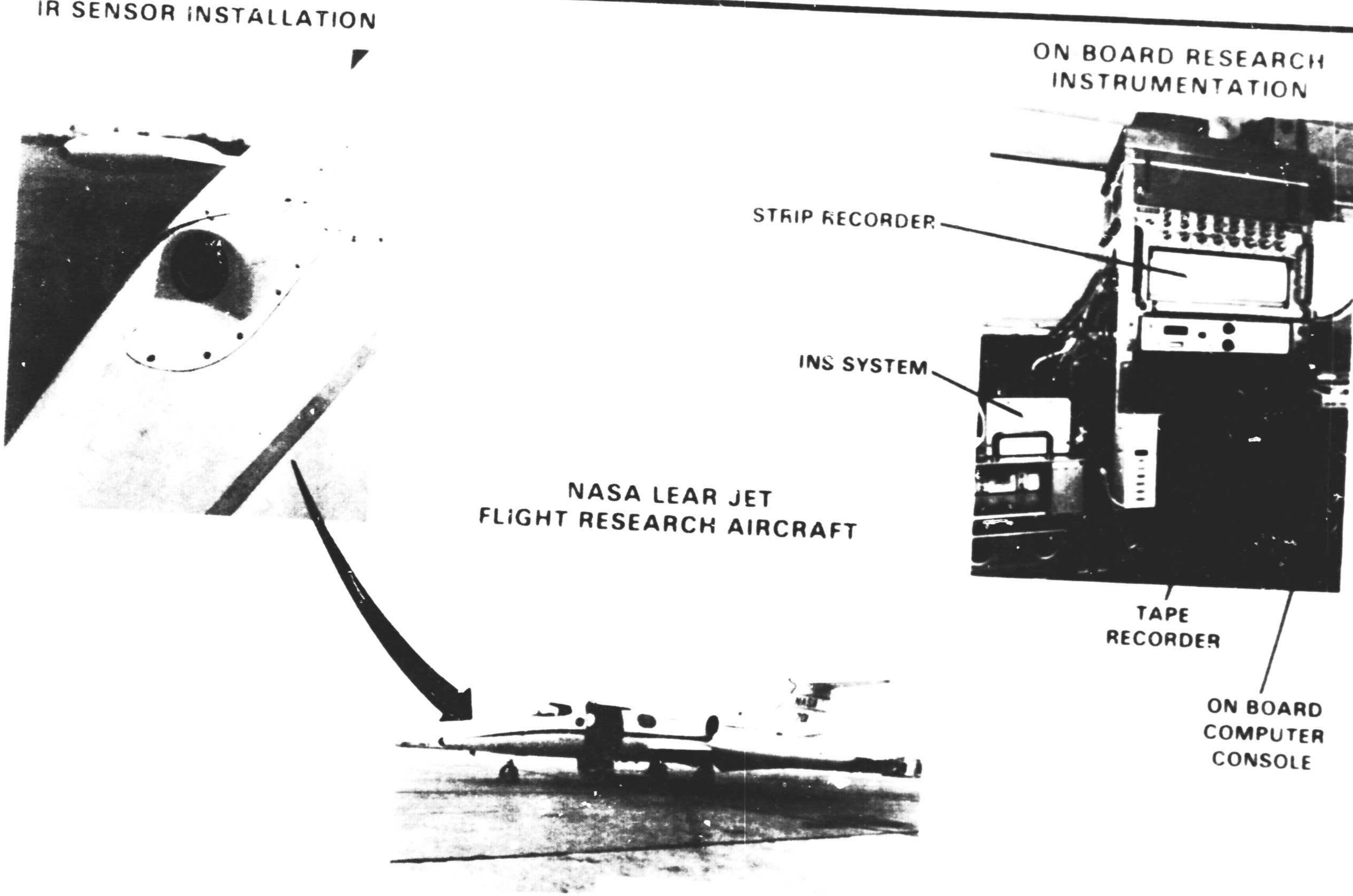
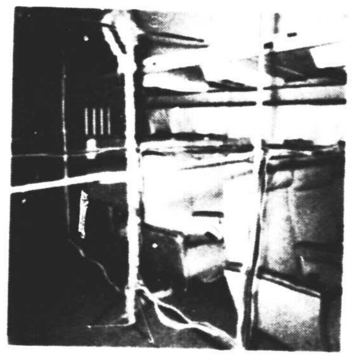


FIGURE 3

FIGURE 4

NASA AVIATION SAFETY OAST

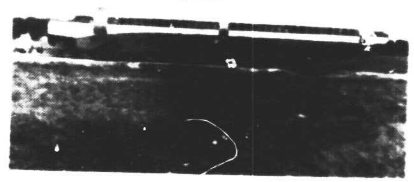
AIRCRAFT FIRE SAFETY R&T: APPLICATION OF NEW "SPACECRAFT" MATERIALS TO AIRCRAFT INTERIORS



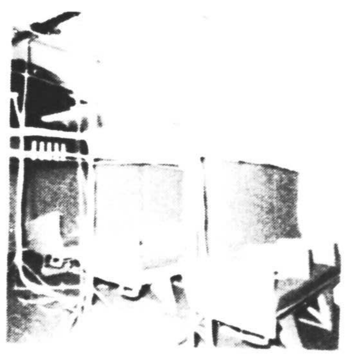
PRE TEST

PRE-1968 MATERIALS TEST

POST-TEST

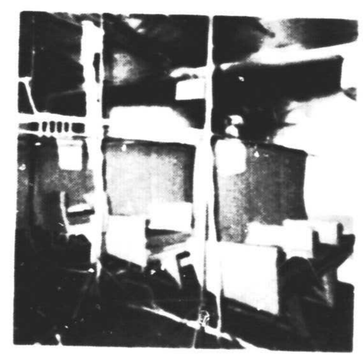


A/C FUSELAGE TEST FACILITY



PRE TEST

NEW MATERIALS TEST



POST TEST

FIGURE 5

TEST FOR PROTECTION OF PASSENGERS IN CRASH FIRES

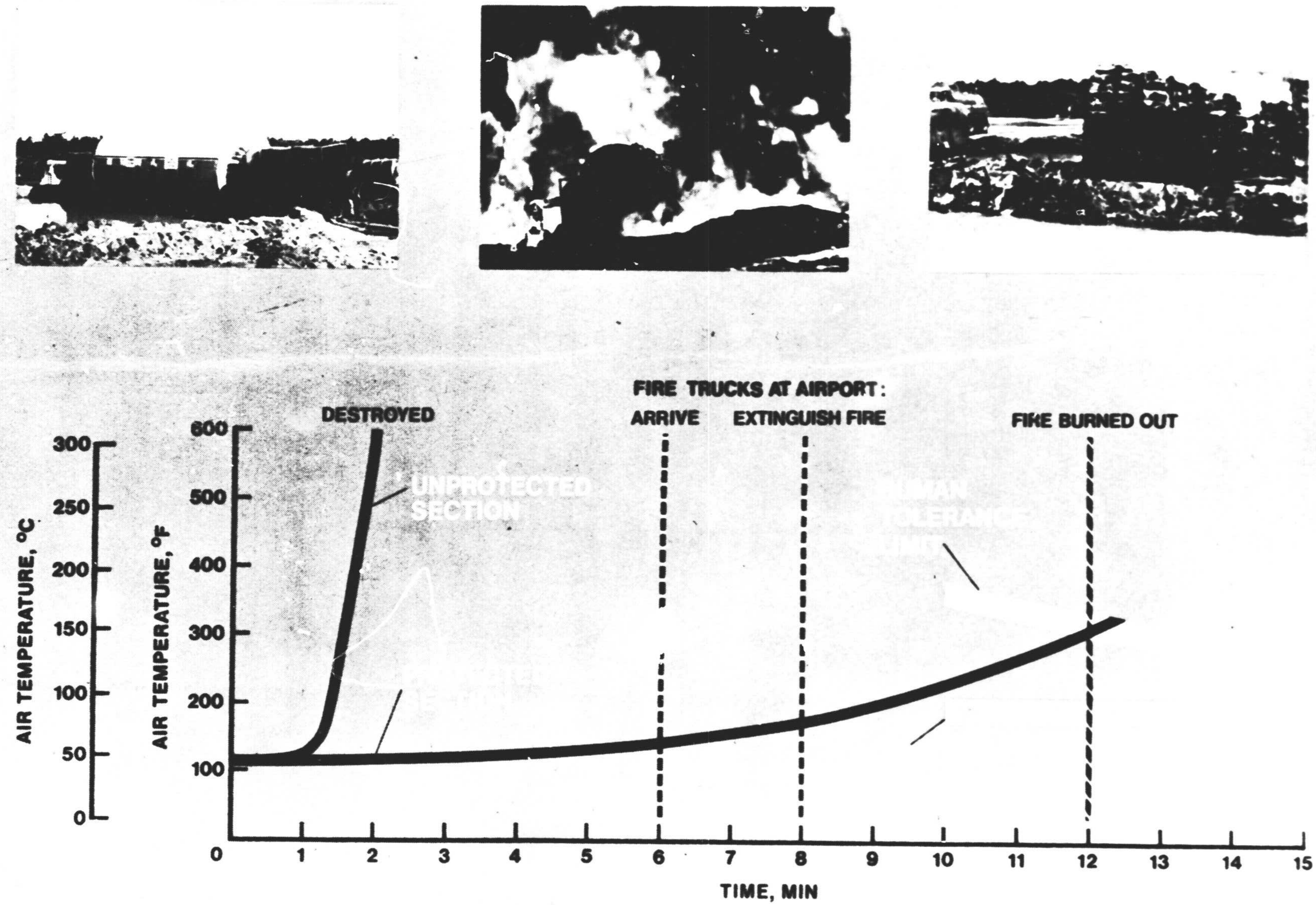


FIGURE 6

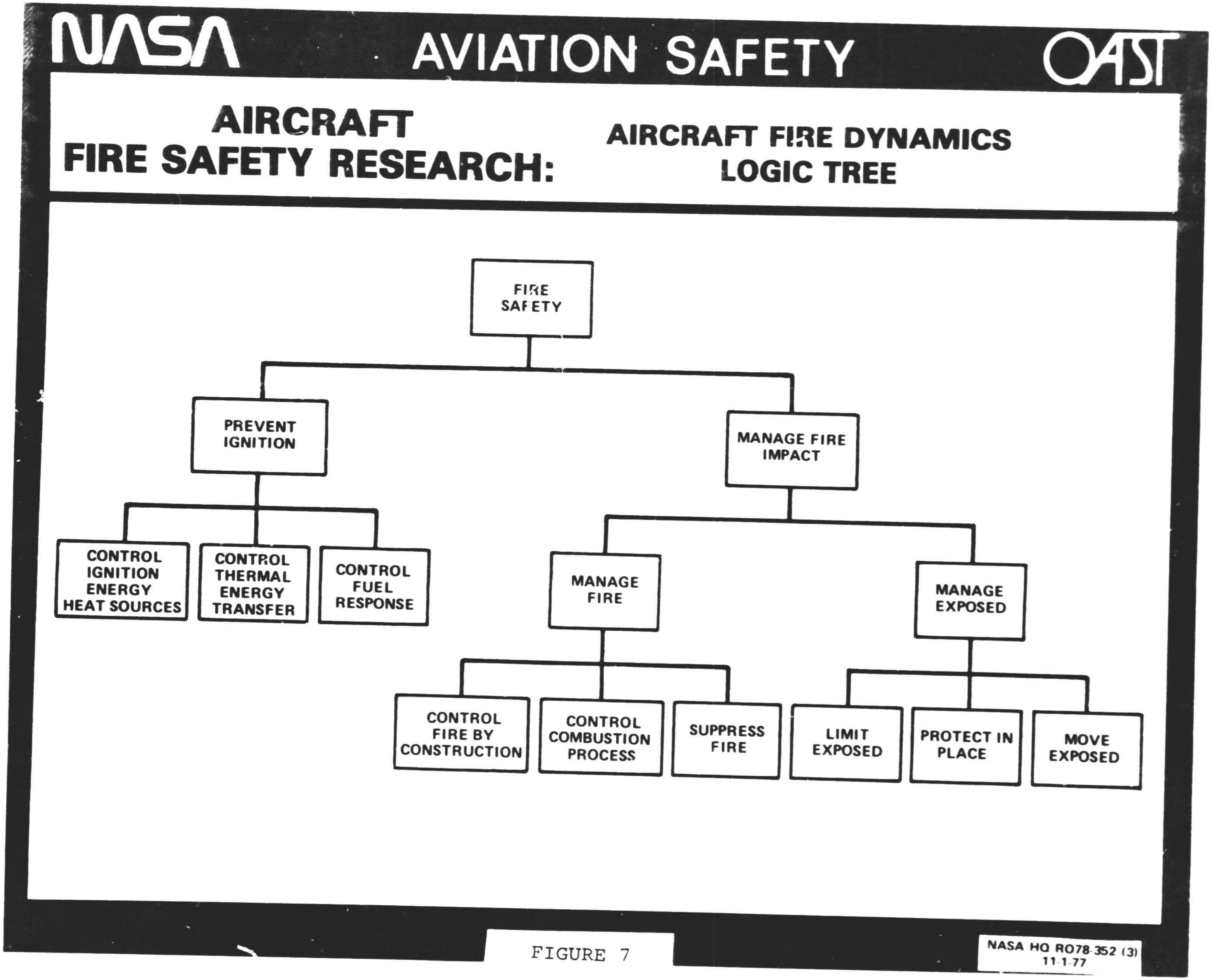
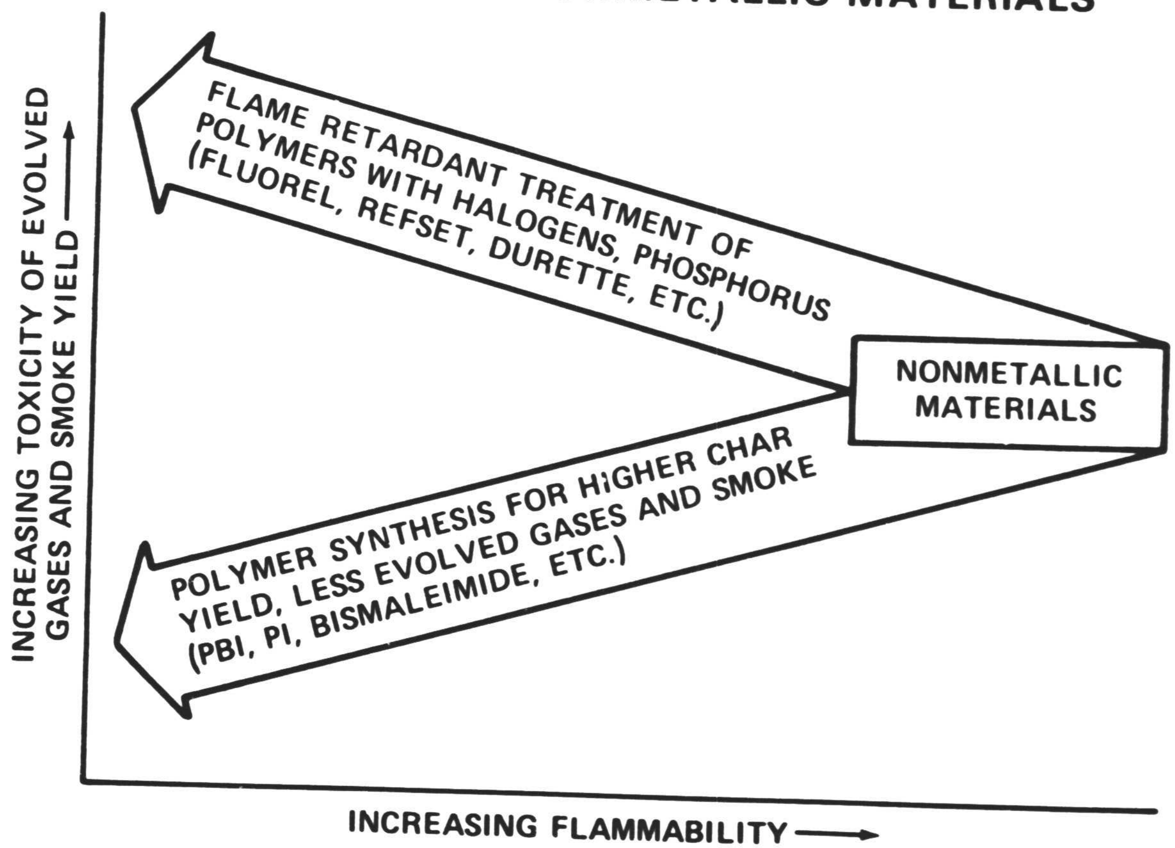

NASA
AVIATION SAFETY
OAST
AIRCRAFT FIRE SAFETY RESEARCH:
AIRCRAFT FIRE DYNAMICS LOGIC TREE
FIRE SAFETY
PREVENT IGNITION
MANAGE FIRE IMPACT
CONTROL IGNITION ENERGY HEAT SOURCES
CONTROL THERMAL ENERGY TRANSFER
CONTROL FUEL RESPONSE
MANAGE FIRE
MANAGE EXPOSED
CONTROL FIRE BY CONSTRUCTION
CONTROL COMBUSTION PROCESS
SUPPRESS FIRE
LIMIT EXPOSED
PROTECT IN PLACE
MOVE EXPOSED
NASA HQ RO78-352 (3)
11-1-77

FIGURE 7

NASA AVIATION SAFETY OAST

AIRCRAFT FIRE SAFETY RESEARCH

CONTRASTING METHODS OF REDUCING FLAMMABILITY OF NONMETALLIC MATERIALS



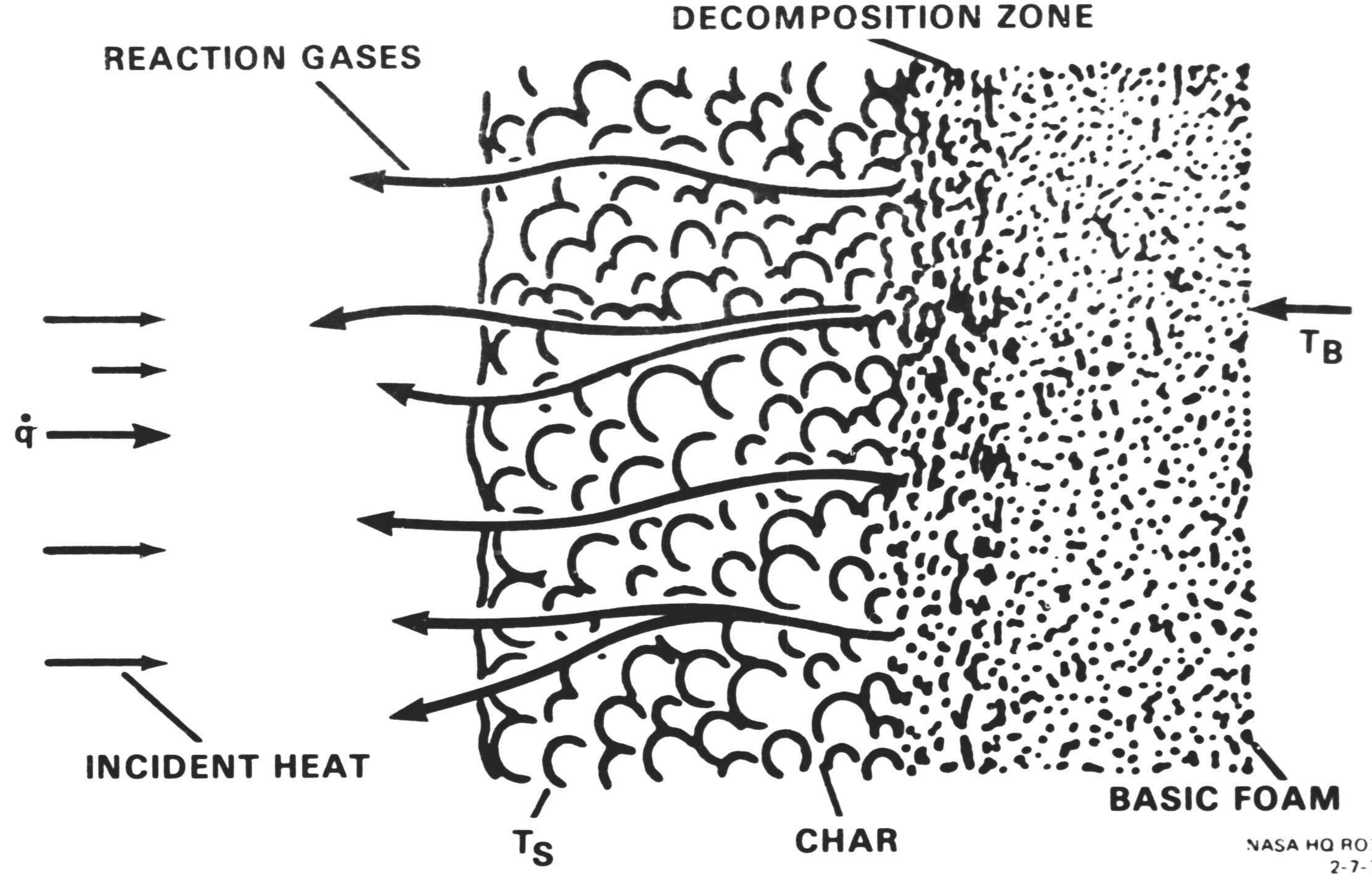
NASA HQ RO78-1309 (1)
2-7-78

FIGURE 8

NASA AVIATION SAFETY OAST

AIRCRAFT FIRE SAFETY RESEARCH

TYPICAL REACTION OF CHAR-FORMING FOAMS DUE TO THERMAL LOADS.



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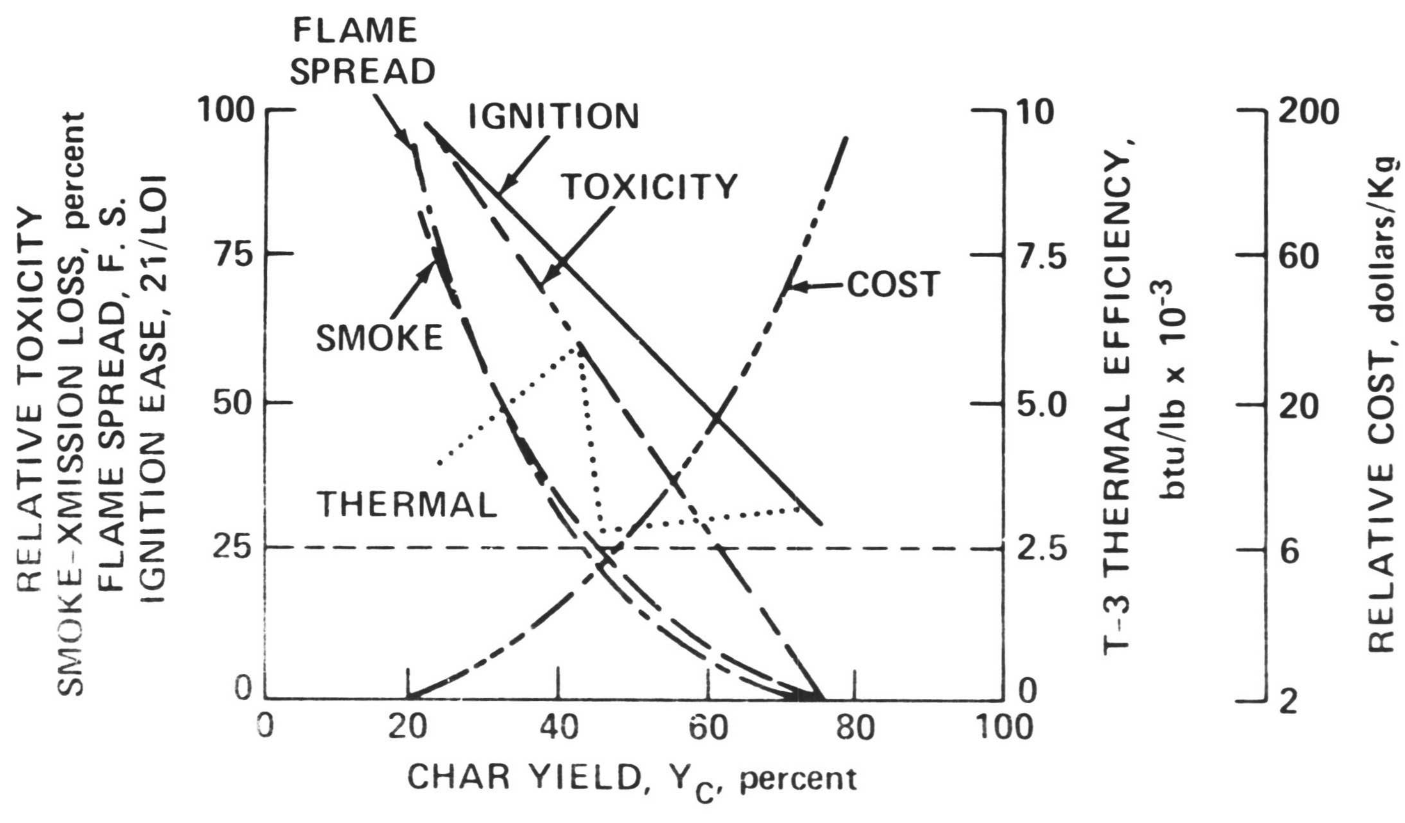
2-7-78

FIGURE 9

NASA AVIATION SAFETY OAST

AIRCRAFT FIRE SAFETY RESEARCH



SUMMARY OF PROPERTIES OF CHAR-FORMING FOAMED POLYMERS.

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2-7-78

FIGURE 10

NASA AVIATION SAFETY OAST

FIREMEN PROGRAM

COMPOSITE CONFIGURATION OF AIRCRAFT INTERIOR PANELS

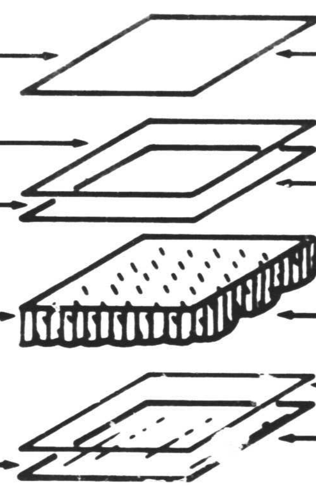
TYPICAL STATE-OF-THE-ART

POLYVINYL FLOURIDE FILM, 0.0025 cm WITH POLYMETHYL METHACRYLATE ADHESIVE UNDERNEATH

POLYVINYL FLUORIDE, 0.005 cm WITH DECORATIVE INK ON TOP

TWO PLIES, TYPE 181 AND TYPE 120 E GLASS EPOXY PREPREG

POLYAMIDE PAPER HONEYCOMB



TYPICAL ADVANCED CANDIDATE

BISPHENOL FLUORENONE POLYCARBONATE FILM WITH DECORATIVE INK ON TOP AND PHOSPHORYLATED EPOXY ADHESIVE UNDERNEATH

ONE PLY TYPE 181 E GLASS PHENOLIC NOVALAK-XYLOK RESIN PREPREG

120 E GLASS PHENOLIC NOVALAK-XYLOK RESIN PREPREG

WITH OR WITHOUT FOAM IN POLYIMIDE HONEYCOMB

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2-7-78

FIGURE 11

NASA AVIATION SAFETY OAST

FIREMEN PROGRAM

COMPARISON OF FIRE CONTAINMENT CAPABILITY OF AIRCRAFT INTERIOR PANELS

POLYQUINOXALINE FOAM, BISMALEIMIDE-GLASS, 96 kg/m³

ALL SAMPLES 2.5 cm THICK

FRONT FACE HEAT FLUX 11×10^4 W/m²

FRONT FACE TEMPERATURE 900°C

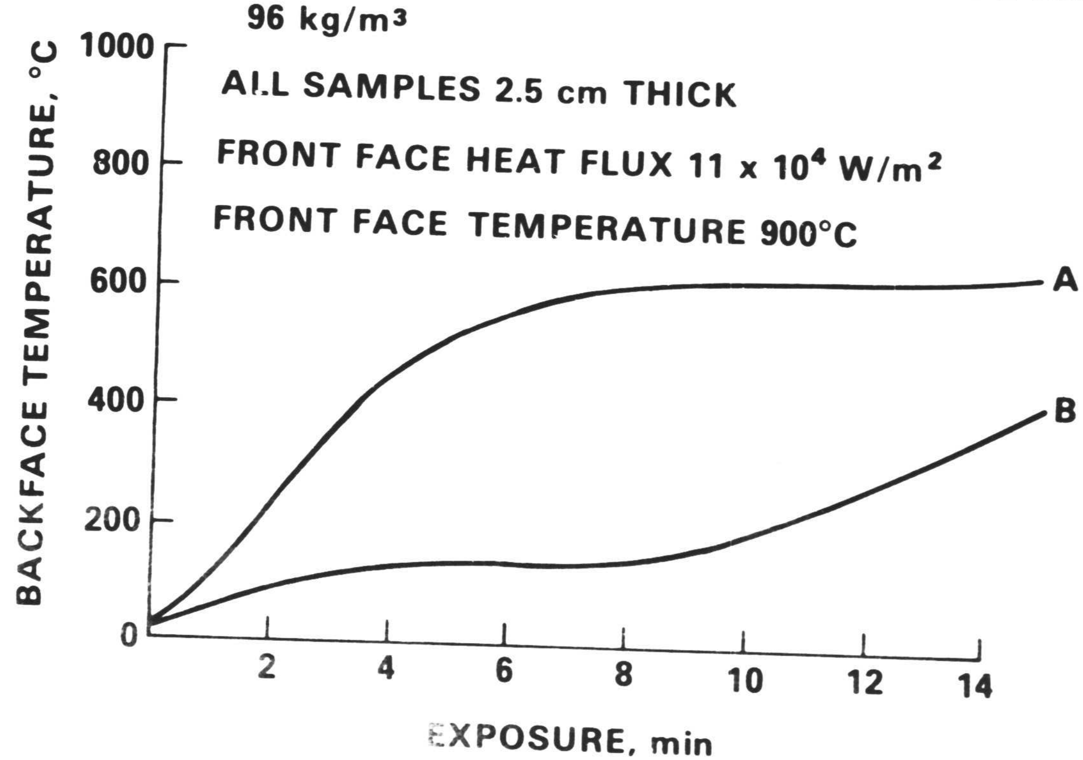

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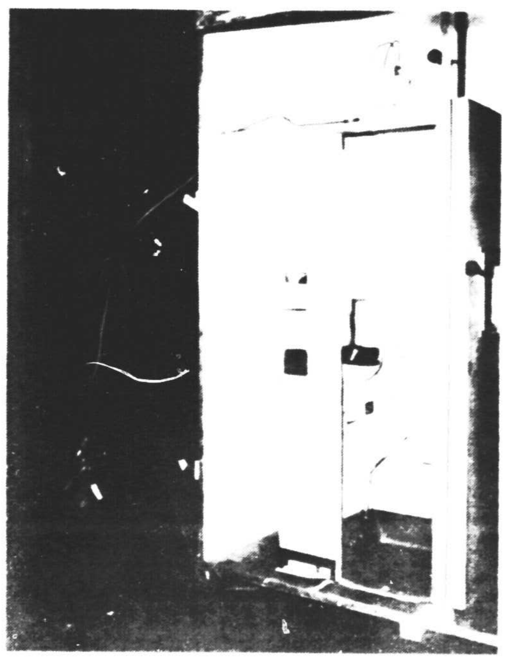
FIGURE 12

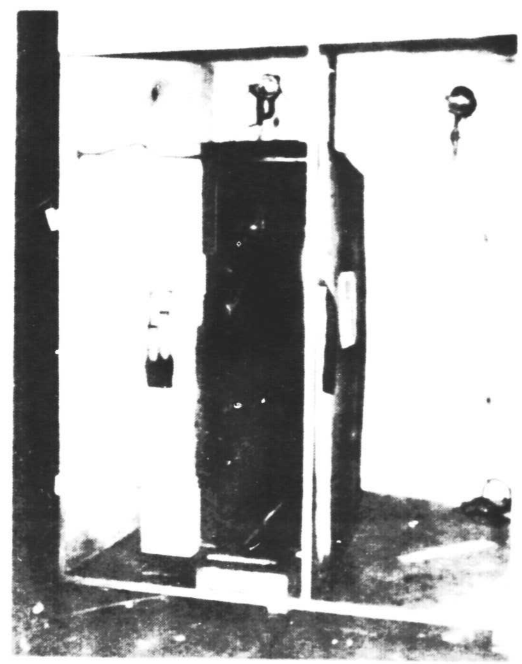
NASA AVIATION SAFETY OAST

FIREMEN PROGRAM

REPRESENTATIVE AIRCRAFT CABIN LAVATORY ENCLOSURE FIRE CONTAINMENT TESTS



BEFORE



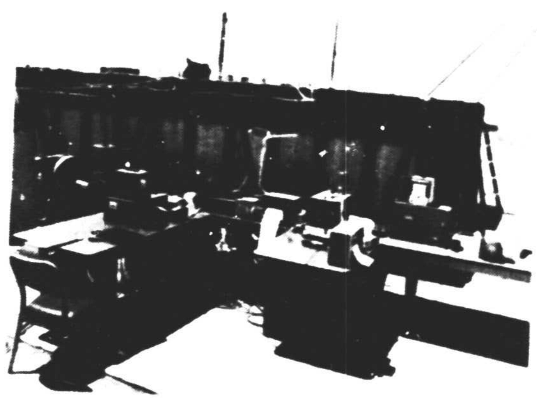
AFTER

NASA AVIATION SAFETY OAST

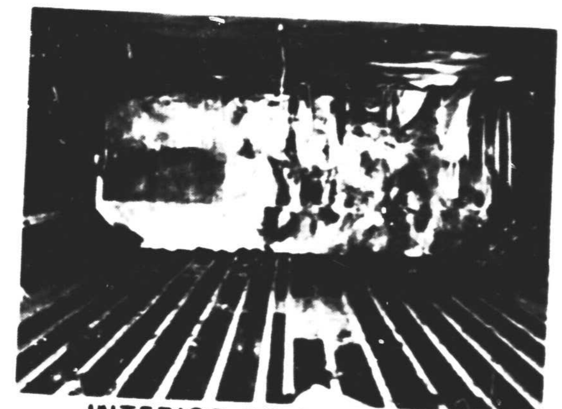
FIREMENT PROGRAM: CARGO BAY FIRE CONTAINMENT RESEARCH

DOUGLAS CARGO BAY SIMULATOR

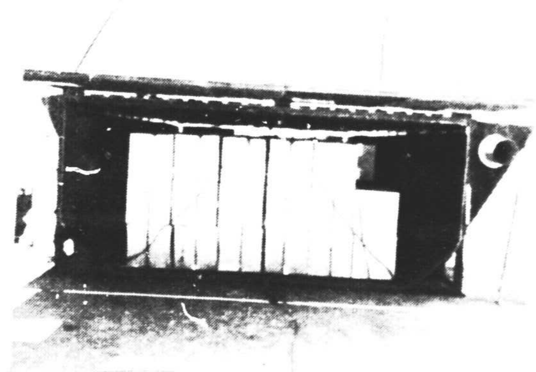
REPRESENTATIVE CARGO



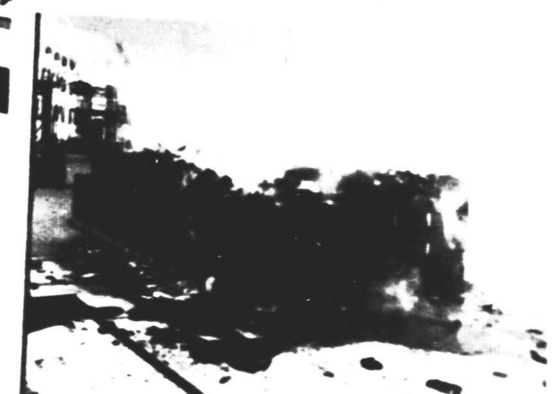
TEST SETUP



INTERIOR OF CARGO BAY AFTER FIRE



SIMULATOR LOADED BEFORE TEST



CARGO ON PALLET WITHDRAWN FROM SIMULATOR AFTER TEST

FIGURE 14

NASA AVIATION SAFETY OAST

FIREMEN PROGRAM

A COMPARISON OF STATE-OF-THE-ART AND ADVANCED AIRCRAFT SEAT MATERIALS

THE FLAMMABILITY OF TEXTILE COMPONENTS OF AIRCRAFT UPHOLSTERY

	FAR 25.853 (b) TESTS				
BASELINE MATERIALS	BURN	SMOKE	FLASH FIRE	LOI	TOXICITY LEVEL
WOOL/NYLON (90:10)	PASSED	FAILED	(NO DATA)	28	FAILED (HIGH)
KNIT COTTON (FR)	FAILED	FAILED	(NO DATA)	31	
NYLON (FR)	MELTS	MELTS	FAILED	26	MEDIUM
POLYESTER	MELTS	FAILED	FAILED		LOW
ADVANCED MATERIALS					
KYNOL	PASSED	PASSED	(NO DATA)	29	MEDIUM
KERMEL	PASSED	PASSED	(NO DATA)	29	MEDIUM
KERMEL/WOOL	PASSED	PASSED	(NO DATA)	30	MEDIUM
MOD ACRYLIC	PASSED	PASSED	(NO DATA)		
NOMEX UPHOLSTERY	PASSED	FAILED	(NO DATA)	31	MEDIUM
ABS	FAILED	FAILED	(NO DATA)	30	HIGH

THE FLAMMABILITY OF THE ELASTOMERIC COMPONENTS OF AIRCRAFT CUSHIONING

	TESTS				
BASELINE MATERIALS	BURN	SMOKE	FLASH FIRE	LOI	TOXICITY LEVEL
POLYURETHANE (FR) P1700FR uu-44	PASSED	PASSED	MELTS & BURNS	23	MEDIUM
ADVANCED MATERIALS					
SILCONE FOAM (14183-B, 11.8 lbs/ft)	PASSED	PASSED	NO FLASH	31	LOW
SILICONE FOAM (SE-5559, 81.61 lbs/ft)	PASSED	PASSED	NO FLASH	40	
POLYCHLOROPRENE (VONAR No. 1)	PASSED	PASSED	NO FLASH	38	LOW
(VONAR No. 2)	PASSED	PASSED	NO FLASH	41	LOW
(VONAR No. 3)	PASSED	PASSED	NO FLASH	62	0
(TOYAD VERSION)	PASSED	PASSED	LOW INTEN	45	0
POLYPHOSPHAZENE	PASSED	PASSED	NO FLASH	65	VERY LOW

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2-7-78

FIGURE 15

NASA AVIATION SAFETY OAST

CRASH SIMULATION TESTING

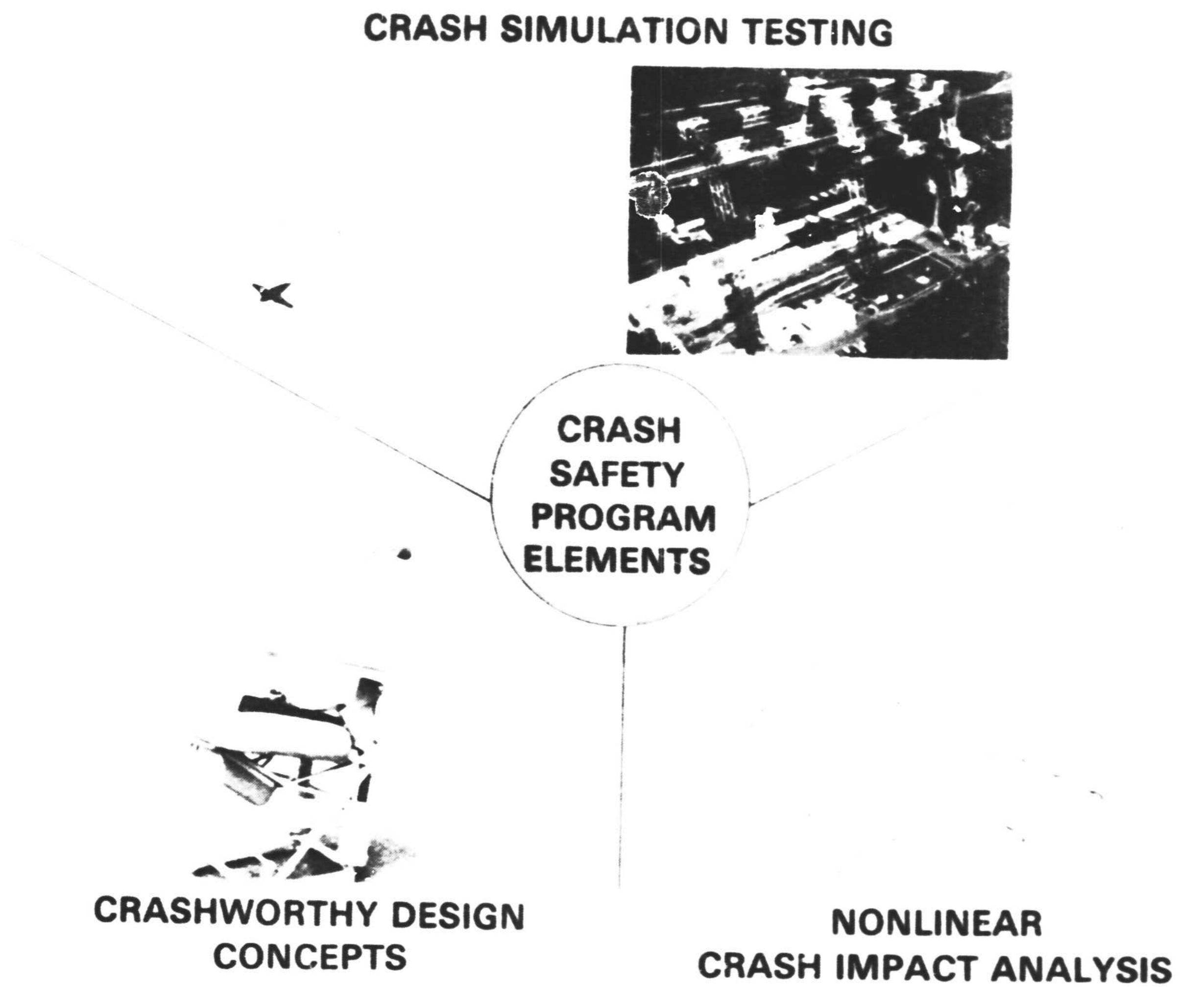
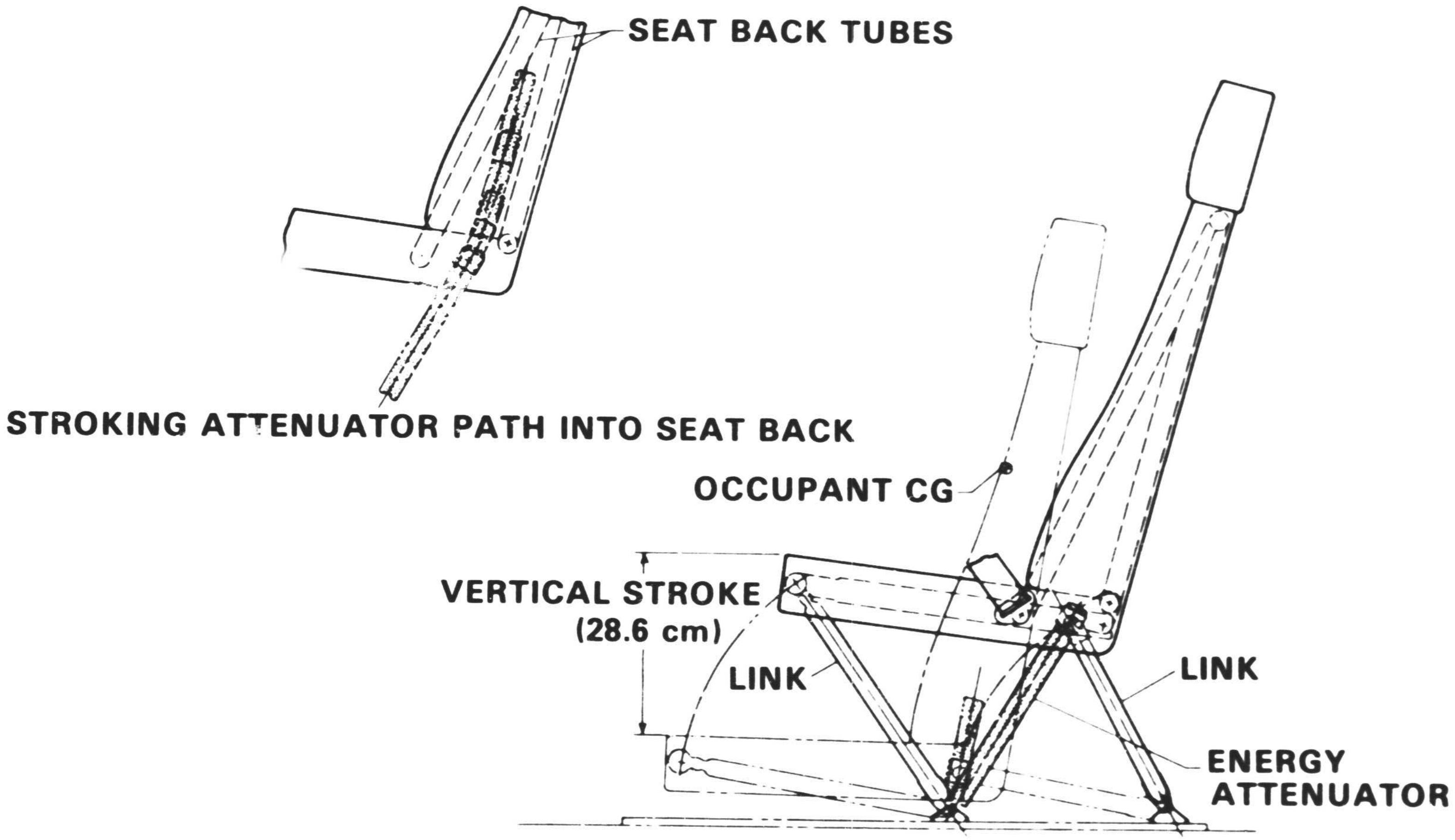


FIGURE 16

NASA AVIATION SAFETY OAST

FLOOR SUPPORTED PASSENGER SEAT WITH WIRE BENDING ENERGY ABSORBERS



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2-7-78

FIGURE 17

NASA AVIATION SAFETY OAST

FIRST TWIN—ENGINE VELOCITY AUGMENTED CRASH TEST

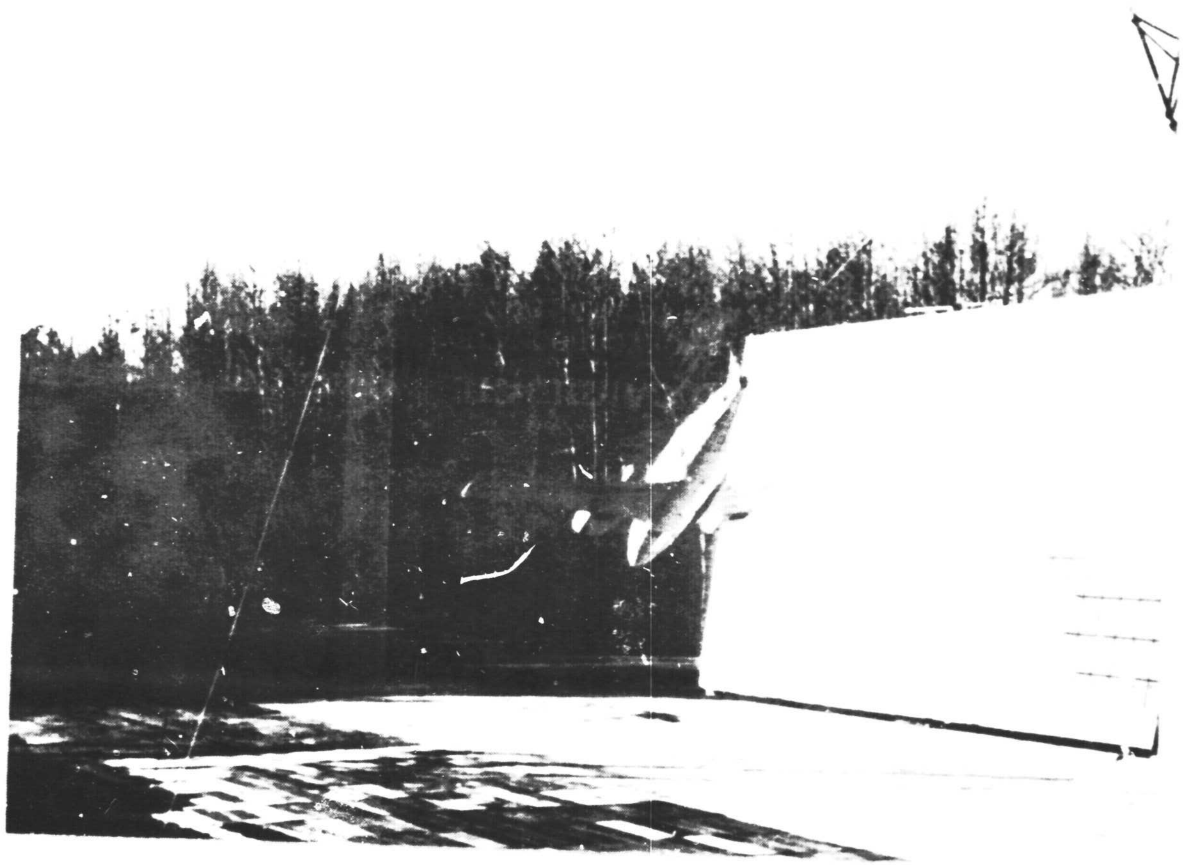

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FIGURE 18

NASA AVIATION SAFETY OAST

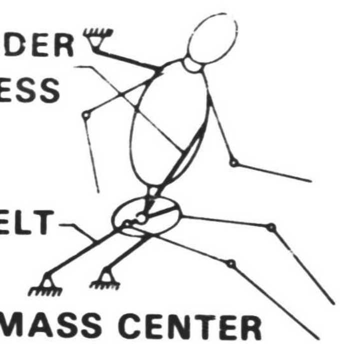
NASA AIRCRAFT SEAT SAFETY RESEARCH

OBJECTIVES:

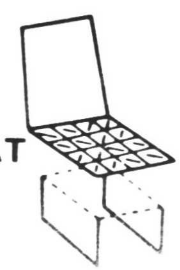
DEVELOP AN ENERGY ABSORBING SEAT, RAIL AND RESTRAINT SYSTEM FOR GENERAL AVIATION AIRCRAFT

SUPPORT THE DEVELOPMENT OF FAA'S COMPUTER PROGRAM TO MODEL THE ENERGY ABSORBING SEAT AND RESTRAINT SYSTEM

OCCUPANT LUMPED-MASS MODEL



RESTRAINT SYSTEM MODEL



FINITE ELEMENT SEAT

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