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# BIBLIOGRAPHY ON AIRCRAFT FIRE HAZARDS AND SAFETY
## Volume I - HAZARDS

compiled by James J. Pelouch, Jr. and Paul T. Hacker
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# BIBLIOGRAPHY ON AIRCRAFT FIRE HAZARDS AND SAFETY

Volume I - HAZARDS, Part 1 - Key Numbers 1 to 817

Compiled by
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

I

## FOREWORD

The mission and objectives of the Aerospace Safety Research and Data Institute are (a) to support NASA, its contractors, and the aerospace industry with technical information and consultation on safety problems; (b) to identify areas where safety problems and technology voids exist and to initiate research programs, both in-house and on contract, in these problem areas; (c) to author and compile state-of-the-art and summary publications in our areas of concern; (d) to establish and operate a safety data bank. As a corollary to its support to the aerospace community, ASRDI is also to establish and maintain a file of specialized information sources (organizations) and recognized, acknowledged experts (individuals) in the specific areas or fields of ASRDI's interest.

To match our resources with our priorties, ASRDI is concentrating on selected areas - fire and explosion; cryogenic systems; propellants and other hazardous materials, with special emphasis on oxygen and hydrogen; aeronautical systems and spacecraft operations; lightning hazards; and the mechanics of structural failure. Staff expertise is backed by a safety library and is further supported by a computerized bank of citations and abstracts built from literature on oxygen, hydrogen, and fire and explosion. Computer files on mechanics of structural failure, fragmentation hazards, and safety information sources are also being established. In addition, ASRDI has two NASA RECON termiqals and people adept at querying the system for safety-related information.

Frank E. Belles, Director
Aerospace Safety Research and Data Institute
National Aeronautics and Space Administration



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# INTRODUCTION

A part of the Aerospace Safety Research and Data Institute's (ASRDI) mission is to compile and store in a computerized system bibliographic citations on hazards and safety in various areas related to aerospace activities. One of these areas is fire and explosion. The program in this area has been underway for about three years and is continuing. At the present time the computerized data bank contains about 2000 bibliographic citations on the subject.

Each citation in the data bank contains many items of information about the document. Some of the main items are title, author, abstract, corporate source, description of figures pertinant to hazards or safety, key references, and descriptors (keywords or subject terms) by which the document can be retrieved. In addition each document is assigned to two main categories that are further divided into subcategories. The two main categories are fire hazards and fire safety. Each document is also further categorized according to its area of applicability such as - aircraft and spacecraft and their associated facilities; aerospace research and development test facilities; buildings; and general applicability.

This report is a compilation of all the document citations in the ASRDI data bank as of April 1974 on fire hazards and fire safety that pertain to aircraft. The report is somewhat preliminary in nature in that input to the data bank is continuing; moreover not all the information contained in the bank has been edited for errors. The report is being published as an illustrative example of the contents of the data dank and to obtain user feedback on the usefulness of such compilations and whether the subject scope should be narrowed in future compilations.

The report is divided into two volumes. Volume I, Hazards, presents bibliographic citations that describe and define the aircraft fire hazards and covers a wide range of subjects such as - combustion characteristics of materials; accidents and incidents reports; causes of fire; methods and techniques of evaluating the fire hazard; and the resulting effects of fire on man and property. Volume II, Safety, presents bibliographic citations that describe and define aircraft fire safety methods, equipment, and criteria. It covers such subjects as prevention, detection, and extinguishment of fire, and codes and standards. Each volume of the report contains, in addition to the citations, an author index and an index of major descriptors (keywords or subject terms). The indices are related to the citations by the ASRDI key number, which appears in the upper right hand corner of the first page of each citation. To facilitate binding, both volumes are broken into parts.

Volume I has two parts -

Part 1 - Key Numbers 1 to 817
Part 2 - Key Numbers 818 to 2146,
Author Index and Descriptor Index

Volume II has three parts -

Part 1 - Key Numbers 1 to 524
Part 2 - Key Numbers 525 to 1064
Part 3 - Key Numbers 1065 to 2165,
Author Index and Descriptor Index

The preparation of this report for printing was essentially accomplished automatically. The search strategy (in this case, subject category) and information on citation content and format was fed into the computer. The output from the computer was placed directly on multilith paper

VOLUME I

PART 1

# IGNITION CHARACTERISTICS OF FUELS AND LUBRICANTS

by

KUCHTA, J.M.
BARTKOWIAK, A.
CATO, R.J.
ZABETAKIS, M.G.

12/00/63

## -ABSTRACT-

Ignition temperatures of n-hexane, n-octane, n-decane, JP-6 jet fuel, and aircraft engine oil MIL-7-7808 (0-60-18) were determined in air using heated Pyrex cylinders of 0.314 to 1.38 in. dia. and Nichrome wires, rods, or tubes of 0.016 to 0.75 in. dia. Ignition temperature varied little with fuel-air ratio, but increased as the size of the heat source was decreased. Expressions are given which define the variation of the hot surface ignition temperatures of these combustibles with the radius and the surface area of the heat source. The expressions are applicable to stagnant or low velocity flow conditions (less than 0.2 in./sec.). In addition, the hot gas ignition temperatures of the combustible vapor-air mixtures were determined with 1/4, 3/8, and 1/2-in. dia. jets of hot air. These ignition temperatures also varied little with fuel-air ratio and increased as the diameter of the heat source was decreased.

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0039 PAGES, 0019 FIGURES, 0004 TABLES, 0006 REFERENCES

# REVIEW OF FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLE COMBUSTIBLES SUPPL. 2

by

PERLEE, H.E.
LIEBMAN, I.
ZABETAKIS, M.G.

04/00/63

## -ABSTRACT-

Mixing, explosion pressure, venting, and autoignition data related to combustibles used in aircraft and missile systems were studied under quiescent and flowing conditions. Vented hydrogen-air mixture explosions showed that a first pressure peak was dependent on rupturing pressure and vent diaphragm inertia, and a second and larger pressure peak was related to vent opening size. Diffusion theory can generally predict the position of the lower limit of flammability but not the upper limit. Venting a liquid pool fire to a low pressure environment tends to increase both liquid regression rate and flame size, with effects increasing with the volatility of the liquid. Preliminary data for n-decane indicate that gravitational fields appear to influence autoignition of fuel-air systems. It is stressed that all flammable fluid storage tanks and lines should be located and routed to prevent leakage into aerospace crew compartments.

## -PERTINENT FIGURES-

FIG. 5 MAXIMUM PRESSURES DEVELOPED DURING THE COMBUSTION OF STRATIFIED LAYERS OF METHANE-AIR MIXTURES IN AIR FOR VARIOUS DIFFUSION TIMES, AND INITIAL PENTANE CONCENTRATIONS PAGE 18// FIG. 6 MAXIMUM PRESSURES DEVELOPED DURING THE COMBUSTION OF STRATIFIED LAYERS OF PENTANE-AIR MIXTURES IN AIR FOR VARIOUS DIFFUSION TIMES, AND INITIAL PENTANE CONCENTRATIONS PAGE 19// FIG. 8 RANGE OF FLAMMABLE MIXTURE COMPOSITIONS FORMED FROM THE DIFFUSION OF PENTANE INTO AIR AT 75 DEG. F. PAGE 21// FIG. 9 POSITION OF FLAME FRONT ALONG A VERTICAL 4-IN. TUBE FOLLOWING IGNITION OF TWO HETEROGENEOUS AND ONE HOMOGENEOUS METHANE-AIR MIXTURES AT ATMOSPHERIC PRESSURE AND 75 DEG. F. PAGE 22// FIG. 10 FLAME SPEEDS THROUGH HOMOGENEOUS AND HETEROGENEOUS METHANE-AIR MIXTURES IN 4-IN. CYLINDRICAL TUBES AT ATMOSPHERIC PRESSURE AND AMBIENT TEMPERATURE PAGE 23// FIG. 24 AUTOIGNITION TIME DELAYS OF N-DECANE IN 5-IN. DIA. STAINLESS STEEL SPHERICAL VESSELS AT 417 DEG. F. FOR ACCELERATIONAL FIELDS OF 1 G. AND 10 G. PAGE 37

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# A STUDY OF AIR TRANSPORT PASSENGER CABIN FIRES AND MATERIALS

by

MARCY, J.F.

12/00/65

-ABSTRACT-

Each of the cabin interior materials used in a four engine civil transport was tested to determine flammability, smoke, and toxic characteristics and to establish the relative fire hazards inherent in aircraft. In addition to the above laboratory tests, fire tests were conducted in situ at different locations inside an airplane fuselage to determine the relative ease with which the materials would ignite and burn; and time for self-ignition, rapidity of flame spread, extent of burned areas, smoke and toxic gas produced were obtained for various sized of ignition sources with and without normal ventilation. The most important factor affecting the degree of fire hazard present inside an aircraft cabin was the flammability of the material in which the fire originates. Materials which have superior self-extinguishing properties are poor ignition sources and confer a high degree of fire protection to the aircraft interior. In the large-scale fire tests, the interior materials used in a passenger cabin can produce a flash fire with little or no warning. Heat, smoke and toxic gases generated by the fire up to about the time of the flash fire were low compared to human survival limits.

-PERTINENT FIGURES-



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# A FEASIBILITY STUDY OF A CRASH-FIRE PREVENTION SYSTEM FOR THE SUPERSONIC COMMERCIAL TRANSPORT

by

EGGLESTON, L.A.
HOFFMAN, H.I.
SMITH, H.M.
YUILL, C.H.

08/01/63

-ABSTRACT-

The feasibility of a crash-fire prevention system as it might be applied to a Mach 3 supersonic commercial transport (SST) was studied. Early efforts directed toward crash-fire prevention were reviewed for applicability to the SST in the light of advances in the state-of-the-art. Design parameters and general requirements for a crash-fire prevention system are outlined, and attention is given to combustibles and ignition sources on the SST and anticipated crash situations. A crash-fire prevention system for the SST based on the suppression of ignition sources is considered feasible and within the capability of industry and government. Weight of such a system is estimated to be within 1500-1800 lbs. The projected use of stainless steel and titanium skin materials presents a serious friction spark ignition problem under some crash conditions. Efforts directed toward the development of arresting gear mechanisms, crash-resistant fuel tanks, and rapid fuel gelling as a means of preventing crash fires are indicated; and work has been done on the development and engineering of arresting gear for heavy, high-performance aircraft.

-PERTINENT FIGURES-

TAB. 1 ESTIMATES OF HAZARDOUS LIQUID CONDITIONS AT GROUND CONTACT PAGE 9// TAB. 3 SUMMARY OF JET ENGINE INERTING PAGE 27//FIG. 4 WATER QUANTITIES USED FOR INERTING PAGE 32//FIG. 2 CRASH-FIRE PREVENTION SYSTEM FOR ALLISON T56 ENGINE PAGE 25//FIG. 3 CRASH-FIRE PREVENTION SYSTEM FOR GE CJ805 ENGINE PAGE 26//FIG. 5 CRASH-FIRE PROTECTION SYSTEM INSTALLED IN J57 ENGINE SHOWING SPRAY NOZZLE LOCATIONS PAGE 33

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key 38

# THE PYROLYSIS OF CELLULOSIC AND SYNTHETIC MATERIALS IN A FIRE ENVIRONMENT

by

LIPSKA, A.E.

12/14/66

-ABSTRACT-

Literature on the pyrolysis and oxidation of cellulosic and synthetic materials is summarized, including studies on the thermal degradation of polymers, methods of heating and analyzing the decomposition products, and current theories on the mechanisms of pyrolysis of these materials. Fire retardants and the toxic hazards resulting from the thermal degradation of the materials found in a fire environment are discussed. The need for additional pyrolysis experiments, particularly at temperatures between 300 and 400 deg. C., is stressed to assist in prediction and control of ignition and fire spread and to yield data on hazards from combustion products. Isothermal studies of treated and untreated cellulosic materials and synthetics are also recommended in this temperature range to provide data on rate of weight loss, rate of decrease in monomer units, degree of polymerization, and chemical aaalysis of the pyrolysis products.

-PERTINENT FIGURES-

TAB. 2 PYROLYTIC DECOMPOSITION OF CELLULOSE PAGE 17//TAB. 3 COMBUSTION PRODUCTS OF TYPICAL MATERIALS PAGE 21

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# INFLUENCE OF FUEL SLOSH UPON THE EFFECTIVENESS OF NITROGEN INERTING FOR AIRCRAFT FUEL TANKS

by

OTT, E.E.
LILLIE, R.A.

02/00/71

-ABSTRACT-

Tests to determine the influence of sloshing fuel within an aircraft fuel tank upon the effectiveness of nitrogen inerting were performed in a closed combustion chamber partially filled with JP-8 fuel. The fuel was severely agitated by a rocking motion of the chamber. The flammability of the tank ullage at various concentrations of air, nitrogen, and fuel vapor was tested by exposure to an electric arc. The sloshing fuel did not alter the maximum concentration of oxygen that could be allowed for inerting of all fuel vapor concentrations. For JP-8 fuel vapor exposed to an electric arc this maximum allowable oxygen concentration was found to be 12 percent by volume. Slosh did extend the flammable region for oxygen concentrations greater than the maximum allowable for inerting. These conclusions, it is believed, are valid for any mode or level of fuel agitation that may be experienced by aircraft fuel tanks.

-PERTINENT FIGURES-

FIG. 7 FUEL VAPOR-OXYGEN FLAMMABILITY ENVELOPES FOR JP-8 FUEL PAGE 17//FIG. 8 PEAK REACTION PRESSURE RISE DATA FOR VARIOUS INITIAL OXYGEN CONCENTRATIONS PAGE 19//FIG. 9 PEAK REACTION PRESSURE RISE FOR JP-8 FUEL IGNITED IN A SLOSHING FUEL TANK WITH NO VENT AND AT VARIOUS INITIAL OXYGEN CONCENTRATIONS PAGE 20//TAB. 2 INITIAL TEST CONDITIONS AND COMBUSTION PRESSURE RISES PAGES 12-15

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# EFFECTS OF FUEL SLOSH AND VIBRATION ON THE FLAMMABILITY HAZARDS OF HYDROCARBON TURBINE FUELS WITHIN AIRCRAFT FUEL TANKS

by

OTT, E.E.

11/00/70

-ABSTRACT-

The effects of liquid fuel motion on the flammability of hydrocarbon turbine fuels in aircraft fuel tanks was studied using three military turbine fuels, JP-4, JP-5, and JP-8. The fuels were placed in an explosion proof cylindrical 80 gal. test vessel and subjected to slosh and vibration. An electric arc was formed within the ullage which ignited any flammable fuel air mixture present. The pressure rise from combustion was measured and correlated with initial conditions. The major effect of fuel slosh and vibration was to lower or abolish the lean flammable temperature limit of the fuel. The rich flammable temperature limit was unchanged. An analysis was performed on these results and an explanation proposed based upon the hypothesis that all the fuel vapor in the ullage burns for combustion below the flash point.

-PERTINENT FIGURES-

APP. 1 INCLUDES INFORMATION ON THE FOLLOWING PROPERTIES OF JP-4, JP-5, AND JP-8 FUELS: MOLECULAR WEIGHT, PENSKY MARTENS CLOSED CUP FLASH POINTS, AND ESTIMATED VAPOR PRESSURES PAGES 41-42

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0059 PAGES, 0025 FIGURES, 0000 TABLES, 0004 REFERENCES

# CRASH RESISTANT FUEL SYSTEMS DEMONSTRATIONS AND EVALUATION

by

SCHEUERMAN, H.P.

08/00/71

## -ABSTRACT-

A crash-resistant bladder fuel tank system incorporating crash actuated valves and crash-resistant bladder material was impact tested in full-scale wing assemblies. The tests were conducted under realistic crash load conditions simulating survivable accidents at approximately 25 and 75 mph. Wing sections were fitted with three bladder cells interconnected by spring-loaded poppet valves designed to close when 50 percent of the load required to tear the valves from the bladders occurred. The experimental bladder fuel tank system is capable of providing fuel containment in a survivable accident considerably better than the integral tank system based on comparison of leakage rates. The average leakage rate of the tanks tested after impact was 6-8 gph, as compared to the extremely high leakage rate experienced in tests of the integral tank. Under rupture by penetration of sharp metal, spraying of the fuel is not likely to take place and spillage is at a minimum over a small area.

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# EVALUATION OF FLAMMABILITY TEST PROCEDURES FOR AIRCRAFT INTERIOR MATERIALS

by

STARRETT, P.S.
BOBERG, J.E.
JOHNSON, C.L.

10/00/69

## -ABSTRACT-

The nature of aircraft fire hazards during flight and at time of crash are reviewed along with factors influencing materials flammability such as composition of the surrounding gas, the heat transfer process, and material properties. The characteristics most important in defining the hazard presented by a material during an aircraft interior fire are, in a rough order of their importance: generation of toxic gases, ignition temperature, flame propagation rate, generation of flammable gases, generation of heat, and generation of smoke. Adequate existing flammability test procedures are available for a definition of these material attributes. In some cases these procedures could be refined, but additional sophistication in small coupon tests appears unwarranted in view of the fact that such tests are not precisely related to real fire behavior. In addition, the recommended tests have gained some industry wide acceptance, making comparative data available on many common materials. A new procedure would require retesting, as well as a long gestation period before wide acceptance and official adoption. Certain analytical tests are valuable to provide supporting information to the basic flammability tests. Because real fire behavior is situation dependent, full-scale fire simulation is a necessary part of any balanced investigation.

## -PERTINENT FIGURES-

FIG. 1 COMPARATIVE BURNING RATE OF 3.46 OXYGEN/SQ. YD. LONG STAPLE COTTON IN OXYGEN AND IN AIR ATMOSPHERES PAGE 12A//FIG. 2 BURNING RATES OF FABRIC MATERIALS IN A 50 PERCENT OXYGEN - 50 PERCENT NITROGEN, 7.5 PSIA ATMOSPHERE PAGE 14A//TAB. 1 ASTM FIRE TESTS (1966 BOOK) PAGES 20-22//TAB. 2 RECOMMENDED TEST PROCEEDURES FOR FIRE HAZARD CHARACTERISTICS OF MATERIALS PAGE 32

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0063 PAGES, 0009 FIGURES, 0002 TABLES, 0019 REFERENCES

# NASA AIRCRAFT SAFETY AND OPERATING PROBLEMS, VOL. 1, PROC. HAMPTON, VA., MAY 4-6, 1971

by

DONLEY, P., GENERAL CHAIRMAN

05/04/71

-ABSTRACT-

Contents: Neel, C.B., and Fish, R.H., Study of Protection of Passengers in Aircraft Crash Fires (See F7100129)//Radnofsky, M.I., Improvement of Fire Safety in Aircraft (See F7100130)

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# STUDY OF PROTECTION OF PASSENGERS IN AIRCRAFT CRASH FIRES

by

NEEL, C.B.
FISH, R.H.

05/04/71

-ABSTRACT-

A fire protection system for passenger aircraft is described. The system involved surrounding the passenger compartment inside the outer skin with a fire retardant shell to protect the occupants long enough for the fire to burn out or for fire fighting equipment to reach the airplane and extinguish the fire. This approach is made possible by the use of two fire retardant materials: a lightweight polyisocyanurate foam and an intumescent paint. Th intumescent paint expands to many times its original thickness when exposed to heat; thus, it insulates the surface on which it is applied. To demonstrate their use in a full scale application, an airplane fuselage was fitted with the materials and tested in a jet fuel fire. The fire test results were analyzed and reported. Many problems, such as protecting against fuselage rupture and providing protection for windows, must be solve before such a system can be used. Nevertheless, results of the test give promise of providing protection for passengers caught in a crash fire.

-PERTINENT FIGURES-

FIG. 2 PORTION OF MCDONNELL DOUGLAS C-47 AIRPLANE FUSELAGE USED FOR TEST SECTION PAGE 22//FIG. 3 INSTALLATION DETAILS OF FIRE-PROTECTIVE MATERIALS PAGE 23//FIG. 10 CABIN AIR TEMPERATURE DURING FIRE PAGE 29//FIG. 11 TEMPERATURES INSIDE CABIN DURING FIRE PAGE 29

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0021 PAGES, 0015 FIGURES, 0001 TABLES, 0011 REFERENCES

# IMPROVEMENT OF FIRE SAFETY IN AIRCRAFT

by

RADNOFSKY, M.I.

05/04/71

-ABSTRACT-

Materials evaluated by NASA for the space program which are applicable or available to aircraft refurbishment are listed and their properties are briefly reviewed. All the materials have flame resistant characteristics. Those which might be used in aircraft furnishings to promote fire protection included: fibrous materials, such as asbestos, beta fiberglas, polyamide fibers (Durette and Fypro), and a fire retardant (Proban) treated wool; a cellulosic material; fluorocarbon elastomers which are basically copolymers of hexafluoropropene and vinyledene fluoride with compounding ingredients and plasticizers to render them nonflammable; and elastomeric coatings. To apply these technological advances for increased fire safety of aircraft interiors, two Air Force T-39 and one NASA Gulfstream aircraft are being refurbished. For the T-39 ceiling panels a skin of Flourel, fiberglas, and Kel-F was laminated to the existing wooden panels. Kick panels were completely replaced by a composite of Pyrelle foam, fiberglas, decorative Flourel, and Kel-F. All seat cushions were treated with ammonium dihydrogen phosphate and Fluorel spray. The entire seats were then upholstered with Durette fabrics, and so on. All these materials have been developed, evaluated for feasibility of installation and fabrication, color keyed to the aircraft decor, procured, and delivered ready for installation. No information is provided on the fire performance of the modified aircraft.

-PERTINENT FIGURES-

FIG. 11 GULFSTREAM - ENTRANCE WALL AND CURTAIN PAGE 46//FIG. 12 GULFSTREAM - SIDE CURTAIN AND WINDOW PANEL PAGE 46//FIG. 13 GULFSTREAM - VESTIBULE AND GALLERY - AREA CURTAINS PAGE 47

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0015 PAGES, 0014 FIGURES, 0000 TABLES, 0000 REFERENCES

# SMOKE AND GASES PRODUCED BY BURNING AIRCRAFT INTERIOR MATERIALS

by

GROSS, D.
LCFTUS, J.J.
LEE, T.G.
GRAY, V.E.

06/00/68

-ABSTRACT-

Measurements are reported of the smoke produced during both flaming and smoldering exposures on 141 aircraft interior materials. Smoke is reported in terms of specific optical density, and a very wide range in the maximum specific optical density was observed. For the majority of materials, more smoke was produced during the flaming exposure test. However, certain materials produced significantly more smoke in the absence of open flaming. During the smoke chamber tests, indications of the maximum concentrations of CO, HCl, HCN and other potentially toxic combustion products were obtained using commercial colorimetric detector tubes. The operation, accuracy, and limitations of these detector tubes were studied. Measurements of the concentrations of HCl were also made using specific ion degradation electrode techniques. The thermal degradation of selected materials at elevated temperatures was studied in a number of ways including thermogravimetry and differential scanning calorimetry. Qualitative identification of the major components of the original test materials was accomplished primarily by infrared absorption spectrophotometry. Some of the materials tested possessed good heat stability properties, and did not generate large quantities of smoke or high concentrations of the combustion products selected for analysis.

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# INVESTIGATION OF MODIFIED TURBINE FUELS FOR REDUCTION OF CRASH FIRE HAZARD

by

POSEY, JR., K.

05/00/69

-ABSTRACT-

Fifty-five modified fuels were tested and rated for their ability to reduce aircraft post-crash fires. The candidate fuels were subjected to a seven- part rating scheme in which combustion and physical properties were examined under both static and dynamic conditions. Measurements were made of flash point, rate of vapor release, burn rate, surface flame propagation rate and fuel spread rate (ignited), as well as fireball size under impact conditions (drop test) and fireball size with sample propelled by a catapult device. Fuels gelled with either alkyl-hydroxybutyramides, amine diisocyanates, aluminum-2-ethylhexanoate (aluminium octoate), or a styrene-type polymer as well as an emulsified fuel were found to provide marked safety benefits. The alkyl-hydroxybutyramide gels, the amine diisocyonates, and the emulsion had a firm, or stiff, consistency which would present a serious tank feed-down problem in present aircraft. The polymer gel was pourable but contained harmful sodium and required a relatively high polymer concentratio and the polymer was not compatible with the deicer contained in JP-4. The aluminum octoate gel was selected as the best of the candidate fuels tested. It was pourable, provided marked safety benefits, required only a low concentration (1 percent), was stable, noncorrosive and was easily prepared.

-PERTINENT FIGURES-

FIG. 1 DROP TEST FIREBALL, 1/2 SEC. AFTER IGNITION, JP-4 PAGE 14//TAB. 1 CANDIDATE SAFETY FUELS PAGES 3-6//TAB. 2 CANDIDATES ELIMINATED FOR VARIOUS NONTEST REASONS PAGES 8-9

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0037 PAGES, 0013 FIGURES, 0004 TABLES, 0013 REFERENCES

# TITANIUM FUSELAGE ENVIRONMENTAL CONDITIONS IN POST-CRASH FIRES

by

SARKOS, C.P.

03/00/71

-ABSTRACT-

A 28-ft. specially modified titanium fuslage was exposed to a 400 sq. ft. JP-4 jet fuel fire for about 2 1/2 min. The titanium fuselage remained intact, thus preventing any flames from entering into the cabin. Heating of the cabin pressure sealant and insulation caused these materials to burn. This, in turn, caused significant increases in temperature, smoke, and toxic and combustible gases within the cabin at about 1 min. after fuel ignition and a flash fire at 2 min. Theoretical heat transfer calculations were compared with thermocouple data from a section of the fuselage where the insulation did not burn. This comparison indicated that if the insulation and sealant were inert, habitable conditions would have been maintained within the cabin for at least 5 min., and perhaps more.

-PERTINENT FIGURES-

FIG. 3 MODEL OF TITANIUM FUSLAGE CROSS SECTION PAGE 6//FIG. 21 HEAT FLUX UPON TITANIUM FUSLAGE DURING AN EXTERNAL FUEL FIRE PAGE 31//FIG. 22 EXTERNAL FUEL FIRE FLAME TEMPERATURE PAGE 32//FIG. 28 TITANIUM FUSELAGE TEMPERATURE (AFT SECTION, MIDDLE GROUP) DURING AN EXTERNAL FUEL FIRE PAGE 40//FIG. 1-6 PREDICTED CABIN AIR TEMPERATURE DURING A SEVERE EXTERNAL FUEL FIRE ADJACENT TO A TITANIUM FUSELAGE PAGE 1-12

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# AN INVESTIGATION OF IN-FLIGHT FIRE PROTECTION WITH A TURBOFAN POWERPLANT INSTALLATION

by

KLUEG, E.P.
DEMAREE, J.E.

04/00/69

-ABSTRACT-

The potential explosive and fire hazards, as well as methods for detecting and controlling in-flight fires on modern aircraft powerplant installations were investigated under full-scale simulated low altitude flight conditions. Studies were made of (1) environmental conditions producing thermal ignition of combustible mixtures and ignition characteristics, (2) characteristics of nacelle fires, (3) system performance and installation requirements for fire and overheat detection, (4) requirements for extinguishing and controlling fires, and (5) effects of fires and explosions on the powerplant installation. The results are presented as fire safety design criteria and engineering data. The effects of environmental conditions, thermal ignition, and the characteristics of ignition are reported as a function of the amount, location, and type of fluid leakage. The size, intensity, radiation level, and propagation rate of nacelle fires are related to flight condition, fluid type, and fluid leakage characteristics. Fire detection requirements and the feasibility of abbreviated and remotely located sensors are presented as a function of detector operating characteristics, available detection time, nacelle design, and fire characteristics. Fire extinguishing requirements are related to the location, size, intensity, and duration of the fires; flight conditions; nacelle ventilation; and extinguishing agent and container. The resistance of the nacelle and engine components to fire and explosive damage, and means of controlling and preventing the spread of fire are discussed.

-PERTINENT FIGURES-

FIG. 4 NACELLE AIR TEMPERATURE CHANGE FOR TRANSIENT FLIGHT CONDITIONS PAGE 8 //FIG. 7 EFECT OF NACELLE VENTILATION ON THE IGNITION OF TYPE A JET FUEL PAGE 17//FIG. 37 EFFECT OF FLIGHT SPEED ON FIRE EXTINGUISHMENT PAGE 83//TAB. 1 IGNITION HAZARD TEST CATEGORIES FOR NACELLE COMPRESSOR AND ACCESSORY SECTION (ZONE 2) PAGE 11//TAB. 9 EFFECT OF SENSITIVITY OF RADIATION-TYPE SENSORS ON FIRE DETECTION PAGE 59//TAB. 16 RELATIVE EFFECTIVENESS OF FIRE EXTINGUISHING AGENTS PAGE 87

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0236 PAGES, 0108 FIGURES, 0045 TABLES, 0008 REFERENCES

# A STUDY OF AIRCRAFT FIRE HAZARDS RELATED TO NATURAL ELECTRICAL PHENOMENA

by

KESTER, F.L.
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PLUMER, J.A.

06/00/68

-ABSTRACT-

The problems of natural electrical phenomena, such as a fire ignition hazard to aircraft, are evaluated. Assessment of the hazard is made over the range of low level electrical discharges, such as static sparks, to high level discharges, such as lightning strikes to aircraft. In addition, some fundamental work is presented on the problem of flame propagation in aircraft fuel vent systems. A laboratory investigation was concerned with the following areas: (1) ignition energies and flame propagation rates of kerosene-air and JP-6 air foams, (2) rate of flame propagation of n-heptane, n-octane, n-nonane, and n-decane in aircraft vent ducts; (3) damage to aluminum, titanium, and stainless steel aircraft skin materials by lightning strikes; (4) fuel ignition by lightning strikes to aircraft skins, and (5) lightning induced flame propagation in an aircraft vent system.

-PERTINENT FIGURES-

FIG. 2 FLAME PROPAGATION IN SIMULATED FUEL VENT DUCT. FUEL IS N-HEPTANE PAGE 19//FIG. 1 TEST CHAMBER FOR HOLE BURNING TESTS CONDUCTED AT GENERAL ELECTRIC HIGH VOLTAGE LABORATORY PAGE 28//FIG. 4 AREA OF HOLE FORMED VS. COULOMB CONTENT OF LIGHTNING STRIKE PAGE 39//TAB. 1 SPARKING AND IGNITION LEVELS OF 640 TURBINE FUEL/AIR FOAMS PAGE 13//TAB. 2 MAXIMUM RATE OF FLAME PROPAGATION IN FUEL DUCT PAGE 22//TAB. 1 TOTAL ENERGY AND NUMBER OF ELECTRICAL STRIKES REQUIRED TO PRODUCE A HOLE IN TEST MATERIALS PAGE 37

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0133 PAGES, 0059 FIGURES, 0013 TABLES, 0018 REFERENCES

# CHEMICAL ROCKET/PROPELLANT HAZARDS, VOL. 2. SOLID ROCKET/PROPELLANT PROCESSING, HANDLING, STORAGE AND TRANSPORTATION

by

JANNAF PROPULSION COMMITTEE

05/00/70

## -ABSTRACT-

This manual is intended as a source of information and as a set of basic guidelines for the processing, handling, storage, and transportation of chemical solid rocket propellants and propellant ingredients. A hazards analysis technique using a systems engineering approach is suggested and test techniques employed in the hazards analysis concept are given; along with the test objective, operating principle, description, limitations, and application to hazard analysis. The tests discussed are: differential thermal analysis, self-heating tests, copper block tests, Wenograd test, Taliani test, standard heat tests, KI-starch tests, methyl violet test, impact test, friction test, electrostatic discharge test, impingement test, thin film propagation test, dust explosibility test, critical height to explosion test, critical diameter for propagation test, bottle drop test, card gap test, Susan test, and shear water hammer test. Regulations and safety codes are included for propellant manufacturing that offer information on identification of hazards, how they might be eliminated or controlled, and what to expect if they are not. A list is given of ingredients used in the manufacture of solid propellants; along with their physical, chemical, and hazardous properties. The hazards and general precautions connected with assembly, launch and static tests of vehicles are listed. Facility plans are reviewed for propellant manufacturing and rocket and missile assembly plants.

## -PERTINENT FIGURES-



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# CHEMICAL ROCKET/PROPELLANT HAZARDS. VOL. 3. LIQUID PROPELLANT HANDLING, STORAGE AND TRANSPORTATION

by

JANNAF PROPULSION COMMITTEE

05/00/70

-ABSTRACT-

This manual provides general guidance on safety criteria, procedures, instructions, precautions, and other related guideline technical information for minimizing the hazards associated with the handling, storage, use and transportation of liquid propellants and associated materials. The liquids considered are the alcohols, anhydrous ammonia, aniline, the boranes, ethylene oxide, fluorine and fluorine-oxygen mixtures, the halogen fluorides, hydrazine and monomethylhydrazine, unsymmetrical dimethylhydrazine and mixed amine fuels, hydrocarbon fuels, liquid hydrogen, hydrogen peroxide, liquid methane, fuming nitric acid, liquid nitrogen, nitrogen tetroxide, mixed oxides of nitrogen, liquid oxygen, pressurizing gases, halogenated solvents, oxygen difluoride, and Otto Fuel II. For the most part, data on these liquid propellants include chemical and physical properties; health, fire, and explosion hazards; safety measures; materials and equipment for transfer and storage; main storage and ready storage; operating tankage; systems and equipment cleaning and passivation; transfer operations; transportation; emergency procedures; disposal; safety precautions; and references. The manual also includes a glossary, a list of cleaning solutions and materials; a brief description of available personnel protective equipment; hazardous gas detection equipment; and criteria for quantity distance standards for liquid propellants.

-PERTINENT FIGURES-

TAB. 3-2 MAXIMUM FILLING DENSITY OF ANHYDROUS AMMONIA IN SHIPPING CONTAINERS PAGE 3-7//TAB. 5-1 PHYSICAL PROPERTIES OF DIBORANE PAGE 5-2//TAB. 11-2 CONTAINERS PROPERTIES OF JP-4 TURBINE FUEL, AVIATION PAGE 11-2//TAB. 12-1 PHYSICAL PROPERTIES OF LIQUID HYDROGEN PAGE 12-2//TAB. 14-1 PHYSICAL PROPERTIES OF METHANE PAGE 14-2//TAB. 16-1 PHYSICAL PROPERTIES OF LIQUID NITROGEN PAGE 16-1

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0412 PAGES, 0000 FIGURES, 0087 TABLES, 0129 REFERENCES

# RESEARCH AND TECHNOLOGY FOR AIRCRAFT FIRE PROTECTION

by

BEERY, G.T.
BOTTERI, B.P.

06/07/66

-ABSTRACT-

The development of high performance, advanced aircraft introduces new problems in fire safety. Insufficient knowledge and experience exist to establish accurately the degree of hazard that results from such considerations as aerodynamic heating of surfaces; higher engine operating temperatures; restricted usage of compartment venting procedures; and the behavior of fuel liquids, mists, and vapors under a greater range of temperatures and pressures. Investigations of these problems as well as of the methods and materials for their solution are currently in progress. These programs include the following: (1) An investigation and analysis are underway to provide definite information on fuel system fire hazards of Mach 3 aircraft, with the emphasis on cool flame phenomena. (2) An analysis on the safety of jet fuels has indicated no significant operational fire safety advantage of a lower volatility fuel such as kerosene over JP-4. (3) An analysis of the current programs by the Federal Aviation Agency and the U.S. Army on emulsfied and gelled fuels indicates that the utilization of such fuels, except for specialized applications, does not appear attractive for jet operations, although the fire safety advantages are significant.

-PERTINENT FIGURES-

FIG. 1 SPONTANEOUS IGNITION TEMPERATURE ZONES FOR TYPICAL HYDROCARBON FUEL IN AIR PAGE 4//FIG. 3 POWER DRAIN WITH TIME FOR SEVERAL FIBERCELL CONFIGURATIONS PAGE 11//TAB. 1 PROPERTIES OF CANDIDATE EXTINGUISHANTS PAGE 14

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keys 123 through 124

# FIRE AND EXPLOSION HAZARD ASSESSMENT AND PREVENTION TECHNIQUES FOR AIRCRAFT.OQUARTERLY PROGRESS RPT. 1 JAN-31 MAR 66

by

KUCHTA, J.M.
CATO. R.J.
MARTINDILL, G.H.

03/31/66

-ABSTRACT-

To insure maximum flight safety, preventative measures must be taken to provide adequate protection throughout the flight performance profile of the supersonic aircraft. This requires a knowledge of ignition, flammability, and other combustion properties of the aircraft combustibles under environmental conditions comparable to those encountered in actual flight operations. Such information, including the correlation of ignition temperatures with heat source dimensions, was obtained for several hydrocarbon type fuels and lubricants. The present program includes ignition temperature, flammability, oxidative stability, and thermal stability studies with representative hydrocarbon combustibles and with new aircraft fuels or lubricants. Cool and hot flame ignition phenomena are to be investigated at the temperature and pressure conditions under which the combustibles can form flammable vapor-air mixtures or flammable foams or mists. A continuing objective is to derive relationships which can be used to predict the ignition behavior of the combustibles of interest from their thermal decomposition or oxidation behavior. Autoignition temperatures of lubricants at high pressures, autoignition temperature and flammability characteristics of aircraft fuels, and oxidation rates are being studied.

-PERTINENT FIGURES-

TAB. 1 COMPARISON OF IGNITION TEMPERATURE, FLAMMABILITY, AND VOLATILITY PROPERTIES OF VARIOUS FUELS PAGE 3//FIG. 1 CROSS-SECTION OF HIGH PRESSURE EXPLOSION VESSEL PAGE 8//FIG. 2 FLAMMABILITY CHARACTERISTICS DIAGRAM FOR F65-3 JET FUEL IN AIR AT ATMOSPHERIC PRESSURE PAGE 9//FIG. 3 CRITICAL PRESSURE FOR RAPID REACTION VS. VESSEL RADIUS IN OXIDATION OF 5 PERCENT N- OCTANE VAPOR-AIR MIXTURES AT 482 DEG. F. PAGE 10//FIG. 4 RATE OF PRESSURE RISE VS. INITIAL TOTAL PRESSURE IN OXIDATION OF 5 PERCENT N-OCTANE VAPOR- OXYGEN-HELIUM MIXTURES AT 482 DEG. F. PAGE 11

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# FIRE AND EXPLOSION HAZARD ASSESSMENT AND PREVENTION TECHNIQUES FOR AIRCRAFT.CQUARTERLY PROGRESS RPT. NO. 2, 1 APR-30 JUNE 1966

by

KUCHTA, J.M.
CATO, R.J.

06/30/66

## -ABSTRACT-

To assess the fire and explosion hazards associated with the use of aircraft fuels and lubricants under various environmental conditions, studies were made on autoignition temperatures of lubricants at high pressures, and the correlation of ignition temperature and oxidation rate data. Minimum autoignition temperature data are presented for three lubricants (Houghto- Safe 1055, Mobil DTE 103, and MIL-L-7808) in air at initial pressures of 1000 and 2000 psig. In addition, computer solutions are given for a semi- empirical rate expression which may be used to predict the autoignition behavior of n-octane vapor-oxygen-nitrogen mixtures at reduced pressures.

## -PERTINENT FIGURES-

FIG. 1 VARIATION OF AUTOIGNITION TEMPERATURE WITH OIL VOLUME FOR HOUGHTO- SAFE 1055 AND MOBIL DTE 103 LUBRICATING OILS AT INITIAL PRESSURE OF 1000 AND 2000 PSIG PAGE 4//FIG. 2 VARIATION OF AUTOIGNITION TEMPERATURE WITH OIL VOLUME FOR MIL-L-7808 ENGINE OIL AT INITIAL PRESSURES OF 1000 AND 2000 PSIG PAGE 5//FIG. 3 CALCULATED RATES OF PRESSURE RISE VS. TEMPERATURE FOR OXIDATION OF 5 PERCENT N-OCTANE VAPOR-OXYGEN-NITROGEN MIXTURES AT VARIOUS OXYGEN CONCENTRATIONS AND TOTAL PRESSURE OF 60 MM HG (1.16 PSIA); (3.16 CU. IN. SPHERICAL PYREX VESSEL) PAGE 6

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# A STUDY OF THE COMPATIBILITY OF A FOUR ENGINE COMMERCIAL JET TRANSPORT AIRCRAFT FUEL SYSTEM WITH GELLED AND EMULSIFIED FUELS. FINAL REPORT

by

PEACOCK, A.T.
HAZELTON, R.F.
GRESKO, L.S.
CHRISTENSEN, L.D.

04/00/70

## -ABSTRACT-

The rheological and physical properties of four gelled and three emulsified turbine fuels were evaluated. One gelled and one emulsified fuel were selected for further test and analysis in a compatibility study with a four engine commercial jet transport aircraft fuel system. Full-scale testing of system components was performed. Penalities and problem areas associated with using the fuels were identified by an analysis of the fuel system. A full-scale ground test program to evaluate an aircraft fuel system's performance on thickened fuels was outlined. Results show significant decreases in available fuel and large increases in system weights are associated with the use of the thickened fuels described. Substantial fuel development is indicated before application to commercial aircraft.

## -PERTINENT FIGURES-

FAB. 1 GELLED AND EMULSIFIED FUEL SUMMARY PAGE 4//FIG. 1 FLOW DIAGRAM FOR GELLED FUEL A PAGE 8//FIG. 4 EFFECT OF TEMPERATURE UPON YIELD VALUES PAGE 13 //FIG. 8 EFFECTS OF ALTITUDE - FUEL A PAGE 20//FIG. 16 COMPONENT PRESSURE DROP-PARKER AIRCRAFT P/N F11D REFUELING NOZZLE AND P/N F406B ADAPTER PAGE 33 //FIG. 32 LINE FRICTION PRESSURE DROP FOR FUELS A AND G PAGE 53

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0190 PAGES, 0074 FIGURES, 0033 TABLES, 0026 REFERENCES

# FLIGHT VIBRATION AND ENVIRONMENTAL EFFECTS ON FORMATION OF COMBUSTIBLE MIXTURES WITHIN AIRCRAFT FUEL TANKS

by

KCSVIC, T.C.
HELGESON, N.L.
BREEN, B.P.

09/00/70

-ABSTRACT-

Fuel tank vapor space characteristics for a simulated helicopter fuel tank were determined. Fuel/air ratios were measured as a function of time and position within the ullage of the fuel tank for specified flight profiles. These results were compared to published flammability limits as a basis for assessing flight hazard potential. The flight profiles were simulated by withdrawing fuel (at rated engine usage) from a vibrating tank held at constant pressure and temperature. Parametric variations were made in fuel temperature (40 to 100 deg. F.) flight altitude (0 to 15,000 ft. ), vibration environment, and fuel properties (liquid JP-4 versus JP-4 emulsion EF4-104H). Another important variable not considered initially but which was uncovered during the course of this investigation was the effect that the rubberized tank liner (PF-10056) could have on the measured fuel/air ratios. The extent of this effect was found to be related to fuel temperature and exposure time of the liner to the fuel. The experimental results showed those ranges of the test variables which had a significant effect on the measured fuel/air ratios. They also demonstrated that fuel/air mixture gradients do exist in fuel tanks under flight conditions. It was found that tanks which would be considered safe as determined by calculations for equilibrium conditions actually contain flammable regions, regions, even for level flight. An analytical model for the ullage space space was written which included transient fuel vapor diffusion and convection which was brought about by venting of the ullage. The sample cases gave results which showed reasonable agreement in both shape and magnitude with the measured composition profiles.

-PERTINENT FIGURES-

FIG. 2 ILLUSTRATIVE COMPOSITION PROFILES IN ULLAGE VOLUME AS A FUNCTION OF TIME FOR VARIABLE VF/VS PAGE 6//FIG. 8 COMPARISON OF COMPOSITION PROFILES BEFORE AND AFTER DESCENT OF HELICOPTER FROM 15,000 FEET TO SEA LEVEL PAGE 15//FIG. 18 EMPTY TANK FUEL/AIR COMPOSITION PROFILE AT VARIOUS FUEL TEMPERATURES PAGE 36

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# FLAMMABILITY IN ZERO-GRAVITY ENVIRONMENT

by

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DOWNS, W.R.
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10/00/66

-ABSTRACT-

PARAFFIN AND OTHER SOLID COMBUSTIBLES WERE BURNED IN A ZERO GRAVITY ENVIRONMENT. AIR, PURE OXYGEN AND 50-50 OXYGEN-NITROGEN MIXTURES AT PRESSURES VARYING FROM 2 1/2 TO 20 PSIA WERE USED AS THE COMBUSTION CHAMBER ATMOSPHERE. ZERO GRAVITY INTERVALS OF MAXIMUM DURATION OF 12 SEC. WERE OBTAINED IN THE CABIN OF AN AIRCRAFT FLYING KEPLERIAN PARABOLAS. EXPERIMENTS WERE PHOTOGRAPHED WITH INFRARED SENSITIVE FILM AT 100 FRAMES/SEC. AND WITH 16-MM COLOR FILM (ER-B) AT 200 FRAMES/SEC. TEST RESULTS INDICATE THAT IGNITION AT ZERO GRAVITY WAS ESSENTIALLY UNCHANGED COMPARED TO A ONE GRAVITY ENVIRONMENT, BUT THAT COMBUSTION IS SOMETIMES SUPPRESSED TO THE EXTENT THAT THE FIRE APPEARED TO BE EXTINGUISHED. IN ALL CASES, THE FLAME WAS BRIGHTEST DURING PERIODS OF ACCELERATION, SUCH AS AT IMPACT OF THE TEST CHAMBER WITH THE AIRCRAFT AND WHEN RETURNING TO LEVEL FLIGHT. FLAME CONDITIONS AT ZERO GRAVITY WERE TYPICAL OF THOSE EXPECTED OF A PURE DIFFUSION FLAME IN WHICH STEADY-STATE CONDITIONS WERE NOT ACHIEVED.

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# INVESTIGATION OF PERFORATED PLASTIC SHPERES CONCEPT FOR FUEL TANK FIRE SUPPRESSION

by

BOTTERI, B.P.
GANDEE, G.W.
MORRISEY, E.J.

04/00/69

-ABSTRACT-

AN INVESTIGATION WAS CONDUCTED TO ESTABLISH THE FEASIBILITY OF USING PERFORATED HOLLOW PLASTIC SHERES TO PACK AIRCRAFT FUEL TANKS TO PROVIDE FIRE AND EXPLOSION SUPPRESSION CAPABILITY. THE PROGRAM INVOLVED ESTABLISHING SEVERAL SHPERE CONFIGURATIONS, PRODUCING TEST QUANTITITES, DETERMINING PERFORMANCE UNDER ELECTRICAL SPARK AND INCENDIARY GUNFIRE CONDITIONS, AND EVALUATING FUEL SYSTEM COMPATIBILITY. THREE SPHERE CONFIGURATIONS VARYING IN DIAMETER FROM 3/4 TO 1 IN. WITH PERFORATIONS OF 0.060 TO 0.100 MILS WERE EVALUATED. ALL CONFIGURATIONS PROVIDED SOME EXPLOSION SUPPRESSION, BUT THE GOAL OF 3 PSI MAXIMUM PEAK PRESSURE RISE REQUIRED FOR FUEL TANK APPLICATIONS WAS NOT ACHIEVED. FUEL SYSTEM COMPATIBILITY WAS SLIGHTLY INFERIOR TO THAT EXPERIENCED WITH POLYURETHANE FOAM. SHPERES WITH OPTIMUM PHYSICAL CHARACTERISTICS WERE NOT PRODUCED DUE TO PROGRAM RESTRICTIONS. STUDIES INDICATED SEVERAL POTENTIAL PRODUCTION METHODS, ALTHOUGH FURTHER DEVELOPMENT WOULD BE REQUIRED.

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# OXYGEN-INDUCED AIRCRAFT CABIN FIRE

by

BRENNEMAN, J.J.

09/00/71

## -ABSTRACT-

A fire occurred during the recharging of the oxygen system of a Boeing 737 aircraft on December 31, 1970, at Washington National Irport. Although it caused heavy damage in the area of fire origin, effective fire fighting techniques prevented greater severity. The loss of critical components in the vicinity of the on-board oxygen equipment complicated positive determination of the cause, but the presumption is that the firh started at the filter element within the filler valve inlet nipple aboard the aircraft, since the temperature there was high enough to burn through the valvebody at two locations. The alarm was recorded as being received 2 min. after ignition and the airport fire department personnel arrived within 90 to 120 sec. to find flames and smoke rising out of a hole burned in the right front side of the fuselage. About 200 lb. of dry chemical was used to secure flame knockdown, 115 gal. of foam concentrate to achieve cooling and final control, and an unestimated quantity of water spray through 1 1/2 in. hose lines and a 1 in. booster line. Tests attempting to reproduce the fire indicate that a contaminant must be present in the filter if the oxygen flow, even in a surge against the filter, is to initiate combustion. The loss in this fire was estimated at $500,000 to $900,000.

## -PERTINENT FIGURES-

DIAGRAM OF PLACEMENT AND USE OF FIRE EQUIPMENT PAGE 26

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# STUDY OF FLAME PROPAGATION THROUGH AIRCRAFT VENT SYSTEMS. FINAL REPORT

by

GILLIS, J.P.

08/00/69

-ABSTRACT-

A study was made of flame propagation in a simulated aircraft vent system to provide design criteria for future vent system installations in aircraft. Determinations were made of flame speeds in various sections of the vent system under conditions of ascent, descent, and aircraft-on-ground. Temperature and altitude effect on flame speed were also investigated. The geometric configuration of the simulated vent system caused momentary flame speeds in excess of 1000 ft./sec., and the associated pressures developed in some instances exceeded the structural limitations of typical aircraft vent ducts. It was concluded that under all flight and ground operating conditions where sufficient fuel and oxygen is present to support combustion, a flame will propagate at varying velocities through a typical vent system when ignited at the outlet. Sharp transitions in duct shape, diameters, direction of travel, dead ended sections, etc. are characteristics which contribute to wave reflections that reinforce flame propagation and should be eliminated. Where duct transitions are necessary, they should be smooth and gradual. Vent systems should not incorporate fuel slosh collection tanks since they provide a driving force which accelerates the flame propagation rates.

-PERTINENT FIGURES-

FIG. 1 THE RELATIVE FLAMMABILITY ENVELOPE OF JET A-1 DURING AIRCRAFT CLIMB PAGE 5//FIG. 11 FUEL TANK VENT SYSTEM ANALYSIS CONFIGURATION 1 PAGE 30//FIG. 15 MAXIMUM AND MINIMUM FLAME SPEEDS IN VENT DUCT FOR CENTER WING TANK PAGE 38//FIG. 16 EFFECT OF ALTITUDE ON FLAME SPEED IN 20 FT. DUCT SECTION WITH CLOSED END IGNITION PAGE 40//FIG. 17 EFFECT OF TEMPERATURE ON FLAME SPEED ON PROPANE-AIR MIXTURES WITH OPEN END IGNITION CONFIGURATION 2 PAGE 42

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0103 PAGES, 0018 FIGURES, 0004 TABLES, 0000 REFERENCES

# EVLUATION OF TEST DATA ON JET ENGINE COMBUSTOR BURN-THROUGH FLAMES

by

PERGAMENT, H.S.
MIKATARIAN, R.R.

03/00/72

-ABSTRACT-

A method is developed to interpret flat plate impingement pressure and temperature data taken in jet engine combustor burn-through flames in terms of free stream velocities, pressures, temperatures, etc. These flames, which are high-temperature, turbulent, underexpanded sonic jets, are caused, in practice, by the combustion gases impinging on (and burning a hole through) the wall of the combustor. The free stream property data are needed to compute local heat transfer coefficients, which must be known to determine whether potential firewall materials can withstand a burn-through flame. Turbulent convective heat transfer coefficients are computed primarily to determine radiation and conduction corrections to the temperature measurements. The influence of mixing between the burn-through flame and ambient air on flame properties is also studied, and a correlation is developed which relates the angle of spread of the mixing region to the enthalpy flux at the burn-through hole. Suggestions regarding future experimental and theoretical programs are made.

-PERTINENT FIGURES-

FIG. 1 COMPARISON BETWEEN SHOCK LOCATIONS IN NAFEC TESTS AND UNDEREXPANDED AIR JET DATA PAGE 1-3//FIG. 2 RELATIVE POSITIONS OF SHOCKS UPSTREAM OF A FLAT PLATE AND A PITOT TUBE PAGE 1-4//FIG. 3 EFFECT OF MACH NUMBER ON SHOCK DETACHMENT DISTANCE FROM A FLAT PLATE PAGE 1-5//FIG. 4A PROPERTY DISTRIBUTIONS ALONG CENTERLINE OF BURN-THROUGH FLAME (95 PERCENT POWER SETTING) PAGE 1-6//TAB. 4 STAGNATION TEMPERATURES ON BURN-THROUGH FLAME CENTERLINE PAGE 2-6

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key 265

# FIRE-RESISTANT FLUIDS. FACTORS IN MATCHING TYPES TO APPLICATIONS

by

HENRIKSON, K.G.

11/11/65

## -ABSTRACT-

The performance characteristics and properties of fire resistant fluids used in hydraulic systems are discussed. The term fire resistant is used to indicate that the fluids are more resistant to burning than oil, although they may not be completely nonflammable. The types of fluids considered are water-in-oil emulsions, oil-in-water emulsions, synthetic fluids, water-glycol solutions, and petroleum oil-synthetic blends. The need for a fire resistant fluid can best be determined by the user in cooperation with his safety or fire department. Hazards are determined based on the operation, ignition source, ambient environment, effect on production, plant and maintenance, and personnel safety. The principal reason for considering all aspects of the hazard is that petroleum fluids are considered the best fluids for hydraulic pump operation. Although tests may show fire resistant fluids to be superior to petroleum oils, such tests do not cover all conditions of hydraulic system operation. The high density of synthetic fluids and the high vapor pressure of water containing fluids may cause pump problems such as cavitation or water vapor formation.

## -PERTINENT FIGURES-

FIG. 1 RELATIVE FIRE RESISTANCE OF HYDRAULIC FLUIDS PAGE 234//FIG. 2 EFFECT OF WATER CONTENT ON VISCOSITY OF WATER-IN-OIL EMULSION PAGE 234//FIG. 5 PERFORMANCE AND MAINTENANCE EFFECTIVENESS OF HYDRAULIC FLUIDS PAGE 240//TAB. 1 PROPERTIES OF SYNTHETIC FIRE-RESISTANT FLUIDS PAGE 238//TAB. 2 PERFORMANCE CHARACTERISTICS OF FIRE-RESISTANT FLUIDS PAGE 240

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key 280

# FLAMMABILITY OF AIRCRAFT FUELS

by

CARHART, H.W.
AFFENS, W.A.

00/00/69

## -ABSTRACT-

An assessment of the fire hazards with fuels aboard an aircraft carrier is examined, along with the approach the Navy takes to reduce these hazards. The fuels which are generally aboard a carrier in a capacity of over 4 million gal. are Navy Special Fuel Oil (NSFO) used for ship propulsion; Av Gas required for helicopters and piston engine aircraft; and JP-5 jet fuel. The flammability characteristics and flame spread of these fuels are reviewed comparing the relative safety of JP-4 with JP-5. The safety merits of JP-5 are those of a fuel designed for compatibility with aircraft carrier use, i.h. a low freezing point and a minumum flash point of 140 deg. F. The effects of ullage and the explosiveness texts as they contribute to the lowering of the flammability temperature limit of JP-5 jet fuel are discussed. The hazard of electrostatic charges in igniting fuel tanks is considered; however, since most electrostatic discharges are not very energetic and are of the corona type, they are seldom incendiary. The Navy gives itself an added measure of safety through its use of JP-5, because JP-5 vapors inside the tank are too lean at ordinary temperatures to be in the flammable range. The hazard reducing measures of reticulated foam, self-sealing liners, and thickened fuels are considered for minimizing the flammability hazards of fuel spills from aircraft.

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# THE DEPENDENCE OF SPONTANEOUS IGNITION TEMPERATURE ON SURFACE TO VOLUME RATIO IN STATIC SYSTEMS FOR FUELS SHOWING A NEGATIVE TEMPERATURE COEFFICIENT

by

GRAY, B.F.

00/00/70

## -ABSTRACT-

Results from an experimental investigation on the spontaneous ignition temperature of kerosene as a function of the surface-volume ratio are believed to indicate that the risk of spontaneous ignition in, for example, an aircraft compartment such as a fuel tank would be reduced by inserting a metal honeycomb in order to increase the surface-volume ratio. An attempt is made to show that this conclusion is not necessarily correct and, possibly hazardous, by using the chain-reaction thermal ignition theory. The discontinuity in the slope of a plot of ignition temperature versus surface-volume is shown to arise from either a negative temperature coefficient ip the heat release rate curve or a point of inflection, thus allowing a double tangency condition for the heat release and loss curves on the usual type of thermal diagram. Heat release curves of this type have been related to oscillatory cool flames and lobes on ignition diagrams. A theoretical interpretation of oscillatory cool flames, ignition lobes, and the negative temperature coefficient are used as evidence for the thesis.

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key 320

# TEMPERATURE DISTRIBUTION WITHIN AIRCRAFT-FUEL FIRES

by

GORDON, W.
MC MILLAN, R.D.

02/00/65

## -ABSTRACT-

When experimentally determining the vulnerability of a nuclear weapon to fire, the weapon is usually suspended in the flames from an overhead support by lugs, or mounted on pedestals within the flames. The method of suspension is to attach the lugs by which the bomb is secured to the aircraft pylon to supports that are attached to a large A-frame. In order to insure that the bomb or other weapon being tested is placed in the hottest portion of the fire, it is necessary to know the temperature distribution within the fire. Analysis of the test data shows that there is a difference, although not a statistically significant one, in the average flame temperature of fires burning 100/130-octane aviation gasoline and those burning JP-4 fuel. There is no difference in the average flame temperature of fires burning different quantities of the same fuel in the quantity range tested. There is a difference, although not a statistically significant one, in the average flame temperature between and within levels of an aircraft fuel fire. There is no significant difference in the average flame temperature between a large, open, aircraft fuel fire with an object in the flame and one without. Analysis of the data is continuing to determine variation in the average flame temperature of a fire between and within levels with respect to time.

## -PERTINENT FIGURES-

FIG. 3 REPRESENTATIVE PICTURE OF AVERAGE FIRE TEMPERATURE-TIME DATA PAGE 56//FIG. 4 VARIATION IN AVERAGE FIRE TEMPERATURE AS A FUNCTION OF HEIGHT ABOVE FUEL SURFACE FOR INNER AREA OF 100/300 OCTANE AVIATION GASOLINE FIRE PAGE 59//TAB. 2 COMPARISON OF TEMPERATURES BETWEEN JP-4 AND AVIATION GASOLINE PAGE 57//TAB. 4 COMPARISON OF FIRE TEMPERATURES FOR DIFFERENT QUANTITIES OF AVIATION GAS PAGE 58

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keys 321 through 323

# AN APPRAISAL OF THE POST CRASH ENVIRONMENT

by

JOHNSON, N.B.
GOEBEL, D.E.
ROBERTSON, S.H.

09/00/69

## -ABSTRACT-

A program was conducted to define the postcrash fire environment for helicopters and light aircraft, and to recommend additional testing, where necessary, to increase knowledge of such fires to a useful level. A thorough literature search indicated that man's survival in an aircraft crash fire is predicated on four main factors: (1) circumambient heat, (2) circumradiant heat, (3) toxic fumes, and (4) the obstruction to his vision. The magnitude of these factors, however, is dependent upon a variety of circumstances, including the degree of structural breakup, type of airframe structure, interior materials, and type of terrain surrounding the crash site. A summary of all available data indicates that, while a great deal of knowledge does exist about fires, applying fire data meaningfully to the aircraft crash fire environment has only begun. Most fire test data found were for large transport type aircraft. Some data were found for smaller aircraft; however, more data must be accumulated and analyzed before the small aircraft crash fire environment can be defined.

## -PERTINENT FIGURES-

FIG. 1 AVERAGE RECORDED AMBIENT AND RADIANT TEMPERATURES IN VARIOUS COMPARTMENTS OF SEVERAL CRASHED BURNING PASSENGER/CARGO FIXED WING AIRCRAFT PAGE 10//FIG. 3 FUEL SPILLAGE PATTERN OF CRASHED C-45 PAGE 16//FIG. 4 RECORDED TEMPERATURES IN CRASHED, BURNING C-45 PAGE 17//FIG. 5 TIME-TEMPERATURE CURVES OF CRASHED, BURNING HELICOPTERS PAGE 21//FIG. 7 AVERAGE RECORDED CO CONCENTRATIONS IN SEVERAL CRASHED, BURNING PASSENGER/ CARGO-TYPE AIRCRAFT PAGE 28//TAB. 3 CONTAMINANTS PRODUCED BY COMBUSTION PAGE 26

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    0095 PAGES, 0019 FIGURES, 0014 TABLES, 0055 REFERENCES

# CRASH FIRE HAZARD RATING SYSTEM FOR CONTROLLED FLAMMABILITY FUELS. FINAL REPORT.

by

KUCHTA, J.M.
FURNO, A.L.
MARTINDILL, G.H.
IMHOF, A.C.

03/00/69

## -ABSTRACT-

A method for rating the potential crash fire hazard of gelled and emulsified hydrocarbon fuels was developed at the request of the Federal Aviation Admiqistration. Use of such thickened aircraft fuels may provide a significant reduction in the crash fire hazard. The rating system is designed primarily for screening candidate thickened fuels with respect to their overall flammability hazard under laboratory-scale conditions. The fuel properties included in the rating system are minimum autoignition temperature, flash point, volatility rate, selfspread rate, regression or burning rate, flame spread rate, and fire ball size under impact conditons. Methods for determining these fuel properties are also described. Experimental data on such fuel properties are presented for JP-4 and JP-5 or Jet A thickened fuels that were formulated with an emulsifying agent or with one of three different gelling agents submitted for evaluation. The results of these determinations and the numerical ratings derived for each fuel composition are discussed.

## -PERTINENT FIGURES-

FIG. 1 VAPOR PRESSURE VS TIME OBTAINED FOR 3 FUELS IN THE MODIFIED REID VAPOR PRESSURE APPARATUS PAGE 4//FIG. 3 SELECTED FRAMES FROM MOTION PICTURE FILMS OF FIRE DEVELOPED IN FUEL DROP FIRE TESTS WITH 5 LBS. OF LIQUID FUEL AT A DROP HEIGHT OF 20 FT. PAGE 6//FIG. 4 THERMAL RADIATION VS TIME OBTAINED FOR 3 FUELS IN FUEL DROP FIRE TESTS (THERMOPILE AT DISTANCE OF 30 FT.) PAGE 8//TAB. 3 SUMMARY OF EXPERIMENTAL DATA FOR JET A LIQUID FUEL AND VARIOUS JET A OR JP-5 THICKENED FUELS PAGE 12//TAB. 4 COMPARISON OF VARIOUS FUELS ACCORDING TO THE PROPOSED FIRE HAZARD RATING SYSTEM PAGE 13//TAB. 5 COMPARISON OF THERMAL RADIATION DATA FROM FUEL DROP FIRE EXPERIMENTS WITH VARIOUS FUELS PAGE 15

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key 331

# FIRE TEST CRITERIA FOR RECORDERS, FINAL REPORT

by

RUST, JR., T.
BCRIS, P.N.

07/00/70

## -ABSTRACT-

Tests were conducted to investigate fire test criteria as applied to flight data and cockpit voice recorder systems and materials. Studies were made to determine the effect of elevated temperature on various types cf recording tapes and highly conspicuous exterior coatings which could be applied to recorder covers. Open flaming and enclosed furnace tests were performed on complete recording units in order to obtain data for formulating improved standardized laboratory test methods suitable for evaluating survivability of flight data and cockpit voice recorders in a crash fire environment. Conclusions based on the results obtained from the investigation are: (1) A suitable and uniform test method for the crash fire testing of aircraft flight data and voice recorders would be to insert the complete recorder for 30 min. duration in an electric furnace operating at 1600 deg. F. (2) The design criteria for cockpit voice recorders employing magnetic recording tape must insure that the tape will not be exposed to temperatures above 300 deg. F. for usable survival of the tape under the above stated test method for simulating a severe aircraft fire accident. (3) The recorded signal strength on magnetic recording tape used in a voice recorder does not decrease excessively when exposed for up to a 60 min. duration to elevated temperatures below the melting temperature of the tape.

## -PERTINENT FIGURES-

FIG. 1 MAGNETIC VOICE RECORDING TAPE TEST SPECIMENS: TAPE WOVEN IN TRAY PAGE 4//FIG. 2 MAGNETIC VOICE RECORDING TAPE TEST SPECIMEN: TAPE WOUND ON A REEL PAGE 7//FIG. 3 GRAPHIC REPRESENTATION OF SIGNAL LOSS ANALYSIS PAGE 10//FIG. 5 STAINLESS-STEEL FLIGHT DATA TAPE TEST SPECIMEN PAGE 16//TAB. 4 STAINLESS STEEL TAPE TEST SCHEDULE PAGE 14//TAB. 6 EXTERIOR COATINGS APPLIED TO STAINLESS STEEL PAGE 26

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key 333

# AIR TRANSPORT CABIN MOCKUP FIRE EXPERIMENTS, FINAL REPORT

by

MARCY, J.F.

12/00/70

## -ABSTRACT-

A study was made of the burning characteristics of airplane interior materials ignited inside a 640 cu. ft. cabin mockup enclosure. Test conditions were varied to investigate the effects of the following factors on the ignition and propagation of flames within enclosures: (1) flammability ratings of the materials as obtained from standard laboratory tests; (2) intensity, duration, and type of the ignition source whether flaming or incandescent; (3) ventilation rate as provided by different size openings into the cabin enclusure; (4) partitioning of the cabin space by use of a fire barrier curtain; and (5) discharge of bromotrifluoromethane into the cabin atmosphere, both at different rates and total quantities of application before and during a fire occurrence. Comparative tests conducted on flame retardant urethane and neoprene foams showed that the flash fire hazard prevalent with the use of regular foam could be greatly reduced by replacement with these two self-extinguishing foams. A high rate discharge system employing bromotrifluoromethane was shown to be effective in rapidly extinguishing the flames of a foam fire. A curtain divider placed across the ceiling was shown to be useful as a fire barrier to arrest flame propagation. Roof venting of the mockup at a location away from the fire was relatively ineffective in preventing rapid buildup of smoke and flame spread from a flash fire involving urethane foam.

## -PERTINENT FIGURES-

TAB. 1 DATA SUMMARY OF CABIN MOCKUP FIRE TESTS PAGE 6//FIG. 2 SEAT FIRE TEST WITH CONVENTIONAL MATERIALS IN CLOSED CABIN (BEFORE FIRE) PAGE 10//FIG. 4 CEILING FLASHOVER TEMPERATURES FROM SEAT FIRE IN CLOSED CABIN PAGE 13

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0050 PAGES, 0020 FIGURES, 0001 TABLES, 0011 REFERENCES

# AIR SAFETY, SURVIVING THE CRASH

by

LEVIN, S.M.

05/00/68

-ABSTRACT-

The ability to survive an aircraft crash depends not only on impact and evacuation capabilities, but on a flame-barrier fuselages, modified fuels, and crash-resistant tanks. Differences in emphasis on safety/cost tradeoffs between FAA and industry are discussed. Latest FAA rules for aircraft design for large transports call for more and larger emergency exits. Industry's objections to increased exits is the added weight and cost and danger of fire spreading through doors. Non-burning fuselages and heat barriers for cabins are considered better protection. The need for a slide or ramp past the exit is cited. The most effective approach to limiting fires involving fuel spills involves use of modified fuels (gels and emulsions). Studies are being performed on feasibility of this approach. New standards have been set for fire resistance of cabin materials, but toxicity standards have not been established. Cost-benefit tradeoffs of use of new materials such as Nomex are discussed. A proposed answer to smoke and fume risks is a plastic hood to be slipped over the head. Other aspects of crashworthiness are related to structural design to limit impact damage. It is stated that the money being proposed for crashworthiness could be better spent on efforts to eliminate crashes.

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# FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLE COMBUSTIBLES. FINAL REPORT

by

LITCHFIELD, E.L.
PERLEE, H.E.

03/00/65

-ABSTRACT-

The sensitivity of liquid hydrogen + solid oxygen + diluent and liquid oxygen + solid hydrocarbon + diluent was investigated employing a projectile impact to determine the shock required to detonate these mixtures. With no diluent, each explosive system is initiated by a shock stimulus of 1.0 to 2.5 kbar. The explosive yields are such that 1-lb. cryogenic mixture is equivalent to 0.6 to 2.0 lb. TNT. Sodium chloride, nitrogen, and methyl chloride had inert desensitizing effects upon the liquid hydrogen mixtures, but did not reduce the explosive yield. Sodium chloride and nitrogen desensitized the liquid oxygen system; sodium chloride or water reduced the explosive yield of this system. Inhibition of detonation initiation by dry powder particle additives was also investigated. The powder additives produced insignificant inhibition in comparison to that produced by gaseous diluents. Flammability limit determinations of four additional halogenated hydrocarbons are included in a discussion of the characteristics of 10 such compounds. Most of the compounds were flammable in oxygen atmospheres at temperatures below 200 deg. F.; their combustion products included toxic halogens or halogen halides.

-PERTINENT FIGURES-

TAB. 3 MINIMUM AUTOIGNITION TEMPERATURES (DEG. F.) OF HALOGENATED HYDROCARBONS IN VARIOUS OXIDANT ATMOSPHERES AT ATMOSPHERIC PRESSURE IN A 250 CC GLASS VESSEL PAGE 14//TAB. 5 LIMITS OF FLAMMABILITY OF VARIOUS HALOGENATED HYDROCARBONS (VOLUME PERCENT) IN GLASS AND STAINLESS STEEL PAGE 16//TAB. 6 LIMITS OF FLAMMABILITY OF VARIOUS HALOGENATED HYDROCARBONS (VOLUME PERCENT) IN AIR, OXYGEN, AND NITROGEN TETROXIDE ATMOSPHERES IN GLASS VESSELS PAGE 17//TAB. 7 MIXIMUM PRESSURES, RATES OF PRESSURE RISE, AND BROMINE CONCENTRATIONS DEVELOPED DURING COMBUSTION OF 5 HALOGENATED HYDROCARBONS IN OXYGEN AND AIR ATMOSPHERES PAGE 18

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0028 PAGES, 0002 FIGURES, 0007 TABLES, 0016 REFERENCES

# A STUDY OF THE HELICOPTER CRASH-FIRE PROBLEM

by

SOMMERS, D.E.

02/00/59

-ABSTRACT-

An analysis of fixed and rotary wing aircraft and crash fire research investigations indicated the need for developing design criteria and determining requirements for helicopter crash fire protection. It was found that abnormal engine displacement, landing gear failures, and damaged drain cocks during a crash all were interrelated to fuel cell failures and fuel spillage. Helicopter design features in many instances increase fire probability and limit passenger survival during a crash. Recommended measures for crash fire safety improvement include: engine shutdown during and after a crash; provision of adequate safety exits to prevent entrapment of occupants should the helicopter roll over on one side; relocation of components which contribute to fuel spillage and ignition; and the construction of undercarriage and forward skin crash contact panels of materials which will not produce sparks and high temperatures as a result of scraping contact with runway surfaces. The chief ignition sources common to all types of jet and reciprocating engine aircraft during a crash are: hot surfaces inside and outside the engine, exhaust system or tail pipe flames, induction system flashback, electrical arcs and electrically heated filaments, flames from chemical agents, sparks caused by abrading metals, and electrostatic sparks. Gasoline, kerosene, or JP fuel in the form of mist outside the aircraft or in the form of liquid or vapor within confined areas of the aircraft are considered the most hazardous of all combustibles associated with aircraft crashes.

-PERTINENT FIGURES-

TAB. 3 SUMMARY OF HELICOPTER ACCIDENTS PAGES 6-9

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0020 PAGES, 0006 FIGURES, 0003 TABLES, 0011 REFERENCES

# EFFECT OF GROUND CRASH FIRE ON AIRCRAFT FUSELAGE INTEGRITY. INTERIM REPORT

by

GEYER, G.B.

12/00/69

-ABSTRACT-

A mathematical model was formulated which permits a calculation to be made of the time required for damage to occur to the aluminum skin covering on an aircraft fuselage when it is exposed to maximum spill fire conditions. The damage time was defined as the time required for the aluminum skin to melt. The model was developed through consideration of the heat transfer rates by convection and radiation across a simplified aircraft fuselage configuration. The resulting differential equation was solved using a numerical technique. The results indicate that the minimum time required for skin damage to occur to the largest commercial aircraft now in service is less than 40 sec. The fuselage damage time predictions, made through the use of the mathematical model, correspond closely with measurements made on simulated aircraft skin configurations employing a 40 ft. stainless steel covered section of a four engine jet aircraft fuselage.

-PERTINENT FIGURES-

FIG. 6 SKIN TEMPERATURES FOR 0.031 IN. STAINLESS STEEL AS A FUNCTION OF FIRE EXPOSURE TIME PAGE 9//FIG. 13 EXPERIMENTAL SKIN TEMPERATURES FOR 0.020 IN. ALUMINUM AS A FUNCTION OF FIRE EXPOSURE TIME PAGE 18//FIG. 14 EXPERIMENTAL SKIN TEMPERATURES FOR 0.090 IN. STAINLESS STEEL AS A FUNCTION OF FIRE EXPOSURE TIME PAGE 19//FIG. 17 EXPERIMENTAL SKIN TEMPERATURES FOR 0.031 IN. STAINLESS STEEL AS A FUNCTION OF FIRE EXPOSURE TIME AS CALCULATED FROM THE MODEL PAGE 23//FIG. 18 CALCULATED MELTING TIME FOR ALUMINUM AIRCRAFT SKINS AS A FUNCTION OF THE TEMPERATURE RISE FOR STAINLESS STEEL PAGE 24//FIG. 19 EXPERIMENTAL SKIN TEMPERATURES FOR 0.020 IN. ALUMINUM AS A FUNCTION OF FIRE EXPOSURE TIME PAGE 25

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AD-698806//NA-69-37(RD-69-46)
OTHER INFORMATION -
0074 PAGES, 0023 FIGURES, 0000 TABLES, 0006 REFERENCES

# AIRCRAFT CARRIER AND FIRE

by

ROBERTS, II, J.W.

02/00/69

-ABSTRACT-

An assessment is made of the fire and explosion dangers aboard an aircraft carrier equipped with large amounts of aircraft fuel, jet fuel, and ordnance. The lack of space compounds the problem of sheer volume of flammable and explosive material. A small uncontrolled incident has the potential of becoming a definite hazard and even a tragedy similar to incidents aboard the USS Oriskany, the USS Forrestal, and the USS Enterprise. High performance jet aircraft are another serious hazard. Partial answers to minimizing these hazards are suggested which make use of the fire fighting ability of light water and Purple K and the design of systems to incorporate these extinguishants for carrier use. Training of crew personnel is also required. However, the reduction of accidents depends on design for safety i.e., overall improvement of aircraft carriers as a total weapons system.

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keys 447 through 454

# FIRE SAFETY MEASURES FOR AIRCRAFT FUEL SYSTEMS, CONF. ON. WASHINGTON, D.C., DEC. 11-12, 1967.

by

FEDERAL AVIATION ADMINISTRATION.

12/11/67

-ABSTRACT-

Contents: Hallman, A.B., NTSB Summary of Transport Aircraft Accidents Involving Fire or Expolsions in the Fuel System (see F7100326)//Horeff, T.G., FAA Propulsion R&D Program on Fuel System Ignition Hazards (see F7100327)//Wright, F.A., Air Force History and Experience with Inerting, Suppression, and Purging Systems (see F7100328)//Hewes, V., ALPA Statements on Needs for Fuel Tank Inerting and/or Flame Suppression on New and In-Service Aircraft (see F7100329)//Dallas, A.W., Air Transport Association Presentation on Fire Safety Measures on Aircraft Fuel Systems (see F7100220)//Weise, C.A., Aerospace Industries Association Presentation. Part 1 - Evaluation of Fuel System Fire Safety in the Aircraft Industry (see F7100331)//Honsberger, B.A., Part 2 - Current Developments of Fire Safety for Aircraft Fuel Systems (see F7100332)//Versaw, E.F., Part 3 - Factors Influencing Application of New Fire Safety (see F7100333)

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REPORT NUMBER -
AD-672036
OTHER INFORMATION -
9999 PAGES, 9999 FIGURES, 9999 TABLES, 9999 REFERENCES

# NTSB SUMMARY OF TRANSPORT AIRCRAFT ACCIDENTS INVOLVING FIRE OR EXPLOSICNS IN THE FUEL SYSTEMS

by

HALLMAN, A.B.

12/11/67

-ABSTRACT-

The National Transportation Safety Board statistical and accident investigation reccrds were used to provide information that related the aircraft fire problem to the total accident picture for the 1957-1966 period. The total accident figures shown are not the same as reflected in the official Board statistics since accidents involving rotary wing and nontransport category aircraft were omitted. Pertinent information regarding certain selected accidents in which, it is believed, the fuel tanks vapor-air content was involved is also presented. Summarizing: in two of the three turbojet accidents discussed, the explosions occurred inflight; the third took place on the ground. Mixtures of Jet A and B fuels were involved in two instances, whereas Jet A was the fuel in one case. Two of the accidents were survivable and one was nonsurvivable. U.S. certificated air carriers operated turbojet aircraft a total of 8,913,185 hr. from the time of their introduction through 1966. Considering the three accidents mentioned, the accident rate per 100,000 hr. of operation is 0.034.

-PERTINENT FIGURES-

FIG. 1 TOTAL AIRCARRIER ACCIDENTS 1957-1966 PAGE 13//FIG. 3 TURBOJET AIRCARRIER ACCIDENTS 1962-1966 VS RECIP. AIRCARRIER ACCIDENTS 1950-1954 PAGE 14//FIG. 4 AIRCARRIER ACCIDENTS INVOLVING FIRE PAGE 15//FIG. 2 TOTAI AIRCARRIER ACCIDENTS INVOLVING FIRE 1957-1966

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(SEE F7100325)
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0013 PAGES, 0004 FIGURES, 0000 TABLES, 0000 REFERENCES

# ALPA STATEMENTS ON NEEDS FOR FUEL TANK INERTING AND/OR FLAME SUPPRESSION ON NEW AND IN-SERVICE AIRCRAFT

by

HEWES, V.

12/11/67

-ABSTRACT-

The fire and explosion hazards involved in operating transport aircraft with partially empty fuel tanks are reviewed. The need for protecting aircraft from fuel system explosions from the time of loading until unloading at the gate, and on the ground and in flight is stressed. Spokesmen from manufacturers who can provide this type of protection describe their companies' progress in research and developing products of a safety nature. Flame and explosion suppression systems are discussed which are automatic, keep oxygen levels below 10 percent by using liquid nitrogen for inerting, use optical detection coupled with Freon 1301 as a suppressant agent, and use explosive squibs to discharge the agent.

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JOURNAL PROCEEDINGS -
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0016 PAGES, 0000 FIGURES, 0000 TABLES, 0000 REFERENCES

# COMBUSTIBLE PROPERTIES OF AIRCRAFT CABIN MATERIALS

## -ABSTRACT-

To determine the smoke and toxic gas hazards of aircraft cabin materials, measurements were made on 141 materials currently used or considered for use in aircraft interiors. The materials studied consisted of natural and artifical fabrics, sheet and laminate siding materials, rugs, pads, and materials used for ceiling and bulkhead insulation. The tests were conducted in a smoke test chamber developed at the National Bureau of Standards. The specimens were subjected to both flaming and nonflaming (smoldering) exposures. The tests showed that a number of materials do not generate large quantities of smoke or gases. Samples were checked for carbon monoxide, hydrogen cyanide, hydrogen chloride, sulfur dioxide, nitrogen oxide plus nitrogen dioxide, ammonia, chlorine, and carbonyl chloride. In general, it was found that HC1 was produced from burning polyvinyl chloride and modacrylic material; HF from polyvinyl fluoride; HCN from wool, urethane, acrylonitrile-butadiene-styrene, and modacrylics; and sulfur dioxide from polysulfone and rubber materials. CO was produced by almost all the samples in varying amounts depending on the type of material.

## -PERTINENT FIGURES-

FIG. 1 SPECIFIC OPTICAL DENSITY IS PLOTTED AS A FUNCTION OF TIME FOR VARIOUS MATERIALS PAGE 29//TAB. 1 DESCRIPTION OF SELECTED MATERIALS PAGE 28//TAB. 2 SUMMARY OF RESULTS; SMOKE AND GAS CONCENTRATION PAGE 28

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key 492

# AIRCRAFT FUEL SYSTEM MAINTENANCE 1971, RECOMMENDATIONS ON SAFEGUARDING

by

NATIONAL FIRE PROTECTION ASSOCIATION

05/00/71

## -ABSTRACT-

Three possible methods which may be followed during aircraft fuel ground handling are recommended to reduce the flammable vapor hazard of aircraft fuel tank atmospheres. The circumstances under which any one procedure may be followed vary and are subject to the discretion of the operator. The three basic procedures suggested are siphon inerting, pressure inerting, and air ventilation. To assist in the selection of the proper or most desirable instrument for determining the fuel tank atmosphere, a list of the various instruments available is included. Suggested procedures are also outlined as safeguards for the repair of integral, bladder, and metal aircraft fuel tanks. General fire safety recommendations are made for aircraft fuel transfer operations and testing aircraft fuel systems during aircraft maintenance and overhaul operations.

## -PERTINENT FIGURES-

TAB. 1 MAXIMUM PERMISSIBLE OXYGEN PERCENTAGES AND MINIMUM INERT GAS CONCENTRATIONS WITH VARIOUS FACTORS OF SAFETY FOR INERTING OF AIRCRAFT FUEL TANKS CONTAINING VARIOUS TYPICAL AVIATION FUELS PAGE 8//TAB. 3 INSTRUMENTS FOR THE DETERMINATION OF FUEL TANK ATMOSPHERES PAGE 26

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NATIONAL FIRE PROTECTION ASSOCIATION, BOSTON, MASS.
REPORT NUMBER -
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OTHER INFORMATION -
0045 PAGES, 0002 FIGURES, 0003 TABLES, 0000 REFERENCES

# AIRPORT WATER SUPPLY SYSTEMS FOR FIRE PROTECTION, RECOMMENDED PRACTICE FOR MASTER PLANNING

by

NATIONAL FIRE PROTECTION ASSOCIATION

00/00/69

## -ABSTRACT-

This booklet provides recommendations to planners of airport water supply systems. Only those features that are applicable to a particular situation, taking into consideration domestic water usage and supply and fire protection needs, should be used in planning. A natural or man-made source of water must be adequate for present and future needs. Sources of water are natural bodies of water, elevated gravity tanks, pressure tanks, water reservoirs, and connections to public water systems. Pumping facilities must be adequate to meet the high water demands imposed by sprinklers in aircraft hangars and other areas. The water distribution system can be separated for fire protection and domestic use, or these uses can be combined into one system. The water flow rate varies with the use of an area and the type of construction. A table of recommended flow rates is provided. Periodic maintenance and testing of equipment should be carried out by an authority with responsibility for the system.

## -PERTINENT FIGURES-

TAB. 1 FIRE FLOW GUIDE FOR AIRPORT MASTER PLANNING BY TYPE OF FACILITIES PAGE 419-17

## -SOURCE INFORMATION-

CORPORATE SOURCE -
    NATIONAL FIRE PROTECTION ASSOCIATION, BOSTON, MASS.
REPORT NUMBER -
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    0023 PAGES, 0000 FIGURES, 0001 TABLES, 0040 REFERENCES

key 506

# CRASH FIRE CONTROL CAPABILITY STUDY

by

ROBERTSON, W.D.

00/06/60

-ABSTRACT-

Standards are reviewed and recommended for the fire protection capabilities at Washington State airports. Data were gathered on 21 commercial aircraft survivable accidents. The statistics indicated that fire-fighting capabilities would be related to 50 percent of the occupants involved. FAA requirements state that evacuation should take place within 2 min., but the crash study indicates that only half of the occupants are able to evacuate in this time under crash fire conditions. Fire test data were reviewed to determine application densities in terms of gal./sq. ft. Protein foam was chosen for the study and it was found that effective fire control could be obtained in less than 2 min. with densities of .15 gpm/sq. ft. The next phase of the study was concerned with evacuation zones. Factors considered were human tolerance to heat, elevation above ground, and size of evacuation zones in relation to passenger loads. Extinguishment application rates should be considered as minimum capabilities to provide protection during landing and take-off.

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OTHER INFORMATION -
0060 PAGES, 0040 FIGURES, 0000 TABLES, 0000 REFERENCES

# LIGHTNING PROTECTION MEASURES FOR AIRCRAFT FUEL SYSTEMS. PHASE 2

by

BOLTA, C.C.
FRIEDMAN, R.
GRINER, G.M.
MARKELS, JR., M.
TOBRINER, M.W. ETAL.

05/00/64

-ABSTRACT-

Experimental and analytical investigations were made of (1) flame propagation characteristics through the Boeing 707 vent system as a result of ignition by simulated lightning discharges and specially developed ignition equipment, (2) the effectiveness of flame arrestors of various designs located at different sections of the vent system with simulated lightning and laboratory ignition equipment, (3) explosion suppression techniques utilizing an explosively disseminated chemical agent to prevent explosion in aircraft tanks upon sensing a flame propagating through the vent tube, (4) the previously reported ultra-high blast pressure effects and large volume plasma generation as a result of simulated lightning discharge in the area of the vent outlet, (5) the addition of air to the combustible vapor mixture to obtain high velocity effluent from the vent outlet to prevent flashback, (6) the use of mechanical valves to isolate vent passages, and (7) the use of bladders as fuel containers. A purely theoretical analysis was performed to evaluate the potential hazards due to icing of selected flame arrestor designs. It was generally concluded that flame propagation tests using simulated lightning discharges directly to the vent outlet showed that flame speeds higher than the usual turbulent speeds are achieved due to the large mass flows caused by an organ pipe action of the vent system. Flame arrestors near the vent outlet were compromised while those further inboard were effective. Explosion suppression systems were effective against flames propagating at speeds typical of those generated by the simulated lightning strike.

-PERTINENT FIGURES-

FIG. 3 COMBUSTIBLE RANGE OF FUELS AS A FUNCTION OF ALTITUDE AND FUEL TEMPERATURE (REFERENCE 10) PAGE 11//FIG. 21 FLAME PROPAGATION TEST AT HIGH- VOLTAGE FACILITY PAGE 45//FIG. 38 RESULTS OF BLAST TESTS PERFORMED BY LIGHTNING AND TRANSIENTS RESEARCH INSTITUTE PAGE 87//FIG. 45 FLAME ARRESTOR SURFACE TEMPERATURE FOR VARIOUS FLOW RATES AND MIXTURE RATIOS PAGE 113// TAB. 14 PRESSURE DROP THROUGH 707 AIRCRAFT VENT SYSTEM DURING FUELING PAGE 109

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    CONTRACT FA-64WA-4955
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    0195 PAGES, 0063 FIGURES, 0016 TABLES, 0030 REFERENCES

# REVIEW OF FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLE COMBUSTIBLES

by

VAN DOLAH, R.W.
ZABETAKIS, M.G.
BURGESS, D.S.
SCOTT, G.S.

10/00/61

## -ABSTRACT-

The prevention of fires and explosions involving combustibles and oxidants likely to be found in flight vehicles requires a knowledge of the flammability and related characteristics of these materials. A compilation of the available characteristics data for a series of combustibles and oxidants of current interest is presented. Vapor pressure and detonability data are given for fluorine, oxygen, chlorine trifluoride, nitrogen tetroxide, nitric acid, hydrogen peroxide, ethylene oxide, hydrogen, ammonia, pentaborane, unsymmetrical dimethylhydrazine, monomethylhydrazine, hydrazine, and a series of hydrocarbons including decalin, tetralin, bicyclohexyl, and other high density fuels. In addition, flammability characteristics diagrams are presented for each of these fuels in contact with air and, where available, other oxidants (e.g., oxygen and nitrogen tetroxide). To assist in an understanding of the data, a discussion is included of pertinent definitions and theory of combustion and detonation. Some speculation is also included on the impact of unusual environmental factors such as intense aerodynamic heating, reduced gravitational forces, and low ambient pressures encountered in aerospace flight. Several illustrative examples of application of the data to specific hazard situations are presented.

## -PERTINENT FIGURES-

FIG. 5 RELATIONSHIP BETWEEN MINIMUM IGNITION ENERGY AND OPTIMUM ELECTRODE SEPARATION (QUENCHING DIAMETER) PAGE 7//FIG. 33 FLAMMABILITY CHARACTERISTICS DIAGRAM OF JP-6 IN AIR AT ATMOSPHERIC PRESSURE PAGE 72//FIG. 42 VARIATION IN LOWER TEMPERATURE LIMIT OF FLAMMABILITY (FLASH POINT) WITH PRESSURE FOR UDMH VAPOR IN AIR PAGE 81//FIG. 48 MINIMUM SPONTANEOUS IGNITION TEMPERATURES OF 7 HYDRAULIC FLUIDS IN AIR AT 1 ATM. IN CONTACT WITH A PYREX GLASS SURFACE AS A FUNCTION OF DIESEL INJECTOR PRESSURE PAGE 87// FIG. 52 SPONTANEOUS IGNITION TEMPERATURES AND CORRESPONDING IGNITION DELAY DATA FOR HYDROCARBON TYPE FUELS UNDER STATIC CONDITIONS IN AIR AT ATMOSPHERIC PRESSURE (1-8 APPARATUS) PAGE 90

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0104 PAGES, 0052 FIGURES, 0005 TABLES, 0105 REFERENCES

key 555

# THEORETICAL DETERMINATION OF THE TIME OF USEFUL FUNCTION (TUF) ON EXPLOSURE TO COMBINATIONS OF TOXIC GASES

by

GAUME, J.G.
BARTEK, P.

12/00/69

-ABSTRACT-

A mathematical model is presented for the determination of the Time of Useful Function (TUF) for the purpose of escape from the toxic atmospheres resulting from fire in habitable spaces, and which contain multiple toxicants of serious import. Little information is available in the literature concerning human tolerance to very short exposures (less than 5 min.) to multiple contaminants at relatively high concentrations. Where information does exist for either single or multiple gases, lethality is usually the endpoint. For a TUF determination, the endpoint is the inability of the individual to escape from the hot, smoky environment due to the inhalation of toxicants from combustion and pyrolysis. The TUF is analogous to the Time of Useful Consciousness (TUC) associated with rapid or explosive decompressions.

-PERTINENT FIGURES-

FIG. 1 CONTAMINANT BUILDUP PAGE 1354//FIG. 2 COMPARISON OF TOXICANTS BREATHED: FIRE BUILDUP VS STEADY STATE MIXTURE PAGE 1356//FIG. 3 AIA TEST NO. 2 TOTAL CONTAMINANT BUILDUP PAGE 1356//TAB. 1 SUMMARY OF TOXIC GASES-- AIA CLEVELAND TESTS PAGE 1355

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0005 PAGES, 0003 FIGURES, 0002 TABLES, 0010 REFERENCES

# EXPERIMENTAL RESULTS ON TIME OF USEFUL FUNCTION (TUF) AFTER EXPOSURE TO MIXTURES OF SERIOUS CONTAMINANTS

by

GAUME, J.G.
BARTEK, P.
ROSTAMI, H.J.

09/00/71

-ABSTRACT-

Fires in habitable spaces produce life-threatening gaseous contaminants of several asphyxiants and irritants. Very little data are available on the critical time (TUF or Time of Useful Function) individuals caught in such fires have to escape the buildup of these contaminants before they become incapacitated. Experimental data are presented from 53 exposures of mice to single, double, and triple gas mixtures of carbon monoxide, carbon dioxide, and ammonia which represent both the asphyxiant and irritant categories. Single gas exposures were completed first to establish baseline data. Next, mice were subjected to double gas exposures of CO/carbon dioxide and CO/ ammonia at several concentrations. Finally, triple gas exposures consisting of CO, carbon dioxide, and ammonia were carried out at various concentrations. The TUF endpoint used was the time of collapse from the moment the gas injection was completed. The TUF for CO exposure was used as a baseline against which other exposures were compared. It was found that double gas exposures extended the TUF, and triple gas exposures extended the TUF even more. A theory is suggested for the mechanism of this extension phenomenon. The results are considered to be preliminary and their validity must be further substantiated. This information is applicable to (1) the selection and development of interior materials which neither burn nor produce dangerous toxic products, and (2) to stimulate further investigation in this neglected area of research.

-PERTINENT FIGURES-

FIG. 1 TUF EXPOSURE CHAMBER PAGE 988//FIG. 2 TIME OF USEFUL FUNCTION (TUF) PAGE 989//TAB. 1 TUF CONTAMINANT EXPOSURES PAGE 988//TAB. 2 TUF STATISTICAL DATA PAGE 988//TAB. 3 TUF VALUES AND ASSOCIATED PROBABILITIES PAGE 989

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# DYNAMICS ANALYSIS FOR TIME OF USEFUL FUNCTION (TUF) PREDICTIONS IN TOXIC COMBUSTIVE ENVIRONMENTS

by

BARTEK, P.
GAUME, J.G.
ROSTAMI, H.J.

12/00/70

## -ABSTRACT-

The margin of safety for escape from a hostile environment containing toxic combustion products is contingent on many variables. These variables may be grouped into two categories: (1) physical factors and (2) physiological factors. The physical factors are the result of the dynamic changes taking place in the external environmental combustive processes. The physiological factors represent the complex physiological changes occurring in response to the toxic environment. The ability to escape is dependent on the magnitude of the consolidated biokinetic forces for environmental deterrence over a given period of time. This period of time has been referred to previously as the Time of Useful Function (TUF). Examples are considered in this approach in which the TUF is based on data of some toxic pyrolysis products generated by combustion processes. Attempts are made to provide a method for determining some common factors essential for TUF predictions.

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key 564

# A HISTORY OF THE NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER, 1958-1970

by

CURTIS, E.P.

08/00/70

-ABSTRACT-

An overview is presented on the organization, resources, employee/management cooperation, technology, and divisional histories of the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N.J. The mission of the center is to develop, modify, test, and evaluate systems, procedures, facilities, and devices to meet the needs for safe and efficient air traffic control of all civil and military aviation. The developments at NAFEC during its first 12 years of operation (1958-1970) included all-weather landing, range and elevation guidance for approach and landing, flarescan, area navigation, air traffic control, radar, airport lighting and marking, air traffic control radar beacon system, collision avoidance in air traffic control, and communications. The history of the aircraft safety technical program at NAFEC falls into three categories: airworthiness, crashworthiness, and environmental hazards. Experimental work carried out in these categories at the Center is briefly summarized.

-PERTINENT FIGURES-

A CATAPULT TEST ON A GENERAL AVIATION AIRCRAFT PAGE 60//A DOOR IS CUT IN THE SIDE OF AN AIRPLANE FUSELAGE BY EXPLOSIVE LIQUID PROPELLANT PAGE 60// MEASUREMENT OF WAKES AND VORTICES PAGE 60//FIRE EXTINGUISHMENT TEST PAGE 60//A STRIKING PHOTOGRAPH OF A NAFEC AIRCRAFT FIRE TEST PAGE 63

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NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER, ATLANTIC CITY, N.J.
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OTHER INFORMATION -
0101 PAGES, 0010 FIGURES, 0003 TABLES, 0000 REFERENCES

# THE CHALLENGE OF AIRCRAFT CRASH FIRE RESCUE

by

KEEGAN, E.W.

04/20/70

## -ABSTRACT-

Records indicate that 40 percent of fatalities in survivable crashes could have been saved by faster fire extinguishment. Most of these fires involved the fuel system, and 95 percent occurred during landing or takeoff. Not more than 90 sec. are likely to be available for escape. Although the average escape time per individual has decreased, the number of passengers per plane and the number of miles flown has increased so that the expected number of fatalities due to fire is more than 1,000 annually. A combination of light water foam and Purple K dry chemical has proved to be the most effective extinguishing medium yet devised. Crash rescue vehicles must be manned by thoroughly trained professionals and must be able to move rapidly over any ground that might be encountered. The "go-for-broke" techniques advocated would involve small, fast vehicles able to crash through fences and ride over obstacles to extinguish the fire and evacuate the passengers. Completely extinguishing the fire is secondary to saving lives.

## -PERTINENT FIGURES-

FIG. 2 EMERGENCY RESCUE ACCESS PAGE 6//TAB. 4 EVACUATION TIMES PAGE 3// TAB. 5 CRASH FIRE AND RESCUE EQUIPMENT AT AIRPORTS PAGE 3//TAB. 6 QUANTITIES OF EXTINGUISHING AGENT PAGE 3

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0007 PAGES, 0002 FIGURES, 0006 TABLES, 0004 REFERENCES

# EMERGENCY ESCAPE AND SURVIVAL FACTORS IN CIVIL AIRCRAFT FIRE ACCIDENTS

by

CARROLL, J.J.

05/06/68

## -ABSTRACT-

Aircraft accidents involving minor impact can become catastrophies as a result of post-crash factors. The greatest hazard is fire and the most critical survival factors become immediate protection against the debilitating effects of fire and the timely evacuation of aircraft. A case is presented of an accident to a turbojet with 73 occupants. Impact was minor, but a torn fuel line spewed out fuel which ignited and set off two explosions within 40 sec. There were 23 survivors who escaped during the first 30 sec. of the accident. An analysis is made of the differences in individuals who survived. Age and sex were important factors, with a disproportionate number of male adult survivors. This may be attributed to such psycho-physiological factors as greater hazard-urgency alertness, physical capabilities, psychological orientation, familiarization with escape procedures, and less need for assistance. Nationality does not appear to be significant. In the case of family groups, it is indicated that ability to escape is impaired by delays imposed by concern for family welfare. It is suggested that special briefings would tend to improve response to emergencies. In the meantime, aircraft design studies should take these human factors into account as problems of escape and survival.

## -PERTINENT FIGURES-

FIG. 2 ALL CARBONIZED EXTENSIVELY - 13 MALE 5 FEMALE PAGE 14//FIG. 3 ALL CARBONIZED EXTENSIVELY - 19 FEMALE 7 MALE PAGE 15

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0015 PAGES, 0003 FIGURES, 0001 TABLES, 0000 REFERENCES

# ANALYSIS OF AIRCRAFT FUEL TANK FIRE AND EXPLOSION HAZARDS

by

KCSVIC, T.C.
ZUNG, L.B.
GERSTEIN, M.

03/00/71

-ABSTRACT-

Under simulated flight environments, fuel-air ratios at various locations of the ullage space were determined using gas chromatograph measurement. Using the shallow tank experimental data showed that during ascent and cruise portion of the flight profile, uniform fuel-air mixtures were found to exist within the entire ullage volume. Significant fuel-air gradients existed during the descent portion of the flight profile, with mainly air near the vent inlet. Evaporative lag was observed during ascent and level flight when liquid Jet A fuel was maintained at 80 deg. F. When the liquid fuel temperature was increased to 120 deg. F., evaporation rate was found to be rapid enough that the evaporative lag phenomena was no longer observed. Vibrating the fuel tank greatly increased the rate of offgassing of dissolved air in the liquid fuel. This in turn significantly changed the fuel-air ratio in the ullage space. Two separate and complementary models were developed to predict fuel-air concentrations within the ullage. The well-stirred model is particularly applicable to wing tanks of aircraft and for tank configurations where the ratio of ullage volume to liquid fuel surface is small. For tank configurations were this is not true, a distributed F-A model was developed. Cool flame limits and transition between cool flame and normal flame ignition limits associated with supersonic flights were also investigated. No ignition limits associated with supersonic flights were also investigated No ignition was observed for Mach numbers below 2.7, and ignition was observed for a Mach number equal to 3.0.

-PERTINENT FIGURES-

FIG. 1 LOGIC FLOW CHART FOR ASSESSMENT OF FUEL TANK HAZARD PAGE 4//FIG. 15 VARIATION OF FUEL/AIR RATIO DURING ASCENT, LEVEL, AND DESCENT FLIGHTS FOR JET-A FUEL PAGE 36//FIG. 16 VARIATION OF FUEL/AIR RATIO FOR JET-A FUEL AT 110 DEG. F. PAGE 37//FIG. 22 JP-4 ASCENT TESTS TO 40,000 FT. PAGE 49//FIG. 34 LOWER IGNITION LIMITS FOR TFA/AIR MIXTURES AT VARIOUS SIMULATED ALTITUDES PAGE 67

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# AUTOIGNITION OF HYDROCARBON JET FUEL

by

KUCHTA, J.M.
BARTKOWIAK, A.
ZABETAKIS, M.G.

00/00/65

## -ABSTRACT-

Experimental data are presented on the autoignition temperature (AIT) characteristics of the hydrocarbon jet fuel, JP-6, in various oxygen-nitrogen atmospheres under conditions of constant volume and constant pressure. AIT's of this fuel in air varied little with fuel injection pressure but increased greatly with decreasing fuel content at low fuel-air ratios. They also increased with decreasing oxygen content of the fuel vapor-oxidant atmosphere. Consistent with thermal ignition theory, the ignition temperatures increased with decreasing initial pressure, ignition delay, and vessel radius; expressions are given which define the observed variation of AIT with these variables for JP-6 fuel vapor-air mixtures. The significance of autoignition temperature data obtained using various ignition criteria is discussed to show the usefulness of such data in evaluating fire and explosion hazards. In addition, data are presented on the extent of oxidation that occurs prior to autoignition of this fuel in air at various temperatures.

## -PERTINENT FIGURES-

TAB. 2 MINIMUM AUTOIGNITION TEMPERATURES OF JP-6 JET FUEL IN QUIESCENT AIR AT VARIOUS PRESSURES AND IN VARIOUS VESSELS PAGE 9// FIG. 7 EFFECT OF FUEL-AIR WT. RATIO ON THE AUTOIGNITION TEMPERATURE OF JP-6 FUEL IN AIR FOR VARIOUS SIZE VESSELS PAGE 11//EFFECT OF VESSEL SIZE ON AUTOIGNITION TEMPERATURE OF JP-6 FUEL IN AIR AT ATMOSPHERIC PRESSURE PAGE 13//FIG. 9 MINIMUM AUTOIGNITION TEMPERATURES OF JP-6 FUEL IN AIR AT VARIOUS INITIAL PRESSURES AND IN VARIOUS SIZED VESSELS PAGE 14//FIG. 10 AVERAGE MAXIMUM TEMPERATURE AND PRESSURE RISES AT MINIMUM AUTOIGNITION TEMPERATURE (AIT) CONDITIONS FOR JP-6 FUEL IN AIR AT VARIOUS INITIAL PRESSURES PAGE 15// FIG. 11 EFFECT OF OXYGEN PARTIAL PRESSURE ON MINIMUM AUTOIGNITION TEMPERATURES OF JP-6 FUEL-OXYGEN-NITROGEN MIXTURES AT VARIOUS INITIAL PRESSURES PAGE 17

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keys 580 through 581

# DECOMPRESSION OF CABINS

by

LANGLEY, M.

08/00/71

## -ABSTRACT-

A number of aircraft accidents have been traced to metal fatigue which has caused fractures in the fuselage which result in explosive decompression of the aircraft cabin. The similarity to ships, especially submarines, is noted and the concept of separating sections of the aircraft with bulkheads is borrowed. If a fault should occur, it would be localized by an airtight bulkhead. The bulkheads would also slow flooding of the aircraft in the event of ditching in water. They would also act as fire breaks. The addition of bulkheads would require design changes that might prove beneficial.

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# EFFECT OF FIRE FIGHTING CHEMICALS ON PARACHUTE COMPONENTS. FINAL REPORT.

by

BOONE, J.O.

03/00/68

## -ABSTRACT-

The effects of light water, protein foam, purple K powder (PKP), light water plus PKP, protein foam plus PKP, and the discharge water from a soda-acid extinguisher were tested on the following materials used in parachutes: 1.1 oz. nylon fabric, MIL-C-7020 sewing thread size E, cadmium-plated steel connector links, and 1/64 in. aluminum plate. Exposures were made for periods of 2 and 30 hr. at 10 to 27 deg. C. In some situations the fire fighting chemicals had a slight degrading effect on nylon. This was most pronounced in the case of the soda-acid extinguisher. Except for the degneration caused by soda-acid chemicals on nylon, the effects are slight when materials are washed within 30 hr. of exposure. All the fire extinguishing chemicals can have a slight corrosive and/or fouling effect on metallic parts.

## -PERTINENT FIGURES-

TAB. 1 TEST RESULTS, BREAKING STRENGTH OF NYLON FABRIC EXPOSED TO CHEMICALS PAGE 6//TAB. 2 TEST RESULTS, BREAKING STRENGTH OF SEWING THREAD EXPOSED TO CHEMICALS FOR 30 HR. PAGE 7

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key 607

# FLAMING AND SELF-EXTINGUISHING CHARACTERISTICS OF AIRCRAFT CABIN INTERIOR MATERIALS. FINAL REPORT

by

MARCY, J.F.
JOHNSON, R.

07/00/68

## -ABSTRACT-

Burning characteristics of some 140 different materials were studied for the purpose of obtaining technical data and criteria needed to support current efforts to improve existing Federal Air Regulations governing the use of cabin interior materials in aviation. Comparative tests were conducted on two groups: (1) materials now in use in air transport, and (2) materials proposed for future use with superior flame resistance. Measurements were made of ignition time, burn and char lengths, flame-out time, burn rate, heat of combustion, flame spread index, etc. Two standard laboratory test methods were employed: (1) Federal Standard CCC-T-191b, Test Method 5902, Vertical Burning Apparatus; and (2) Federal Standard 00136b (ASTM E-162), Radiant Panel Apparatus. Results of the tests were analayzed to indicate major flammability trends for different material classifications. Practical allowable flammability limits based on available materials technology were recommended for increasing the present fire protection requirements of interior materials.

## -PERTINENT FIGURES-

FIG. 3 FREQUENCY DISTRIBUTION OF CHAR LENGTH BY MATERIAL CLASSIFICATION - TEST METHOD 5903T PAGE 18//FIG. 5 FREQUENCY DISTRIBUTION OF FLAME-SPREAD INDEX VALUES BY MATERIAL CLASSIFICATION - RADIANT PANEL TEST PAGE 27//TAB. 1 DATA SUMMARY FOR VERTICAL TESTS PAGE 14//TAB. 3 DATA SUMMARY FOR RADIANT PANEL TESTS PAGE 23//APP. I TABLES OF MATERIAL DESCRIPTION AND LAB. FIRE TEST DATA PAGE 1-1

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key 608

# FLAMMABILITY AND SMOKE CHARACTERISTICS OF AIRCRAFT INTERIOR MATERIALS

by

MARCY, J.F.
NICHOLAS, E.B.
DEMAREE, J.E.

01/00/64

-ABSTRACT-

Flammability and smoke characteristics of interior materials were determined from a selection of 109 materials representative of present usage in the aviation industry. A comparison was made of the flame resistant characteristics exhibited by the different materials on the basis of: (1) test method; (2) thickness, weight, composition, and backing; (3) fire retardant treatment; and (4) degradation from use and cleaning. By employing test methods defined in Federal Aviation Agency Flight Standards Service Release 453 and Federal Specification CCC-T-191b, burning characteristics were obtained in terms of burn rate, burn length, and self-extinguishing time. A flame spread index and smoke factor also were obtained by making use of the Radiant Panel Test Apparatus. It is concluded that the FSS Release 453 Test Method is not a suitable test procedure for materials other than fabrics; the vertical test method is a satisfactory alternate as a test method for fabrics that are self-extinguishing. The large number of interior materials containing vinyls or other plastics produce greater quantities of smoke during burning than do the cellulose derived materials of the same flammability range. The effect of the condition of the material on the flame resistance of the fabrics and rugs tested was not significant.

-PERTINENT FIGURES-

FIG. 1 HORIZONTAL RATE OF BURNING APPARATUS PAGE 29//FIG. 2 VERTICAL RATE OF BURNING APPARATUS PAGE 31//FIG. 3 RADIANT PANEL FLAME-SPREAD APPARATUS (ASSEMBLY) PAGE 32

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key 610

# FUEL TANK EXPLOSION PROTECTION

by

KUCHTA, J.M.
CATO, R.J.
GILBERT, W.H.
SPOLAN, I.

03/00/69

## -ABSTRACT-

Small scale and large scale experiments were conducted to determine the flame arrestor effectiveness of three types of hollow, perforated polyethylene spheres proposed for fuel tank fire and explosion protection. In small scale experiments, the flame quenching effectiveness of the spheres decreased with an increase in initial pressure and flame run-up distance (ignition void length) and with a decrease in sphere size and packing density. Randomly packed beds of sphere types A (1 in. dia., 0.1 in. perforations) and B (1 in. dia., 0.05 in. perforations) were effective in preventing flame propagation at pressures up to 5 and 0 psig, respectively, whereas sphere type C (3/4 in. dia., 0.10 in. perforations) failed at 0 psig; with uniformaly packed beds, none of the spheres failed at 0 psig. All three types were noticeably less effective than 10 pore/in. reticulated polyurethane foam. Results from most of the large scale gun firing experiments with randomly packed spheres revealed that the spheres were not effective in preventing flame propagation at 0 psig in a 74 gal. modified fuel tank. Other data that were obtained in pressure drop experiments at various air velocities indicated that the flow resistance is slightly greater for sphere type C than for A or B. Empirical relationships are presented for predicting the pressure drop gradients across dry and wet beds of the spheres at air velocities from 5 to 25 ft./sec.

## -PERTINENT FIGURES-

FIG. 5 PRESSURE RISE VS PACKING DENSITY FROM FLAME ARRESTOR EXPERIMENTS WITH 1 IN. DIA. PERFORATED POLYETHYLENE SPHERES (TYPE A) AND APPROXIMATELY 2.5 PERCENT N-PENTANE-AIR MIXTURES AT 0 PSIG PAGE 9//FIG. 8 PRESSURE-TIME TRACES FROM FLAME ARRESTOR EXPERIMENTS IN FULLY-PACKED VESSELS WITH RANDOMLY-PACKED POLYETHYLENE SPHERES AND 10 PPI POLYURETHANE FOAM AT VARIOUS INITIAL PRESSURES (APPROXIMATELY 2.5 PERCENT N-PENTANE-AIR MIXTURES) PAGE 14//FIG. 13 REDUCTION IN BED LENGTH VS AIR VELOCITY FOR 24 IN. LONG BEDS OF RETICULATED POLYURETHANE FOAM IN 8 IN. DIA. STEEL PIPE PAGE 25//FIG. 15 PRESSURE DIFFERENTIAL PER UNIT LENGTH VS AIR VELOCITY FOR 24 IN. LONG PACKED BEDS OF 1 IN DIA. AND 3/4 IN. DIA. POLYETHYLENE SPHERES IN 8 IN. DIA. STEEL PIPE PAGE 29//TAB. 2 PRESSURE GAS TEMPERATURE AND LIGHT EMISSION DATA

PAGE 17//TAB. 4 PRESSURE DROP AS A FUNCTION OF AIR VELOCITY AND LONGITUDINAL POSITION PAGE 24

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key 621

# IMPACT ACTUATED MECHANISM FOR ENGAGING FIRE EXTINCTION SYSTEMS (RUSSIAN)

by

KOROLEV, A.I.
VINOGRADOV, A.S.

06/11/64

-ABSTRACT-

If an airplane makes a forced landing with the landing gear retracted, an outbreak of fire is possible as a result of the shock against the ground. An impact mechanism is therefore proposed which operates on ground impact and automatically engages an emergency fire extinguishment system. A design depicting the placement of the mechanism on an airplane is included. The mechanism functions not only on straight impact with the ground, but also in the case of sliding or landing with inclination to the side.

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key 647

# AIRCRAFT CRASH. EAST HAVEN, CONNECTICUT

by

WATROUS, L.D.

09/00/71

## -ABSTRACT-

On June 7, 1971, an Allegheny Airlines Convair 580 crashed short of the runway in East Haven, Connecticut, into a group of summer cottages on the beach. The alarm was first turned in by a nearby woman resident, then by the airport tower. Fire equipment responded from a municipal station located next to the airport. The crash was not in the same jurisdiction as the airport and permission to cross into the next town was requested and received. Investigators concluded that the loss of life was due to the fire and explosions rather than the impact. More rapid and effective fire extinguishment would have saved most of the 28 lives lost. If the fire had occurred two weeks later, the summer cottages would have been occupied and the loss of life would have been much greater. Two people escaped the crash: one, who had carefully studied the emergency card and had located the exits before the flight, exited by a window; the other followed him out. Both survivors reported that people were moving about in the cabin when they escaped.

## -PERTINENT FIGURES-

FIG. 2 FIRE CONDITIONS UPCN THE ARRIVAL OF NEARBY RESIDENTS WHO HEARD THE CRASH PAGE 10//FIG. 3 PLAN OF CRASH AREA PAGE 10

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# NON-NEWTONIAN FUELS FOR AIRCRAFT SAFETY

by

BEERBOWER, A.
NIXON, J.
WALLACE, T.J.

07/00/68

-ABSTRACT-

The fire hazard associated with aircraft accidents involving fuel spillage may be minimized by using thickened fuel, which exhibits its original vapor pressure but is rendered safer in three distinct ways: the rate of vaporization per unit area is reduced, the tendency to atomize on impact is much less, and the fuel breaks into discrete gobs preventing rapid flame spread. Emulsion-thickened fuels provide relative ease of removal from tanks, good atomization in engines, constant rheology over a wide temperatur range, and ability to be demulsified if required. Military requirements for such emulsions are that they contain at least 97 percent fuel and be stable in storage between -30 and 130 deg. F. The yield stress can be varied from 1000 to 3500 dynes/sq. cm. Plant-scale batches of such fuels were prepared but reproducibility from batch has not been satisfactory. Considerable research must still be carried out to improve reproducibility. Engine operation was close to normal when a steady supply of clean fuel reached the engine, and modifications required to insure this proved to be minor. Beyond bench-type testing, fire safety must still be demonstrated.

-PERTINENT FIGURES-

FIG. 3 EVAPORATION RATE OF FUEL EMULSION VS JP-4 PAGE 369//FIG. 6 SEPARATION OF JP-4 FROM EMULSIONS IN NOZZLES PAGE 371//FIG. 10 TRANSIENT RECORDING OF ENGINE START PAGE 372//TAB. 1 GOALS OF ARMY FUEL EMULSION CONTRACT PAGE 367//TAB. 2 EMULSION FORMULATIONS PAGE 368//TAB. 3 ENGINEERING PROPERTIES OF AIRCRAFT FUEL EMULSION PAGE 369

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key 669

# FIELD EVALUATION OF REVERSIBLE FIRE RESISTANT FLIGHT COVERALLS; LETTER REPORT CONCERNING

by

WURZEL, E.M.

08/22/66

-ABSTRACT-

A field evaluation was carried out to compare the acceptability of two types of summer flying coveralls. One group of coveralls was reversible, one side green and the other orange, and made from 4.5 oz./sq. yd. fire-resistant Nomex filament fabric, while the other group was non-reversible and made of natural white Nomex staple fiber fabric of the same weight and construction. Questionnaires concerning the comfort, utility, and design of these coveralls were filled out by the wearers. It is recommended that (1) cognizance be taken of the indication that reversibility is feasible, if desired, and (2) the 4.5 oz./sq. yd. herringbone fabric, which is currently in use, if it is determined that greater fire protection is needed.

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# FLAMMABILITY IN COCKPIT/CABIN ENVIRONMENTS

by

SMITH, F.S.

06/00/68

-ABSTRACT-

This study indicates that U.S. Air Force effort toward development and use of nonflammable/flame-resistant materials in cockpit/cabin environments was precipitated by two fatalities in 1956 attributed to failure of the parachute during exposure to heat and flame during in-flight fires. Flame-retardant materials development was given its first impetus in 1958 when duPont produced a high temperature resistant polyamide fiber called HT-1 or Nomex. This material has been successfully used for parachute packs, gloves, and as an outer shell for multilayer garments. In 1963, synthetic fibers and resins known as PBI (polybenzimidazole) were developed. This development provided marked advances in the ability to substitute reinforced plastics for metals and in the use of this fiber for flight clothing. It will withstand 1200 deg. F. before charring as compared to 800 deg. F. for Nomex. During the past few years, beta fiberglass, woven teflon cloth, modacrylic cloth, and asbestos-containing fabrics have become available. Fire-retardant urethane foam is also available for seat cushions. The slow progress in the use of flame-resistant materials in aircrew and passenger compartmnts is due to the complex nature of this effort. Although this study shows that the vast majority of in-flight fires involves engines and systems outside of the crew compartment, it is acknowledged that an in-flight fire caused by flammable materials in the cockpit/cabin environment cannot be tolerated due to the loss of life.

-PERTINENT FIGURES-

TAB. 1 US AIR FORCE IN-FLIGHT FIRES (1965-1967) PAGE 3//TAB. 2 US AIR FORCE COCKPIT/CABIN IN-FLIGHT FIRES (1962-1967) PAGE 4

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REPORT NUMBER -
STUDY-NO.-25-68
OTHER INFORMATION -
0054 PAGES, 0000 FIGURES, 0002 TABLES, 0030 REFERENCES

# CRASH SURVIVAL DESIGN GUIDE

by

TURNBOW, J.W.
CARROLL, D.F.
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REED, W.H.
ROBERTSON, S.W.ET AL.

12/00/67

-ABSTRACT-

A design guide was assembled to provide the engineer with an understanding of the basic problems associated with the development of crashworthy U.S. Army aircraft. Where possible, solutions to specific problems are indicated. In other areas, in which little design data are available, only the general philosophy appropriate to the problem solution is presented the details of such solutions, as well as the degree of crashworthiness to be achieved, must be left, at present, to the ingenuity of the designer. This guide presents in a condensed form the data, design techniques, and criteria which are presently available in the following areas: (1) aircraft crash kinematic and survival envelopes; (2) airframe crashworthiness design criteria; (3) aircraft seat design criteria (crew and troop passenger); (4) restraint system design criteria (crew, troop/passenger, and cargo); (5) occupant environment design criteria; (6) aircraft ancillary equipment stowage design criteria; (7) emergency escape provisions; and (8) postcrash fire design criteria.

-PERTINENT FIGURES-

FIG. 8-1 TANK GEOMETRY PAGE 192//FIG. 8-4 RESISTANCE OF MATERIALS TO PENETRATION PAGE 199//FIG. 8-13 FRANGIBLE FILLER NECK INSTALLATION PAGE 207//FIG. 8-20 ELECTRICAL COMPONENT DEENERGIZING METHOD PAGE 217//FIG. 8-22 JP-4 IGNITION DELAY VERSUS SURFACE TEMPERATURE PAGE 222//FIG. 8-23 HOT-SURFACE INERTING SYSTEM SCHEMATIC PAGE 223

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0259 PAGES, 0108 FIGURES, 0012 TABLES, 0079 REFERENCES

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# INVESTIGATION OF MECHANISMS OF POTENTIAL AIRCRAFT FUEL TANK VENT FIRES AND EXPLOSIONS CAUSED BY ATMOSPHERIC ELECTRICITY

by

GERSTEIN, M.

01/00/64

-ABSTRACT-

The important mechanisms involved in the ignition of fuel vapors issuing from a fuel tank vent under conditions of atmospheric electrical activity were determined. The study included a literature review and experimental and analytical investigation of: (1) the mixing of the fuel vent effluent with ambient air for three vent configurations at simulated flight conditions; (2) the electrical environment in the vicinity of an aircraft during lightning activity, including measurements of the far field pressures associated with a high energy discharge; (3) a study of ignition and flame propagation through channels smaller than the normal quenching distance using high energy spark sources; and (4) a study of simulated lightning discharges as to their capability of producing flames capable of propagating through a typical fuel vent with and without a flame arrester. Profiles of constant observed fuel-air ratio were mapped using simulated vents installed in a wind tunnel. Characteristics of the electrical environment about an aircraft and the vent exit were derived from literature sources as well as actual probings. Pressure measurements associated with a high energy discharge were measured with a pressure transducer and a Schleiren optical system. Flame propagation through normally quenching channels was studied by installing electrodes in a channel and supplying discharge energies of varying magnitudes. Results from these programs were correlated by installing a vent model in a simple wind tunnel and striking the model with simulated lightning discharges.

-PERTINENT FIGURES-

FIG. 3 VARIATION OF FUEL-AIR RATIO IN A TEST TANK DURING SIMULATED FLIGHT. 5 GAL. OF HEXANE IN A 50 GAL. TANK PAGE 76//FIG. 51 PASCHEN DIAGRAM FOR 5 PERCENT PROPANE-AIR MIXTURE MEASURED WITH 8.8 MM. GAP PAGE 145//FIG. 21 NATURAL LIGHTNING DISCHARGE TO JET TRANSPORT WINGTIP PRODUCES LARGER HOLE THAN 300 COULOMB DISCHARGE IN LABORATORY PAGE 112//FIG. 22 DIAGRAM OF MULTIPLE GENERATORS WHICH PRODUCE TYPICAL EFFECTS OF NATURAL LIGHTNING STROKES, INDIVIDUALLY OR AS A COMPOSITE SINGLE DISCHARGE PAGE 113//FIG. 37 BLAST WAVES FROM OPEN AIR ARC PAGE 129

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0183 PAGES, 0071 FIGURES, 0004 TABLES, 0017 REFERENCES

# INVESTIGATION OF MECHANISMS OF POTENTIAL AIRCRAFT FUEL TANK VENT FIRES AND EXPLOSIONS CAUSED BY ATMOSPHERIC ELECTRICITY. PROGRESS REPORT NO. 3.

by

GERSTEIN, M.

06/05/62

-ABSTRACT-

An investigation of mechanisms of potential aircraft fuel tank vent fire and explosions caused by atmospheric electricity involved research into the combustible environment, ignition and flame propagation, and the electrical environment. It was found that empirical correlation in the combustible medium investigations can be obtained for the mixing effects at discrete locations, but that it is difficult to find a relationship which includes the coordinate variations. Experimentally, the presence of appreciable turbulence in the approach flow and the large volume of boundary layer thickness studied indicated the need for experiements in a low turbulence tunnel and with thin boundary layers. The effects produced when a spark containing considerably more than the minimum ignition energy is introduced into a fuel-air mixture were investigated. Visual and photographic observations showed that the original energy zone spreads over a distance which depends on experimental variables and can fill the complete cross section of the tube. It was also found that, under some conditions, a blue combustion zone starts and propagates away from the end of the energy zone. Preliminary experimental results on the influence of excess energy on quenching parameters are presented.

-PERTINENT FIGURES-

FIG. 5 FUEL VAPOR CONCENTRATIONS AT THREE SPATIAL POINTS PAGE 12//FIG. 7 QUENCHING DISTANCE AS A FUNCTION OF PRESSURE PAGE 20//FIG. 14 GRADIENTS OF DIFFERENT STAGES OF LIGHTNING DISCHARGE THROUGH AIRCRAFT PAGE 35//FIG. 15 ELECTRIC FIELD PLOTS ABOUT SEVERAL VENT TYPES PAGE 36//FIG. 20 EQUIVALENT CIRCUIT FOR LOCALIZED DISCHARGE PAGE 67//FIG. 19 FUEL VENT CONFIGURATIONS PAGE 56

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0082 PAGES, 0024 FIGURES, 0003 TABLES, 0031 REFERENCES

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# DEVELOPMENT OF A FUEL CELL INERTING SYSTEM FOR INFLIGHT PROTECTION OF SUPERSONIC AIRCRAFT

by

ROPER, R.M.

09/20/65

-ABSTRACT-

A summary discussion is presented of the technical development, testing, and early flight test use of an airborne system to keep fuel cell vapor spaces inert. An outline of the study and decisions to arrive at a concept based on using an inert gas in the cells is given. Testing to finalize design and prove airworthiness is summarized. Experience with the system during the initial flights of the XB-70, a Mach 3 aircraft, is presented. In conclusion, it was stated that an airborne fuel inerting system based on safe limits below those demonstrated to present autoignition hazards has been developed and system hardware manufactured. Airworthiness tests have been successfully completed and a complete set of components has functioned satisfactorily as a system, on a full-scale fuel system simulator. Inerting may raise the fuel thermal stability temperature limits for supersonic aircraft.

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FIG. 1 COMBUSTION PRESSURE RISE JP-6 FUEL ABOVE 430 DEG. F. PAGE 4//FIG. 2 INERTING AND PRESSURIZATION SYSTEM PAGE 6//FIG. 3 FUEL SYSTEM SERVICING PAGE 7//FIG. 4 INERTING SYSTEM PERFORMANCE IN FLIGHT PAGE 8

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# IGNITION OF FUEL VAPORS BENEATH TITANIUM AIRCRAFT SKINS EXPOSED TO LIGHTNING FINAL REPORT

by

KCSVIC, T.C.
HELGESON, N.L.
GERSTEIN, M.

09/00/71

-ABSTRACT-

Hot-spot and puncture ignition of fuel vapors by simulated lightning discharges was studied experimentally. The influences of skin coating, skin structure, discharge polarity, skin thickness, discharge current level, and current duration were measured and interpreted. Ignition thresholds are reported for titanium alloy constructed as sheets, sheets coated with sealants, and sandwich skins. An analytical model was developed to provide insight into the mechanism controlling ignition of fuel tank ullage vapors. In addition, a moving electrode experiment was conducted to obtain a measure of typical arc dwell times. Results indicated that the ignition threshold charge transfer for coated sheets, honeycomb, and truss skins is respectively about 200 percent, 100 percent, 800 percent that of bare alloy sheet of 0.102 cm. (0.040 in.) thickness. It was found that hot-spot ignition can occur well after termination of the arc, and that sandwich materials allow ignition only if punctured.

-PERTINENT FIGURES-

TAB. 7 IGNITION TESTS WITH HONEYCOMB SANDWICH PAGE 50//TAB. 8 IGNITION TESTS WITH LIGHT-TRUSS SANDWICH PAGE 51//FIG. 10 IGNITION TESTS WITH BARE ALLOY (.102 CM. (.040 IN.)), NEGATIVE CHARGE PAGE 65//FIG. 11 IGNITION TESTS WITH BARE ALLOY SHEET (.127 CM. (.050 IN.)), POSITIVE CHARGE PAGE 66//FIG. 34 CONCEPTUAL EFFECT OF CURRENT LEVEL ON REGRESSION RATE, PRECURSOR LEAD TIME, HOT-SPOT IGNITION, AND PUNCTURE PAGE 89//FIG. 35 SWEPT-STROKE SIMULATOR PAGE 90

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0108 PAGES, 0045 FIGURES, 0011 TABLES, 0031 REFERENCES

key 797

# AIRCRAFT WELDING OPERATIONS IN HANGARS 1970, RECOMMENDED SAFE PRACTICES FOR

by

NATIONAL FIRE PROTECTION ASSOCIATION

00/00/70

-ABSTRACT-

Specific safety recommendations are presented for welding in aircraft hangars. Only gas shielded-arc welding should be performed on aircraft. Aircraft welding operations should be performed outdoors whenever possible; if done indoors, a written special permit should be obtained for each welding operation with a safety checklist attached to the permit. The work area should be screened and the aircraft should be in a towable condition. Only qualified welders should be permitted to do any work. Other people in the area should be notified and no other work permitted within 20 ft. No flammable liquids or any container that was used to store flammable liquids should be in the vicinity. No electrical components other than flexible lea cables should be within 18 in. of the floor. The hangar should have fixed fire protection equipment and there should be a fire watcher behind the welder with a fire extinguisher.

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by

FIRE RESEARCH STATION

00/00/67

-ABSTRACT-

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9999 PAGES, 9999 FIGURES, 9999 TABLES, 9999 REFERENCES

key 807

# AIRCRAFT FIRE STATISTICS

by

FRY, J.F.

00/00/67

## -ABSTRACT-

The source of aircraft fire statistics reported includes statistics from fires attended by local authority fire brigades, Ministry of Aviation record of civil aircraft accidents, reports from airfield fire and rescue teams, and a report of the Working Party on aviation kerosene and wide-cut gasoline The conclusions which were drawn from the statistics are: (1) Aircraft fire statistics do not, at present, show that the situation in the United Kingdom gives cause for great concern. (2) Accidents in circuit are more frequent than those en route, but are less likely to result in fatalities. (3) Fatalities tend to occur most frequently in accidents in which there is fire but most of the deaths result from impact injuries. (4) There is some indication of a tendency for the fatal casualty rate and the fire incidence to increase with the size of aircraft involved in accidents. (5) Fire occur more frequently in accidents off the airfield than in those on it. (6) A high proportion of fire incidents on airfields are small and, given adequate facilities for dealing with them, present little hazard. (7) Greatly improved fire fighting facilities would not, in present circumstances, be likely to result in a large reduction in the loss of life in aircraft accidents.

## -PERTINENT FIGURES-

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# SOME ASPECTS OF AIRCRAFT FUEL SAFETY

by

MILLER, R.E.

00/00/67

## -ABSTRACT-

During major crashes, an aircraft is subject to fracture of fuel tanks and hydraulic systems which may cause release of flammable liquids. Explosive vapor-air mixtures may be formed and flammable mists produced. Since ignition sources will, in general, be present, the necessary conditions for fire and explosion are present. The extent of each of these hazards will depend on the nature of the flammable atmosphere present and, hence, in principle, can be controlled by altering the fuel properties. Three main aspects of the problem are considered. Studies of the way in which the spontaneous ignition characteristics of fuels can be modified by additives, or by changing the chemical composition, are relevant to crash fires and explosions as well as to those occurring in flight. Published work on reducing the hazards of spontaneous ignition is discussed. Spark ignition hazards and the way in which these depend upon fuel properties are also discussed briefly, along with rate of flame spread. Current developments in lowering fuel mobility by the use of gelling of fuels are reviewed.

## -PERTINENT FIGURES-

FIG. 7.1 TRACES SHOWING VARIATION OF IGNITION WITH THETA VALUE N-NONANE AT 300 DEG. C. AND 1 ATM. PAGE 55//FIG. 7.4 SPONTANEOUS IGNITION TEMPERATURES OF SOME TYPICAL HYDROCARBONS PAGE 57//FIG. 7.5 FLAMMABLE REGIONS FOR FUEL- AIR MIXTURES PAGE 61//TAB. 7.1 MINIMUM SPONTANEOUS IGNITION TEMPERATURE FOR SOME TYPICAL HYDROCARBONS PAGE 56//TAB. 7.2 SPONTANEOUS IGNITION PERFORMANCE OF CURRENT AVIATION FUELS AT 250 DEG. C. AND 3:1 AIR-FUEL RATIO IN A 12 IN. SPHERICAL VESSEL PAGE 58//TAB. 7.3 LIMITS OF IGNITION OF SPECIAL FUELS AT 250 DEG. C. AND 3:1 AIR-FUEL RATIO IN A 12 IN. SPHERICAL VESSEL PAGE 58

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0012 PAGES, 0005 FIGURES, 0003 TABLES, 0042 REFERENCES

# DESIGN ASPECTS RELATING TO AIRCRAFT FIRES

by

LYDIARD, W.G.
MACDONALD, J.A.

00/00/67

## -ABSTRACT-

Statistics are reviewed on the frequency and causes of aircraft fires. Data are presented in some detail on the process of ignition by heated surfaces. Fire precautions, adopted in aircraft, are discussed and include segregation of combustibles from ignition sources, fire detection, and control and extinction of fire by aircraft equipment. Measures which could reduce damage and casualties due to crash fire are considered to be those which reduce the likelihood of appreciable fuel and oil leakage, reduce the number of ignition sources, make the aircraft fluids less ignitable and slower burning to reduce the intensity of fire, isolate the passengers from the effects of fire, and improve the rescue techniques. It is concluded that the greatest benefit in crash fires would come from improved containment of the fuel or from the use of a variety of fuel or a treated fuel which had a low rate of flame spread and heat release under crash conditions.

## -PERTINENT FIGURES-

FIG. 8.1 STATISTICS ON ACCIDENTS INVOLVING FIRE IN U.K. CIVIL AIRCRAFT PAGE 68//FIG. 8.3 SPARK AND SPONTANEOUS IGNITION LIMITS FOR AVTUR PAGE 71//FIG. 8.4 THE EFFECT OF SIZE ON THE MINIMUM SPONTANEOUS IGNITION TEMPERATURE OF AVTUR VAPOUR IN UNIFORMLY HEATED VESSELS PAGE 71//FIG. 8.11 THE RATE OF FLAME PROPAGATION FOR A NUMBER OF FLUIDS PAGE 79//TAB. 8.2 MAJOR BRITISH MILITARY JET AIRCRAFT FIRES (OTHER THAN CRASH FIRES) PAGE 70//TAB. 8.4 IGNITION CHARACTERISTICS OF AIRCRAFT FLUIDS PAGE 72

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# INVESTIGATION OF SUPERSCNIC AIRCRAFT FUEL TANK FIRE AND EXPLOSION HAZARDS. FINAL REPORT.

by

FISHER, D.H.
WEISS, H.G.

09/00/66

-ABSTRACT-

Experiments aimed at defining the cool and normal flame minimum autogenous ignition properties, as well as factors governing the transition from cool flame to normal flame, were conducted for various homogeneous fuel-oxygen- nitrogen mixtures under static test conditions and as a function of pressure and heating rate. The JP-4, JP-6, and FS 65-3 low volatility hydrocarbon fuel were selected as representatives of jet fuels. Data obtained included pressure and temperature rise histories over the pressure-temperature domain. The effects of fuel thermal degradation and slow oxidaticn on cool flame and thermal ignition properties were investigated. The effect of more practical flight environment situaticns on the hazards was assessed in other experiments. This entailed the investigation of the cool and normal flame autogenous ignition properties, as well as the possibility of transition from cool flame to normal flame under simulated normal and emergency dynamic flight environment conditions. The problem of preventing or minimizing flames in aircraft and the effects of trimethylamine and other possible flame inhibitors on ignition were also investigated. The nitrogen requirements necessary to prevent ignition, under the conditions found to cause ignition under flight environment conditions, were determined.

-PERTINENT FIGURES-

FIG. 4 FLAME BOUNDARIES FCR 15.7 PERCENT N-DECANE IN AIR PAGE 18//FIG. 9 NORMALIZED PRESSURE INCREASE FOR VARIOUS N-DECANE MIXTURES AS A FUNCTION OF OPERATING PRESSURES PAGE 24//FIG. 12 FLAME BOUNDARIES FOR 10 PERCENT JP-4 IN AIR PAGE 29//FIG. 22 FLAME BOUNDARY FOR 8 PERCENT LOW VCLATILITY HYDROCARBON FUEL IN AIR AS A FUNCTION OF OPERATING PRESSURE PAGE 41//TAB. 16 EFFECT OF DIMETHYLAMINE ON THE IGNITION CHARACTERISTICS OF 4 PERCENT LOW VOLATILITY HYDROCARBON-AIR MIXTURES PAGE 124//TAB. 18 EFFECT OF IRON PENTACARBONYL ON THE IGNITION CHARACTERISTICS OF 4 PERCENT FUEL-AIR MIXTURES PAGE 128

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0142 PAGES, 0051 FIGURES, 0024 TABLES, 0004 REFERENCES

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# BIBLIOGRAPHY ON AIRCRAFT FIRE HAZARDS AND SAFETY

Volume I - HAZARDS, Part 2 - Key Numbers 818 to 2146
(Includes Author Index and Descriptor Index)

Compiled by
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Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

134-A

# FOREWORD

The mission and objectives of the Aerospace Safety Research and Data Institute are (a) to support NASA, its contractors, and the aerospace industry with technical information and consultation on safety problems; (b) to identify areas where safety problems and technology voids exist and to initiate research programs, both in-house and on contract, in these problem areas; (c) to author and compile state-of-the-art and summary publications in our areas of concern; (d) to establish and operate a safety data bank. As a corollary to its support to the aerospace community, ASRDI is also to establish and maintain a file of specialized information sources (organizations) and recognized, acknowledged experts (individuals) in the specific areas or fields of ASRDI's interest.

To match our resources with our priorties, ASRDI is concentrating on selected areas - fire and explosion; cryogenic systems; propellants and other hazardous materials, with special emphasis on oxygen and hydrogen; aeronautical systems and spacecraft operations; lightning hazards; and the mechanics of structural failure. Staff expertise is backed by a safety library and is further supported by a computerized bank of citations and abstracts built from literature on oxygen, hydrogen, and fire and explosion. Computer files on mechanics of structural failure, fragmentation hazards, and safety information sources are also being established. In addition, ASRDI has two NASA RECON terminals and people adept at querying the system for safety-related information.

Frank E. Belles, Director
Aerospace Safety Research and Data Institute
National Aeronautics and Space Admiqistration

134-B

# INTRODUCTION

A part of the Aerospace Safety Research and Data Institute's (ASRDI) mission is to compile and store in a computerized system bibliographic citations on hazards and safety in various areas related to aerospace activities. One of these areas is fire and explosion. The program in this area has been underway for about three years and is continuing. At the present time the computerized data bank contains about 2000 bibliographic citations on the subject.

Each citation in the data bank contains many items of information about the document. Some of the main items are title, author, abstract, corporate source, description of figures pertinant to hazards or safety, key references, and descriptors (keywords or subject terms) by which the document can be retrieved. In addition each document is assigned to two main categories that are further divided into subcategories. The two main categories are fire hazards and fire safety. Each document is also further categorized according to its area of applicability such as - aircraft and spacecraft and their associated facilities; aerospace research and development test facilities; buildings; and general applicability.

This report is a compilation of all the document citations in the ASRDI data bank as of April 1974 on fire hazards and fire safety that pertain to aircraft. The report is somewhat preliminary in nature in that input to the data bank is continuing; moreover not all the information contained in the bank has been edited for errors. The report is being published as an illustrative example of the contents of the data dank and to obtain user feedback on the usefulness of such compilations and whether the subject scope should be narrowed in future compilations.

The report is divided into two volumes. Volume I, Hazards, presents bibliographic citations that describe and define the aircraft fire hazards and covers a wide range of subjects such as - combustion characteristics of materials; accidents and incidents reports; causes of fire; methods and techniques of evaluating the fire hazard; and the resulting effects of fire on man and property. Volume II, Safety, presents bibliographic citations that describe and define aircraft fire safety methods, equipment, and criteria. It covers such subjects as prevention, detection, and extinguishment of fire, and codes and standards. Each volume of the report contains, in addition to the citations, an author index and an index of major descriptors (keywords or subject terms). The indices are related to the citations by the ASRDI key number, which appears in the upper right hand corner of the first page of each citation. To facilitate binding, both volumes are broken into parts.

Volume I has two parts -

Part 1 - Key Numbers 1 to 817
Part 2 - Key Numbers 818 to 2146,
Author Index and Descriptor Index

Volume II has three parts -

Part 1 - Key Numbers 1 to 524
Part 2 - Key Numbers 525 to 1064
Part 3 - Key Numbers 1065 to 2165,
Author Index and Descriptor Index

The preparation of this report for printing was essentially accomplished automatically. The search strategy (in this case, subject category) and information on citation content and format was fed into the computer. The output from the computer was placed directly on multilith paper by a high-speed printer.

VOLUME I

PART 2

134-E

# ELASTOMERIC COATINGS AID FLAME RETARDANCE

by

HOLMES, R.L.

05/00/71

## -ABSTRACT-

Development efforts are reviewed in the compounding and testing of nonflammable materials which have resulted in the discovery of a number of valuable materials that are of especial value for products used in oxygen enriched environments. Preliminary data indicate that substrates such as wood, paper, textiles, metals, organic resins, and elastcmers may be made nonflammable under atmospheric conditions by coating these substrates. Thes coatings (REFSET) have been proposed for the fireproofing of military and commercial aircraft. Coated aluminum or epoxy glass laminates, for example, are capable of passing the FAA requirement of no flame penetration when exposed to a 2000 deg. F. flame for 15 min. A modified test method for flammability rating, the Candle Test, is described. The test procedure involves the mounting of the sample in the test fixture, introducing the gas mixture of oxygen and nitrogen under known velocities, igniting the sample with a known heat source, removing the ignition source, and determining whether the test material is nonignitable, self-extinguishing, or burns completely. Some of the variables encountered in this test method include precent oxygen, velocity of gases, ignition temperatures, sample shape and thickness, and the composition of the material being used.

## -PERTINENT FIGURES-

TAB. 1 EFFECT OF GAS MIXTURE VELOCITY ON CANDLE TESTER BURN RATE PAGE 67// TAB. 2 EFFECT OF MATERIAL SELECTION ON FLAMMABILITY RATING PAGE 68//TAB. 3 EFFECT OF SAMPLE GAUGE ON FLAMMABILITY RATING, COMPOUND L-3203-6 PAGE 68

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# THE CLEVELAND AIRCRAFT FIRE TESTS, JUNE 30 AND JULY 1, 1966

by

HEINE, D.A.
BRENNEMAN, J.J.

00/00/66

-ABSTRACT-

Tests were conducted to determine if survival time in an aircraft cabin could be extended under post-crash fire conditions by using high expansion foam to completely fill the occupied portions of the cabin interior. It was believed that the high expansion foam would hold the temperature within survivable limits while controlling smoke, toxic gases, and other products of combustion, thus providing a cool breathable atmosphere for a prolonged period of time for the occupants, pending ultimate evacuation or rescue. A secondary objective was to determine the composition of the smoke, gases, and other products of combustion or pyrolysis that may be present in a post- crash fire in which typical modern aircraft cabin materials such as vinyl, polypropylene, polyvinyl chloride, etc. are involved in the fire. As a result of the testing of the effects of the products of combustion or pyrolysis on the expansion ratio of the high expansion foam, it was concluded that foam breakdown was the primary reason for its failure to control flame spread, temperature rise and smoke production in the aircraft fire test. Existing (1966) foam generators depend on ambient cabin air which is heavily charged with smoke and other products of combustion which can prove lethal even before cabin temperatures become elevated beyond survivable limits. Successful use of high expansion foam to extend survival time is dependent upon the development of new airborne and ground foam generators.

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CORPORATE SOURCE -
NORTH CENTRAL AIRLINES, MINNEAPOLIS, MINN.//UNITED AIR LINES, INC., CHICAGO, ILL.
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keys 832 through 833

# THE CLEVELAND AIRCRAFT FIRE TESTS

by

BRENNEMAN, J.J.
HEINE, D.A.

02/00/68

-ABSTRACT-

Tests were conducted to determine if survival time in an aircraft cabin could be extended under post-crash fire conditions by using high expansion foam to completely fill the occupied portions of the cabin interior. It was believed that the high expansion foam would hold the temperature within survivable limits while controlling smoke, toxic gases, and other products of combustion, thus providing a cool, breathable atmosphere for a prolonged period of time for the occupants, pending ultimate evacuation or rescue. A secondary objective was to determine the composition of the smoke, gases, and other products of combustion or pyrolysis that may be present in a post-crash fire in which typical modern aircraft cabin materials such as vinyl, polypropylene, polyvinyl chloride, and other plastics are involved in the fire. As a result of the testing of the effects of the products of combustion or pyrolysis on the expansion ratio of the high expansion foam, it was concluded that foam breakdown was the primary reason for its failure to control flame spread, temperature rise, and smoke production in the aircraft fire test. Existing foam generators depend on ambient cabin air which is heavily charged with smoke and other products of combustion which can prove lethal even before cabin temperatures become elevated beyond survivable limits. Successful use of high expansion foam to extend survival time will depend upon the development of more effective airborne and ground foam generators.

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CORPORATE SOURCE -
UNITED AIR LINES, INC., CHICAGO, ILL.//NORTH CENTRAL AIRLINES, MINNEAPOLIS, MINN.
JOURNAL PROCEEDINGS -
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0012 PAGES, 0011 FIGURES, 0001 TABLES, 0000 REFERENCES

key 836

# THE EFFECTS OF CABIN ATMOSPHERE ON COMBUSTION OF SOME FLAMMABLE AIRCRAFT MATERIALS

by

KLEIN, H.A.

04/00/60

-ABSTRACT-

The effects of varying atmospheric conditions on the combustion of certain flammable materials creating fire hazards in aircraft were measured in a test chamber. Atmospheric compositions used were pure oxygen and oxygen-nitrogen and oxygen-helium mixtures in various proportions. Pressures varied from sea level to 25,000 ft. altitude. Flammable materials tested included cotton cloth, 8 samples of aircraft wire, and aircraft fluids including JP-4 fuel, hydraulic fluids, and lubricating oils. Test data indicated the burning rate or ignition temperatures for each type of material under specific atmospheric conditions and proved that no advantage would be derived by using helium. Plots of the data illustrated the trends shown by the test results. Since the composition and pressure of the test atmospheres were maintained within habitable limits, flammability limits of the materials tested were not generally determined. From the trends, it was concluded that using the minimum oxygen content with maximum inert gas content would provide an optimum atmosphere for a space vehicle insofar as reducing fire hazards is concerned.

-PERTINENT FIGURES-

FIG. 5 EFFECTS OF ATMOSPHERE CONPOSITION AND PRESSURE ON BURNING OF COTTON FABRIC PAGE 10//TAE. 6 COMPARATIVE IGNITION TEMPERATURES OF AIRCRAFT FLUIDS PAGE 13

-SOURCE INFORMATION-

CORPORATE SOURCE -
WRIGHT AIR DEVELOPMENT COMMAND, WRIGHT-PATTERSON AFB, OHIO.
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0033 PAGES, 0016 FIGURES, 0006 TABLES, 0000 REFERENCES

# INHALATION TOXICITY OF PYROLYSIS PRODUCTS OF MONOBROMOMONOCHLOROMETHANE AND MONOBROMOTRIFLUOROMETHANE

by

HAUN, C.C.
VERNOT, E.H.
MACEWEN, J.D.
GEIGER, D.L.
MCNERNEY, J.M. ET AL.

03/00/67

-ABSTRACT-

The toxicities of the pyrolysis products of two fire extinguishant compounds, bromochloromethane and bromotrifluoromethane, were investigated using albino rats; 14 day LC50 values were determined for single 15 min. exposures. Both fire extinguisher compounds, currently used by the U.S. Air Force for aircraft fires, were pyrolyzed at 800 deg. C. in a hydrogen-oxygen flame. The pyrolysis products of each compound were examined and the principal consituents were identified and quantitated. The determined LC50 value of 2300 ppm for pyrolyzed bromotrifluoromethane produced a hydrogen fluoride concentration of 2480 ppm consistent with the reported LC50 value for a single 15 min. exposure to this gas. Bromochloromethane pyrolysis products were found to have a LC50 of 465 ppm under the experimental parameters tested. The toxic response producing this LC50 value appeared to result from a mixture of hydrogen chloride, hydrogen bromide, and bromine gases.

-PERTINENT FIGURES-

FIG. 2 SCHEMATIC OF BROMOTRIFLUOROMETHANE PYROLYSIS SYSTEM PAGE 4//FIG. 4 MORTALITY VS CONCENTRATION OF PYROLYSIS PRODUCTS PAGE 17//FIG. 5 THERMAL DECOMPOSITION CURVES PAGE 21//TAB. 4 CONCENTRATION OF PYROLYSIS PRODUCTS PRODUCED BY IGNITION OF BROMOCHLOROMETHANE PAGE 11//TAB. 6 RESULTS OF EXPOSURE TO THE PYROLYSIS PRODUCTS OF BROMOTRIFLUOROMETHANE MILITARY SPECIFICATION MIL-B-4394-B PAGE 14//TAB. 9 MEAN WEIGHTS OF RATS SURVIVING EXPOSURE TO THE PYROLYSIS PRODUCTS OF BROMOTRIFLUOROMETHANE PAGE 19

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0030 PAGES, 0005 FIGURES, 0009 TABLES, 0016 REFERENCES

# REVIEW OF FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLE COMBUSTIBLES (SUPPLEMENT 1)

by

SCOTT, G.S.
PERLEE, H.E.
MARTINDILL, G.H.
ZABETAKIS, M.G.

04/00/62

## -ABSTRACT-

Ignition energy and flammability limit requirements were determined for methyl alcohol, acetone, methylene chloride, and trichloroethylene under a variety of conditions in air, oxygen, nitrogen tetroxide, and contaminated air atmospheres. In addition, work was carried out on: (1) the effect of blending of fuels on the spontaneous ignition temperature; (2) the effect of temperature on the flammability limits and minimum oxygen requirements for flame propagation of selected combustibles; (3) the behavior of layered vapor and liquid-vapor mixtures in various oxidizing atmospheres; and (4) the behavior of flame arrestors in static and in laminar and turbulent flowing mixtures. The electric spark ignition experiments indicated that, when autoignition does not occur, the energy requirements for ignition were greater in nitrogen tetroxide atmospheres than in air or oxygen. Further, the quenching distance was larger in the flammable vapor-nitrogen tetroxide mixture than in the corresponding mixture in air. An increase in ambient temperature tended to widen the flammable range of a combustible in air, oxygen, and nitrogen tetroxide atmospheres.

## -PERTINENT FIGURES-

FIG. 1 MINIMUM IGNITION ENERGIES OF CERTAIN GASES AND VAPORS IN VARIOUS ATMOSPHERES PAGE 15//FIG. 3 FLAMMABILITY OF ACETONE-WATER-AIR MIXTURES AT 212 DEG. F. 392 DEG. F., AND 617 DEG. F. PAGE 17//FIG. 7 FLAMMABILITY OF TRICHLOROETHYLENE-WATER-AIR MIXTURES AT 212 DEG. F.AAND 392 DEG. F. AND ATMOSPHERIC PRESSURE (F-11 APPARATUS, 4 IN. ID TUBE) PAGE 21//FIG. 9 CONCENTRATION PROFILE OF PENTANE DIFFUSING INTO AIR FOLLOWING EXPOSURE OF A HOMOGENEOUS PENTANE-AIR MIXTURE OF INITIAL CONCENTRATION PAGE 23//FIG. 14 LIQUID REGRESSION RATES OF A BURNING POOL OF ACETONE IN ATMOSPHERES OF AIR AND 60 PERCENT NITROGEN OXIDE-40 PERCENT AIR PAGE 28//FIG. 22 APPARATUS FOR EVALUATING FLAME ARRESTERS AND FLASH BACK IN HIGH VELOCITY STREAMS PAGE 43

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0050 PAGES, 0022 FIGURES, 0003 TABLES, 0011 REFERENCES

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# IGNITION OF AIRCRAFT FLUIDS BY HOT SURFACES UNDER DYNAMIC CONDITIONS

by

STRASSER, A.
WATERS, N.C.
KUCHTA, J.M.

11/00/71

-ABSTRACT-

Data are presented on the ignition characteristics of various aircraft fluids under conditions in which they impinge upon a high surface in the presence of air flow similar to that possible in an aircraft enclosure. The fluids included two jet fuels (JP-4 and JP-8), two hydraulic fluids (MIL-H-5606 and MIL-H-83282), and an engine oil (MIL-L-7808). Ignition temperatures were determined with heated cylindrical steel targets which varied from 1 to 4 in. dia. and from 12 to 24 in. in length; a flat target which measured 3-5/8 in. by 12 in. was also used. Generally, the ignition temperatures decreased with an increase in target diameter or surface area and increased with increasing air velocity. The results were lower with the use of preheated air (350 deg. F.), particularly for the fluids of low volatility. At all test conditions, the ignition temperatures of the fluids were noticeably higher than their minimum autoignition temperatures which are determined in uniformly heated vessels. The variation of ignition temperature with target surface area was more sensitive to changes of diameter than length.

-PERTINENT FIGURES-

FIG. 5 IGNITION TEMPERATURE VS AIR VELOCITY FOR JP-4 JET FUEL WITH VARIOUS HEATED CYLINDRICAL STEEL TARGETS PAGE 13//FIG. 6 IGNITION TEMPERATURE VS AIR VELOCITY FOR JP-8 JET FUEL WITH VARIOUS HEATED CYLINDRICAL STEEL TARGETS PAGE 14//FIG. 7 IGNITION TEMPERATURE VS AIR VELOCITY FOR MIL-L-7808 ENGINE OIL WITH VARIOUS HEATED CYLINDRICAL STEEL TARGETS PAGE 15//FIG. 8 IGNITION TEMPERATURE VS AIR VELOCITY FOR MIL-H-5606 HYDRAULIC FLUID WITH VARIOUS HEATED CYLINDRICAL STEEL TARGETS PAGE 16//FIG. 13 VARIATION OF IGNITION TEMPERATURE WITH FUEL CONTACT TIME FOR JP-4 JET FUEL UNDER STATIC AND FLOW CONDITIONS PAGE 24//TAB. 2 IGNITION TEMPERATURES OF AIRCRAFT FLUIDS UNDER VARIOUS FLOW CONDITIONS WITH 12 IN. LONG HEATED STAINLESS STEEL TARGETS IN AN 8 IN. DIA. FLOW TUBE PAGES 10-11

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0035 PAGES, 0016 FIGURES, 0003 TABLES, 0008 REFERENCES

# FIRE HAZARDS ASSOCIATED WITH THE USE OF TITANIUM IN AIRCRAFT

by

MAYKUTH, D.J.
ERNST, R.H.

06/00/64

## -ABSTRACT-

The conditions under which the ignition and combustion of titanium aircraft components were most likely to occur are reviewed. Laboratory tests show that sheets of commercially pure titanium and several of its alloys can be ignited in air by using an oxyacetylene torch to heat these materials to their melting temperatures (about 3000 deg. F.). The sensitivity of titanium toward ignition and combustion in oxygen atmospheres increased with increasing oxygen pressure and concentration, such that with sufficiently high pressures and concentrations, burning can occur at appreciably lower temperatures. It was shown that a thermic reaction can be initiated and propagated on an unheated 0.025 in. thick sheet of the Ti-6Al-4V alloy by subjecting this material to molten droplets of mild steel in the presence of a high velocity air jet. The sliding friction of titanium on bare or foamed runways can be expected to cause significant friction sparking of titanium. The resulting sparks can ignite fuel mists. Reports were received of 8 aircraft gas turbine fires involving titanium components in U.S. produced engines and in 5 engines produced in Canada or England. While details on many of these experiences are lacking, the available information suggests most of these fires were caused either by the rubbing friction of titanium parts or by the service failure of their components.

## -PERTINENT FIGURES-

FIG. 1 IGNITION BEHAVIOR OF TITANIUM AS A FUNCTION OF THICKNESS AND AIR VELOCITY PAGE 2//TAB. 1 IGNITION TEMPERATURES OF TITANIUM SHEET IN PRESSURIZED ATMOSPHERES PAGE 3

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0007 PAGES, 0001 FIGURES, 0001 TABLES, 0013 REFERENCES

key 880

# AN INVESTIGATION OF METHODS TO CONTROL POST-CRASH FUEL SPILL FROM INTEGRAL FUEL TANKS

by

ROBINSON, K.D.

12/00/71

## -ABSTRACT-

Elastomer coatings, curtains, and other more novel materials were investigated for use in eliminating or reducing the amount of post crash fuel spill from aircraft fuel tanks. It was felt that selective application of the materials, while not completely eliminating fuel spill, could provide some control of the spillage. If fire potential resulting from control of fuel spillage were reduced, then those passengers able to survive the crash impact might have sufficient time to safely evacuate the aircraft. Through the use of comparative screening tests, elastomeric liner, curtain, and multilayer liner, and boot type liner concepts were selected for evaluation in aircraft wing sections. Results of aircraft wing section drop tests showed that very little improvement was realized with the various systems installed. The structural damage to the wing sections was of such magnitude as to preclude success of any of the systems evaluated.

## -PERTINENT FIGURES-

FIG. 2 DROP TOWER BUCKLING TEST ON DC-7 WING TANK SECTION PAGE 6//FIG. 3 TYPICAL DAMAGE SUSTAINED BY DC-7 TANK AFTER BUCKLING TEST PAGE 7//FIG. 11 SLOSH TEST TANK ON TILTING TABLE PAGE 19//APP. B MULTILAYER LINER CONCEPT SKETCHES PAGES 2-1 THRU 2-3//TAB. 1 TEST RESULTS OF THE FIVE DIFFERENT CONTAINMENT METHODS PAGE 42//TAB. 1-5 PHYSICALS AFTER SOAKING FOR 72 HR. IN TYPE 1 TEST FLUID PAGE 1-6

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GOODYEAR TIRE AND RUBBER CO., AKRON, OHIO.
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FEDERAL AVIATION ADMINISTRATION, WASHINGTON, D.C. SYSTEMS RESEARCH AND DEVELOPMENT.
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0069 PAGES, 0015 FIGURES, 0007 TABLES, 0000 REFERENCES

# SORBENT-BASED AIRCRAFT FUEL TANK INERTING SYSTEM

by

LIMBERG, G.E.
NORMAN, R.H.
RUDER, J.M.

05/00/72

-ABSTRACT-

The Sorbent-Based Aircraft Fuel Tank Inerting System (SAFTIS) studied makes use of the solid sorbent fluomine to inert air by the absorption of oxygen. Fluomine is a solid sorbent which is specific for oxygen. Various pressure and temperature conditioning schemes are considered to obtain a high inerting performance capability. A vapor cycle refrigerator (heat pump) system is used to thermally condition the sorbent beds and a bootstrap turbocompressor is employed to boost the engine bleed air pressure to the absorbing bed. Stripping of absorbed oxygen is accomplished at near ambient pressure and temperatures of 200 to 230 deg. F. accomplish the desorption process. The system meets the desired performance and weight objectives for application to the B-1 aircraft. In addition, the system compares favorably with the stored liquid nitrogen and the catalytic reactor inerting concepts. The basic concept is so similar to the sorbent-based oxygen generator systems for crew breathing that it is advantageous to integrate the two concepts into a single system.

-PERTINENT FIGURES-

FIG. 2-1 FLUOMINE EQUILIBRIUM CHARACTERISTICS PAGE 11//FIG. 2-3 FLUOMINE DYNAMIC ABSORPTION COEFFICIENTS PAGE 13//FIG. 3-2 PACKAGED CONFIGURATION OF INERTING SYSTEM PAGE 43//FIG. 3-9 PRELIMINARY DESIGN, FREON TURBOCOMPRESSOR PAGE 63//TAB. 1-4 SORBENT-BASED INERTING SYSTEM PERFORMANCE PAGE 7//TAB. 2-2 SUMMARY OF SORBENT BED CONDITIONING CONCEPTS PAGE 25

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CORPORATE SOURCE -
GARRETT CORP., LOS ANGELES, CALIF. AIRESEARCH MFG. DIV.
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0091 PAGES, 0029 FIGURES, 0019 TABLES, 0000 REFERENCES

keys 911 through 913

# AIRCRAFT FUELS, LUBRICANTS, AND FIRE SAFETY

by

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

08/00/71

-ABSTRACT-

Contents: Fristrom, R.M. and Sawyer, R.F., Flame Inhibition Chemistry (See F7200659)//Botteri, B.P., Flammability Properties of Jet Fuels and Techniques for Fire and Explosion Suppression (See F7200660)//Sharma, O.P. and Sirignano, W.A., Ignition of Fuels by a Hot Projectile (See F7200661)// Fiala, R., Contribution to the Selection of Fire Extinguishing Systems and Agents for Aircraft Fires (See F7200662)//Strawson, H. and Lewis, A., Electrostatic Charging in the Handling of Aviation Fuels (See F7200663)// Russell, Jr., R.A., Crash-Safe Turbine Fuel Development by the Federal Aviation Administration (1964-1970) (See F7200664)//Weatherford, Jr., W.D. and Schaekel, F.W., Emulsified Fuels and Aircraft Safety (See F7200665)// Kuchta, J.M., Murphy, J.N., Furno, A.L., and Bartkowski, A., Fire Hazard Evaluation of Thickened Aircraft Fuels (See F7200666)//Macdonald, J.A. and Wyeth, H.W.G., Fire and Explosion Protection of Fuel Tank Ullage (See F7200667)//Fiala, R. and Winterfeld, G., Investigation of Fire Extinguishing Powders by Means of a New Measuring Procedure (See F7200668)//Miller, R.E. and Wilford, S.P., Simulated Crash Tests as a Means of Rating Aircraft Safet Fuels (See F7200669)//Tuve, R.L., Surface Active Considerations in Fuel Fires (See F7200670)

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# FLAMMABILITY PROPERTIES OF JET FUELS AND TECHNIQUES FOR FIRE AND EXPLOSION SUPPRESSION

by

BOTTERI, B.P.

08/00/71

-ABSTRACT-

Because of the large quantity and dispersed storage of fuel onboard aircraft under combat environment conditions, a high probability exists that gunfire hits will occur in fuel areas with consequent damaging effects of fire, explosion, and/or fuel depletion. Results of investigative efforts to establish the practical flammability envelopes and associated combustion damage potential for conventional jet fuels such as JP-4, JP-8 (similar to JET A-1), and JP-5 under simulated hostile operating environment conditions are presented. Testing included liquid-space gunfire hits to assess external fire hazard and vertical (liquid to vapor) firing trajectories to determine explosion hazard associated with projectile-induced fuel sprays and mists. All tests were performed in instrumented replica target tanks varying in volume from 15 to 90 gal. Principal test variables were fuel temperature, pressure, fuel depth, external void space, and internal and external air flow. All tests were conducted utilizing 0.50 caliber armor piercing incendiary projectiles. These tests indicate a considerable extension in the flammability range of all fuels compared to the equilibrium flammability limit values which are commonly utilized for fire safety analysis. Recent progress in the use of reticulated polyurethane foam, halogenated hydrocarbon chemical extinguishants, and other fuel-tank inerting techniques are reviewed.

-PERTINENT FIGURES-

FIG. 3 EXTENDED LEAN FLAMMABILITY (SLOSHING AT 17 CPM AND 1 ATM. INITIAL ULLAGE PRESSURE) PAGE 13-9//FIG. 6 EXPLOSION HAZARD UNDER VERTICAL GUNFIRE (ATMOSPHERIC PRESSURE, 90 GAL. TANK, 4 IN. FUEL DEPTH) PAGE 13-10//FIG. 10 TYPICAL PRESSURE-TIME PROFILES FOR JP-4, JP-8, AND JP-5 GUNFIRE INDUCED REACTIONS (ATMOSPHERIC PRESSURE, 70 DEG. F., 90 GAL. TANK, 4 IN. FUEL DEPTH) PAGE 13-11//TAB. 2 FIRE PROPERTIES OF JET FUELS PAGE 13-7//TAB. 3 RESULTS OF LIQUID-PHASE FUEL GUNFIRE TESTS PAGE 13-7//TAB. 4 QUALITATIVE COMPARISON OF JP-4 AND JP-8 FOR JET AIRCRAFT OPERATIONS PAGE 13-8

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# IGNITION OF FUELS BY A HOT PROJECTILE

by

SHARMA, O.P.
SIRIGNANO, W.A.

08/00/71

## -ABSTRACT-

The combustible gaseous mixture, which is present above the surface of certain liquid fuels, may be ignited by a hot projectile. A short discussion is given of the results of earlier theoretical investigations performed by approximating, firstly, the flow at the forward end of the projectile to the stagnation flow towards a hot axisymmetric body; secondly, the flow over its surface to a laminar flow over a hot plate; and, thirdly, the flow in the wake of the projectile to a plane laminar mixing of the cold unreacted mixture with the hot combustion products. After the premixed mixture is exhausted, there is a possibility of ignition of unmixed reactants by the hot inert products which are left behind and are sandwiched between the oxidizer and the fuel. A theoretical analysis for the ignition delay time as a function of the temperature and the width of the hot gas region is also presented.

## -PERTINENT FIGURES-

FIG. 7 VARIATION OF THE TEMPERATURE OF THE MIXTURE AT A PARTICULAR STATION WITH RESPECT TO TIME PAGE 15-14//FIG. 8 TEMPERATURE DISTRIBUTION FOR DIFFERENT VALUES OF RATIO OF THE VELOCITY OF THE HOT REACTED GAS IN THE LAMINAR MIXING PROBLEM TO THAT OF THE PROJECTILE WHEN THERMAL DIFFUSIVITY EQUALS 3.0 AND L EQUALS 5 CM. PAGE 15-14//FIG. 10 DEPENDENCE OF IGNITION DELAY TIME ON THE WIDTH OF THE HOT INERT STREAM (L) WHEN THERMAL DIFFUSIVITY EQUALS 2.0 AND L EQUALS 5 CM. PAGE 15-13//FIG. 11 VARIATION OF THE IGNITION DELAY TIME WITH THE TEMPERATURE OF THE HOT STREAM (THERMAL DIFFUSIVITY) WHEN ITS WIDTH L EQUALS 5 CM. AND 10 CM. PAGE 15-16

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# ELECTROSTATIC CHARGING IN THE HANDLING OF AVIATION FUELS

by

STRAWSON, H.
LEWIS, A.

08/00/71

-ABSTRACT-

Electrostatic charging of the fuel during fuelling can result in the possibility of incendive sparking in aircraft tanks; some of the more recent experimental results on the different phases of this process are presented. These results confirm that, in the absence of special precautions, discharges creating a tank explosion hazard can exist during aircraft refuelling in certain circumstances. Unless the fuel conductivity is controlled, however, these hazardous circumstances cannot be precisely predicted. The use of a static dissipator additive eliminates the hazard. Methods of introducing the additive and of maintaining the correct conductivity during fuel distribution are discussed, as well as possible side effects and interactions with other fuel additives. On the basis of world-wide airline use over many years, supported by many laboratory tests, it is concluded that the additive provides a safe, simple and trouble-free solution to the problem.

-PERTINENT FIGURES-

FIG. 1 FILTER OUTLET CHARGE DENSITY FOR FOUR DIFFERENT AIRCRAFT FUELING FILTERS. AVIATION KEROSINE, CONDUCTIVITY 2.2 TO 3.5 PS/M. AT 5 DEG. C. PAGE 19-8//FIG. 2 FUEL CHARGING IN HYDRANT DISPENSER AT 2.3 CU. M./MIN. (600 US GAL./MIN.) PAGE 19-9//FIG. 4 VARIATION OF FILTER CHARGING WITH FUEL CONDUCTIVITY PAGE 19-10//FIG. 5 EFFECT OF ASA-3 CONCENTRATION ON CHARGE DENSITY IN KEROSENE MEASURED AFTER 2 SEC. RESIDENCE TIME DOWNSTREAM OF 1 MICROLITER PAGE 19-11//FIG. 7 EFFECT OF ADDITIVE A UPON CHARGE DENSITY IN KEROSENE MEASURED AFTER 2 SEC. RESIDENCE TIME DOWNSTREAM OF 1 MICROLITER PAGE 19-11//TAB. 1 CONDUCTIVITY CHANGE DURING OCEAN TRANSPORT PAGE 19-7

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# CRASH-SAFE TURBINE FUEL DEVELOPMENT BY THE FEDERAL AVIATION ADMINISTRATION (1964-1970)

by

RUSSELL, JR., R.A.

08/00/71

## -ABSTRACT-

One of the approaches being taken to reduce the probability and/or severity of fire in commercial jet transports is the development of a modified aviation turbine fuel that will provide a significant reduction in the crash fire hazard. The modified fuels program, initiated in 1964, brought to light that under small-scale simulated crash conditions the fire reduction benefits of fuel thickeners result from their ability to physically bind the fuel and thus reduce the rate of vaporization and the exposed surface area available to support a fire. Dozens of thickened fuel candidates have undergone cursory screening, and a small percentage of those that appeared promising have been subjected to a crash fire rating system designed to provide relative values of candidate fuels. Subsequent efforts to investigate the compatibility to two of the earlier available thickened fuels with a unmodified commercial jet aircraft fuel system indicated that the fuel system could not effectively utilize the modified fuels. If chemical and physical studies, not underway, on two of the leading fuel candidates successfully improve their fluidic property, as well as retain their fire retardative properties, then FAA plans to demonstrate the safe operation of aircraft using the modified fuel and demonstrate the improvement in crash fire safety by conducting full-scale crash tests.

## -PERTINENT FIGURES-

FIG. 1 SAMPLES OF 1.5 PERCENT FAA 1069-1 GELLED FUEL PAGE 20-2//FIG. 2 1 GAL OF JP-4 CONVERTED TO FUEL MIST AND EXPOSED TO OPEN FLAMES PAGE 20-3//FIG. 3 1 GAL. OF GELLED JP-4 FUEL CONVETRED TO FUEL MIST AND EXPOSED TO OPEN FLAMES PAGE 20-3//FIG. 8 J47-GE-25 ENGINE OPERATING ON GELLED FUEL FEED FROM EXTERNAL SUPPLY SYSTEM PAGE 20-4//FIG. 10 RHEOLOGICAL PROFILE OF DOW XD7129. (FAA) GELLED FUEL-ROTOVISCO MVI VCSCOMETER PAGE 20-6

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# EMULSIFIED FUELS AND AIRCRAFT SAFETY

by

WEATHERFORD, JR., W.D.
SCHAEKEL, F.W.

08/00/71

## -ABSTRACT-

To reduce the helicopter crash fire danger, the US Army has conducted tests of high-internal-phase-ratio aqueous emulsions. A candidate fuel emulsion must render a fuel less flammable without significantly diminishing the engine combustion performance of the fuel. When there is a minimum of applied stress, the high-internal-phase-ratio emulsion retains its shape, but when an applied shear stress exceeds the yield stress, deformation and flow occur. Newtonian-type flow occurs after the applied shear stress at the pipe wall exceeds the yield stress of the emulsion. Flow abnormalities stem from localized demulsification of phase inversion. At extremely high stress levels, the flow properties approach those of the base fuel. A miniature trough used for fuel-surface flame velocity tests showed that in liquid form JP-8 had a 70 fold reduction in flame velocity relative to JP-4; in their emulsified form JP-8 showed a 250 fold reduction in flame velocity relative to JP-4. JP-4 and JP-8 mist showed similar flammability characteristics. The JP-8 emulsion required substantially more air-assisted shear for flashback to occur. A fuel tank containing emulsified JP-8 was impacted at 20 m./sec. against a concrete wall with two steel spikes set in it. No significant fire occurred. Ignition sources included electric sparks, a continuous heat source, and five highway type smudge pots.

## -PERTINENT FIGURES-

FIG. 1 CALCULATED INFLUENCE OF EMULSION YIELD STRESS ON MINIMUM TUBE DIAMETER FOR SPONTANEOUS GRAVITY FLOW OF EMULSION IN VERTICALLY ORIENTED TUBE OPEN AT BOTH ENDS PAGE 21-10//FIG. 2 RHEOLOGICAL CHARACTERISTICS OF A TYPICAL AQUEOUS EMULSION CONTAINING 97 PERCENT JP-8 FUEL AS THE INTERNAL PHASE PAGE 21-10//FIG. 3 IMPACT-DISPERSION FIRE PROPERTIES AT 38 DEG. C.--PHOTOGRAPHS OF VIDEOTAPE PLAYBACK PAGE 21-11//FIG. 4 MIST FLASHBACK TEST-- DEFINITION OF CHARACTERISTIC FLAME TYPES PAGE 21-12

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# FIRE HAZARD EVALUATION OF THICKENED AIRCRAFT FUELS

by

KUCHTA, J.M.
MURPHY, J.N.
FURNO, A.L.
BARTKOWSKI, A.

08/00/71

## -ABSTRACT-

Various gelled or emulsified fuels were proposed for reducing the aircraft crash-fire hazard. Results are presented from bench-scale tests for screening the fuels and from large-scale drop tests for evaluating their fire hazard under simulated crash conditions. Jet A and Jet B type thickened fuels were investigated. Their minimum autoignition temperatures and burning rates varied little, whereas their flash points, volatility rates, self-spread rates, and flame spread rates varied noticeably with either the base fuel or thickening agent composition; minimum ignition energies are also compared for liquid sprays. The performance of the thickened fuels, particularly Jet B emulsions, was not very promising under impact conditions. In fuel drops made from a 150 ft. three-tower facility, the fireball size and radiation intensity varied with impact velocity, impact angle, and type of fuel container. Generally, the fireball hazard was greatest for the highest volatility fuels.

## -PERTINENT FIGURES-

FIG. 2 VAPOR PRESSURE VS TIME FOR LIQUID AND EMULSIFIED FUELS BY MODIFIED REID VAPOR PRESSURE METHOD PAGE 22-7//FIG. 7 VARIATION OF PEAK FIREBALL WIDTH WITH IMPACT VELOCITY FOR VERTICAL FUEL DROPS WITH 5 GAL. METAL CONTAINERS PAGE 22-10//FIG. 10 IMPACT AND IGNITION OF 5 GAL. JP-4 EMULSION B IN VECTORIAL (60 DEG.) FUEL DROP AT AN IMPACT VELOCITY OF 36 MPH PAGE 22-11//TAB. 1 VARIATION OF YIELD STRESS WITH RELAXATION PERIOD FOR FOUR EMULSIFIED FUELS PAGE 22-1//TAB. 3 SUMMARY OF BENCH-SCALE TEST DATA FOR JET A TYPE BASE FUELS AND EMULSIFIED OR GELLED FUELS PAGE 22-4//TAB. 4 RADIATION FROM FIRES IN VERTICAL FUEL DROPS WITH 5 GAL. OF FUEL (METAL CONTAINERS) AT AN IMPACT VELOCITY OF 60 MPH PAGE 22-6

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# FIRE AND EXPLOSION PROTECTION OF FUEL TANK ULLAGE

by

MACDONALD, J.A.
WYETH, H.W.G.

08/00/71

## -ABSTRACT-

This paper examines the conditions that can lead to an explosion within aircraft fuel tank ullages (spaces above liquid fuel) and reviews the need for protection systems. Principles employed in providing the desired degree of protection are outlined, such as oxygen reduction, vapor or mist inerting and plastics foam fillers, and the results are presented of work at the Royal Aircraft Establishment to develop a suitable system for military aircraft. Relevant studies undertaken in the United Kingdom over the last 30 years are summarized and brief descriptions given of prototype and trial installations fitted to aircraft. Comparisons have been made between the various systems and their relative merits discussed. It is concluded that plastics foam is an effective system provided that the material is compatible with the environment. Liquid nitrogen is also attractive from the weight aspect, but could pose logistics problems.

## -PERTINENT FIGURES-

FIG. 1 FLAMMABILITY LIMITS FOR AVTUR FUEL VAPOR AND MIST PAGE 23-5//FIG. 2 SPARK IGNITION LIMITS FOR OXYGEN CONCENTRATION IN OXYGEN/NITROGEN AND OXYGEN CARBON DIOXIDE MIXTURES WITH WIDE CUT AVIATION FUEL PAGE 23-6//FIG. 3 COMBUSTOR GAS PROTECTION SYSTEM PAGE 23-6//FIG. 4 GASEOUS NITROGEN EXPLOSION PROTECTION SYSTEM PAGE 23-7//FIG. 5 EFFECT OF FOAM FILLING ON PEAK EXPLOSION PRESSURE RISE PAGE 23-7//TAB. 1 FUEL TANK PROTECTION SYSTEMS PAGE 23-5

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# SIMULATED CRASH TESTS AS A MEANS OF RATING AIRCRAFT SAFETY FUELS

by

MILLER, R.E.
WILFORD, S.P.

08/00/71

## -ABSTRACT-

Two tests are described for assessing the flame resistance of Avtur containing polymeric additives which reduce its ability to form flammable mists. In the standard test, a tank containing 10 or 20 gal. of fuel is propelled on a rocket sled at speeds of 114 or 188 ft./sec. and decelerated after contact with an aircraft arrestor wire. Fuel is allowed to spill from a slit in the tank onto a series of ignition sources. In the run on test, the tank travels at speeds up to 240 ft./sec. past a series of ignition sources while spilling fuel from a slit on the leading edge. Significant variables in these tests included the fuel velocity relative to the air stream and the number and placement of the ignition sources. The addition of 0.5 percent FM3, which is a mist inhibiting additive consisting of a high molecular weight polymer, to Avtur produced a considerable reduction in the incidence and intensity of fires.

## -PERTINENT FIGURES-

FIG. 1 VARIATION OF AIRCRAFT VELOCITY AND EXIT VELOCITY WITH TIME FOR THE 95TH PERCENTILE ACCIDENT PAGE 25-10//FIG. 5 FUEL TANK AND LAYOUT OF IGNITION SOURCES PAGE 25-12//FIG. 6 VELOCITY PROFILES FOR STANDARD TESTS (10 GAL. TANK) PAGE 25-12//FIG. 7 TYPICAL DECELERATION PULSES FOR STANDARD TESTS PAGE 25-13//TAB. 1 COMPARISON OF AVTUR WITH MODIFIED FUEL IN SIMULATED CRASH TESTS AT 188 FT./SEC. PAGE 25-5//TAB. 4 EFFECT OF VELOCITY ON IGNITION BEHAVIOUR OF AVTUR AND MODIFIED FUEL PAGE 25-8

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# STUDY TO DETERMINE THE APPLICATION OF AIRCRAFT IGNITION-SOURCE CONTROL SYSTEMS TO FUTURE ARMY AIRCRAFT

by

DRUMMOND, J.K.

06/00/71

-ABSTRACT-

Design information applicable to future Army aircraft, on crash sensors, ignition source suppression systems, and circuitry for the automatic activation of the suppression systems was studied. The program involved a comprehensive literature search, the development of requirements for the initiating sybsystem of the overall ignition source control system, and the consideration and comparison of several illustrative activating circuits. The development of a workable ignition source suppression system was found to be feasible. Several systems have already been developed to cool hot surfaces, to inert atmospheres, and to deenergize electical systems. The areas of the ignition source control problem which require development are: the selection and the degree of redundancy of crash sensors, the locations of the sensors on the aircraft, and the complexity of the activating and control circuitry.

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# FUMES IN THE COCKPIT

by

RAYMAN, R.B.

05/00/72

-ABSTRACT-

During the six year period, 1 Jan. 1966 to 1 Jan. 1972, there were 55 reported cases of fumes in aircraft cockpits. Forty-eight aircraft were involved: fighter (21), transport (17), trainer (9), and helicopter (1). All the substances identified are, in some way, toxic and, therefore, threaten flying safety. The toxic fumes were identified as JP-4, oil, electrical fire, oxygen contamination, carbon monoxide, chlorobromomethane, hydrochloric acid, naphtha, ether, methyl ethyl ketone, propane, and ammonia. These substances can cause a number of symptoms to incapacitate a crewman: irritation and burning of the eyes, ears, nose, and throat; spasm of the larynx with difficulty breathing; headache, giddiness, and vertigo; nausea and vomiting; and drowsiness and stupor. Of the 55 reported cases, two aircraft were destroyed due to fumes in the cockpit (carbon monoxide in an A-1E and electrical fire fumes in a B-57); several others narrowly averted disaster. Aircrewmen should take appropriate action when foreign odors are detected: use of 100 percent oxygen or emergency bailout bottle; removal of oxygen mask; canopy jettison; aborting a takeoff, if fumes are detected on the ground or landing if fumes are detected while airborne.

-PERTINENT FIGURES-

TAB. 1 TOXIC FUMES IN THE COCKPIT PAGE 21

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# AIRCRAFT FIRE DETECTION: REPORT OF CONFERENCE

by

ROLLE, S.H.

00/00/71

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# TECHNICAL EVALUATION REPORT ON PROPULSION AND ENERGETICS PANEL 37TH MEETING ON AIRCRAFT FUELS, LUBRICANTS, AND FIRE SAFETY


by

WHYTE, R.B.
GARDNER, L.


08/00/71

-ABSTRACT-


A summary is presented of a meeting concerned with aircraft fuels, lubricants, and fire safety. Comments on each section of the meeting are breifly reported. They include fuels, production, analysis and testing; fuel handling; lubricants; and fire safety. It appeared from the information presented that from an operational aspect the fuels and lubricants presently used for aircraft engines are satisfactory for use up to at least Mach 2.2. This has occurred because of close collaboration between designers of aircraft and their engines and the fuel and lubricant suppliers. An evaluation is not presented of the fire safety session; however, a section is included on an ad hoc session during which fuel and fire safety problems were discussed.


-SOURCE INFORMATION-


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NATIONAL RESEARCH COUNCIL OF CANADA, OTAOWA (ONTARIO). DIV. OF MECHANICAL ENGINEERING.
REPORT NUMBER -
AGARD-AR-44//SEE ALSO F7200658
JOURNAL PROCEEDINGS -
AGCPAV, AGARD CONF PROC, 37TH PANEL MEETING, NO. 84, THE HAGUE, NETHERLANDS (AUG. 1971)
OTHER INFORMATION -
0008 PAGES, 0000 FIGURES, 0000 TABLES, 0034 REFERENCES

key 1081

# A STUDY OF SOME FACTORS INFLUENCING THE IGNITION OF A LIQUID FUEL POOL

by

MURAD, R.J.
LAMENDOLA, J.
ISODA, H.
SUMMERFIELD, M.

00/00/70

-ABSTRACT-

Two particular problems concerning the ignitability of a pool of liquid fuel are considered. First is the problem of defining the domain of ignitability of a pool of fuel at a superflash temperature subjected to a cross wind. It is postulated that this domain is bounded by the lean mixture limit or by the blowoff limit of the local fuel-air mixture, whichever is encountered first above the surface. This domain is calculated for a laminar boundary layer over a flat pool of fuel. The agreement between this predicted boundary and the boundary found experimentally is generally quite good. Second is the problem of determining what factors control the ignitability of a liquid pool of fuel at a subflash temperature. The heating of such a pool to the point of ignition, by an energy source in the space above it, is retarded considerably by motion inducted in the pool. Suppression of the motion enhances the ignitability markedly. The induced motion produces a vortex cell whose size depends on various fuel and igniter parameters. The driving force causing this fluid motion is postulated to be a combination of the forces resulting from buoyancy in the pool and surface tension gradient on the surface.

-SOURCE INFORMATION-

CORPORATE SOURCE -
PRINCETON UNIV., N.J. GUGGENHEIM LABS. FOR THE AEROSPACE PROPULSION SCIENCES.//NORTHERN RESEARCH AND ENGINEERING CORP., CAMBRIDGE, MASS.//NOTRE DAME UNIV., IND.//TOKYO UNIV. (JAPAN).

JOURNAL PROCEEDINGS -
CBFMAO, COMBUST FLAME, VOL. 15, 289-298 (1970)

SPONSOR -
BALLISTIC RESEARCH LABS., ABERDEEN PROVING GROUND, MD.

CONTRACT NUMBER -
CONTRACT DAAD05-68-C-0450

OTHER INFORMATION -
0010 PAGES, 0006 FIGURES, 0002 TABLES, 0009 REFERENCES

# SAFETY EVALUATION OF EMULSIFIED FUELS. FINAL REPORT

by

SHAW, M.L.

06/00/71

-ABSTRACT-

A series of screening tests was formulated and conducted to obtain fuel characteristics for emulsified and gelled fuels as a function of hot surface ignition, wind shear, and impact dynamics associated with fuel breakup, atomization/dispersion, and ignition. The date obtained from these tests were used to establish emulsified fuel safety evaluation criteria. A simulated full scale experiment was designed to simulate the full scale helicopter crash environment adequately and, in addition, to be reproducibly controllable at minimal cost. The screening tests revealed that for the emulsified fuels, safety was directly dependent upon the fuel yield stress and its internal phase base fuel. A safety evaluation criterion was established in terms of an ignition susceptibility parameter which was shown to be related to an empirical equation containing fuel properties. The data obtained from the simulated full scale tests provided the definition of a nonhazardous limiting value for the ignition susceptibility parameter. Three of the emulsified fuels tested were found to result in a nonhazardous post-crash fire: (1) EF8R-104H emulsion, (2) EF8R-104 emulsion, and (3) Jet- A EXP-4 emulsion. The gelled fuels did not perform as well as the emulsified fuels; however, one gel, Jet-A gel-1, indicated a sizeable advantage over liquid fuels.

-PERTINENT FIGURES-

FIG. 39 IGNITION SUSCEPTIBILITY PARAMETER VERSUS NOZZLE SHEAR FUEL VELOCITY FOR JP-4 BASE EMULSION EF4R-104 PAGE 69//FIG. 71 IGNITION SUSCEPTIBILITY PARAMETER VERSUS WIND SHEAR VELOCITY FOR JP-4 BASE EMULSION EF4R-104 PAGE 94//FIG. 74 IGNITION SUSCEPTIBILITY PARAMETER VERSUS WIND SHEAR VELOCITY FOR JP-4 BASE EMULSION EF4R-104H PAGE 98//FIG. 90 AVERAGE MAXIMUM TEMPERATURE DATA OBTAINED FROM SPARK AND HOT-SURFACE IGNITER TESTS PAGE 125//TAB. 3 SIMULATED POSTCRASH FIRE RESULTS PAGE 141

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    DYNAMIC SCIENCE CORP., PHOENIX, ARIZ.
REPORT NUMBER -
    AD-729330//N72-14784//USAAMRDL-TR-71-29
SPONSOR -
    ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LAB., FORT EUSTIS, VA.
CONTRACT NUMBER -
    CONTRACT DAAJ02-69-C-0030
OTHER INFORMATION -
    0207 PAGES, 0102 FIGURES, 0007 TABLES, 0008 REFERENCES

# ANALYSIS OF THE GASEOUS PRODUCTS ARISING FROM INSULATION COATINGS ON AIRCRAFT CABLING AT ELEVATED TEMPERATURES

by

BUTT, R.I.
COTTER, J.L.

07/00/71

-ABSTRACT-

The insulation coatings from five commercial aircraft cables were pyrolyzed in an inert atmosphere and most of the volatile degradation products were identified by combined gas chromatography-mass spectrometry. The cable materials were polyalkame imide modified aromatic-polyimide insulation, polyimide copolymer of hexafluoropropylene/tetrafluoroethylene (FEP) insulation, polyvinyl chloride with an extruded nylon coating, silicone rubber/polyethylene terephthalate insulation, and composite polytetrafluoroethylene (PTFE)/glass fiber insulation. The principal pyrolysis products of non-fluorine containing insulation systems were carbon monoxide, methane, carbon dioxide, ethylene, propylene, and benzene. Insulations based on PTFE and FEP gave low molecular weight fluorine containing compounds as well as carbon monoxide and carbon dioxide. Pyrolysis of the insulation material based on silicone rubber produced appreciable amounts of silicon containing cyclic compounds.

-PERTINENT FIGURES-

FIG. 2 SCHEMATIC OF THE PYROLYSIS-GAS CHROMATOGRAPH MASS SPECTROMETER SYSTEM//FIG. 3 GAS CHROMATOGRAM OF THE PYROLYSIS PRODUCTS OF A POLYALKANE-IMIDE/MODIFIED AROMATIC-POLYIMIDE INSULATION MATERIAL

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-SOURCE INFORMATION-

CORPORATE SOURCE -
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REPORT NUMBER -
AD-736235//TR-71134
OTHER INFORMATION -
0021 PAGES, 0013 FIGURES, 0000 TABLES, 0011 REFERENCES

key 1090

# CHEMICAL AND PHYSICAL STUDY OF FUELS GELLED WITH CARBOHYDRATE RESINS

by

TENG, J.
LUCAS, J.M.

09/00/71

-ABSTRACT-

A carbohydrate derivative was designed as a gelling agent for turbine fuel. The gelling agent was effective in reducing the fire hazard of the fuel. The rheological profile of this gelled fuel was established over a range of conditions by means of a rotation viscometer equipped with special measuring heads. Among the rheological parameters which were measured, the viscoelasticity of the gelled fuel appeared likely to be a major factor in contributing to the crash safe character of the fuel. Pertinent physical properties and microbiological data were also compiled to demonstrate that fuel gelled with the carbohydrate based gelling agent was compatible with present aircraft fuel systems. The combined studies of electron microscopy, rheological measurement, and chemical analysis indicated that the gel structure was composed mainly of dissolved polymers. These macromolecules were linked through weak polar attractive forces.

-PERTINENT FIGURES-

TAB. 1 YIELD STRESSES AT VARIOUS TEMPERATURE AND GELLING AGENT CONCENTRATION LEVELS PAGE 3//TAB. 4 EQUILIBRIUM STRESS AT VARIOUS TEMPERATURE AND CONCENTRATION LEVELS PAGE 28//TAB. 5 RELAXATION TIME AT VARIOUS TEMPERATURE AND CONCENTRATION LEVELS PAGE 29//TAB. 13 NET HEAT OF COMBUSTION OF GELLED FUEL PAGE 57//TAB. 14 EFFECT OF GELLED FUEL ON GROWTH OF HORMODENDRUM SP PAGE 62//TAB. 16 SUMMARY OF GEL PROPERTIES GEL E PAGE 75

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KUCHTA, J., FURNO, A., MARTINDILL, G.H., AND IMHOF, A.C.: CRASH FIRE HAZARD RATING SYSTEM FOR CONTROLLED FLAMMABILITY FUELS. REP. NO. NA-69-17, FEDERAL AVIATION ADMINISTRATION, MAR. 1969//PEACOCK, A.T., HAZELTON, R.F., GRESKO, L.S., AND CHRISTENSEN, L.C.: A STUDY OF THE COMPATIBILITY OF A FOUR-ENGINE COMMERCIAL JET TRANSPORT AIRCRAFT FUEL SYSTEM WITH GELLED AND EMULSIFIED FUELS. REP. NO. NA-70-11, FEDERAL AVIATION ADMINISTRATION, APR. 1970//URBAN, C.N., BOWDEN, J.N., AND GRAY, J.T.: EMULSIFIED FUELS CHARACTERISTICS AND REQUIREMENTS. USAAVLABS TECH. REP. 69-24, MAR. 1969// HIROSHI, I., AND KAZUO, K.: MICROBIAL STUDIES ON PETROLEUM AND NATURAL GAS. J. OF GENERAL APPLIED MICROBIOLOGY, VOL. 10, NO.

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SPONSOR -
FEDERAL AVIATION ADMINISTRATION, WASHINGTON, D.C. SYSTEMS RESEARCH AND DEVELOPMENT SERVICE.
CONTRACT NUMBER -
CONTRACT DOT-FA70NA-497
OTHER INFORMATION -
0090 PAGES, 0049 FIGURES, 0016 TABLES, 0018 REFERENCES

key 1099

# THE EFFECT OF ULLAGE ON THE FLASH POINT AND LOWER FLAMMABILITY LIMIT TEMPERATURES OF JP-5 JET FUELS

by

AFFENS, W.A.
CARHART, H.W.

11/00/66

-ABSTRACT-

From theoretical considerations it can be shown that the relative size of the free space or ullage above a liquid fuel mixture can be a significant factor in the flammability properties of such a system. A simple apparatus was used to test the effect of ullage on flash point and lower flammability limit temperatures of JP-5 jet fuels. Results indicated that both ullage and time to achieve equilibrium conditions are factors. In general, flammability limit temperatures decreased with decreasing ullage, the rate and magnitude of the decrease depending on the composition of the fuel. Thus, at smaller ullages, the flammability hazard is increased. In one instance, the extrapolated flammability temperature of a specification JP-5 jet fuel was 2 deg. F. lower than its ASTM flash point as ullage approached zero. The data suggested that both the rate of temperature decrease with decreasing ullage, and the limiting value at zero ullage are important information in evaluating flammability properties of JP-5 fuel mixtures.

-PERTINENT FIGURES-

FIG. 2 LOWER FLAMMABILITY TEMPERATURE LIMIT VERSUS ULLAGE FOR JP-5 JET FUELS PAGE 8

-SOURCE INFORMATION-

CORPORATE SOURCE -
NAVAL RESEARCH LAB., WASHINGTON, D.C.
REPORT NUMBER -
AD-645046//NRL MEMORANDUM REP. 1735
CONTRACT NUMBER -
NRL PROBLEM C01-03//SR 001-06-02-0600
OTHER INFORMATION -
0011 PAGES, 0002 FIGURES, 0001 TABLES, 0002 REFERENCES

key 1101

# PIPE FLOW TESTS WITH NORMAL AND ANTI-MISTING (FM4) AVTUR FUEL

by

TIMBY, E.A.
WELLS, R.F.

10/00/72

## -ABSTRACT-

Pipe flow tests were conducted to compare the flow indexed of normal AVTUR fuel and anti-misting (FM4) kerosene fuel, over a temperature range 24 deg. C. to -40 deg C. The anti-misting kerosene (FM4 fuel) increases the fire suppression properties of aviation kerosene. The pipe used in the tests was a 12.7 mm. bore jointless Perspex tube. Measurements were made of pressure and flow rate of the two fuels. The results were treated by the standard method for the flcw of non-Newtonian fluids, and the theoretical explanation of this method is presented in the article. Conclusions drawn from the experimental results were: (1) within the laminar regime, at ambient temperatures, FM4 (anti-misting kerosene) behaves as a power law fluid with a flow index of 0.9 and an effective viscosity of 5,000ths Newton -sec./sq. m. at ambient temperature; (2) the flow resistance (pressure drop per unit length at any velocity) of FM4 is approximately twice that of AVTUR and this factor is maintained down to -40 deg. c.; (3) in the turbulent regime, at room temperature, the flow resistance of FM4 is less than that of AVTUR.

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REPORT NUMBER -
AD-907166//RAE-TR-72146
OTHER INFORMATION -
0052 PAGES, 0016 FIGURES, 0011 TABLES, 0007 REFERENCES

key 1105

# MLO-68-5, A LESS-FLAMMABLE HYDRAULIC FLUID FOR MIL-H-5606(B) REPLACEMENT

by

ADAMCZAK, R.L.
LOVING, B.A.
SCHWENKER, H.

09/00/70

-ABSTRACT-

A less fammable hydraulic fluid, MLO-68-5, was developed at a replacement fluid for MIL-H-5606B for use in tactical aircraft without requiring retrofit. The evaluation demonstrated that this fluid can be used as a replacement hydraulic fluid in Air Force aircraft, missiles, spacecraft, and their support equipment without requiring retrofit of their hydraulic systems within the -40 to +275 deg. F. operational temperature. It will also provide a significant reduction in vulnerability of these vehicles and equipment due to hydraulic fires resulting from enemy ground fire, accidents, and system malfunctions. MLO-68-5 has an additional advantage over MIL-H-5606B in that it has a high temperature capability in excess of 400 deg. F., whereas the latter is limited to 275 deg. F. Eight fire tests were performed to determine the fire resistance of the fluid and to give a meaningful flammability profile.

-PERTINENT FIGURES-

TAB. 9 FLAMMABILITY CHARACTERISTICS OF MLO-68-5 HYDRAULIC FLUID COMPARED TO MIL-H-5606(B) PAGE 19

-SOURCE INFORMATION-

CORPORATE SOURCE -
AIR FORCE MATERIALS LAB., WRIGHT-PATTERSON AFB, OHIO.
REPORT NUMBER -
AD-885338//X71-80393//AFML-TR-71-5
OTHER INFORMATION -
0054 PAGES, 0000 FIGURES, 0013 TABLES, 0008 REFERENCES

key 1116

ALOHA AIRLINES, INC., VICKERS VISCOUNT MODEL 745D, N7415, INTERNATIONAL AIRPORT, HONOLULU, HAWAII, AUGUST 8 , 1971. AIRCRAFT ACCIDENT REPORT.

by

NATIONAL TRANSPORTATION SAFETY BOARD.

12/29/71

-ABSTRACT-

After landing of a Vickers Viscount 745D, N7415 plane at Honolulu and during the taxi to the terminal, smoke was detected coming from below the passenger cabin floor. The aircraft was stopped on the taxiway, the engines were shut down, and all passengers and crew members were evacuated without incident. The fire was extinguished by airport emergency equipment. The Investigative Board determined that the probable cause of this incident was an undetected electrical short within the left nickel-cadium aircraft battery, which resulted in the absorption of an increasing amount of heat energy over an unknown period of time, and progressed to a state of thermal runaway. The causes of this incident were investigated, and structural changes made to minimize the potential consequences are described.

-SOURCE INFORMATION-

CORPORATE SOURCE -
NATIONAL TRANSPORTATION SAFETY BOARD, WASHINGTON, D.C.
REPORT NUMBER -
PB-207902//NTSB-AAR-72-2
OTHER INFORMATION -
0016 PAGES, 0000 FIGURES, 0000 TABLES, 0000 REFERENCES

key 1117

# JAPAN AIR LINES, LTD., DOUGLAS DC-8-33, JA-8006, SAN FRANCISCO, CALIFORNIA, DECEMBER 25, 1965. AIRCRAFT ACCIDENT REPORT

by

NATIONAL TRANSPORTATION SAFETY BOARD

06/26/67

-ABSTRACT-

On December 25, 1965, a Japan Air Lines, Douglas DC-8, departed the San Francisco, California Airport for Tokyo, Japan. At 4,500 ft. in a scattered cloud condition, there was an explosion in the No. 1 engine and fire broke out in the engine area. The fire was subsequently extinguished and the aircraft was landed safely. There were no injuries to the crew of 10 and 31 passengers; the aircraft was substantially damaged by the explosion and fire that followed. The Investigative Board determined that the probable cause of this accident was a disintegrating engine failure and inflight fire caused by the failure of maintenance personnel to properly secure the low pressure compressor section torque ring during engine overhaul.

-SOURCE INFORMATION-

CORPORATE SOURCE -
NATIONAL TRANSPORTATION SAFETY BOARD, WASHINGTON, D.C.
REPORT NUMBER -
PB-196968//N71-72477
OTHER INFORMATION -
0020 PAGES, 0001 FIGURES, 0000 TABLES, 0000 REFERENCES

key 1118

# UNITED AIR LINES, INC., BOEING 727-22C, N7434U, NEAR LOS ANGELES, CALIFORNIA, JANUARY 18, 1969. AIRCRAFT ACCIDENT REPORT

by

NATIONAL TRANSPORTATION SAFETY BOARD

03/18/70

-ABSTRACT-

An investigative report is presented of a United Airlines Flight 266 accident which occurred on 18 January 1969. The aircraft crashed into Santa Monica Bay and was destroyed and the 6 crew members and 32 passengers on board all perished. The probable cause of this accident was loss of attitude orientation during a night instrument departure in which the attitude instruments were disabled by loss of electrical power. The Board was unable to determine (1) why all generator power was lost and (2) why the standby electrical power system either was not activated or failed to function. The flight experienced a fire warning on the No. 1 engine during climbout and the engine was shut down. However, there was no physical evidence in the recovered wreckage to indicate that an inflight fire had occurred.

-SOURCE INFORMATION-

CORPORATE SOURCE -
NATIONAL TRANSPORTATION SAFETY BOARD, WASHINGTON, D.C.
REPORT NUMBER -
N71-10914//PB-190812//NTSB-AAR-70-6
OTHER INFORMATION -
0042 PAGES, 0001 FIGURES, 0000 TABLES, 0000 REFERENCES

# EVALUATION OF SELF-SEALING BREAKAWAY VALVES FOR CRASHWORTHY AIRCRAFT FUEL SYSTEMS

by

ANSON, B.

11/00/71

-ABSTRACT-

The program was aimed at improving the component performance characteristics of breakaway valves used to eliminate fuel spillage and subsequent fire in otherwise survivable aircraft crashes. It consisted of an initial study and literature survey to establish the state of the art followed by two series of static and dynamic tests of various types of valves to define problem areas and to verify that the problems had been corrected. It was recommended that the self-sealing mechanism of the breakaway valves actuate before a maximum separation distance of 0.125 in. is achieved between the separating valve halves. This recommendation allows for ,the use of boots and seals to prevent external leakage before this actuation occurs as in current practice.

-SOURCE INFORMATION-

CORPORATE SOURCE -
DYNAMIC SCIENCE CORP., PHOENIX, ARIZ.
REPORT NUMBER -
AD-738204//N71-24547//USAAMRDL TR 71-65
SPONSOR -
ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LAB., FORT EUSTIS, VA.
CONTRACT NUMBER -
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OTHER INFORMATION -
0072 PAGES, 0048 FIGURES, 0000 TABLES, 0003 REFERENCES

key 1122

# FIRE SAFETY-AN ACHIEVABLE GOAL

by

RADNOFSKY, M.I.

10/25/71

## -ABSTRACT-

The fire safety goals of NASA and the program plans for their achievement are discussed. Progress made in the development of nonflammable materials for both space and nonspace oriented usage is described. Specifically, fibrous asbestos, glass, polyimides, Teflon, metallics, halogenated materials, fluoropolymers, nonflammable paper, and composite layups and their commercial applications are described. Material selection and fabrication processes for aircraft interiors, housing construction and interiors, and fire fighter suits are discussed. Material applications criteria, such as flammability, weight, cost, durability, texture, color, decoration, fabrication, and installation considerations are presented in qualitative terms.

## -PERTINENT FIGURES-

FIG. 3 A. STRUCTURAL FIREFIGHTERS SUIT B. CONCEPTS FOR IMPROVED FIREFIGHTERS CLOTHING PAGE 6//FIG. 10 HOUSING MODULE NUMBER 1 PAGE 9//FIG. 11 THE T-39 AIRCRAFT PASSENGER SEATING AREA PAGE 9

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, HOUSTON, TEX. MANNED SPACECRAFT CENTER.
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A71-44595
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OTHER INFORMATION -
0010 PAGES, 0014 FIGURES, 0000 TABLES, 0000 REFERENCES

# CRASHWORTHINESS OF SAFE FUELS

by

BOCKOW, R.A.
SHAW, L.M.

03/26/72

## -ABSTRACT-

A quantitative evaluation was made to characterize the safety performance of emulsified and gelled safety fuels which are normally used to reduce the post crash fire hazard associated with aircraft accidents. An initial series of screening tests was designed to obtain the characteristics of safe fuels in the aircraft crash environment. The authenticity of the screening tests relative to the full scale crash environment was evaluated through a second series of experiments designed to simulate a full scale aircraft crash environment. A crashworthiness evaluation criterion was established in terms of an ignition susceptibility parameter to quantitize the relative safety performance of different fuels. The safe fuels studied consisted primarily of emulsified formulations with liquid JP-4 or JP-8 as the internal base fuel. Several gel formulations were tested in the simulated full scale tests to gain a comparison between emulsified and gelled fuel performance. The performance of JP-4 was selected as a baseline. The results obtained in the simulated full scale tests set an empirical value of 0.12 for the upper limit for the ignition susceptibility parameter corresponding to a nonhazardous post-crash condition. The only emulsified fuels tested which exhibited a value of 0.12 or less at the maximum crash survivable conditions were JP-8 base emulsions.

## -PERTINENT FIGURES-

FIG. 12 IGNITION SUSCEPTIBILITY PARAMETER VERSUS WIND SHEAR VELOCITY FOR JP-4 BASE EMULSION PAGE 11//FIG. 13 IGNITION SUSCEPTIBILITY PARAMETER VERSUS IMPACT KINETIC VELOCITY FOR JP-4 BASE EMULSION PAGE 12

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JOURNAL PROCEEDINGS -
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OTHER INFORMATION -
0015 PAGES, 0014 FIGURES, 0000 TABLES, 0010 REFERENCES

key 1125

# IGNITION OF AIRCRAFT FLUIDS ON HIGH TEMPERATURE ENGINE SURFACES

by

WESTFIELD, W.T.

02/00/71

## -ABSTRACT-

A full scale turbofan installation fire test program was used to evaluate the hot surface ignition possibilities of the proposed C-5A/TF 39 installation. The flammable fluid systems used to simulate leakage conditions were entirely independent of the engine or aircraft systems. The fluids were some of those that are normally used in various engine installations, Types A and B jet fuel and MIL-H-5606 hydraulic fluid. They were released either as a coarse pressurized spray or an essentially unpressurized running leak. Results showed that all ignitions of flammable fluids on the hot turbine case surface of the modified engine installation occurred in the form of explosions of varying degrees of severity. Severity of ignition was directly proportional to the length of time that fluid released prior to ignition. When conditions were such that occurrence of ignition was considered marginal, the severity of the ignition was greater than if conditions were such that ignition was assured. It was concluded that the hot surface temperature value of 500 deg. F., which has been considered as the maximum acceptable temperature for the prevention of ignition of flammable fluid leakage, is conservative for engine installations having secondary cooling air provisions. Precautions should be taken in the design of installations in which the surface temperatures are in excess of 700 deg. F.

## -PERTINENT FIGURES-

FIG. 3 TYPICAL IGNITION TRACE WITH INITIAL TEMPERATURE RAMP SHOWN PAGE 74

## -SOURCE INFORMATION-

CORPORATE SOURCE -
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JOURNAL PROCEEDINGS -
FITCAA, FIRE TECHNOL, VOL. 7, NO. 1, 69-81 (FEB. 1971)
OTHER INFORMATION -
0013 PAGES, 0013 FIGURES, 0000 TABLES, 0000 REFERENCES

key 1146

# PHYSIOLOGICAL AND TOXICCLOGICAL ASPECTS OF SMOKE DURING FIRE EXPOSURE

by

EINHORN, I.N.

07/14/72

## -ABSTRACT-

The fundamental aspects of combustion and degradation of polymeric materials are reviewed with special emphasis placed on the physiological and toxicological factors resulting from exposure to smoke. The parameters governing smoke development during pyrolysis and combustion are discussed. Techniques utilized in the characterization of smoke are mentioned and factors influencing smoke development noted. A status-of-the-art survey of the literature is presented pertaining to the physiological and toxicological aspects of combustion. This includes topics on the physiological factors affecting survival during fire exposure, the visual parameters affecting survival, the human escape response, respiratory burns, smoke poisoning, toxic effects from gases and thermal degradation products, and toxicological studies on selected plastics. A brief review is also presented on the special aspects of smoke in commercial aircraft.

## -PERTINENT FIGURES-

FIG. 13 CORRELATION BETWEEN RADIANT-PANEL AND TUNNEL TESTS PAGE 26//FIG. 14 TYPICAL SMOKE DEVELOPMENT CURVES FOR TWO MATERIALS PAGE 32//TAB. 4 COMPARISON OF SMOKE TEST SYSTEMS FOR MEASURING SMOKE OBSCURATION PAGE 21// TAB. 8 RADIANT PANEL FLAME SPREAD DATA PAGE 27//TAB. 11 SMOKE DEVELCPMENT BY URETHANE FOAMS PAGE 39//TAB. 23 RECENT TOXICOLOGICAL STUDIES OF PLASTICS DURING PYROLYSIS AND COMBUSTION PAGE 61

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JOURNAL PROCEEDINGS -
IN ITS: POLYMER CONF SER, (JULY 10-14, 1972) (SEE F7200864)
SPONSOR -
FEDERAL AVIATION ADMINISTRATION, WASHINGTON, D.C. SYSTEMS RESEARCH AND DEVELOPMENT AND SERVICE.
CONTRACT NUMBER -
CONTRACT DOT-FA-70-NA-445
OTHER INFORMATION -
0085 PAGES, 0026 FIGURES, 0023 TABLES, 0098 REFERENCES

key 1155

# EXPLORATORY DEVELOPMENT OF NEW AND IMPROVED SELF-SEALING SYSTEMS FOR AIRCRAFT INTEGRAL FUEL TANKS. FINAL REPORT

by

HEITZ, R.M.
HILL, F.

06/29/71

-ABSTRACT-

Self-sealing materials systems were developed for the protection of aircraft integral fuel tanks against catastrophic destruction by small arms ground gunfire. Hydraulic ram phenomena and factors affecting the functioning of 0.50 caliber API (armour piercing incendiary) projectiles were also investigated. The successful self-sealing materials systems developed were composites of flexible laminated and compressed elastomeric foam. Results of gunfire tests showed this type of self-sealing system to be effective against 20 mm AP (armour piercing) projectiles as well as 0.50 caliber AP and API projectiles. Functioning of an API projectile was found to be dependent upon the projectile's impact velocity, the thickness of the tank's wall, and the projectile's impact angle. The presence of damage control and self-sealing materials altered the behavior of API projectiles. The cause for catastrophic rupture of fuel tank exit walls when impacted by small arms projectiles aas determined to be the ramming force of the pressure wave induced by a tumbling projectile in a tank filled with liquid. The destructive forces within a fuel tank are much greater when a projectile strikes a rib rather than when it merely pierces a metal skin.

-SOURCE INFORMATION-

CORPORATE SOURCE -
NORTHROP CORP., HAWTHORNE, CALIF.
REPORT NUMBER -
AD-889869L//X72-71881
OTHER INFORMATION -
0064 PAGES, 0047 FIGURES, 0000 TABLES, 0001 REFERENCES

key 1156

# HYDRAULIC FLUID FLAMMABILITY TEST (MIL-H-5606 VERSUS MLO 68-5)

by

KNAGGS, H.J.

04/00/70

## -ABSTRACT-

Test comparisons were made of the flammability of standard hydraulic fluid, MIL-H-5606, and prototype fluid, MLO 68-5, resulting from small arms fire. Test data were generated by firing caliber 0.50 API (armour piercing incendiary rounds into pressurized hydraulic reservoirs (30 psig) containing the fluids and recording the results on film. No significant difference between the number of fires caused by the two fluids was observed. The maximum burn areas for the standard hydraulic fluid fires appeared larger than the maximum burn areas for the MLO fires. It appeared that the longer the fire burned for either fluid the larger the maximum burn area became.

## -SOURCE INFORMATION-

CORPORATE SOURCE -
AIR FORCE ARMAMENT LAB., ELGIN AFB, FLA.
REPORT NUMBER -
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OTHER INFORMATION -
0024 PAGES, 0001 FIGURES, 0001 TABLES, 0003 REFERENCES

key 1162

# EVALUATION OF JP-8 VERSUS JP-4 FUEL FOR ENHANCEMENT OF AIRCRAFT COMBAT SURVIVABILITY

by

BOTTERI, B.P.
CLODFELTER, R.G.
MANHEIM, J.R.
OTT, E.E.

06/00/70

-ABSTRACT-

Investigations were directed toward the establishment of aircraft combat survivability advantages offered by lower volatility fuels such as JP-8 and JP-5 compared to the present Air Force operational JP-4 fuel. The principal elements of the approach included (1) vulnerability of these fuels to external fire due to incendiary projectile hits in the liquid space; (2) the flammability of fuel mists and sprays generated as a result of fuel sloshing and vibration; and (3) the explosion potential of these fuels as a result of vertical gunfire (liquid to vapor) trajectories. Results ot testing have shown a considerable extension of the static lean flammability limit of fuels due to mists and sprays generated by dynamic environment and, particularly, projectile penetration effects. Although the lower volatility fuels such as JP-8 exhibited much lower peak explosion overpressures than JP-4, the aircraft survivability advantages to be gained by the reduced combustion overpressures are presently unknown and dependent on the assessment of the true pulse capability of typical operational aircraft fuel cell structures. In limited test flights it was found that JP-8 will be intermediate bewteen JP-4 and Navy JP-5 in cold start and altitude relight.

-SOURCE INFORMATION-

CORPORATE SOURCE -
AIR FORCE AERO PROPULSION LAB., WRIGHT-PATTERSON AFB, OHIO.
REPORT NUMBER -
AD-876594//X71-71111
OTHER INFORMATION -
0043 PAGES, 0016 FIGURES, 0001 TABLES, 0001 REFERENCES

key 1169

# THERMAL PROTECTION CAPACITY OF THE A/P22S-4 HIGH ALTITUDE FLYING OUTFIT

by

HOCHWALT, J.R.

04/00/71

-ABSTRACT-

One A/P22S-4 Flying outfit was subjected to the flames of JP-4 fuel to determine how much thermal protection the outift would provide to a subject when exposed to direct contact with an open flame. Upon completion of the test, all of the temperature sensors on the mannequin were examined. It is concluded that an individual wearing the high altitude flying outfit could survive, without injury, when in contact with fuel flames of 1800 to 2300 deg. F. for a time period of three seconds. The flying outfit is a multilayer garment consisting of an inner layer of nylon cloth, a chloroprene coated nylon fabric gas container, a restraint assembly consisting of Nomex cord, and an outer cover consisting of two layers of Nomex fabric in a herringbone weave and weighing 4.5 to 5.0 oz./sq.yd.

-SOURCE INFORMATION-

CORPORATE SOURCE -
AERONAUTICAL SYSTEMS DIV., WRIGHT-PATTERSON AFB, OHIO.
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OTHER INFORMATION -
0034 PAGES, 0020 FIGURES, 0000 TABLES, 0000 REFERENCES

key 1172

# ENGINEERING TEST OF LIGHTWEIGHT UNDERWEAR OF THE WINTER FLIGHT CLOTHING SYSTEM: THERMAL PROTECTION

by

KNOX, III, F.S.
MCCAHAN, JR., G.R.
WACHTEL, T.L.
TREVETHAN, W.P.
MARTIN, A.S.
ET AL.

06/00/71

-ABSTRACT-

Bioassay techniques were used to evaluate the fire resistant and thermal protection capabilities of fabrics considered for use in the lightweight underwear of the Army winter flight clothing system. Samples of fabrics were mounted on a template and held in contact with the side of a pig. Thus protected, the pig was exposed to a flame source calibrated to simulate a well developed JP-4 fire. Exposure times of 1.75, 3.50, and 7.0 seconds were used. Evaluation of resultant skin burns showed that none of the fabric systems met the essential requirement of 10 seconds protection. Single layered fabric (Nomex shell fabric) offered slight protection and double layered fabric systems (Nomex outer shell with either Nomex underwear or 50 percent cotton/50 percent wool underwear) offered more than three times the protection of single layers, but still failed to provide 10 seconds of protection. Washing did not affect thermal protection. The data further indicated that the method using pigs provided a consistent and meaningful way of evaluating thermal protective fabrics.

-PERTINENT FIGURES-

FIG. 1 EXPERIMENTAL APPARATUS PAGE 3//FIG. 2 TEMPLATE SHOWING SIZE, LOCATION AND CODE NUMBER FOR EACH TEST SITE PAGE 4//FIG. 5 AVERAGE DEG. OF BURN (GROSS EVALUATION)VS. EXPOSURE TIME PAGE 13//FIG. 6 TIME-TEMPERATURE RELATIONSHIPS FOR A 1.75 SEC. BURN PAGE 14//FIG. 7 TIME-TEMPERATURE RELATIONSHIPS FOR A 3.5 SEC. BURN PAGE 15//FIG. 8 TIME-TEMPERATURE RELATIONSHIPS FOR A 7.0 SEC. BURN PAGE 16//TAB. 1 FLAME GUN CALIBRATION DATA PAGE 9//TAB. 2 GRADING SYSTEM FOR GROSS BURN EVALUATION PAGE 10//TAB. 3 DEG. OF BURN ASSOCIATED WITH TIME-TEMPERATURE RELATIONSHIPS IN FIG. 6,7, AND 8 PAGE 17//TAB. 5 DEG. OF BURN (MICROSCOPIC) COMPARED FOR DIFFERENT PROTECTIVE SYSTEMS PAGE 27//TAB. 6 TIME TO REACH SEVERE 2ND DEG. BURN PAGE 30//TAB. 7 MORTALITY PAGE 30

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OTHER INFORMATION -
0035 PAGES, 0011 FIGURES, 0007 TABLES, 0012 REFERENCES

# EXPERIMENTAL DETERMINATION OF THE IGNITION LIMITS OF JP-4 FUEL WHEN EXPOSED TO CALIBER .30 INCENDIARY PROJECTILES

by

PEDRIANI, C.M.

07/00/71

-ABSTRACT-

Experiments were carried out to define the ignition limits of JP-4 vapors subject to 0.30 caliber incendiary projectiles. A test fixture was fabricated which allowed a functioning incendiary projectile to pass through a known, uniform fuel/air mixture. The resultant reaction was observed using high speed photography. Ignitions between fuel/air ratios of 0.5 and 3.0 percent JP-4 volume were observed. Additional tests were conducted to observe the flame suppression properties of reticulated polyurethane foam and to determine the fact that the impact flash from inert projectiles can ignite combustible fuel/air vapor. It was concluded that reticulated foam is an effective method of suppressing explosions of flammable mixtures which would be extremely hazardous in an unprotected tank. It was also found the flammable mixtures could be ignited by the impact flash caused by an otherwise inert projectile. Comparison with spark ignition shows the upper limit to be lower for the projectiles.

-SOURCE INFORMATION-

CORPORATE SOURCE -
ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LAB., FORT EUSTIS, VA.
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0030 PAGES, 0014 FIGURES, 0000 TABLES, 0006 REFERENCES

# NON-MISTING FUELS AS AN AID TO AIRCRAFT SAFETY

by

MILLER, R.E.
WILFORD, S.P.

10/18/71

-ABSTRACT-

A promising method of reducing the incidence of crash fires lies in modifying or containing the fuel. To assess the performance of candidate anti-misting fuels, a realistic fire test was designed to reflect as accurately as possible the conditions encountered in aircraft crashes. In the method, a fuel tank was mounted on a rocket propelled sled and accelerated down a track into an aircraft arrester wire. Fire test results using Avtur and Avtur with four high molecular weight polymeric additives are reported. In these tests, fuel was ejected onto the ignition source after the sled struck the arrester wire. The rocket sled test provided a convenient method of evaluating aircraft safety fuels under a wide variety of conditions. Using one rocket, the test conditions are comparable with those encountered by the fuel in relatively mild crashes. With two rockets, the conditions are severe enough to include 95 percent of crashes occurring at a speed of 80 mile/hour. The mist inhibiting additives gave a considerable increase in the fire resistance of kerosene type fuels under severe crash conditions. Handling properties of A Avtur containing mist suppressants were also studied.

-PERTINENT FIGURES-

TAB. 1 COMPARISON OF AVTUR WITH MODIFIED FUELS IN SIMULATED CRASH TESTS WITH SLED SPEED IMMEDIATELY BEFORE ARRESTER 57 M./SEC. PAGE 13//TAB. 2 COMPARISON OF AVTUR WITH MODIFIED FUELS IN SIMULATED CRASH TESTS WITH SLED SPEED IMMEDIATELY BEFORE ATTRSTER 34.7 M./SEC. PAGE 14//TAB. 3 COMPARISON OF AVTUR WITH FM 3 MODIFIED IN SIMULATED RUN ON CRASH TESTS AT 57 M./SEC. PAGE 16//TAB. 4 EFFECT OF VELOCITY ON IGNITION BEHAVIOR OF AVTUR AND FM 3 MODIFIED FUEL PAGE 17//TAB. 5 VARIATION OF MODIFIED FUEL VISCOSITIES WITH TEMPERATURE PAGE 18

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A72-18837

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OTHER INFORMATION -
0027 PAGES, 0009 FIGURES, 0005 TABLES, 0014 REFERENCES

# DEVELOPMENT OF CRASH-RESISTANT AIRCRAFT FLAMMABLE FLUID SYSTEMS. PART 1. DELINEATION OF THE PROBLEM

by

BENNETT, C.V.
RODGERS, JR., R.R.

03/00/59

-ABSTRACT-

A study was carried out on reports and data pretaining to on-the-scene aircraft accidents. Particular attention in this study was devoted to determining the contribution of post crash fires to aircraft accident fatality rates. It was found that the fatality rate in crashes of fixed and rotary-wing aircraft, when such crashes are followed by fire, is approximately 25 and 39 percent greater, respectively, than in crashes not followed by fire. A recent investigation was conducted using some helicopter drop crash tests. Twc types of investigations were pursued in an effort to establish a criteria for the severity of crash impact which could be used (1) in the design of crash resistant flammable fluid system (particularly fuel tanks and their appendages), and (2) in determining the safest location on a fixed or rotary wing aircraft in respect to fire protection. It was concluded that a crash load factor in the order of 35 may be considered likely in aircrafts under severe but survivable crash conditions. Therefore, a load factor of 35 is recommended for the design of crash-resistant flammable fluid systems installed in fuselages of fixed and rotary-wing aircraft. In respect to location on fixed-wing aircraft it is recommended (1) that fuel tanks be located in the outboard portion of the wings, (2) that fuel tanks be located and/or protected such to prevent ground scraping action, and (3) that fuel tanks not be located forward of the plane of the wing front spar. In the case of helicopters (rotary-wing aircraft) almost any location appears to be suitable for the aircrafts crash-resistant flammable fluid system. The design of crash-resistant fuel tanks for interval fluid pressure loads resulting from squashing conditions is now recognized as being feasible. They should be equipped with accessories and components which will not tear the cell and which are capable of sealing the fuel inside the cell.

-PERTINENT FIGURES-

FIG. 4 SIDE ELEVATION REFERENCE FOR ACCELERATION MEASUREMENTS ON H05S-1 HELICOPTER. FULL-SCALE GRID SPACING IS 1 FT.//FIG. 5 SIDE ELEVATION REFERENCE FOR ACCELERATION MEASUREMENTS ON SIMULATED H-13 HELICOPTER FULL-SCALE GRID SPACING IS ONE HALF FT.//FIG. 6 ANTHROPOMORPHIC DUMMY NO. 1 ACCELERATIONS EXPERIENCED DURING TEST NO. 2 ANTHROPOMORPHIC DUMMY NO. 2 ACCELERATIONS EXPERIENCED

DURING HO5S-1 DROP CRASH TEST NO. 2//TAB. 1 SUMMARY OF FATALITIES IN SCHEDULED PASSENGER AIR CARRIER OPERATION PAGE 18//TAB. 2 RESULTS OF SOME DROP-CRASH TESTS OF SIKORSKY HO5S-1 HELICOPTERS AND SIMULATED H-13 HELICOPTER STRUCTURES PAGE 19//TAB. 3 RESULTS OF ON-THE-SCENE STUDIES OF HELICOPTER ACCIDENTS BY TDC INVESTIGATORS PAGE 21//TAB. 4 ACCIDENT DATA RECEIVED FROM ON-THE-SCENE MILITARY INVESTIGATIONS PAGE 22/TAB. 5 FLIGHT-PATH ANGLES AND VELOCITIES AND FUSELAGE ATTITUDES AT A POINT 50 FT. ABOVE THE GROUND FOR 4 HELICOPTERS MAKING AUTOROTATIVE LANDINGS TO A PANEL PAGE 24

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CORPORATE SOURCE -
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REPORT NUMBER -
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CONTRACT NUMBER -
CONTRACT 21X2040 709-9062 P5030-07 S 44-019
OTHER INFORMATION -
0035 PAGES, 0010 FIGURES, 0005 TABLES, 0000 REFERENCES

key 1202

# CHEMICAL AND PHYSICAL STUDY OF FUELS GELLED WITH HYDROCARBON RESINS

by

ERICKSON, R.E.
KRAJEWSKI, R.M.

07/00/71

-ABSTRACT-

Jet A type fuels, thickened with experimental resin XD-7038.00, were modified to obtain the most acceptable compromise between fluidity and explosion safety to increase the fire safety aspect. Many modifications are explored in terms of change in rheological behavior and fluidity. Fuel safety testing was conducted by the National Aviation Facilities Experimental Center providing a guide during the program to the final selection of a low viscosity thickened fuel with exceptionally good explosion safety features. It was concluded from the data that Jet A-1 or Jet A fuels can be modified to give fire explosion resistance while maintaining relatively low viscosity at low shear rates. Fuel flow rates at gravity conditions of the modified fuels are significantly increased compared to former high viscosity thickened fuels, and approach the rates for unmodified jet fuel. The rheological profile of the modified thickened fuel shows it bo be dilatant at low shear, psuedoplastic at high shear, with thixotropy existing across the entire shear range. A reduction in viscosity at low shear is apparent at elevated temperatures; however, no adverse effect on fire explosion resistance was observed.

-SOURCE INFORMATION-

CORPORATE SOURCE -
DOW CHEMICAL CO., MIDLAND, MICH.
REPORT NUMBER -
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FEDERAL AVIATION ADMINISTRATION, WASHINGTON, D.C. SYSTEMS RESEARCH AND DEVELOPMENT SERVICE.
CONTRACT NUMBER -
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OTHER INFORMATION -
0103 PAGES, 0051 FIGURES, 0009 TABLES, 0000 REFERENCES

# AN INVESTIGATION OF THE CRASH-FIRE PROBLEMS IN TRANSPORT AIRCRAFT FUEL TANKS

by

FIELD, R.L.
MILLER, M.F.

01/00/51

-ABSTRACT-

A general summary is presented of completed tests on the evaluation of aircraft fuel tanks, of the broad deductions which can be reached from actual airplane crash experience, and of the results of detailed considerations which have been given possible solutions to the crash fire problems in transport aircraft fuel tanks. Three types of tests were conducted: deceleration, impact, and deformation. It was concluded from the study of airplane crashes that: (1) The wing structure containing fuel cells can suffer extensive damage in the type of crash where the fuselage and personnel are relatively unharmed. The basic rupture forces present in the wing in various combinations are fluid pressure forces resulting from inertia or change of volume, direct impact forces, and general bending or torsion of the entire wing. (2) Any wing type of fuel cell, including present convential types, will have maximum safety in crashes if placed outboard in the wing; if located at a position where the wing is not likely to break off; if center spar wing construction is used separating the tanks fore and aft; and if protected from impact in front by heavy spars and leading edge structures. Crash and test experience indicated that development of flexible bladder tanks offer the most promising solution to the fuel tank crash problem.

-SOURCE INFORMATION-

CORPORATE SOURCE -
TECHNICAL DEVELOPMENT AND EVALUATION CENTER, INDIANAPOLIS, IND.
REPORT NUMBER -
TECH. DEV. REP. 134
OTHER INFORMATION -
0022 PAGES, 0014 FIGURES, 0000 TABLES, 0000 REFERENCES

key 1346

# FIRE DETECTION SYSTEM PERFORMANCE IN USAF AIRCRAFT

by

DELANEY, C.L.

08/00/72

## -ABSTRACT-

Data on false fire warnings and aircraft engine nacelle fires was taken from Air Force accident/incident reports. This data included the time period 1965 through 1970 and is restricted to noncombat related accidents. Analysis of the data showed that false fire warnings are a major problem in the majority of USAF aircraft (83 percent of all reported alarms are false). These false fire warnings resulted in damage or destruction to aircraft as well as crew injuries and fatalities. In addition, it was found that in approximately 50 percent of the engine nacelle fires, where the performance of the detection system could be determined, the system did not provide an alarm. It was also found that the fire detection system in a number of aircraft had been partially or totally removed to reduce or eliminate the false fire warning problem. As a consequence the majority of the fires which occurred in these aircraft were not detected.

## -SOURCE INFORMATION-

CORPORATE SOURCE -
AIR FORCE AERO PROPULSION LAB., WRIGHT-PATTERSON AFB, OHIO.
REPORT NUMBER -
AFAPL-TR-72-49
OTHER INFORMATION -
0021 PAGES, 0000 FIGURES, 0006 TABLES, 0000 REFERENCES

key 1367

# A STUDY OF THE FUEL/AIR VAPOR CHARACTERISTICS IN THE ULLAGE OF AIRCRAFT FUEL TANKS

by

PEDRIANI, C.M.

06/00/70

-ABSTRACT-

The fuel/air vapor studies were initiated to reduce the vulnerability of aircraft fuel tanks to small arms fire. The specific phenomenon studied is that of incendiary ignition of the fuel/air mixture in the ullage of the tank. The ullage characteristics under various dynamic and atmospheric conditions were studied. A test tank was constructed and mounted on a vibration table. The tank was filled with JP-4 fuel and withdrawn at various aircraft usage rates under controlled temperature and vibration. The fuel/air ratio of the ullage was measured with an infrared analyzer, and the data were recorded. A fuel/air ratio gradient was found in the ullage. It varied from a lean mixture (less than 1 percent) near the top of the tank, due to the inflow of air, to a rich mixture (as high as 12 percent) near the surface of the fuel, due to fuel surface oscillations. It was concluded that under dynamic conditions, fuel vapor within the flammable range exists in Army aircraft fuel tanks using JP-4 fuel over a minimum temperature range of 12 to 110 deg. F. Temperature is the primary variable affecting the overall vapor content and the flammable volume. However, small changes in the vapor content may be effected by a change in fuel withdrawal rates or vibrational frequency. The use of JP-8 fuel would significantly reduce hazardous vapor in the ullage of fuel tanks.

-SOURCE INFORMATION-

CORPORATE SOURCE -
ARMY AVIATION MATERIAL LABS., FORT EUSTIS, VA.
REPORT NUMBER -
AD-873252//USAAVLABS TN-3
OTHER INFORMATION -
0035 PAGES, 0029 FIGURES, 0006 TABLES, 0000 REFERENCES

key 1392

# APPLICATION OF HALON 1301 TO ARICRAFT CABIN AND CARGO FIRES

by

GASSMANN, J.J
MARCY, J.F.

00/00/72

## -ABSTRACT-

Test procedures and test results are summarized on the application of Halon 1301 to aircraft cabin and cargo fires. Based on an analysis of the results of the cabin mockup tests, it was determined that: (1) a high rate discharge system utilizing Halon 1301 at a concentration of 5.8 percent in air is effective in rapidly extinguishing a Class A fire in urethane seat padding; (2) prolonged exposure in a cabin fire to flames and heat from incandescent hot bodies can cause pyrolysis of Halon 1301 into extremely toxic gases in concentrations that may be harmful; and (3) although Halon 1301 concentrations as low as 3 to 4 percent in air were sufficient to extinguish Class A fires, the propane gas burner could still be ignited to flame by electrical sparking. It was concluded from the cargo compartment tests that: (1) the use of Halon 1301 released at the time of detection of a cargo fire can prevent the occurrence of flash fire, greatly reduce the maximum temperatures, and provide effective fire control for periods of at least 2 hours; and (2) the use of as little as 3 percent by volume of Halon 1301 can effectively control cargo fires in a compartment with a 10 percent and a 50 percent load configuration.

## -PERTINENT FIGURES-

FIG. 2 REGULAR URETHANE FOAM FIRE PARAMETERS IN CLOSED CABIN PAGE 181

## -SOURCE INFORMATION-

CORPORATE SOURCE -
NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER, ATLANTIC CITY, N.J.

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# PRINCIPLES OF FIRE PREVENTION AND FIRE FIGHTING, TRANSLATION OF RUSSIAN BOOK (SEE: F7300093-F7300105)

by

BAKER, J.E., TR.

00/00/70

-ABSTRACT-

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OTHER INFORMATION -
9999 PAGES, 9999 FIGURES, 9999 TABLES, 9999 REFERENCES

# COMBUSTION OF LIQUIDS IN TANKS WITH REDUCING FUEL LEVEL

by

BLINOV, V.I.
ARTEMENKO, E.S.

00/00/68

-ABSTRACT-

The combustion process of liquids in tanks with reducing fuel level was investigated in transparent quartz tubes with diameters of 15, 22, 36, 50, and 80 mm., and a thin walled cylindrical steel tank with a diameter of 150 mm. Surface temperature and the combustion rate were measured for aviation fuel and isoamyl alcohol. The following conclusions were drawn: If the reservoir is filled with a fuel and the latter is ignited, at first the flame height decreases and the rate at which the liquid burns away also decreases. Then the base of the flame enters the reservoir, and the combustion rate increases. As the liquid level drops still more, there is a regular decrease in the combustion rate, and the flame goes out at a certain critical depth. It was found that there are 3 types of liquid combustion in reservoirs. One is laminar, in reservoirs with 10 mm. dia. or less, when the flame does not enter the reservoir. The second type, laminar and transitional flame conditions, occurs in reservoirs with a 10 to 80 mm. dia. Turbulent combustion takes place in reservoirs with a dia. above 80 mm. Energy is transferred from the flame to the liquid mainly by radiation if the dia. is not less than 30 mm.

-SOURCE INFORMATION-

JOURNAL PROCEEDINGS -
IN: PRINCIPLES OF FIRE PREVENTION AND FIRE FIGHTING (SEE: F7300093)
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0020 PAGES, 0009 FIGURES, 0006 TABLES, 0008 REFERENCES

keys 1463 through 1464

# INVESTIGATION AND EVALUATION OF NONFLAMMABLE, FIRE-RETARDANT MATERIALS, FINAL REPORT

by

ATALLAH, S.
BUCCIGROSS, H.L.

11/00/72

-ABSTRACT-

A TEST PROGRAM WAS UNDERTAKEN TO EVALUATE FIRE PROTECTIVE MATERIALS AND TO TEST THEM IN FULL-SCALE HELICOPTER FIRES. THE GOAL WAS TO CONTAIN OR RESTRICT IN-FLIGHT OR POSTCRASH HELICOPTER FIRES TO ALLOW THE CREW AND PASSENGERS TO ESCAPE OR REMAIN WITHIN A LIVABLE ENVIRONMENT UNTIL THE FIRE COULD BE EXTINGUISHED OR THE BURNING FUEL CONSUMED. LABORATORY TESTS SHOWED THAT INTUMESCENT PAINTS PROVIDE INADEQUATE FIRE PROTECTION TO EXTERIOR WALLS IN HELICOPTER FIRES AND MOST OF THEM PRODUCE NOXIOUS FUMES. A NUMBER OF COMPOSITE MATERIAL SYSTEMS WERE FOUND PROMISING FOR INTERIOR WALL PROTECTION IN THE HELICOPTERS. VARIOUS COMBINATIONS OF ISOCYANURATE FOAMS, SODIUM SILICATE HYDRATE PANELS, A MINERAL INSULATION, AND INTUMESCENT MASTIC PAINTS WERE APPLIED TO THE WALLS OF TWO TEST HELICOPTERS AND FULL-SCALE FIRES SIMULATING IN-FLIGHT AND POSTCRASH FIRES WERE OBSERVED. THE IN-FLIGHT TESTS INDICATED THAT SODIUM SILICATE HYDRATE PANELS PLACED ON THE FIRE SIDE PROVIDED SUFFICIENT PROTECTION FOR A HABITABLE COMPARTMENT AGAINST A FIRE OCCURING IN AN ADJACENT COMPARTMENT. POSTCRASH FIRE TESTS SHOWED THAT TOTAL WALL PROTECTION OF EXISTING HELICOPTERS COULD NOT BE OBTAINED. PENETRATIONS OCCURRED IN THE CH-47 WALLS WHERE THE PRESENCE OF WIRING, AIR DUCTS AND HYDRAULIC OIL TUBES HAD PREVENTED THE APPLICATION OF ISOCYANURATE FOAM, AND IN THE UH-1D WALLS WHERE THE SODIUM SILICATE HYDRATE PANELS COLLAPSED BECAUSE OF THE ABSENCE OF STRUCTURAL SUPPORT. HEAT FLUXES AFTER 5 MIN. WERE TOO HIGH FOR HUMAN TOLERANCE, AND CONCENTRATIONS OF SMOKE AND TOXIC GASES WERE HIGH.

-PERTINENT FIGURES-

FIG. 34 LIGHT TRANSMISSION AT THE 4-FT AND 1-FT LEVELS DURING THE CH-47 POSTCRASH FIRE TEST PAGE 58//TAB. 1 FURNACE TEST RESULTS FOR PAINTS AND COATINGS PAGE 10//TAB. 2 FURNACE TEST RESULTS FOR INORGANIC INSULATIONS PAGE 13//TAB. 3 FURNACE TEST RESULTS FOR ORGANIC FOAMS PAGE 14

-SOURCE INFORMATION-

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OTHER INFORMATION -

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keys 1495 through 1496

# PRELIMINARY INVESTIGATION OF FUEL TANK ULLAGE REACTIONS DURING HORIZONTAL GUNFIRE

by

CLODFELTER, R.G.
OTT, E.E.

11/00/72

## -ABSTRACT-

TEST WERE CONDUCTED TO MEASURE THE EFFECT OF HORIZONTAL GUNFIRE ON THE FLAMMABILITY OF HYDROCARBON TURBINE FUEL IN AIRCRAFT FUEL TANKS. JP-4 AND JP-8 JET FUELS WERE USED IN THE TESTING. THE FUELS PLACED IN AN EXPLOSION PROFF TEST VESSEL AND SUBJECTED TO CAL. 50 (ARMOR-PIERCING INCINDIARY) GUNFIRE. SEVERAL TYPES OF TANKS WERE USED, AND MEASUREMENTS WERE MADE OF FUEL AND ULLAGE TEMPERATURES AND PRESSURES. RESULTS SHOWED THAT: (1) THERE IS A FUEL RICH FLAMMABILITY TEMPERATURE LIMIT FOR JP-4 JET FUEL, AT ATMOSPHERIC PRESSURE THIS LIMIT IS IN THE 51 DEG. F. TO 59 DEG. F. REGION AND AT 30 PSIA IT IS BETWEEN 89 DEG. F. AND 101 DEG. F.; AND (2) WITH JP-8 FUEL, THE ULLAGE IS IGNITABLE AT TEMPERATURES WELL BELOW THE FLASH POINT (105 DEG. F.) AND THE RESULTING OVERPRESSURE DECREASES WITH DECREASING TEMPERATURE. IT IS SUGGESTED THAT THE EQUILIBRIUM FUEL VAPOR CONCENTRATION IN THE ULLAGE IS INCREASED AS TEMPERATURE RISES, AND THAT ADDITIONAL FUEL IN THE FORM OF VAPOR OR SPRAY MAY ENTER THE ULLAGE AS THE GUFNIRE TESTS PROCEED FUEL UNDER EQUILIBRIUM CONDITIONS WHILE THE STANDARD LEAN LIMIT WAS EXTENDED FOR JP-8 FUEL AND THE RESULTING OVERPRESSURE DECREASED WITH DECREASING TEMPERATURE; (2) A VERY LEAN FUEL VAPOR ULLAGE WITH LIQUID PRESENT DOES NOT PREVENT COMBUSTION TRANSFER BETWEEN COMPARTMENTED FUEL TANKS; (3) HIGHER THAN EXPECTED OVERPRESSURE MAY RESULT IF UNBURENED GAS IS TRANSFERRED FROM THE HIT COMPARMENT TO THE WALL INTERCONNECTED COMPARTMENT; AND (4) THE NONEQUILIBRIUM CONDITIONS OF AIRCRAFT FUEL TANKS INCREASE THE FLAMMABILITY HAZARD. FURTHER INVESTIGATIONS OF NONEQUILIBRIUM CONDITIONS AND THEIR EFFECTS WERE RECOMMENDED.

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CORPORATE SOURCE -
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REPORT NUMBER -
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OTHER INFORMATION -
0073 PAGES, 0022 FIGURES, 0009 TABLES, 0000 REFERENCES

# THE EFFECT OF ICING INHIBITOR AND COPPER PASSIVATOR ADDITIVES ON THE FLAMMABILITY PROPERTIES OF HYDROCARBON FUELS

by

AFFENS, W.A.
MCLAREN, G.W.

08/00/72

-ABSTRACT-

tHE NAVY IS USING BENZOTRIAZOLE (bt) COPPER PASSIVATOR AND ETHYLENE GLYCOL MONOMETHYL ETHER (egme) ICING INHIBITOR AS ADDITIVES IN jp-5 JET FUEL. a STUDY WAS MADE TO DETERMINE THE EFFECT OF THESE ADDIVITIES AT INTENDED USE CONCENTRATIONS OF 5-7 PPM bt, AND 0.1-0.15 PERCENT V/V egme, ON THE FLAMMABILITY PROPERTIES OF HYDROCARBON FUELS. bY MEASUREMENTS OF FLASH POINT AND FLAMMABILITY INDEX, IT WAS OBSERVED THAT ALTHOUGH bt DID NOT APPEAR TO AFFECT THE FLAMMABILITY OF HYDROCARBON FUELS AT INTENDED USE CONCENTRATIONS, THE egme INCREASED THE FLAMMABILITY, aT A CONCENTRATION OF 0.15 PERCENT egme, THE FLASH POINT OF jp-5 JET FUEL, FOR EXAMPLE, WAS REDUCED BY 7 DEG. f., AND THE FLAMMABILITY INDEX WAS INCREASED BY 11 PERCENT. tHESE RESULTS WERE MUCH GREATER THAN WOULD BE PREDICTED FOR IDEAL HYDROCARBON SOLUTIONS.

-SOURCE INFORMATION-

CORPORATE SOURCE -
NAVAL RESEARCH LAB., WASHINGTON, D.C.
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OTHER INFORMATION -
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key 1616

# THE FEASIBILITY OF BURNER-CAN BURN-THROUGH THERMAL DETECTION PRIOR TO ENGINETCASE RUPTURE. FINAL REPORT.

by

HILL, R.

01/00/73

-ABSTRACT-

FIRE TESTS WERE PERFORMED TO DETERMINE THE FEASIBILITY OF DETECTING A BURNER-CAN BURN-THROUGH PRIOR TO AN ENGINE CASE RUPTURE BY MONITORING JET- ENGINE DIFFUSER CASE AND BURNER CASE SKIN TEMPERATURES. A J57 ENGINE WAS MOUNTED IN A B57 AIRPLANE, AND HOLES WERE CUT IN THE DIFFUSER CASE AND IN THE FUEL LINES, ALLOWING FUEL TO FLOW INTO PARTS OF THE ENGINE NOT DESIGNED FOR COMBUSTION. FOUR THERMOCOUPLES WERE SPACED 90 DEG. APART AROUND THE DIFFUSER CASE. THE ENGINE WAS THEN ACCELERATED TO FULL POWER AND SHORTLY AFTER BURN-THROUGH THE ENGINE WAS SHUT DOWN. THE RESULTS SHOWED THAT THE THERMOCOUPLES IN THE GENERAL PROXIMITY (WITHIN 45 DEG.) OF THE BURN-THROUGH RECORDED A RAPID AND LARGE INCREASE IN TEMPERATURE BEGINNING 40 SEC. PRIOR TO BURN-THROUGH. THE THERMOCOUPLES LOCATED APPROXIMATELY 150 DEG. AROUND THE ENGINE FROM THE BURN-THROUGH ALSO SHOWED AN INCREASE IN SKIN TEMPERATURE, BUT OF A MUCH LOWER MAGNITUDE. EVEN IN A FULLY-COWLED-ENGINE TEST, A RAPID TEMPERATURE RISE SHORTLY BEFORE BURN-THROUGH WAS FOUND. IT WAS CONCLUDED THAT IT IS POSSIBLE TO DETECT A BURNER-CAN BURN-THROUGH PRIOR TO ENGINE CASE RUPTURE BY MONITORING DIFFUSER CASE AND/OR BURNER CAN CASE SKIN TEMPERATURE. AS FEW AS 4 THERMOCOUPLES SPACED 90 DEG. APART ON THE DIFFUSER CASE, AND/OR THE BURNER-CAN CASE, CAN DETECT A BURNER-CAN BURN-THROUGH PRIOR TO ENGINE CASE RUPTURE.

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# RELATIVE TOXICITY OF SELECTED POLYMERIC MATERIALS DUE TO THERMAL DEGRADATION

by

EPSTEIN, G.
HEICKLEN, J.

12/15/69

-ABSTRACT-

THE TOXICITY OF PYROLYSIS PRODUCTS OF POLYMERIC MATERIALS IS A HAZARD IN AIRCRAFT AND OTHER INTERIORS FINISHED WITH THESE MATERIALS. SEVERAL OF THESE HEAT RESISTANT MATERIALS WERE STUDIED IN ORDER TO DETERMINE THE TOXICITY OF THEIR PRODUCTS OF THEMAL DEGRADATION. A MATHEMATICAL EXPRESSION FOR THE RELATIONSHIP BETWEEN DECOMPOSITION RATE AND TEMPERATURE, AS WELL AS THE CONCENTRATION OF THE VARIOUS DECOMPOSITION PRODUCTS AND THEIR TOXICITY, IS PRESENTED. THIS THERMAL-DECOMPOSITION-TOXICITY INDEX IS A DIRECT MEASURE OF THE HAZARD DUE TO TOXIC PRODUCT PRODUCTION. DATA ARE PRESENTED ON THE DECOMPOSITION RATES OF SEVERAL MATERIALS AT VARYING TEMPERATURES UP TO 700 DEG. F. THE MATERIALS STUDIED ARE RANKED IN THE FOLLOWING LIST FROM THE LOWEST TO THE HIGHEST VALUES OF THE THERMAL-DECOMPOSITION-TOXICITY INDEX: (1) TEFLON TFE, (2) TEFLON FEP, (3) KAPTON POLYIMIDE FILM, (4) VITON, (5) PERFLUOROPROPYLENE POLYMER, AND (6) CARBOXY NITROSO RUBBER.

-SOURCE INFORMATION-

CORPORATE SOURCE -
AEROSPACE CORP., EL SEGUNDO, CALIF.
REPORT NUMBER -
AD-703711//TR-0066(5250-20)-3//SAMSO-TR-70-115
SPONSOR -
SPACE AND MISSILE SYSTEMS ORGANIZATION, LOS ANGELES AIR FORCE STATION, CALIF
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# THE ACUTE TOXICITY OF BRIEF EXPOSURES TO HYDROGEN FLOURIDE; HYDROGEN CHLORIDE, NITROGEN DIOXIDE, AND HYDROGEN CYANIDE SINGLY AND IN COMBINATION WITH CARBON MONOXIDE

by

DIPASQUALE, L.C.
DAVIS, H.V.

12/00/71

## -ABSTRACT-

THE TOXICITY OF PYROLYSIS PRODUCTS PRODUCED DURING THE COMBUSTION OF AIRCRAFT INTERIOR MATERIALS SUCH AS POLYURETHANE FOAMS WAS STUDIED IN EXPERIMENTS WITH RATS AND MICE. THE TOXIC GASES USED IN THE EXPERIMENTS WERE HYDROGEN CHLORIDE, HYDROGEN FLUORIDE, HYDROGEN CYANIDE, AND NITROGEN DIOXIDE, USED BOTH SINGLY AND IN COMBINATION WITH CARBON MONOXIDE. RESULTS ENABLED THE DETERMINATION OF LETHAL DOSE VALUES FOR FIVE-MIN. EXPOSURES TO EACH OF THE TOXIC GASES. THE FOLLOWING LIST RANKS THE TOXIC GASES IN ORDER OF THEIR FIVE-MIN. LETHAL DOSE VALUES, FROM MOST TOXIC TO-LEAST TOXIC: (1) HYDROGEN CYANIDE, (2) NITROGEN DIOXIDE, (3) HYDROGEN FLOURIDE, AND (4) HYDROGEN CHLORIDE. IT WAS CONCLUDED THAT BY KNOWING THE RELATIVE AMOUNTS PER UNIT MASS OF SPECIFIC TOXIC PRODUCTS, ONE CAN COMPARE THE HAZARDS OF VARIOUS AIRCRAFT CABIN MATERIALS. THE RESULTS ALSO SHOWED THAT CARBON MONOXIDE CONCENTRATIONS WHICH ARE NOT HAZARDOUS TO LIFE DO NOT ENHANCE THE TOXICITY OF THE FOUR COMPOUNDS AS TESTED.

## -SOURCE INFORMATION-

CORPORATE SOURCE -
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SPONSOR -
AEROSPACE MEDICAL RESEARCH LABS., WRIGHT-PATTERSON AFB, OHIO.
CONTRACT NUMBER -
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OTHER INFORMATION -
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key 1680

# DEVELOPMENT OF NONFLAMMABLE FIBROUS MATERIALS

by

ROSS, J.H.

01/00/69

-ABSTRACT-

POLYBENZIMIDAZOLE (PBI) FIBERS HAVE BEEN FOUND FLAME RESISTANT AND COMFORTABLE FOR USE IN PROTECTIVE CLOTHING. A SERIES OF TESTS TO FIND A FLAME RESISTANT FIBER WERE INITIATED BECAUSE OF THE MELTING AND FUSING OF MATERIALS USED IN AIRCRAFT INTERIORS, PARACHUTES, AND CLOTHING. NOMEX NYLON WAS THE FIRST FLAME RESISTANT FABRIC TO BE STUDIED, BUT ITS PRIMARY DISADVANTAGE WAS LOW MOISTURE REGAIN WHICH CAUSED A CLAMMINESS IN CLOTHING MADE FROM THE FIBER. NEVERTHELESS, IT WAS FOUND THAT 2 LAYERS OF 7.25 OZ./SQ.YD. NOMEX WOULD PROVIDE BETTER PROTECTION THAN A DOUBLE LAYER OF FLAME RETARDANT COTTON FABRIC THAT HAD A WEIGHT OF 21.7 OZ./SQ. YD. OTHER THERMALLY STABLE POLYMERIC FIBERS, INCLUDING THOSE MADE WITH POLYAMIDES, POLYIMIDES, AND POLYBENZIMIDAZOLE, WERE STUDIED. PBI FIBERS WERE FOUND TO BE FLAME RESISTANT AND THE MOST COMFORTABLE. DATA ARE PRESENTED COMPARING PBI FIBERS AND OTHER FLAME RESISTANT FIBERS. THE HIGH MOISTURE REGAIN OF 13 PERCENT FOR PBI FIBER IS EQUIVALENT TO COTTON AND AN INDICATION THAT THE FIBER WOULD TRANSMIT MOISTURE AND THUS BE COMFORTABLE AS A CLOTHING FABRIC.

-PERTINENT FIGURES-

TAB. 3 PRESSURE-TEMPERATURE EFFECTS PERCENT LOSS IN STRENGTH AGED AT 350 DEG. F. PAGE 21//TAB. 4 EFFECT OF HEATED AIR ON VARIOUS FABRICS, AIR VELOCITY-225 FT./MIN. 1200 DEG. F. PAGE 22

-SOURCE INFORMATION-

CORPORATE SOURCE -
AIR FORCE MATERIALS LAB., WRIGHT-PATTERSON AFB, OHIO.
JOURNAL PROCEEDINGS -
MNTXAF, MOD TEXT, VOL. 50, NO. 1, 18-23, 32 (JAN. 1969)
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key 1686

# MODIFICATION OF JET FUELS TO DECREASE THE FIRE HAZARD IN SURVIVABLE AIRCRAFTTCRASHES

by

ERICKSON, R.E.
KRAJEWSKI, R.M.
COHRS, W.E.

03/26/72

-ABSTRACT-

SOME HIGHLIGHTS OF THE DEVELOPMENT OF MODIFIED JET FUELS TO REDUCE THEIR FIRE HAZARDS ARE BRIEFLY REVIEWED. THE SPECIFIC FUEL MODIFIED WAS BASED ON JET A-1, THICKENED WITH A HYDROCARBON POLYMER. THE MISTING TENDENCY WAS REDUCED IN THE SHEAR RANGE ASSUMED TO BE ENCOUNTERED IN A SURVIVABLE AIRCRAFT CRASH ENVIRONMENT. THE CALORIFIC VALUE OF THE FUEL WAS NOT DECREASED. PRELIMINARY TESTS SHOWED ADEQUATE COMBUSTION IN THE BURNER CAN. FLOW RATES WERE INCREASED SIGNIFICANTLY COMPARED TO THE FORMER THICK GELS AND EMULSIONS. PREVIOUS CORROSION TEST DATA SHOWED NO PROBLEMS WITH VARIOUS GRADES OF ALUMINUM, MAGNESIUM, BRASS, TITANIUM, AND STEEL. A NOTICEABLE DECREASE IN FLAME SPREAD RATE IS ACHIEVED. THE POLYMER ADDITIVE IS A FINE POWDER AND CAN READILY BE DISPERSED IN THE JET FUEL WITH AGITATION AT AMBIENT TEMPERATURE. NO ADDITIONAL ECOLOGICAL PROBLEMS ARE ANTICIPATED SINCE THE FUEL MODIFIERS WILL PRODUCE CARBON MONOXIDE AND WATER WHEN DECOMPOSED DURING COMBUSTION. PRELIMINARY FIRE FIGHTING TESTS INDICATED NO CHANGE REQUIRED IN CONVENTIONAL METHODS.

-SOURCE INFORMATION-

CORPORATE SOURCE -
DOW CHEMICAL CO., MIDLAND, MICH.
JOURNAL PROCEEDINGS -
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# AIRCRAFT GROUND FIRE SUPPRESSION AND RESCUE SYSTEMS-BASIC RELATIONSHIPS IN MILITARY FIRES. PHASES 1 AND 2. INTERIM REPORT-12 JANUARY TO 1 SEPTERMBER 1971

by

ALGER, R.S.
CAPENER, E.L.

04/00/72

## -ABSTRACT-

EXPERIMENTAL POOL FIRES OF JP-5 JET FUEL 3 FT. AND 10 FT. IN DIA. WERE INSTRUMENTED TO MEASURE HEAT FLUXES, BURNING RATES, AND SUPPRESSION CHARACTERISTICS. TEST SUBSTRATES INCLUDED WATER, SAND, AND GRAVEL. IN THESE TESTS THE IDEAL EXTINGUISHMENT SYSTEM WAS DESIGNED TO GIVE A UNIFORM RATE OF APPLICATION OVER THE BURNING FUEL SURFACE. THE SUPPRESSANT SPRAY WAS CHARACTERIZED AS TO UNIFORMITY, AVERAGE DROP SIZE, AND INTERACTION KINETICS WITH THE FUEL SURFACE. RADIATION FLUXES AT VARYING DISTANCES FROM THE FIRE WERE AFFECTED BY WIND VELOCITY, LOCATION OF MEASURING STATION, TYPE OF SUBSTRATE AND THE WATER CONTENT OF THE SUBSTRATE. FUEL BURNING RATES WERE INFLUENCED BY WIND VELOCITY AND SUBSTRATE CHARACTERISTICS. SUPPRESSION WITH 6 PERCENT AQUEOUS FILM FORMING FOAM SOLUTION WAS FOUND TO BE INFLUENCED PRIMARILY BY THE FIRE SIZE AND, SECONDLY, BY THE TYPE OF SUBSTRATE. TEST PLANS FOR THE 50 FT. BY 50 FT. FIRES WERE COMPLETED AND THE WORK INITIATED. SITE PREPARATIONS HAVE BEGUN FOR THE 100 FT. BY 100 FT. FIRES.

## -PERTINENT FIGURES-

FIG. 2.2 FLAME TEMPERATURES IN JP5 FIRE-POOL SIZE 8 BY 16 FT. PAGE 10//FIG. 2.3 BURNING RATES AND FLAME HEIGHTS OF LIQUID FUEL FIRES PAGE 15//FIG. 2.13 EFFECT OF APPLICATION RATE ON THE AREA EXTINGUISHED AS A FUNCTION OF TIME FOR A 35 FT. BY 63 FT. TEST FIRE PAGE 36//TAB. 4.3 AQUEOUS FILM FORMING FOAM SUPPRESSANT RATE VS POSITION OF SAMPLING BEAKERS IN 3 FT. PAN PAGE 98//TAB. 4.7 EXTINGUISHMENT OF 10 FT. FIRES ON SAND SUBSTRATES PAGE 108

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MENLO PARK, CALIF.
REPORT NUMBER -
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SPONSOR -
AIRCRAFT GROUND FIRE SUPPRESSION AND RESCUE, WRIGHT-PATTERSON AFB, OHIO. TRI-SERVICE SYSTEM PROGRAM OFFICE.
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key 1848

# THE IGNITION OF FLAMMABLE LIQUIDS BY HOT SURFACES

by

GOODALL, D.G.
INGLE, R.

00/00/67

-ABSTRACT-

A SERIES OF TESTS WERE CONDUCTED TO STUDY THE EFFECTS OF CERTAIN PARAMETERS ON THE IGNITION OF FLAMMABLE LIQUIDS BY CONTACT WITH HOT SURFACES. THE EXPERIMENTAL CONFIGURATIONS SIMULATED THE SPACE BETWEEN THE UPPER SURFACE OF AN AIRCRAFT ENGINE AND THE ADJACENT COWLING IN WHICH THE IGNITION RISK WAS ASSUMED TO RESULT FROM A FLAMMABLE LIQUID LEAK. RESULTS OF THIS WORK SHOWED THAT THE RISK OF SPONTANEOUS IGNITION IN ANY GIVEN APPLICATION IS DETERMINED BY THE TEMPERATURE OF A CRITICAL VOL. OF MIXTURE RATHER THAN BY A HOT SURFACE TEMPERATURE AND THAT THE SURFACE TEMPERATURE IS A CONTROLLING FACTOR ONLY IN SO FAR AS IT AFFECTS THE TEMPERATURE OF ANY FLAMMABLE MIXTURE. IT IS POSSIBLE, THEREFORE, TO JUSTIFY CURRENT AIRCRAFT PRACTICE IN WHICH IT IS CONSIDERED SAFE TO OPERATE WITH LOCAL SURFACES MUCH HOTTER THAN CLOSED -VESSEL IGNITION TESTS WOULD INDICATE. WHERE ALL THE SURFACES OF THE ENCLOSURE ARE AT A HIGH TEMPERATURE, AS IN SUPERSONIC AIRCRAFT SPACES OR WHERE THE TEMPERATURE OF VENTILATING AIR IS HIGH, SPONTANEOUS IGNITION WILL BE POSSIBLE AT TEMPERATURES APPROACHING THOSE OF CLOSED VESSELS OF SIMILAR SIZE. HOWEVER, IT MAY BE POSSIBLE TO RAISE THE IGNITION LIMIT BY CONSIDERING TRANSIT TIME IN THESE CASES, BUT ANY STAGNANT REGIONS WILL CONSTITUTE AN IGNITION HAZARD AT TEMPERATURES NEAR THOSE FOR CLOSED VESSELS. CALCULATIONS OF MIXTURE TEMPERATURE GRADIENTS ADJACENT TO HOT SURFACES MAY YET PROVE TOO COMPLICATED TO BE PRACTICABLE, PARTICULARLY WHERE INCIDENTAL OR DELIBERATE AIRFLOWS ARE PASSING OVER IRREGULARLY SHAPED SURFACES, SUCH AS THAT FORMED BY A FLANGED PIPE JOINT.

-PERTINENT FIGURES-

FIG. 3 STATIC HOT PLATE RIG, IGNITION BOUNDARIES FOR VARIOUS LIQUIDS PAGE 119//FIG. 5 WIND TUNNEL RIG, IGNITION BOUNDARY AT ALTITUDE PAGE 122

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# A STUDY OF THE DECOMPOSITION PRODUCTS OF POLYURETHANE FOAM RELATED TO AIRCRAFT CABIN FLASH FIRES. FINAL REPORT

by

PAABO, M.
CCMEFORD, J.J.

07/00/73

-ABSTRACT-

A LABORATORY MODEL OF A FLASH FIRE CELL USING A HIGH VOLTAGE ARC AS AN IGNITION SOURCE WAS ASSEMBLED AND TESTED. THE CELL IS DESIGNED TO PYROLYZE THE SAMPLE IN AIR WHILE MEASURING THE TIME OF ONSET OF A FLASH FIRE AND SIMULTANEOUSLY ALLOWING WITHDRAWAL OF GAS SAMPLES FOR ANALYSIS. SOME OF THE LOW MOLECULAR WT. PRODUCTS PRODUCED FROM THE PYROLYSIS OF FLEXIBLE POLYETHER TYPE URETHANE FOAMS WERE IDENTIFIED. THE FLASH FIRE CELL WAS USED TO COMPARE THE FLASH FIRE POTENTIAL OF POLYMERS OF POTENTIAL INTEREST TO THE AIRCRAFT INDUSTRY. STUDIES OF THE ROLE OF SMOKE IN FLASH FIRE PRODUCED IN THE PYROLYSIS OF FLEXIBLE URETHANES WERE UNDERTAKEN. FLASH FIRES IN THE CELL WERE RECORDED ON 16 MM. MOTION PICTURE FILM. IT WAS CONCLUDED THAT: 1) A LAB. SCALE MODEL CAN PROVIDE A SMALL SCALE SYSTEM WITH APPROPRIATE INSTRUMENTATION FOR OBTAINING PRECISE GAS ANALYSIS DATA ULTIMATELY LEADING TO AN UNDERSTANDING OF FLASH FIRES, 2) A LAB. MODEL CAN BE USED TO INTERCOMPARE FLASH FIRE POTENTIAL OF POLYMERS, AND 3) OF THE LIMITED NO. OF MATERIALS TESTED TO EVALUATE THE MODEL, POLYURETHANE AND LATEX FOAMS WOULD APPEAR TO DEVELOP A FLASH FIRE MOST READILY.

-PERTINENT FIGURES-

TAB. 2 POLYURETHANE PYROLYSIS PRODUCTS PAGE 17//TAB. 5 INTERCOMPARISON OF MATERIALS-FLASH FIRE POTENTIAL PAGE 29

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NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. BUILDING FIRES AND SAFETY SECTION.
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# HEAT RADIATION FROM FIRES OF AVIATION FUELS

by

FU, T.T.

12/08/72

## -ABSTRACT-

FIRE TESTS WERE CONDUCTED TO MEASURE THE STEADY STATE HEAT RADIATION FROM FREE BURNING AIRCRAFT FUELS. THE PURPOSE OF THE TESTS WAS TO STUDY THE EFFECTS OF DIFFERENT DIA. OF POOL FIRES ON HEAT RADIATION, AND TO OBSERVE THE EFFECTS OF WIND AND WATER SPRAYS. JP-4 AND JP-5 JET FUELS AND AV GAS (AVIATION GASOLINE) WERE USED IN POOL FIRES OF 3 TO 8 FT. IN DIA. DATA WERE OBTAINED FOR THE AVERAGE VERTICAL AND HORIZONTAL RADIATION PROFILES. THE RESULTS SHOWED THAT RADIATION DEPENDED STRONGLY ON THE DISTANCE-TO -DIAMETER RATIO, BUT ONLY WEAKLY ON THE DIA. THE RESULTS OF THE WIND TUNNEL EXPERIMENTS SHOWED THAT WIND CAUSED SIGNIFICANT RADIATION INCREASES IN THE DOWNWIND DIRECTION OF A FIRE, BUT DECREASED THE DATA SCATTER COMPARED WITH NO-WIND DATA. THE MAGNITUDE OF THIS INCREASE AT VARIOUS WIND SPEEDS WAS RELATIVELY SMALL, HOWEVER. WIND AFFECTED THE RADIATION LEVEL SLIGHTLY IN THE UPWIND AND CROSS WIND DIRECTIONS. THE RESULTS OF THE WATER SPRAY EXPERIMENTS SHOWED THAT WATER SPRAY CAN SOMETIMES EXTINGUISH RELATIVELY SMALL FIRES, AND THAT THE HEAT ATTENUATION EFFECT OF THE SPRAY IS APPRECIABLE.

## -PERTINENT FIGURES-

FIG. 5 EFFECT OF WATER SPRAY ON RADIATION-4DJP5 FIRE PAGE 14//FIG. 10 WIND EFFECTS ON RADIATION PAGE 19

## -SOURCE INFORMATION-

CORPORATE SOURCE -
NAVAL CIVIL ENGINEERING LAB., PORT HUENEME, CALIF.
JOURNAL PROCEEDINGS -
EAST SECT, COMBUST INST, FALL MEETING, PRINCETON UNIV., PRINCETON, N.J. (DEC. 7-8, 1972)
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# WHAT PLASTICS FOR THE NEW AIRCRAFT?

by

WRIGHT, V.

11/00/69

-ABSTRACT-

THE INCREASING USE OF PLASTICS IN AIRCRAFT INTERIORS POSES FALMMABILITY AND SMOKE GENERATION HAZARDS. THE FEDERAL AVIATION ADMINISTRATION (FAA) HAS BEEN CONSIDERING ISSUING PERFORMANCE STANDARDS FOR MATERIALS USED IN INTERIOR FINISHES, AND SEVERAL NEW MATERIALS HAVE BEEN DEVELOPED IN ANTICIPATION OF THE STANDARDS. NOMEX FIBER CAN BE CONVERTED TO A LIGHTWEIGHT HONEYCOMB CORE WHICH CAN BE BONDED BETWEEN 2 FACES TO FORM A SANDWICH PANEL WHICH OFFERS THE HIGHEST STRENGTH-TO-WEIGHT AND RIGIDITY-TO-WEIGHT RATIOS CURRENTLY ATTAINABLE. DATA FROM FAA TESTS ARE PRESENTED WHICH SHOW THAT OTHER PROMISING MATERIALS INCLUDE VARIOUS NYLON FORMULATIONS, POLYCARBONATES, AND POLYSULFONES. THE CRITERIA USED BY FAA IN SELECTING MATERIALS APPROPRIATE FOR AIRCRAFT INTERIORS INCLUDE: (1) HIGH RESISTANCE TO IGNITION AND FLAME PROPAGATION; (2) HIGH IGNITION TEMPERATURE AND LOW RATE OF COMBUSTION AND TOTAL HEAT; (3) HIGH TEMPERATURE AT WHICH SMOKE IS PRODUCED, AND LOW RATE AND AMOUNT OF SMOKE GENERATION; (4) HIGH FLASHPOINT TEMPERATURE AND LOW COMBUSTIBILITY OF GASES RELEASED; (5) HIGH TEMPERATURE THERMAL DECOMPOSITION AND GASEOUS PRODUCTS OF COMBUSTION HAVING LOW TOXICITY. SEVERAL TEST METHODS ARE DESCRIBED. LABORATORY TESTS HAVE BEEN CONDUCTED BY FAA'S NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER ON APPROXIMATELY 150 AIRCRAFT MATERIALS. ADDITIONAL TESTS WERE CARRIED OUT BY THE NATIONAL BUREAU OF STANDARDS.

-PERTINENT FIGURES-

TAB. 2 COMPARATIVE BURNING TESTS ON REPRESENTATIVE PLASTIC MATERIALS PAGE 81

-SOURCE INFORMATION-

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OTHER INFORMATION -
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key 1992

# A FIRE PROBLEM IN AIRCRAFT ACCIDENT INVESTIGATION

by

WILLIAMS-LEIR, G.

01/00/66

## -ABSTRACT-

IN THE WRECKAGE OF CRASHED AIRCRAFT, FRAGMENTS ARE OFTEN FOUND TO SHOW SIGNS OF FIRE, AND IT MAY BE OF GREAT IMPORTANCE TO DETERMINE WHETHER FIRE PRECEDED OR FOLLOWED THE CRASH. IF A CERTAIN NUMBER OF FIRE-MARKED FRAGMENTS SHOULD BE FOUND TO FIT ON TO ONE ANOTHER, THIS MAY BE DUE TO CHANCE OR TO MARKING BEFORE FRACTURE. AFTER FRAGMENTS HAVE BEEN COLLECTED AND COUNTED, AN EQUATION CAN BE USED TO CALCULATE THE PROBABILITY THAT THE MARKED PIECES THAT FIT TOGETHER IN A CONTIGUOUS MANNER DO SO BY CHANCE EFFECTS. IF THIS PROBABILITY THAT THE PIECES FIT TOGETHER BY CHANCE IS LOW, THE EVIDENCE FAVORS THE SUPPOSITION THAT THEY RECEIVED THEIR MARKING BEFORE FRACTURE.

## -SOURCE INFORMATION-

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# THE PERFORMANCE OF SOME PORTABLE GAS DETECTORS WITH AVIATION FUEL VAPOURS AT ELEVATED TEMPERATURE. PART 2. TESTS WITH AVCAT, KERO B AND AVTUR VAPOURS

by

FARDELL, P.J.

01/00/73

-ABSTRACT-

TESTS WERE CONDUCTED TO MEASURE THE PERFORMANCE OF SOME PORTABLE GAS DETECTORS WITH AVIATION FUEL VAPORS AT ELEVATED TEMPERATURES. THE FUEL USED WERE AN AVIATION TURBINE FUEL (AVCAT), A KEROSENE FUEL (KERO B) AND JP-1 JET FUEL (AVTUR). THE TESTS WERE CONDUCTED AT 65 DEG. C. VARIOUS CONCENTRATIONS OF FUEL VAPOR IN AIR WERE PASSED INTO AN EXPLOSION LIMITS TUBE AND SUBJECTED TO AN ELECTRICAL SPARK. WHEN A VAPOR CONCENTRATION WAS FOUND WHICH, WHEN EXCEEDED, GAVE RISE TO A SELF-PROPAGATING FLAME, THIS WAS TAKEN AS THE LOWER EXPLOSION LIMIT (LEL) CONCENTRATION. THE LEL MIXTURE WAS THEN PASSED THROUGH THE DETECTOR AND THE READING CHECKED IN EACH CASE. RESULTS SHOWED THAT THE RESPONSE OF THE DETECTORS WAS LOW. IT WAS RECOMMENDED THAT A VAPOR BE FOUND WHICH, WHEN USED TO CALIBRATE THE DETECTORS, WOULD INSURE CORRECT OR HIGH (AND THUS ERRING ON THE SIDE OF SAFETY) READINGS WITH THESE FUELS.

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0013 PAGES, 0008 FIGURES, 0003 TABLES, 0001 REFERENCES

key 2021

# STATIC ELECTRICITY IN FUELING OF SUPERJETS

by

BACHMAN, K.C.
DUKEK, W.G.

00/00/72

## -ABSTRACT-

HIGHER FUELING RATES FOR JUMBO JET AIRPLANES MAY PRESENT A GREATER RISK OF IGNITION BY STATIC ELECTRICITY. TESTS WERE CONDUCTED WITH A FULL-SCALE FUELING RIG TO STUDY STATIC ELECTRICITY IN SUPERJET FUELING. FILTERING OF FUEL TO REMOVE WATER AND PARTICULATE MATTER CAN LEAD TO GENERATION OF STATIC CHARGE BECAUSE THE IONIZABLE MATERIALS PRESENT IN THE FUEL OR TRAPPED ON THE FILTER-SEPARATOR SURFACES LEAD TO CHARGE SEPARATION. BONDING BETWEEN FUELING EQUIPMENT AND THE AIRCRAFT AND EXTERNAL GROUNDING ARE ESSENTIAL TO MAINTAIN THE AIRCRAFT AT THE SAME POTENTIAL AS GROUND EQUIPMENT. IN THE TESTS, MEASUREMENTS WERE MADE OF CHARGE DENSITY, CURRENT FLOW BETWEEN TANK AND GROUND, FIELD STRENGTH AT THE TOP OF THE TANK, SPARK DISCHARGE, AND SPARK ENERGY IN THE DISCHARGES. RESULTS SHOWED THAT DISCHARGES INCREASED WITH INCREASING CHARGE DENSITY. UNDER NORMAL CONDITIONS, IT WAS FOUND THAT AT MAXIMUM FUELING RATE: (1) NO SPARKS WERE PRODUCED UNDER CONDITIONS SIMULATING A MANIFOLD INLET AS USED IN SUPERJETS TO DISTRIBUTE FUEL INTO SEVERAL COMPARTMENTS; (2) SPARKS WERE PRODUCED, HOWEVER, WHEN FUELING THROUGH A SINGLE SUBMERGED INLET AT CHARGE DENSITY LEVELS ABOVE 70 MICRO COULOMBS PER CU. M.; AND (3) MAXIMUM SPARK ENERGIES CONCURRENT WITH CHARGE DENSITIES UP TO 370 MICRO COULOMBS PER CU. M. WERE LESS THAN 0.06 MILLIJOULES (LESS THAN 1/4TH OF THE MINIMUM IGNITION ENERGY FOR HYDROCARBON/ AIR MIXTURES). IT WAS CONCLUDED THAT MANIFOLDING A FUEL INLET IS HIGHLY EFFECTIVE IN MINIMIZING THE STATIC HAZARD.

## -PERTINENT FIGURES-

FIG. 8 SPARK GENERATION, SPARK ENERGY (BASED ON IGNITION TESTS) AND CHARGE DENSITY VS FUEL CONDUCTIVITY PAGE 150//TAB. 1 SPARK DISCHARGES VS CHARGE DENSITY PAGE 149

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CORPORATE SOURCE -
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# AIRCRAFT FUEL SYSTEM FIRE AND EXPLOSION PROTECTION CONCEPTS

by

CLODFELTER, R.G.

09/27/71

## -ABSTRACT-

A DESCRIPTION IS GIVEN OF AIRCRAFT FUEL SYSTEM VULNERABILITY TO GUNFIRE, TECHNIQUES THAT ARE AVAILABLE OR UNDER DEVELOPMENT TO COUNTERACT THE FIRE AND EXPLOSION THREAT, AND IMPLICATIONS CONCERNING FUTURE REQUIREMENTS. THE FIRE HAZARD POSED BY GUNFIRE IS THE HIGH FLAMMABILITY OF THE FUEL-AIR MIXTURE WHEN THE FUEL TANK IS VENTED. IT IS REPORTED THAT GIVEN THE APPROPRIATE FUEL-AIR MIXTURE, INTERNAL PRESSURES APPROXIMATELY 8 TIMES THE INITIAL AMBIENT PRESSURE CAN BE GENERATED IN LESS THAN 100 M.SEC. RESULTING IN MASSIVE, EXPLOSIVE STRUCTURAL FAILURE. SEVERAL AIRCRAFT FIRE AND EXPLOSION PROTECTION TECHNIQUES ARE DESCRIBED, INCLUDING: (1) FLAME ARRESTORS USED INSIDE THE FUEL TANK, SUCH AS LIGHTWEIGHT OPEN-CELL POLYURETHANE FOAM; (2) INERTING OF FUEL TANK ULLAGE, EITHER BY MEANS OF LIQUID NITROGEN OR BY CATALYTIC COMBUSTION INERTING; (3) EXPLOSION SUPPRESSION BY CHEMICAL MEANS SUCH AS HALOGENATED HYDROCARBONS; AND (4) EXPLOSION SUPPRESSION BY ULLAGE FUEL ENRICHMENT, THUS EXCEEDING THE UPPER FLAMMABILITY LIMIT. THE VULNERABILITY OF VARIOUS AVIATION FUELS TO GUNFIRE IS DISCUSSED. A SUMMARY OF RECOMMENDATIONS IS PRESENTED FOR ENHANCING AIRCRAFT FIRE PROTECTION.

## -PERTINENT FIGURES-

FIG. 1 FLAMMABILITY LIMITS VS TEMPERATURE FOR TYPICAL HYDROCARBON FUEL IN AIR PAGE 11//FIG. 2 FLAMMABILITY LIMITS OF FUELS OF DIFFERENT VOLATILITY PAGE 12//FIG. 3 C-130A WING TANKS (80 PERCENT VOID CONCEPT) PAGE 13

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# SUPPRESSION OF EVAPORATION OF HYDROCARBON LIQUIDS AND FUELS BY AQUEOUS FILMS

by

LEONARD, J.T.
BURNETT, J.C.

00/00/72

-ABSTRACT-

TESTS WERE CONDUCTED TO DETERMINE THE EFFECTIVENESS OF AQUEOUS FILMS CONTAINING A FLUOROCARBON SURFACTANT IN SUPPRESSION OF EVAPORATION OF HYDROCARBON LIQUIDS AND FUELS. THE HYDROCARBON LIQUIDS INCLUDED THE HOMOLOGOUS SERIES OF N-ALKANES FROM PENTANE TO DODECANE, AROMATIC COMPOUNDS, MOTOR AND AVIATION GASOLINES, AND JET FUELS JP-4 AND JP-5. FILMS OF THE SURFACTANT SOLUTION, IN VARIOUS THICKNESSES, WERE PLACED ON THE SURFACE OF THE HYDROCARBON LIQUID TO TEST THE ABILITY OF THE FILM TO SUPPRESS EVAPORATION OVER A 1-HR. PERIOD. RESULTS INDICATED THAT FOR THE N-ALKANES AND THE HYDROCARBON FUELS THE EVAPORATION RATES WERE SUPPRESSED IN EXCESS OF 90 PERCENT. A CERTAIN CRITICAL THICKNESS OF SURFACTANT SOLUTION WAS REQUIRED FOR OPTIMUM VAPOR SUPPRESSION, INCREASING WITH THE VOLATILITY OF THE HYDROCARBON. IT WAS FOUND MUCH MORE DIFFICULT TO SUPPRESS EVAPORATION OF THE AROMATIC COMPOUNDS BECAUSE OF THE GREATER SOLUBILITY OF THE AROMATICS IN THE AQUEOUS FILM. FLAMMABILITY TESTS IN AN OPEN CUP DEVICE SHOWED THAT THE EVAPORATION OF ALL OF THE LIQUIDS EXCEPT BENZENE COULD BE SUPPRESSED SUFFICIENTLY TO PREVENT IGNITION OF THE FLAMMABLE GASES. HOWEVER, WHEN THE SAME LIQUIDS WERE TESTED IN A CLOSED CUP APPARATUS, IT WAS FOUND THAT, FOR THE MORE VOLATILE HYDROCARBONS AND FUELS, SUFFICIENT VAPORS ESCAPED TO FORM A FLAMMABLE MIXTURE IN THE VAPOR SPACE OF THE TEST DEVICE. IT WAS CONCLUDED THAT ALTHOUGH THE SURFACTANT FILM MAY BE AN EFFECTIVE MEANS OF SUPPRESSING EVAPORATION AND THEREBY PREVENTING IGNITION IN AN OPEN ENVIRONMENT, IT IS NOT SUITABLE IN A CLOSED TANK SITUATION.

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# UNIQUE FIBROUS FLAME ARRESTOR MATERIALS FOR EXPLOSION PROTECTION

by

HOUGH, R.L.
LAVY, M.W.

12/00/72

-ABSTRACT-

TESTS WERE CONDUCTED TO FIND MATERIALS TO REPLACE ORGANIC FOAMS NOW BEING UTILIZED IN AIRCRAFT FUEL CELLS AS FLAME ARRESTORS. THE LIMITATIONS OF THE PRESENT ARRESTORS ARE HYDROLYTIC AND THERMAL INSTABILITY WHILE IN THE FUEL TANK ENVIRONMENT. SEVERAL INORGANIC MATERIALS WHICH CAN WITHSTAND INDEFINITE EXPOSURE TO TEMPERATURES OF 500 DEG. F. TO 1000 DEG. F. WERE TESTED. THE FOLLOWING GEOMETRY-MATERIAL COMBINATIONS WERE EXAMINED: (1) FOAM-NICHROME, CARBON, COPPER, AND ALUMINUM OXIDE; (2) WOVEN FORMS-STAINLESS STEEL, AND SILICA; (3) GRIDS-BORON AND SILICON CARBIDE; (4) MATS-BORON, SILICON CARBIDE, CARBON ALLOY, SILICA, AND ZIRCONIA. THE FABRICATED MATERIALS WERE TESTED IN A CYLINDRICAL FLAME TUBE. THEY WERE ALSO EXAMINED FOR SUCH PROPERTIES AS AIR FLOW AND DENSITY. RESULTS SHOWED THAT NICHROME FOAM, SILICON CARBIDE MAT, BORON MAT, AND WOVEN MULTI-PLY SILICA WERE MORE EFFECTIVE THAN THE CONVENTIONAL POLYURETHANE FOAM IN ARRESTING FLAMES. DATA ARE ALSO REPORTED COMPARING THE PROPERTIES OF AIR FLOW, DENSITY, AND COST OF THE INORGANIC MATERIALS TO POLYURETHANE FOAM. IN MOST RESPECTS, THE INORGANIC MATERIALS WERE SUPERIOR TO POLYURETHANE FOAM.

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CORPORATE SOURCE -
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# DESIGN CALCULATIONS FOR A HALON 1301 DISTRIBUTION TUBE FOR AN AIRCRAFT CABIN FIRE EXTINGUISHING SYSTEM

by

JONES, J.
SARKOS, C.P.

04/00/73

## -ABSTRACT-

THEORETICAL CALCULATIONS WERE PERFORMED TO AID IN THE DESIGN OF A PERFORATED TUBE THAT WILL UNIFORMLY DISTRIBUTE HALON 1301 THROUGHOUT THE UNVENTILATED PASSENGER CABIN OF A COMMERCIAL AIR TRANSPORT. CONDITIONS FOR THE CALCULATIONS WERE THOSE OF A PASSENGER CABIN OF A DC-7 FUSELAGE, WITH A VOLUME OF 4000 CU. FT. AND A LENGTH OF 72 FT., BEING USED AS A TEST ARTICLE FOR EVALUATING THE PERFORMANCE OF SUCH A SYSTEM. FOUR SEPARATE CALCULATIONS WERE MADE TO DETERMINE THE (1) SIZE AND NUMBER OF ORIFICES IN THE TUBE REQUIRED FOR VARIOUS HALON 1301 DISCHARGE RATES; (2) PRESSURE DROP AS A FUNCTION OF TUBE DIA. AND DISCHARGE RATES; (3) TIME REQUIRED TO FILL THE TUBE WITH HALON 1301 FOR VARIOUS TUBE DIA.; AND (4) CABIN TEMPERATURE AND PRESSURE AFTER COMPLETION OF HALON 1301 DISCHARGE. THE FIRST CALCULATIONS INDICATED THAT FOR A GIVEN DISCHARGE TIME, THE REQUIRED ORIFICE DIA. DECREASED SLIGHTLY WITH INCREASING ORIFICE NUMBER FOR A LARGE NUMBER OF ORIFICES (ABOUT 40-50). THE PRESSURE DROP WAS SHOWN TO BE A STRONG FUNCTION OF BOTH TUBE DIA. AND DISCHARGE TIME; HOWEVER, PRACTICAL TUBE DIA. COULD BE SELECTED TO ASSURE A NEGLIGIBLE PRESSURE LOSS. IT WAS DEMONSTRATED THAT THE FILL TIME WOULD BE LESS THAN 10 PERCENT OF MOST NORMALLY USED DISCHARGE TIMES. THERMODYNAMIC CALCULATIONS PREDICTED A 38 DEG. F. CABIN TEMPERATURE AFTER COMPLETE DISCHARGE OF AGENT WITH AN INITIAL CABIN TEMPERATURE OF 70 DEG. F. AND RELATIVE HUMIDITY OF 50 PERCENT.

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# JET ENGINE BURN-THROUGH INVESTIGATION. VOLUME 1: SONIC ANALYSIS

by

SCHUMACKER, R.W.

03/00/73

-ABSTRACT-

TESTS WERE PERFORMED WITH JET ENGINES TO STUDY THE ACOUSTIC CHARACTERISTICS OF SIMULATED BURN-THROUGH FAILURES. TO DETERMINE THE FEASIBILITY OF DETECTING THIS FAILURE ACOUSTICALLY, 2 TYPES OF JET ENGINES (J-47 AND J-57) WERE MODIFIED TO SIMULATE BURN-THROUGH FAILURES. MAGNETIC TAPE RECORDINGS OF THE MODIFIED ENGINES WERE MADE TO DETERMINE THE EXTENT OF THE ACOUSTIC SPECTRUM, THE RELATIONSHIP OF ENGINE SPEED TO FAILURE, RELATED SOUND PRESSURE LEVELS AND ACOUSTIC SPECTRUM, THE EFFECT OF SENSOR LOCATION TO DETECT THE FAILURE ACOUSTICALLY, AND CHARACTERISTIC ACOUSTIC SPECTRA AT BURN-THROUGH. THE RECORDED DATA WERE ANALYZED BY REAL TIME SPECTRUM ANALYSIS AND MEAN SQ. TECHNIQUES. RESULTS INDICATED THAT THE SIMULATED BURN-THROUGH FAILURE ACOUSTIC SPECTRA CONSISTS PRIMARILY OF BROADBAND RANDOM NOISE ABOVE 5 KILOHERTZ. IT WAS ALSO DETERMINED THAT SENSOR LOCATION IS AN IMPORTANT FACTOR IN DETECTING BURN-THROUGH FAILURES. BASED ON THE RESULTS IT IS CONCLUDED THAT ACOUSTIC DETECTION OF A BURN-THROUGH FAILURE IS FEASIBLE. RECOMMENDATIONS FOR A MONITOR AND DETECTOR BASED ON THE RESULTS OF THIS PROGRAM ARE INCLUDED.

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