INTERIOR MATERIALS OF INCREASED FLAME RETARDANCE

by
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INTRODUCTION:

IN RECENT YEARS CONSIDERABLE ATTENTION HAS BEEN GIVEN TO THE POTENTIAL CONTRIBUTION OF PRESENTLY USED CABIN INTERIOR MATERIALS TO THE AIRCRAFT FIRE HAZARD AND TO THE EFFECTS WHICH COMBUSTION OF THESE MATERIALS MAY HAVE ON PASSENGER SURVIVAL. SIGNIFICANT PROGRESS HAS BEEN MADE BY GOVERNMENT AGENCIES IN THE DEVELOPMENT OF TEST METHODS LEADING TO QUANTITATIVE CLASSIFICATION OF MATERIALS WITH RESPECT TO THEIR FLAMMABILITY AND THE MATERIALS INDUSTRY HAS PRODUCED NEW PRODUCTS WHOSE USE IN PASSENGER AIRCRAFT WILL RESULT IN APPRECIABLE IMPROVEMENTS IN FIRE SAFETY. THESE MATERIALS ARE SAID TO HAVE INCREASED "FLAME RETARDANCE."

EXPERIMENTAL WORK ON CABIN INTERIOR MATERIALS HAS BEEN CONDUCTED AND SPONSORED BY THE FEDERAL AVIATION ADMINISTRATION SINCE 1963 AND HAS BEEN DIRECTED TOWARD (1) INVESTIGATING THE CHARACTERISTICS OF CABIN FIRES (2) ESTABLISHING LABORATORY TEST METHODS FOR MEASURING THE PERTINENT MATERIAL PROPERTIES AND (3) PROVIDING TEST RESULTS

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ON A SIGNIFICANT NUMBER OF AIRCRAFT MATERIALS AS AN AID IN ESTABLISHING ACCEPTABLE LIMITS.

SIGNIFICANCE OF THE TERM "FLAME RETARDANT":

WHAT IS IMPLIED BY THE TERM "A MATERIAL OF INCREASED FLAME RETARDANCE?" THE ANSWER IS VERY COMPLEX BUT AS USED IN THIS PAPER MAY BE CONSIDERED AS A MATERIAL WHOSE USE AS COMPARED TO PRESENT MATERIALS DECREASES IN SOME WAY THE PROBABILITY OF AIRCRAFT DAMAGE OR OCCUPANT INJURY FROM FIRE. MATERIALS USED IN AIRCRAFT CONSTRUCTION HAVE FOR SOME YEARS BEEN DIVIDED INTO FOUR CLASSIFICATIONS. THESE ARE, IN ORDER OF DECREASING SEVERITY OF THE REQUIREMENT (1) FIREPROOF, (2) FIRE RESISTANT, (3) FLAME RETARDANT, AND (4) FLASH RETARDANT. THE PRESENT SEVERITY OF REQUIREMENTS FOR AIRCRAFT CABIN INTERIOR MATERIALS PLACE THEM IN THE GENERAL CATEGORY OF "FLAME RETARDANT," OR IN FAA TERMINOLOGY "FLAME RESISTANT."

CHARACTERISTICS OF CABIN FIRES:

ANALYSIS OF AIRCRAFT CABIN FIRES AND EXPERIMENTAL TESTS HAVE INDICATED THE SIGNIFICANT MATERIAL-RELATED ELEMENTS OF A CABIN FIRE ENVIRONMENT, ANY ONE OF WHICH MAY IMPAIR ESCAPE, LIMIT SURVIVAL TIME OR RESULT IN OCCUPANT INJURY.

THESE ARE: (SLIDE NO. 1)

(1) HIGH AMBIENT TEMPERATURE OR FLAMES

(2) LOW VISIBILITY FROM SMOKE

(3) THE OCCURRENCE OF FLASH FIRE

(4) TOXIC PRODUCTS OF COMBUSTION

IN CONSIDERATION OF THE CABIN FIRE HAZARD, DESIREABLE MATERIAL PROPERTIES SHOULD THEREFORE INCLUDE (SLIDE NO. 2)

1. HIGH RESISTANCE TO IGNITION AND FLAME PROPAGATION.

2. HIGH IGNITION TEMPERATURE AND LOW RATE OF COMBUSTION AND HEAT OF COMBUSTION.

3. HIGH TEMPERATURE AT WHICH SMOKE IS PRODUCED AND A LOW RATE AND AMOUNT OF SMOKE PRODUCED.

4. HIGH FLASHPOINT TEMPERATURE AND LOW RATE AND LOW COMBUSTIBILITY OF GASES RELEASED.

5. HIGH TEMPERATURE OF THERMAL DECOMPOSITION AND GASEOUS PRODUCTS OF COMBUSTION HAVING LOW TOXICITY.

LABORATORY TEST METHODS

HAVING IDENTIFIED THE CRITICAL ENVIRONMENTAL ELEMENTS OF A CABIN FIRE AND THE RELATED MATERIAL PROPERTIES, LET US NOW BRIEFLY EXAMINE THE LABORATORY METHODS USED IN

TESTING MATERIALS. THESE ARE DESCRIBED AS FOLLOWS:

(SLIDE NO.)

1. HORIZONTAL AND VERTICAL BURN RATE, METHODS 5906 AND 5902, FEDERAL SPECIFICATION CCC-T-191b

THESE METHODS AND RELATED APPARATUS HAVE BEEN DESCRIBED IN FAA-ADS-3 REPORT DATED JANUARY 1964 AND TITLED, "FLAMMABILITY AND SMOKE CHARACTERISTICS OF AIRCRAFT INTERIOR MATERIALS.

THESE METHODS EXPOSE A 3-INCH BY 12-INCH SAMPLE TO A BUNSEN BURNER FLAME AND ARE CONDUCTED WITH THE SPECIMEN AT ROOM TEMPERATURE.

IN TERMS OF BURN LENGTH AND BURN RATE MEASUREMENTS, THE SEVERITY OF THE VERTICAL TEST WAS OBSERVED, IN LABORATORY TESTS TO BE ABOUT 8 TIMES THAT OF THE HORIZONTAL TEST.

THESE TEST METHODS ARE DESIGNED FOR USE IN TESTING FABRICS AND ARE NOT ENTIRELY SUITABLE FOR MATERIALS OTHER THAN FABRICS.

MATERIAL PROPERTIES WHICH INFLUENCE RESULTS OBTAINED BY THESE TEST METHODS ARE:

(1) RESISTANCE TO IGNITION AND (2) RATE OF FLAME PROPAGATION OR SELF-EXTINGUISHING CHARACTERISTICS AFTER REMOVAL OF THE IGNITION SOURCE.

(SLIDE NO.)

UP TO THE PRESENT TIME FAA REQUIREMENTS FOR TESTING MATERIALS PROVIDE FOR USE OF THESE TWO METHODS ONLY AND IT IS BY SUCH METHODS THAT MATERIALS MAY BE CLASSIFIED AS SELF-EXTINGUISHING. THE TABULATION OF PAST AND PRESENT REQUIREMENTS IN THE CHART (SLIDE) REFLECTS THE INCREASE IN MINIMUM REQUIREMENTS AS OF OCTOBER 1967 AND THE FURTHER INCREASE THAT IS PENDING.

2. NBS RADIANT PANEL FLAMESPREAD METHOD FEDERAL STANDARD 00136b (ASTM E-162)

(SLIDE NO.)

THIS TEST METHOD IS ALSO DESCRIBED IN REPORT ADS-3 AND EXPOSES AN 18-INCH x 6-INCH SAMPLE OF MATERIAL TO RADIANT HEAT. A FLAMESPREAD INDEX VALUE IS OBTAINED FROM FLAME PROPAGATION VELOCITY AND THE HEAT PRODUCED BY THE BURNING MATERIAL. TEST RESULTS ARE INFLUENCED BY A MATERIALS RESISTANCE TO IGNITION, RATE OF COMBUSTION AND HEAT OF COMBUSTION. THIS METHOD WAS CAPABLE OF COVERING THE

EVOLUTION OF FAA REGULATIONS ON CABIN INTERIOR MATERIALS

Date	Materials	Test Method	Measurement	Limits	Self-Extinguishing
Aug. 1947 (Past)	One Class All materials	Method 5906	Hor. burn rate	< 4 inches/min	No
Oct. 1967 (current)	Class (a) Paneling - wall and ceiling, Coated Fabrics Baggage racks	Methods 5906 and 5902	Hor. and vert. char lengths	< 4 inches char (hor.) < 8 inches char (vert.)	Yes
	Class (b) Upholstery Fabric and Padding Carpeting	Method 5906	Hor. burn rate	< 4 inches/min	No
1969 (Proposed)	Class (a) Paneling - wall and Ceiling, Baggage Racks, Insulation Batts, Flooring, Galley	Method 5902 (60-secs burner exposure)	Vert. burn length	< 6 inches	Yes
	Class (b) Upholstery Fabrics, Coated Fabrics, Seat Padding, Air ducts Carpets, wiring	Method 5902 (12-secs burner exposure)	Vert. burn length	< 8 inches	Yes
	Class (c) Acrylic windows Seat belts Small Fabricated items	Method 5906	Hor. burn rate	< 2.5 inches/min	No

ENTIRE FLAMMABILITY RANGE OF ALL MATERIALS TESTED.

3. SETCHKIN HOT AIR IGNITION TEST ASTM STANDARD D1929-62T.

THIS TEST METHOD IS USED IN DETERMINING THE FLASH POINT AND SELF-IGNITION TEMPERATURES OF SOLID MATERIALS AND PROVIDES AND INDICATION OF THE MATERIAL TEMPERATURE AT WHICH COMBUSTIBLE GASES ARE PRODUCED.

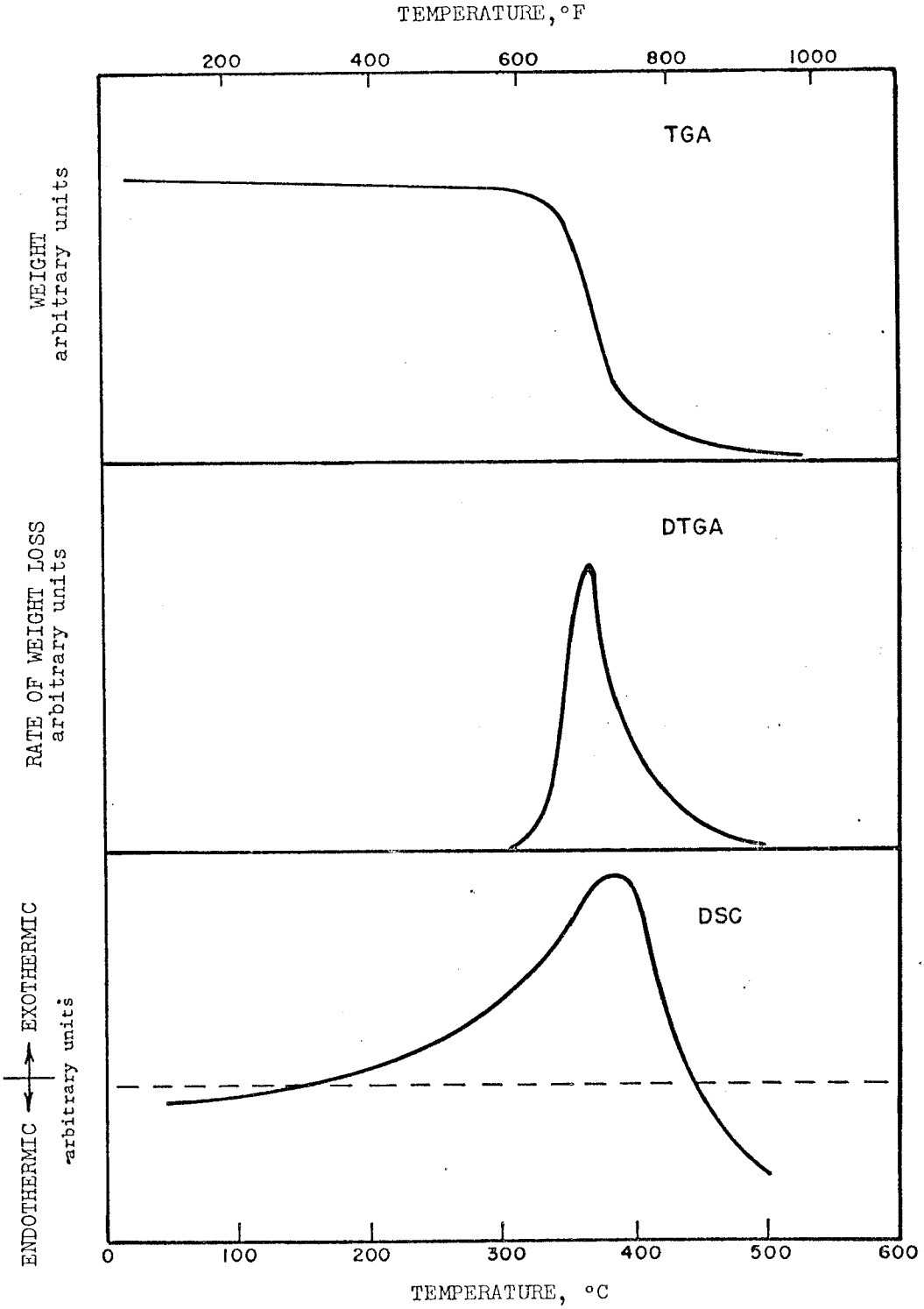
4. THERMOGRAVIMETRIC ANALYSIS (TGA), DIFFERENTIAL THERMOGRAVIMETRIC ANALYSIS (DTGA) AND DIFFERENTIAL, SCANNING COLORIMETRY (DSC).

THESE COMPLIMENTARY METHODS WERE EXPLORED FOR CHARACTERIZING THE ELEVATED TEMPERATURE THERMAL DECOMPOSITION OF MATERIALS: TGA, IN WHICH A SPECIMEN IS CONTINUOUSLY WEIGHED AS IT IS HEATED, AND DSC, IN WHICH THE MAGNITUDES OF EXOTHERMIC AND ENDOTHERMIC PROCESSES ARE MEASURED AS A FUNCTION OF INCREASING TEMPERATURE.

AN EXAMPLE OF THE KIND OF INFORMATION OBTAINED BY THESE MEASUREMENTS IS SHOWN IN THE FOLLOWING FIGURE.

(SLIDE NO.)

FOR AN ACRYLONITRILE/BUTADIENE/STYRENE (ABS) COPOLYMER,



Thermal Decomposition of Sample No. 10
Acrylonitrile/Butadiene/Styrene (25:10:65) Sheet

A SIGNIFICANT LOSS IN WEIGHT BEGAN AT 650°F, AND CEASED AT ABOUT 950°F. THE RATE OF WEIGHT LOSS REACHED A PEAK AT ABOUT 675°F AS SHOWN IN THE DTGA GRAPH. THE DSC SCAN SHOWS A SUBSTANTIAL EXOTHERM EXTENDING OVER A TEMPERATURE RANGE OF 338°F TO 824°F WITH A PEAK AT APPROXIMATELY 725°F. THESE VALUES ARE BELIEVED TO PROVIDE SIGNIFICANT INFORMATION ON THE IGNITION PROPERTIES AND THE FLASH-FIRE RELATED PROPERTIES OF MATERIALS BUT ADDITIONAL STUDIES ARE NEEDED TO ESTABLISH THIS USEFULNESS.

5. NBS SMOKE MEASUREMENT (ASTM SPECIAL TECHNICAL PUBLICATION 422, 1967).

AS USED HERE, THE TERM "SMOKE" REFERS TO THE VISIBLE SOLID PARTICLES PRODUCED DURING COMBUSTION OF A MATERIAL. THE MAJOR CONCERN AT THE PRESENT TIME REGARDING SMOKE PRODUCTION IS THE DEGREE TO WHICH IT MAY EFFECT VISIBILITY AND IMPAIR EVACUATION DURING A FIRE.

THE NATIONAL BUREAU OF STANDARDS HAS DEVELOPED A SMOKE CHAMBER NOW COMMERCIALLY AVAILABLE WHICH WAS UTILIZED IN MEASURING THE SMOKE PRODUCED DURING FLAMING AND SMOLDERING EXPOSURES ON 141 AIRCRAFT INTERIOR

MATERIALS. RESULTS OF THESE TESTS, A DESCRIPTION OF THE SMOKE CHAMBER, AND TEST PROCEDURES ARE REPORTED IN FAA TECHNICAL REPORT NA-68-36 (DS-68-16), JUNE, 1968.

IT APPEARS, AS A RESULT OF THIS WORK, THAT THE NBS LABORATORY TEST METHOD FOR GENERATING SMOKE AND MEASURING ITS OPTICAL DENSITY IS A USEFUL TOOL FOR THE QUANTITATIVE CLASSIFICATION OF MATERIALS. OPTICAL DENSITY IS CONSIDERED TO BE THE SINGLE, MOST CHARACTERISTIC MEASURE OF THE VISUAL OBSCURING QUALITY OF SMOKE. IT WAS NOTED THAT FOR THE MAJORITY OF MATERIAL, MORE SMOKE WAS PRODUCED DURING THE FLAMING EXPOSURE TEST BUT THAT CERTAIN MATERIALS PRODUCED MORE SMOKE IN THE ABSENCE OF OPEN FLAMING, THUS, BOTH SMOLDERING AND ACTIVE FLAMING CONDITIONS SHOULD BE CONSIDERED. ALSO OBSERVED IN OTHER TESTS WAS THE INDICATION THAT CHEMICAL TREATMENT OF MATERIALS FOR REDUCING FLAMMABILITY MAY RESULT IN A SIGNIFICANT INCREASE IN SMOKE PRODUCED. THIS POINTS UP THE NEED FOR EVALUATING MATERIALS WITH RESPECT TO SMOKE PRODUCTION AS WELL AS FLAMMABILITY.

6. MEASUREMENT OF POTENTIALLY TOXIC GASES (FAA REPORT NA-68-36 (DS-68-16) JUNE, 1968)

THE GREATEST CHALLENGE OF THOSE POSED IN ATTEMPTING

MEASUREMENTS OF MATERIAL PROPERTIES PERTINENT TO FIRE IS THE MEASURE OF TOXICOLOGICAL EFFECTS OF THE GASES PRODUCED BY COMBUSTION.

THE NATIONAL BUREAU OF STANDARDS HAVE NOTED THAT INDICATIONS OF CONCENTRATIONS OF POTENTIALLY TOXIC COMBUSTION PRODUCTS CAN BE CONVENIENTLY AND INEXPENSIVELY OBTAINED DURING THE SMOKE PRODUCTION TEST USING CALIBRATED COMMERCIAL COLORIMETRIC TUBES. SUCH TUBES HOWEVER ARE SUITABLE ONLY WHERE INTERFERENCES BY OTHER GASES ARE ABSENT AND WHERE PRECISION IS NOT OF PRIMARY IMPORTANCE. FURTHERMORE, ANY ATTEMPT TO RELATE THE INDICATED CONCENTRATIONS MEASURED IN THE SMOKE CHAMBER TO TOXICOLOGICAL LIMITS MUST BE DONE WITH CAUTION AND PROPER CONSIDERATION OF (A) SCALING OF THE AREAS AND VOLUMES IN THE PROPOSED SITUATION, (B) THE INTEGRATED DOSAGE WHERE CONCENTRATION VARIES WITH TIME, (C) THE SYNERGISTIC EFFECTS OF SEVERAL COMPONENTS (AND SMOKE PARTICLES) AND THE EFFECTS OF RELATIVE HUMIDITY, ELEVATED TEMPERATURE, STRATIFICATION, ADSORPTION ON SURFACES, AND PHYSIOLOGICAL FACTORS NOT CONSIDERED IN THE STUDY CONDUCTED. THUS, IT IS EVIDENT THAT ADDITIONAL WORK ON THIS VERY IMPORTANT ASPECT OF THE CABIN

FIRE HAZARD IS NEEDED. HOWEVER, UTILIZATION OF THE COLORIMETRIC TUBES WOULD BE VALUABLE IN THE INTERIM.

LARGE SCALE TESTING:

IN ADDITION TO THE LABORATORY TESTING DESCRIBED, WORK BY THE FAA DURING THE PAST SIX YEARS INCLUDES LARGE SCALE TESTS OF CABIN FIRE, FIRST IN A DC-7 FUSELAGE AND SUBSEQUENTLY IN A LARGE INSULATED TRAILER. RESULTS OF THE EARLIER TESTS ARE GIVEN IN FAA REPORT ADS-44, DECEMBER 1965, AND REFLECT THE NECESSITY FOR CONSIDERING THE SMOKE AND FLASH-FIRE CHARACTERISTICS OF MATERIALS AS WELL AS FLAMMABILITY. MORE RECENT TESTS USING THE TRAILER HAVE PROVIDED INFORMATION ON THE IGNITION AND BURNING CHARACTERISTICS OF INDIVIDUAL CABIN COMPONENTS SUCH AS SEATS AND ON INDIVIDUAL MATERIALS SUCH AS URETHANE FOAM.

(A FILM DEPICTING TESTS ON URETHANE FOAM WILL BE SHOWN AT THIS TIME)

RESULTS OF TESTS ON MATERIALS

THE MORE RECENT FAA WORK INCLUDED LABORATORY TESTS ON 150 AIRCRAFT CABIN MATERIALS WITH RESPECT TO FLAMMABILITY, SMOKE AND TOXIC GASES. THESE MATERIALS MAY BE DIVIDED INTO

FIVE GENERAL CATEGORIES, NAMELY: FABRICS, RUGS, SHEETS, LAMINATES AND ASSEMBLIES. THEY RANGED FROM THIN FILMS A FEW THOUSANDTHS OF AN INCH THICK TO SEAT PADDING AND COMPLICATED HONEYCOMB ASSEMBLIES 4 INCHES THICK.

ABOUT ONE HALF OF THE MATERIALS TESTED ARE IN PRESENT USE. THE OTHER HALF WERE NEWER MATERIALS OF PRESUMABLY SUPERIOR FLAME RETARDANCE SUPPLIED BY THE CHEMICAL INDUSTRY.

NEARLY ALL MATERIALS WERE COMPOSED EITHER ENTIRELY OR IN PART OF ORGANICS AND WERE THEREFORE COMBUSTIBLE TO SOME DEGREE.

THE MOST TYPICAL PLASTICS WERE THE VINYLS, ACRYLICS AND ACRYLONITRILE/BUTADEINE/STYRENES (ABS). OF SPECIAL INTEREST WERE THE MORE RECENTLY DEVELOPED HIGH TEMPERATURE POLYMERS: NAMELY, NOMEX, A NEW TYPE OF NYLON POLYCARBONATE, POLYSULPHONE AND THE FLUOROCARBONS. THE SECOND GROUP WAS ALSO NOTABLE FOR ITS GREATER USE OF NONCOMBUSTIBLES.

AS A RESULT OF THESE TESTS THE FOLLOWING WAS NOTED:

1. A VERY SUBSTANTIAL INCREASE IN FLAME RETARDANCE

HAD BEEN ACHIEVED WITH THE DEVELOPMENT OF NEW MATERIALS.

2. TESTS OF GREATER SEVERITY THAN THE HORIZONTAL AND VERTICAL BURN RATE TESTS, SUCH AS THE RADIANT PANEL TEST, IS NECESSARY TO DIFFERENTIATE BETWEEN IMPROVED MATERIALS AND TO ADEQUATELY TEST HEAVIER WEIGHT MATERIALS AND ASSEMBLIES.

3. MORE SMOKE IS EVOLVED BY THE MAJORITY OF PLASTICS UNDER A FLAMING CONDITION RATHER THAN A SMOLDERING CONDITION.

4. MATERIALS CURRENTLY IN USE AS INTERIOR FURNISHINGS FOR AIRCRAFT CABINS, AND THOSE BEING CONSIDERED FOR FUTURE USE, VARY CONSIDERABLY IN THEIR DECOMPOSITION AND HEAT RELEASE RATES AT ELEVATED TEMPERATURES, AND IN THEIR PRODUCTION OF SMOKE AND POTENTIALLY TOXIC PRODUCTS UNDER SIMULATED FIRE CONDITIONS. UNDER THE CONDITIONS STUDIED, CERTAIN MATERIALS HAVE GOOD HEAT STABILITY PROPERTIES AND DO NOT GENERATE LARGE QUANTITIES OF SMOKE OR HIGH CONCENTRATIONS OF THE GASEOUS PRODUCTS SELECTED FOR ANALYSIS.

5. THE CHEMICAL TREATMENT GIVEN SOME MATERIALS TO MAKE THEM SELF-EXTINGUISHING CAUSE A SIGNIFICANT INCREASE

IN SMOKE PRODUCED DURING BURNING.

SUMMARY OF FAA PROGRAM RESULTS

RESULTS OF THE FAA STUDIES ON CABIN INTERIOR MATERIALS ARE SUMMARIZED IN THE FOLLOWING CONCLUSIONS:

1. BOTH EXPERIMENTAL TESTS AND AIRCRAFT CABIN FIRE OCCURRENCES INDICATE THAT SMOKE AND GASES PRODUCED BY BURNING INTERIOR MATERIALS AS WELL AS HEAT PRODUCED MAY IMPAIR ESCAPE, PRODUCE INJURY OR LIMIT SURVIVAL.

2. DEVELOPMENTS IN LABORATORY TESTING TECHNIQUES PROVIDE METHODS FOR MEASURING NOT ONLY FLAMMABILITY BUT ALSO THE SMOKE AND GASES PRODUCED BY BURNING MATERIALS.

3. IMPROVED CABIN FIRE SAFETY AND THE DEVELOPMENT AND USE OF INTERIOR MATERIALS OF IMPROVED "FLAME RETARDANCE" REQUIRES THE MEASUREMENT AND LIMITATION OF SMOKE AND GASES PRODUCED AS WELL AS THE MEASUREMENT AND LIMITATION ON FLAMMABILITY.

FUTURE PROGRAM

THE NEED FOR ADDITIONAL WORK IN SEVERAL AREAS IS EVIDENCED FROM THE RESULTS OBTAINED THUS FAR. A METHOD SUITABLE FOR

MEASURING SMOKE PRODUCED BY BURNING MATERIALS IS NOW AVAILABLE BUT THE CRITERIA FOR SMOKE LIMITS HAS NOT BEEN FIRMLY ESTABLISHED. A MEANS OF OBTAINING INDICATIONS OF THE CONCENTRATIONS OF POTENTIALLY TOXIC PRODUCTS OF COMBUSTION HAS BEEN DEVELOPED USING COLORIMETRIC TUBES BUT THIS METHOD HAS SEVERAL LIMITATIONS REQUIRING FURTHER STUDY ON THE METHOD OF MEASUREMENT AND SUBSEQUENTLY ON THE SIGNIFICANCE OF THE VALUES OBTAINED. FURTHER STUDY SHOULD ALSO BE MADE ON THE MATERIAL PROPERTIES RELATING TO FLASH-FIRE AND ON THE SIGNIFICANCE OF THE TGA AND DSC MEASUREMENTS.

THE R & D PROGRAM ON INTERIOR MATERIALS AT NAFEC WILL CONTINUE FOR AT LEAST ANOTHER YEAR.

PRESENT PLANS INCLUDE:

1. A RESEARCH CONTRACT TO INVESTIGATE THE CHEMICAL NATURE OF ORGANICS RESPONSIBLE FOR SMOKE EMISSION. IT IS HOPED THAT A PRACTICAL BENEFIT OF THIS STUDY WILL BE THE DEVELOPEMENT OF NEW TYPES OF FLAME RETARDANT ADDITIVES IN PLASTICS PRODUCING MINIMUM SMOKE.

2. A CONTINUATION OF FAA'S INTERAGENCY AGREEMENT WITH THE NATIONAL BUREAU OF STANDARDS FOR CONDUCTING

FURTHER STUDY OF THE FLASH-FIRE PHENOMENA.

3. INHOUSE EFFORT IN SUPPORT OF STUDIES LEADING TO ESTABLISHING A SMOKE LIMIT.