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NASA CONFERENCE ON MATERIALS FOR IMPROVED FIRE SAFETY

Held at
NASA Manned Spacecraft Center
Houston, Texas

May 6 and 7, 1970

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TO PARTICIPANTS OF THE NASA CONFERENCE ON MATERIALS FOR IMPROVED FIRE SAFETY

It is well known that for more than a decade NASA has been discovering new things about the Earth, the Moon, the Sun, the nearby planets, and the universe itself. Not nearly so well known, however, is the important fact that NASA has also been discovering new things about human beings, materials and equipment. Some of the agency's most significant and satisfying work in recent years has been directly concerned with the control or elimination of fire hazards.

Recognizing that maximum benefit can be obtained from space research only when our discoveries are widely shared, we welcome the opportunity of participating in conferences such as this one. We sincerely hope that you will find ways of adapting some of the many and varied findings presented here to relieve and reduce the hazards of fire in everyday working and living: in housing, hospitals, nursing homes, ships, passenger cars, aircraft, theaters, auditoriums, factories, or wherever people and their valued possessions may be.

T. O. Paine
Administrator

AGENDA

MAY 6, 1970

Welcome

Robert R. Gilruth, Director, NASA Manned Spacecraft Center

Opening Remarks

Honorable Jerry L. Pettis, Representative from California

Introduction to Conference

Philip H. Bolger, Deputy Director, Manned Space Flight Safety, Washington, D.C.

SESSION I — FLAMMABILITY REQUIREMENTS AND TEST TECHNIQUES

Chairman: Aleck C. Bond, Assistant Director for Chemical and Mechanical Systems, NASA Manned Spacecraft Center

1 THE COMBUSTION PROCESS

W. R. Downs

2 MANNED SPACECRAFT NONMETALLIC MATERIALS FLAMMABILITY SELECTION CRITERIA AND REQUIREMENTS

C. J. Katsikas and J. H. Levine

3 THE DEVELOPMENT OF MATERIALS SCREENING TESTS FOR OXYGEN-ENRICHED ENVIRONMENTS

R. L. Johnston and D. L. Pippen

4 COMPONENT FLAMMABILITY TESTING

Gary R. Primeaux

5 FULL-SCALE SPACECRAFT MOCKUP FLAMMABILITY TESTS

R. W. Bricker, J. P. Crabb, and I. K. Spiker

SESSION II — MATERIALS DEVELOPMENT

Chairman: Edward L. Hays, Deputy Chief, Crew Systems Division, NASA Manned Spacecraft Center

MAY 7, 1970

SESSION III — CONFIGURATION CONTROL AND MATERIALS APPLICATIONS

Chairman: Joseph N. Kotanchik, Chief, Structures and Mechanics Division, NASA Manned Spacecraft Center

DEFINITIONS

The following is a brief listing of some of the symbols, abbreviations, acronymns, and technical terms from the various papers presented at this conference.

Acronyms

ABS	see Chemical Terms
AOT	alinement optical telescope used in the Apollo command module for navigation
ASTM	American Society for Testing Materials
CM	Apollo spacecraft command module and reentry vehicle
CNR	carboxy nitroso rubber (see Chemical Terms)
CWG	constant-wear garment
DTA	differential thermal analysis (see Chemical Terms)
°F	degrees Fahrenheit
in.	inch
IVCL	intravehicular cover layer
LCG	liquid cooled garment
LEVA	lunar extravehicular visor assembly
LITMG	lunar integrated thermal micrometeoroid garment
LM	Apollo spacecraft lunar module, the lunar landing spacecraft
MEK	methylethylketone (see Chemical Terms)
MIBK	methylisobutylketone (see Chemical Terms)
MFR	manufacturer
MQF	Mobile Quarantine Facility
MSC	Manned Spacecraft Center

MSFC	Marshall Space Flight Center
NF	nonflammable
NFM	nonflammable material
NMM	nonmetallic material
PGA	pressure garment assembly
psia	pounds per square inch absolute (pressure)
PVA	see Chemical Terms
PVC	see Chemical Terms
RTV	see Chemical Terms
SE	self-extinguishing
SM	Apollo spacecraft service module
TLSA	torso-limb suit assembly

Special Terms

conformal coating — A material uniformly applied over another material for protection.

cuff cards — Cards fixed to the arms of the space suits used on the lunar surface to remind the astronauts of task sequence.

denier — The weight in grams of 9000 meters of yarn or fiber; a measure of fiber or yarn fineness. The word was derived from a French coin, weighing approximately 0.5 gram, that was used as an actual weight for the purchase and sale of silk.

dielectric — Electrically nonconducting.

durometer — A measure of the hardness of a material.

edgelock — Treatment of the edge of a fabric to prevent fraying.

flammability — The propensity of a material to burn.

hyperbaric — Pressures greater than sea level pressure.

hypobaric — Pressures less than sea level pressure.

intumescence — The property of certain special plastics to swell upon application of heat.

lockstitch — Prevention of fraying of the edge of fabric by sewing along the edge.

Marquisette — A thin, lightweight fabric of cotton, silk, rayon, nylon, or glass with square, open meshes.

tricot — A type of knitting characterized by a runproof stitch.

wax pick — A measure of the resistance of the surface of a material to stain.

Chemical Terms

ABS — acrylonitrile butadiene styrene.

acrylic — A generic name for a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85 percent by weight of acrylonitrile units.

brominated polyester — A polyester with bromine added. (See polyester.)

carboxy nitroso rubber (CNR) — A flame-resistant terpolymer of trifluoronitrosomethane, tetrafluoroethylene, and nitroperfluorobutyric acid with rubberlike properties.

chloroprene — A colorless liquid, C_4H_5Cl, made from acetylene. It can be polymerized to form a synthetic rubber.

CO — carbon monoxide.

copolymer — A synthetic substance formed by the addition or condensation polymerization of two or more monomers.

dimethyl/siloxene — A type of silicone resin.

DTA — Differential thermal analysis which measures phase changes (endothermic and exothermic) with increasing temperatures.

ethylene — A colorless, inflammable, gaseous hydrocarbon of the olefin series.

fluoropolymer — A polymer containing fluorine.

fluorosilicone — A silicone resin in which hydrogen atoms have been replaced by fluorine.

hexafluoropropene — a fluorocarbon monomer.

melamine formaldehyde — A thermosetting resin made from melamine and formaldehyde, used chiefly in molded products, coatings, adhesives, and textile finishes.

methylethyl ketone (MEK) — An organic solvent.

methylisobutyl ketone (MIBK) — An organic solvent.

modacrylic — A generic name for a synthetic fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of less than 85 percent but at least 35 percent by weight of acrylonitrile units.

phenol formaldehyde — A thermosetting resin made from phenol and formaldehyde.

phenolic — Of, derived from, or containing phenol.

polyamide — A polymer in which the structural units are linked by amide or thiomide groupings.

polybenzimidazole (PBI) — A high-temperature-resistant polymeric fiber containing characteristic imide groups.

polycarbonate — A transparent plastic used for helmet visors. It is characterized by exceptionally high impact strength.

polyester — A generic name for a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85 percent by weight of an ester of a dihydric alcohol and terephthalic acid.

polyimide — A polymer containing characteristic imide groups.

polymer — A high-molecular-weight organic compound, natural or synthetic, whose structure can be represented by a repeated small unit.

polyquinoxaline — A high-temperature thermosetting resin derived from quinoline by substitution of a nitrogen atom for a methylidine group.

polysulfone — A high-temperature transparent polymer characterized by the sulfonyl group doubly united by means of its sulfur, usually with carbon.

polyurethane — Any of various synthetic rubber polymers produced by the polymerization of a hydroxyl (OH) radical and an NCO group from two different compounds.

PVA — polyvinyl acetate.

PVC — polyvinyl chloride.

RTV — A commercial potting compound.

silicone — Any of a group of synthetic resins, oils, greases, plastics, in which the carbon has been replaced by silicon.

terpolymer — A product of three different polymerizing substances.

tetrabromopthalicanhydride — A highly brominated hydrocarbon commonly used as a fire retardant.

tetrafluoroethylene — A fluoropolymer.

thermoplastic — A polymer that becomes or remains soft and moldable when subjected to heat.

thermosetting — Becoming permanently hard and unmoldable when once subjected to heat.

toluene — A colorless liquid hydrocarbon.

urea formaldehyde — A thermosetting resin made from urea and formaldehyde.

SESSION I

FLAMMABILITY REQUIREMENTS AND TEST TECHNIQUES

Session Chairman: Aleck C. Bond

THE COMBUSTION PROCESS

By W. R. Downs
NASA Manned Spacecraft Center

ABSTRACT

Combustion is defined as any relatively fast reaction between gases that produces heat. The chemical and physical mechanisms that constitute the combustion process are defined and described in detail, using the candle flame as a model. The production of chemical free radicals (reactive fuel fragments) and the interactions between free radicals, coupled with energy and material transport factors, are illustrated. Continuous or sustained combustion is shown to involve a feedback mechanism in which part of the energy derived from the process goes into the driving of the mechanism and is limited only by the ability to bring together the reactants. On the basis of chemical and thermodynamic considerations, combustion factors such as fuel composition effects, exposed surface areas, fuel density, fuel geometry, convective environment effects, and diffusion effects are discussed. It is observed that convection and diffusion forces promote combustion rate, whereas thermal conduction and reactant starvation diminish combustion rate.

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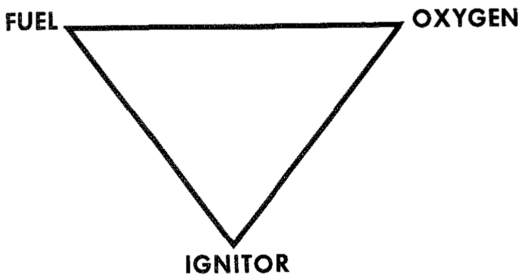
FIRE TRIANGLE



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COMBUSTION OF METHANE

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O + HEAT$$

NASA-S-70-1771-X

METHANE IGNITION

$$CH_4 + IGNITOR \longrightarrow CH_3 + H$$

NASA-S-70-1768-X

CHAIN MECHANISM FOR METHANE COMBUSTION

	$2\ CH_4$ + IGNITOR	$\longrightarrow$	$2\ H + 2\ CH_3$	
STEPS IN CHAIN MECHANISM	$2\ H + 2\ O_2$	$\longrightarrow$	$2\ OH + 2\ O$	(1)
	$CH_4 + OH$	$\longrightarrow$	$H_2O + CH_3$	(2)
	$O_2 + CH_3$	$\longrightarrow$	$CH_2O + OH$	(3)
	$CH_2O + O$	$\longrightarrow$	$HCO + OH$	(4)
	HCO	$\longrightarrow$	$H + CO$	(5)
	$CO + OH$	$\longrightarrow$	$CO_2 + H$	(6)
	$2\ OH$	$\longrightarrow$	$H_2O + O$	(7)
	$2\ O$	$\longrightarrow$	O_2	(8)
OVERALL REACTION	$CH_4 + 2\ O_2$	$\longrightarrow$	$2\ H_2O + CO_2$	

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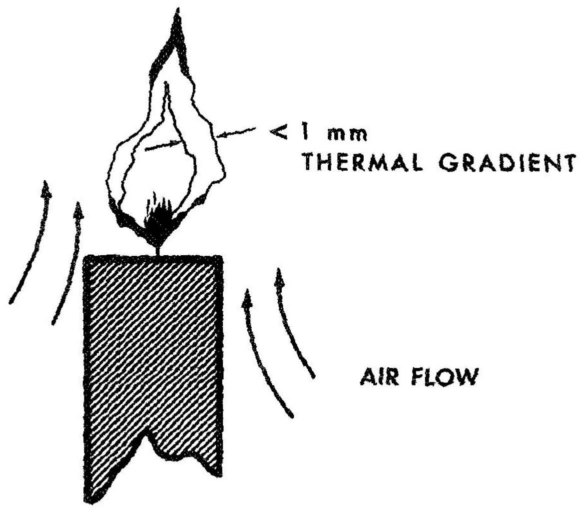
CANDLE FLAME ON EARTH



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MATERIAL AND ENERGY TRANSPORT FACTORS TO PRODUCE FLAME

- DIFFUSION
- CONVECTION
- VISCOSITY
- CONDUCTION
- RADIATION

NASA-S-70-1581-X

ENERGY TRANSPORT FROM A CANDLE FLAME ON EARTH

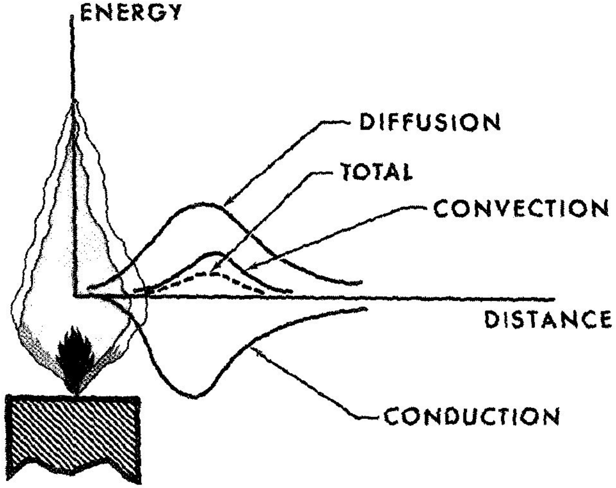

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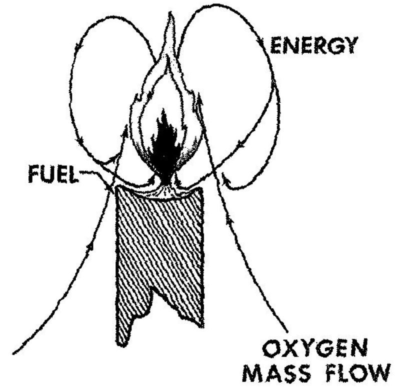
ILLUSTRATION OF FEEDBACK



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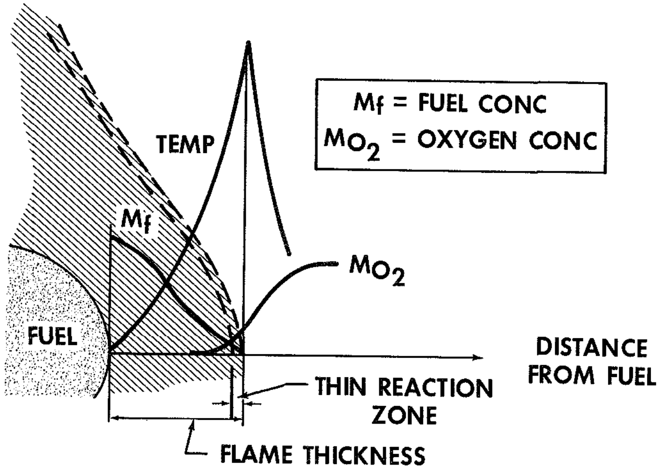
COMBUSTION UNDER CONVECTION CONDITIONS



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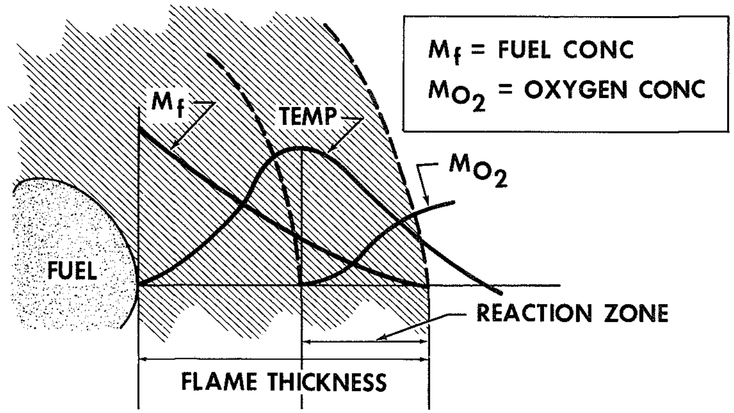
POSTULATED COMBUSTION CONDITIONS UNDER ZERO GRAVITY



NASA-S-70-2128-X

GROSS FACTORS IN THE COMBUSTION PROCESS

- FUEL COMPOSITION
- EXPOSED AREA
- DENSITY OF FUEL
- GEOMETRY OF FUEL
- CONVECTIVE ENVIRONMENT
- DIFFUSION
- CONDUCTION

MANNED SPACECRAFT NONMETALLIC MATERIALS FLAMMABILITY

SELECTION CRITERIA AND REQUIREMENTS

By C. J. Katsikas and J. H. Levine
NASA Manned Spacecraft Center

ABSTRACT

This paper reviews the criteria and requirements governing the selection of nonmetallic materials for use in manned spacecraft to control potential fire hazards. To illustrate how these criteria were met, the development of the NASA Manned Spacecraft Center (MSC) flammability requirements are discussed and traced through their historical evolution. The events that dictated the changes that have taken place are also covered.

The current nonmetallic material requirements are presented and include the following areas:

1. A new approach, nonmetallic materials usage categories, emphasizes acceptance based on the location and the amount of the nonmetallic materials used in the spacecraft, as well as the fire-resistant performance characteristics of the materials.

2. The importance of the test ignitor is presented, and the current standard ignitor and several special-usage ignitors are described.

3. The flammability screening and application tests are presented, and their importance in the final verification and acceptance of nonmetallic materials is emphasized.

Significant features of the Nonmetallic Materials Design Guidelines and Test Data Handbook are discussed. This handbook includes materials selection guidelines, test requirements, and materials control programs. The handbook also includes an extensive compilation of materials test results and performance characteristics obtained from tests conducted over the past several years. Finally, a brief discussion of the application of the MSC criteria and requirements to nonaerospace areas is given.

NASA-S-70-2223-X

GENERAL FIRE CONTROL CRITERIA

- MINIMIZE IGNITION SOURCES
- PREVENT PROPAGATION
- PREVENT STRUCTURAL DAMAGE
- ASSURE CREW SAFETY
- ASSURE MISSION SUCCESS OR SAFE ABORT

NASA-S-70-2225-X

SCOPE OF TALK

- DEVELOPMENT OF REQUIREMENTS
- CURRENT REQUIREMENTS
- SOURCES OF TEST DATA

NASA-S-70-2217-X

DEVELOPMENT OF REQUIREMENTS

- BACKGROUND EXPERIENCE
- INPUTS FROM INDUSTRY, NASA, OTHER AGENCIES
- MORE RESTRICTIVE REQUIREMENTS
- VIABLE REQUIREMENTS DOCUMENT

NASA-S-70-2228-X

CURRENT REQUIREMENTS

- SPACECRAFT NONMETALLIC MATERIAL USAGE (LOCATION AND AMOUNT)
- TEST IGNITION SYSTEM
- TEST REQUIREMENTS

NASA-S-70-2327-X

NONMETALLIC MATERIALS USAGE

- AMOUNT
- LOCATION
- APPLICATION
- FLAMMABILITY PROPERTIES

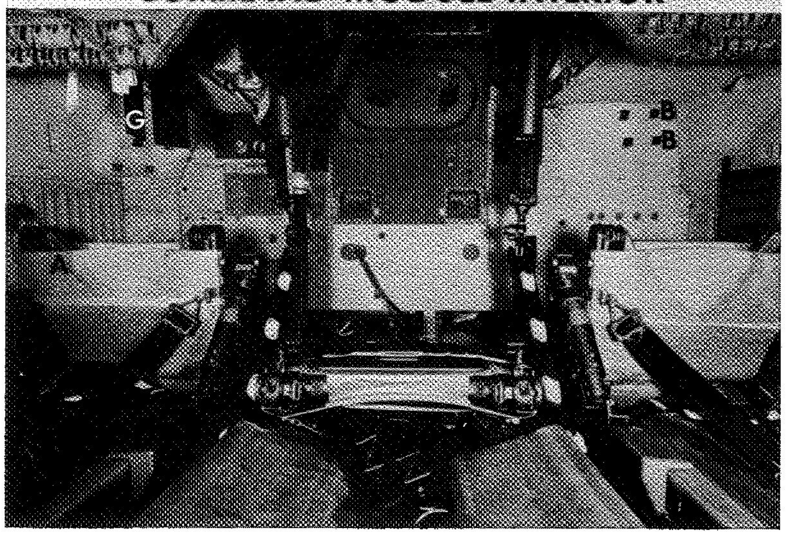
NASA-S-70-2226-X

NONMETALLIC MATERIALS USAGE CATEGORIES

CATEGORY	MATERIAL USAGE	PRIMARY ACCEPTANCE CRITERIA
A	MAJOR EXPOSED	SELF-EXTINGUISHING
B	MINOR EXPOSED	NO PROPAGATION
C	SUIT LOOP	SELF-EXTINGUISHING
D	HIGH PRESSURE OXYGEN SYSTEMS	NO DETONATION NO PROPAGATION
E	SEALED CONTAINERS	DO NOT BURST CONTAINER NO FLAME
F	VENTED CONTAINERS	DO NOT BURST CONTAINER NO FLAME
G	NONFLIGHT EQUIPMENT	DEPEND ON SPECIFIC USAGE
H	IN AND AROUND SPACECRAFT OUTSIDE OF CREW BAY	DEPEND ON USAGE

NASA-S-70-2221-X

COMMAND MODULE INTERIOR



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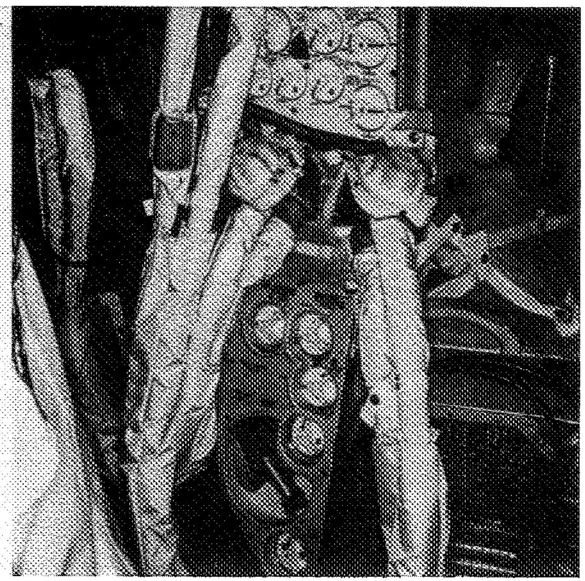
LUNAR MODULE SUIT LOOP

CATEGORY C



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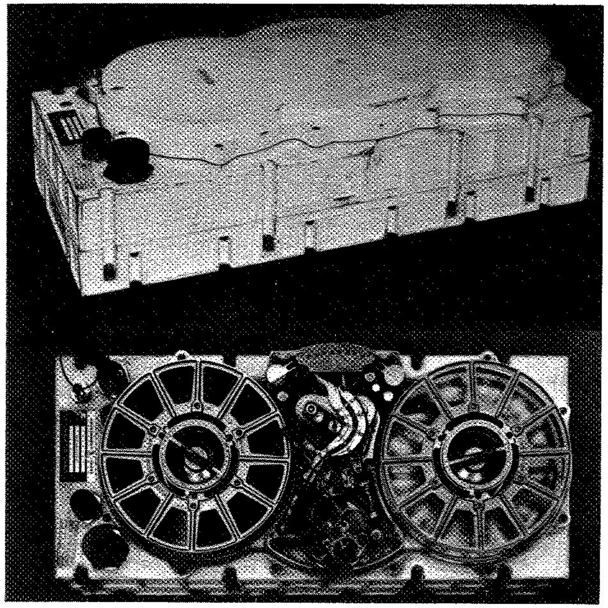
SEALED CONTAINER DATA RECORDING SYSTEM

CATEGORY E



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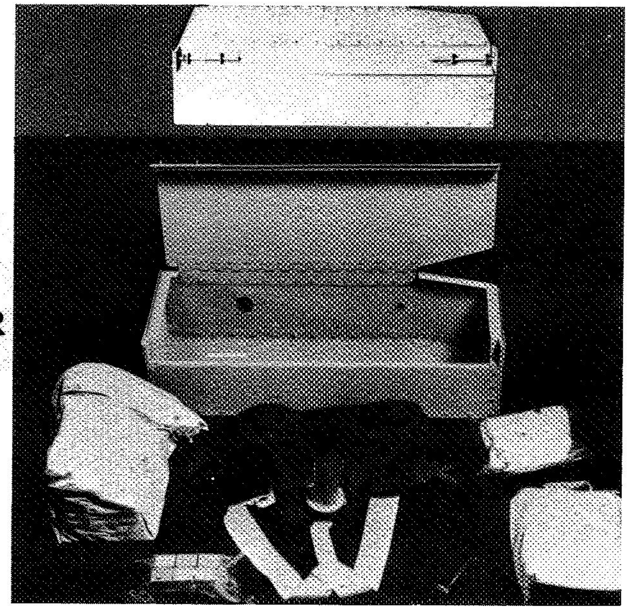
COMMAND MODULE VENTED CONTAINER

CATEGORY F



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TEST REQUIREMENTS

- CHAMBERS AND SPECIAL EQUIPMENT
- TEST ENVIRONMENT
  (USUALLY ENRICHED OXYGEN ATMOSPHERE)
- TEST IGNITION
- TEST TYPES (SCREENING AND APPLICATION)

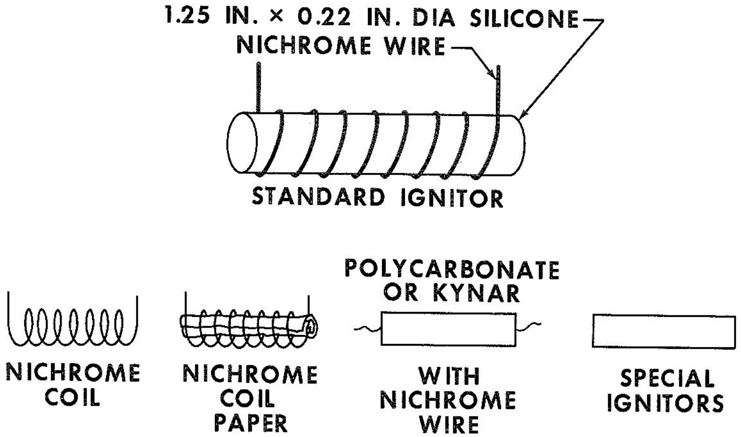
NASA-S-70-2218-X

TEST IGNITOR REQUIREMENTS

- REALISTIC IGNITION SOURCE
- REPEATABLE RESULTS
- UNIFORM HEAT DISTRIBUTION AND
  TIME OF BURN CHARACTERISTICS

NASA-S-70-2224-X

IGNITORS



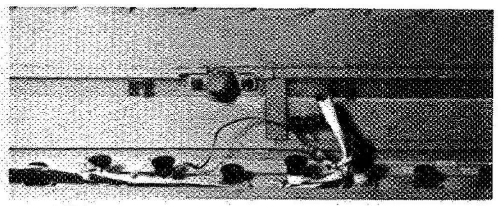
NASA-S-70-2216-X

NONMETALLIC MATERIALS FLAMMABILITY TEST TYPES

- SCREENING TESTS
  - CHARACTERISTICS
    - FLASH AND FIRE POINT
    - UPWARD AND DOWNWARD PROPAGATION RATES
    - CARBON MONOXIDE
    - TOTAL ORGANICS
    - ODOR
  - USE AS GUIDE
- APPLICATION TESTS
  - CONFIGURATION TESTS
  - SYSTEMS TESTS
  - USE AS FINAL ACCEPTANCE OF NONMETALLIC MATERIALS

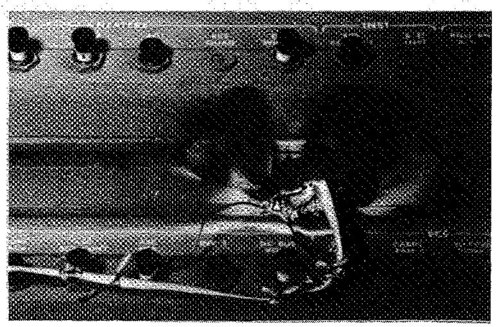
NASA-S-70-2358-X

CONFIGURATION TEST LUNAR MODULE CIRCUIT BREAKER PANEL



BEFORE

AFTER



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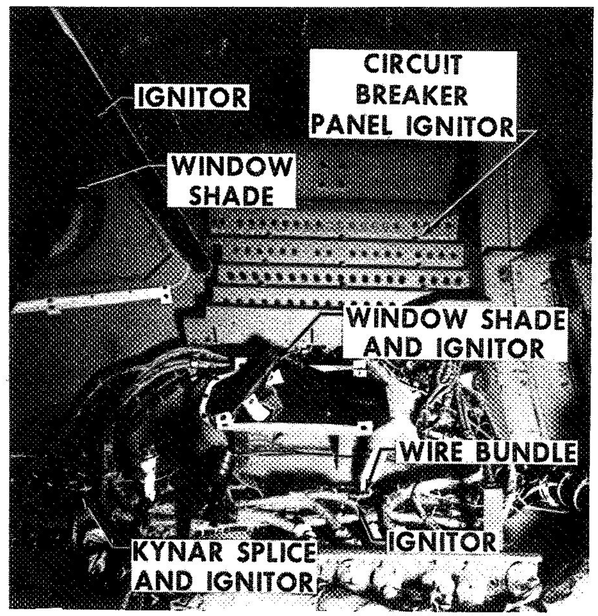
LUNAR MODULE SYSTEM TEST



NASA-S-70-2231-X

NONMETALLIC MATERIALS FLAMMABILITY AND OFFGASSING TEST DATA

- NASA CENTERS AND CONTRACTORS
- NONMETALLIC MATERIALS HANDBOOK

NASA-S-70-2232-X

SUMMARY

- REQUIREMENTS HAVE BEEN DEFINED AND IMPLEMENTED
  - RECOGNITION OF IMPORTANCE OF USAGE CATEGORIES
  - TEST IGNITION SYSTEM
  - TEST PROCEDURES (SCREENING AND APPLICATION)
- VALIDITY OF TEST REQUIREMENTS HAS BEEN DEMONSTRATED
- NONAEROSPACE APPLICATIONS

NASA-S-70-2227-X

NONMETALLIC MATERIALS DESIGN GUIDELINES AND TEST DATA HANDBOOK

- TEST DATA
  - FLAMMABILITY RATE
  - FLASH AND FIRE POINT
  - CARBON MONOXIDE
  - TOTAL ORGANIC OFFGASSING
- ANALYTICAL DISCUSSIONS
  - CRITERIA AND MATERIALS SELECTION
  - COMBUSTION
  - IGNITION
  - FIRE PREVENTION

THE DEVELOPMENT OF MATERIALS SCREENING TESTS FOR OXYGEN-ENRICHED ENVIRONMENTS

By R. L. Johnston and D. L. Pippen
NASA Manned Spacecraft Center

ABSTRACT

The development of materials flammability screening tests for the Apollo Program was built upon earlier test work performed on the Mercury and the Gemini programs. This background of experience was used to define the initial screening test program which led to the development of a set of practical standard tests. These tests yield sufficiently reproducible results to provide a strong foundation for the selection of materials to be used in the design of manned spacecraft. The screening tests that were devised for the Apollo Program are described and evaluated, and the current test program is discussed. Comments are made relative to use of these materials screening test techniques for nonspacecraft applications.

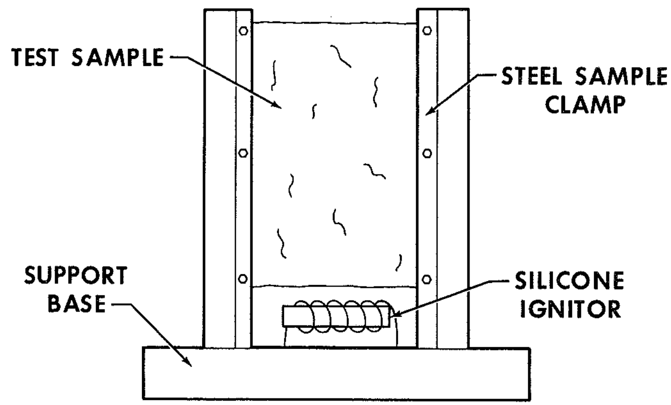
NASA-S-70-1601-X

USAGE CATEGORIES AND REQUIRED MATERIALS FLAMMABILITY TESTS

- MAJOR EXPOSED MATERIALS
  - UPWARD PROPAGATION, FLASH AND FIRE POINT
- SPECIAL APPLICATIONS AND MINOR EXPOSED MATERIALS
  - DOWNWARD PROPAGATION RATE OR ELECTRICAL POTTING AND COATING FLASH AND FIRE POINT
- CREW OXYGEN SUPPLY MATERIALS
  - UPWARD PROPAGATION, FLASH AND FIRE POINT
- HIGH PRESSURE OXYGEN SYSTEM MATERIALS
  - FLASH AND FIRE POINT, FRICTION AND IMPACT IGNITION
- MATERIALS IN SEALED CONTAINERS
- MATERIALS IN VENTED CONTAINERS

NASA-S-70-2060-X

FLAME PROPAGATION TEST FIXTURE



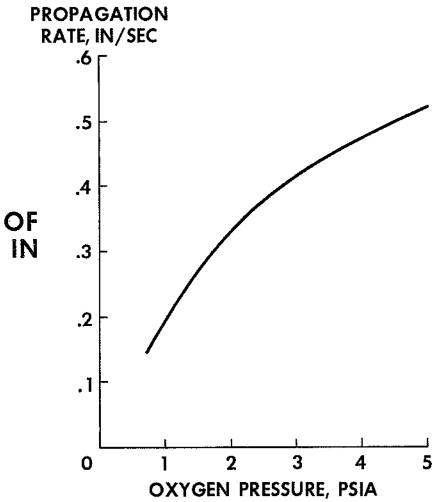
NASA-S-70-2183-X

TYPICAL UPWARD PROPAGATION TEST RESULTS

MATERIAL	6.2 PSIA, 100% OXYGEN TEST RESULT
BETA CLOTH (FIBER GLASS)	SELF-EXTINGUISHED
TEFLON SHEET, 10 MIL	PROPAGATED
TEFLON SHEET, 40 MIL	SELF-EXTINGUISHED
NYLON CLOTH	PROPAGATED
POLYBENZIMIDAZOLE CLOTH	SELF-EXTINGUISHED
MODIFIED VITON	SELF-EXTINGUISHED

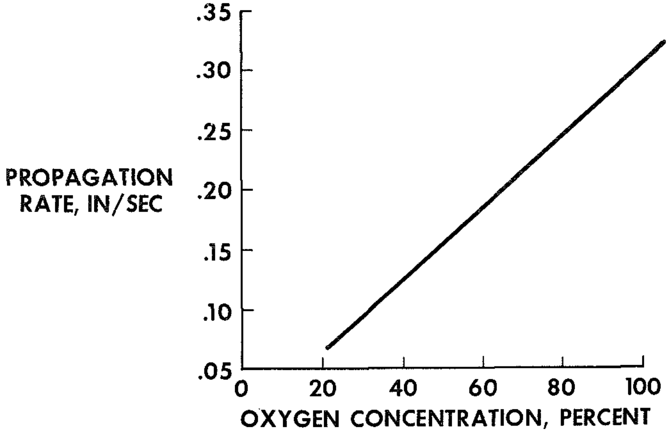
NASA-S-70-2185-X

DOWNWARD FLAME PROPAGATION OF NYLON VELCRO IN 100 PERCENT OXYGEN



NASA-S-70-2186-X

DOWNWARD FLAME PROPAGATION OF NYLON SHEET AT 16.5 PSIA



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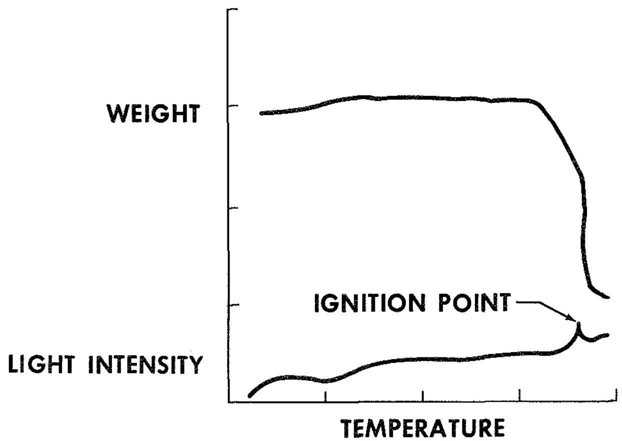
TYPICAL THERMOGRAVIMETRIC SPARK IGNITION TEST RESULTS



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TYPICAL DOWNWARD PROPAGATION RATES

MATERIAL	PROPAGATION RATE, IN/SEC		
	100% O_2, 16.5 PSIA	60% O_2/40% N_2, 16.5 PSIA	100% O_2, 6.2 PSIA
SILASTIC TUBING	0.16	0.06	—
NEOPRENE TUBING	0.08	0.04	—
TEFLON SHEET	0.00	0.00	0.00
NYLON SHEET	0.30	0.19	0.22
HOLLAND CLOTH	0.41	0.26	0.39
POLYETHYLENE	0.17	0.15	—
TRILOCK PLASTIC	0.96	0.45	0.67
MYLAR SHEET	0.54	0.41	0.35

COMPONENT FLAMMABILITY TESTING

By Gary R. Primeaux
NASA Manned Spacecraft Center

ABSTRACT

This report describes the testing techniques used in determining the combustion characteristics of nonmetallic materials in the component configurations used in the Apollo spacecraft. Test articles were either identical to those used in the spacecraft or realistic component simulations. Tests were set up to represent accurately all of the worst-case conditions which a component would encounter during actual use. These tests covered five categories: (1) Electrical Wire Insulation and Accessories, (2) Electrical Component Pottings and Coatings, (3) Nonmetallic Components in Vented Containers, (4) Nonmetallic Components in Sealed Containers, and (5) Electrical Assemblies, Subsystems, and Systems. The test program provided flammability data quickly for the analysis of a large number of nonmetallic materials applications. With these data, the success of the final design flammability verification of the Apollo spacecraft was significantly enhanced.

NASA-S-70-2053-X

COMPONENT TESTING OBJECTIVES

- PROVIDE NONMETALLIC MATERIALS DESIGN DATA QUICKLY AND ECONOMICALLY
- PROVIDE FLAMMABILITY CHARACTERISTICS FOR A VARIETY OF SIZES, SHAPES AND CONFIGURATIONS OF MATERIALS WHICH MAKE UP A FUNCTIONAL ASSEMBLY, SUBSYSTEM OR SYSTEM

NASA-S-70-2059-X

SELECTION OF TEST CRITERIA

- COMPONENT CONFIGURATION CONTROL
- TEST CONDITIONS
  - WORST CASE
  - IGNITION TYPES
  - GENERAL TEST REQUIREMENTS
- TEST EQUIPMENT
  - 18 INCH DIAMETER TEST CHAMBERS
  - COMMAND MODULE TEST CHAMBER
- DATA REQUIREMENTS
  - PHOTOGRAPHIC
  - TEMPERATURE AND PRESSURE MEASUREMENTS
  - COMBUSTION PRODUCTS

NASA-S-70-2058-X

COMPONENT CONFIGURATION CONTROL

- FLIGHT QUALIFIED HARDWARE
- ACCURATE TEST ARTICLE SIMULATION

NASA-S-70-2054-X

TEST CONDITIONS

- WORST CASE
  - AMOUNT OF FLAMMABLE MATERIAL
  - PROPAGATION PATHS
  - MOST SEVERE ATMOSPHERE
  - LOCATION, NUMBER AND TYPE OF IGNITION SITES

NASA-S-70-2043-X

TEST CONDITIONS

- IGNITION TYPES
  - INTERNAL - SIMULATES WIRE OR ELECTRICAL COMPONENT OVERLOAD
  - EXTERNAL - SIMULATES FLAME IMPINGEMENT FROM NEARBY SOURCE

NASA-S-70-2048-X

TEST CONDITIONS

- GENERAL TEST REQUIREMENTS
  - CONFIGURATIONS AND MATERIALS MUST DUPLICATE FLIGHT ARTICLE
  - TEST ARTICLE ORIENTATION MUST REPRESENT NORMAL OPERATION
  - TEST CHAMBER VOLUME MUST BE LARGE ENOUGH TO ALLOW
    - SUFFICIENT OXYGEN FOR COMPLETE COMBUSTION
    - OBSERVATION OF EXTENT OF BURNING

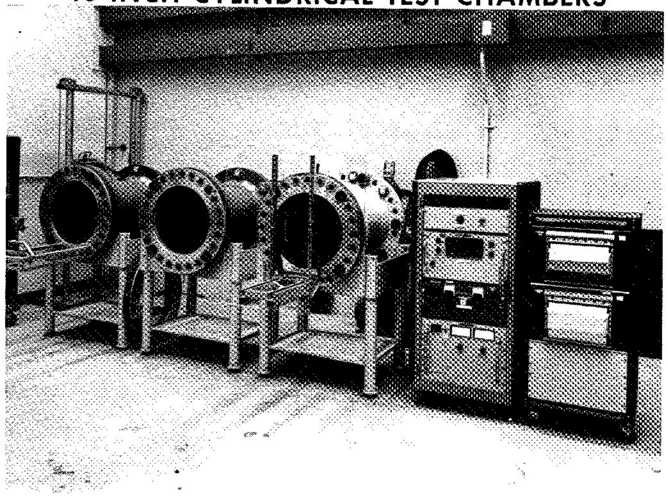
NASA-S-70-2047-X

TEST CONDITIONS

- THERMAL INTERFACES SHOULD SIMULATE
  - COLD PLATES
  - MOUNTING STRUCTURE
  - CONVECTION CAUSED BY FORCED AIR CIRCULATION
  - RADIATION CHARACTERISTICS
- ATMOSPHERIC CONDITIONS REPRESENT
  - TEMPERATURE
  - PRESSURE
  - GASEOUS CONCENTRATION

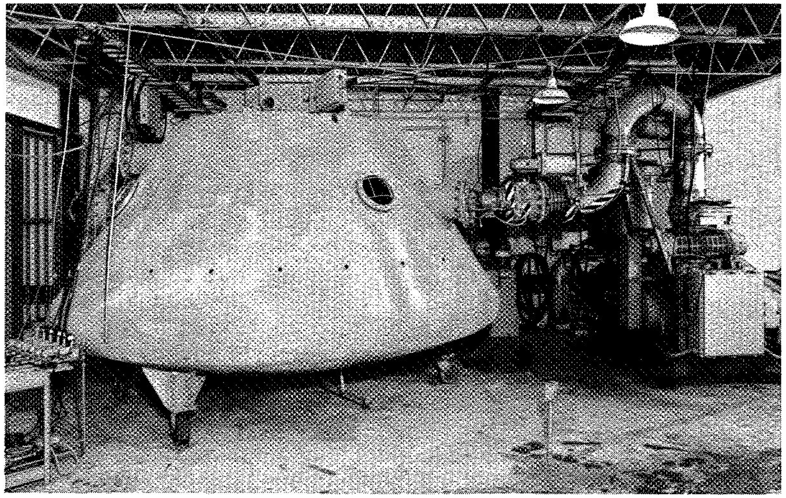
NASA-S-70-1987-X

18-INCH CYLINDRICAL TEST CHAMBERS



NASA-S-70-1985-X

COMMAND MODULE BOILERPLATE TEST CHAMBER



NASA-S-70-2041-X

COMPONENT CONFIGURATION CATEGORIES

- ELECTRICAL WIRE INSULATION AND ACCESSORIES
- ELECTRICAL COMPONENT POTTINGS AND COATINGS
- NONMETALLIC COMPONENTS IN VENTED CONTAINERS
- NONMETALLIC COMPONENTS IN SEALED CONTAINERS
- ELECTRICAL ASSEMBLIES, SUBSYSTEMS, AND SYSTEMS

NASA-S-70-2157-X

CONCLUDING REMARKS

- 800 SPACECRAFT COMPONENT FLAMMABILITY TESTS PROVIDED DATA FOR
  - SELECTION OF SPACECRAFT MATERIALS DESIGN
  - VERIFICATION OF MINOR DESIGN CHANGES
- COMPONENT TESTING USEFUL IN OTHER AREAS

FULL-SCALE SPACECRAFT

MOCKUP FLAMMABILITY TESTS

By R. W. Bricker, J. P. Crabb, and I. K. Spiker
NASA Manned Spacecraft Center

ABSTRACT

After extensive materials and component-level tests, a series of full-scale spacecraft-mockup flammability tests provided the final verification that the Apollo command module and lunar module were firesafe. Two possible spacecraft launch atmospheres were evaluated, and the safer of the two atmospheres was defined. An interior mockup of a command module and a lunar module was used in a series of 173 flammability tests. Tests were conducted in 5.8-psia, 6.2-psia, and 16.2-psia 100-percent-oxygen atmospheres and in a 16.2-psia 60-percent-oxygen/40-percent-nitrogen atmosphere. The latter two series of tests represented possible launch atmospheres. Fires were deliberately started in the mockups at locations selected as representative of potential ignition hazards. For each test, data were recorded to determine possible propagation paths and to identify potentially toxic products which might evolve. It was determined that, with minor changes in materials or configuration, the command module and the lunar module are firesafe in the 6.2-psia 100-percent-oxygen flight atmosphere, and the command module is firesafe in the 16.2-psia 60-percent-oxygen/40-percent-nitrogen launch atmosphere. This test series confirmed the importance of the full-scale mockup tests and demonstrated the value of several basic design approaches, such as (1) the elimination of long propagation paths, (2) the use of nonflammable coatings and containers, and (3) the use of fire breaks. Some of the tests that were conducted in support of the verification program are discussed in this paper. The applicability of full-scale-mockup flammability test techniques to areas outside the space program is also considered.

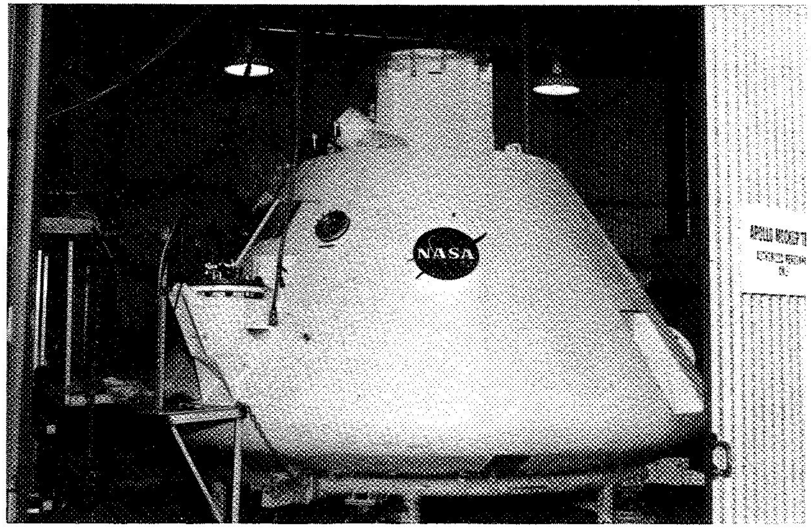
NASA-S-70-2140-X

INTRODUCTION

- FINAL VERIFICATION THAT THE CM AND LM WERE SAFE FOR FLIGHT
- SUPPORT SELECTION OF LAUNCH ENVIRONMENT

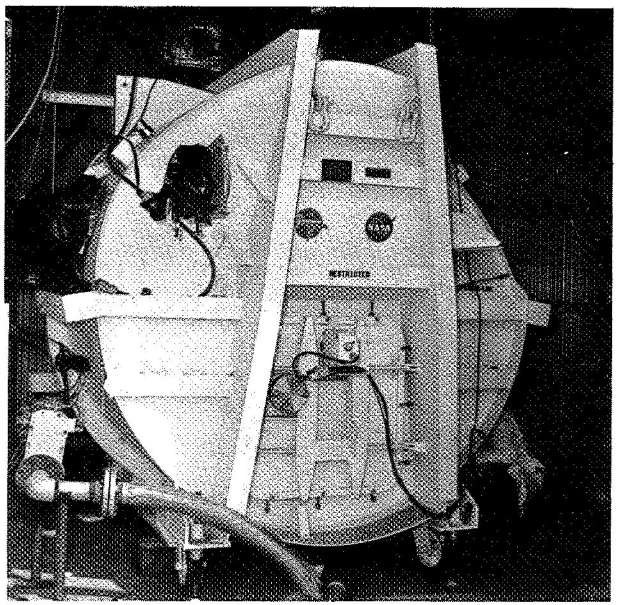
NASA-S-70-2102-X

COMMAND MODULE MOCKUP



NASA-S-70-2103-X

LUNAR MODULE MOCKUP



NASA-S-70-2141-X

TEST ENVIRONMENTS

	LM TESTS	CM TESTS		
ENVIRONMENT	5.8 PSIA 100% O_2	6.2 PSIA 100% O_2	16.2 PSIA 60% O_2/ 40% N_2	16.2 PSIA 100% O_2
TOTAL TESTS	72	37	34	30

NASA-S-70-2110-X

OBJECTIVES

- EVALUATE PROPAGATION
- DETERMINE EFFECTS OF COMBUSTION ON CABIN PRESSURE AND TEMPERATURE
- IDENTIFY COMBUSTION PRODUCTS

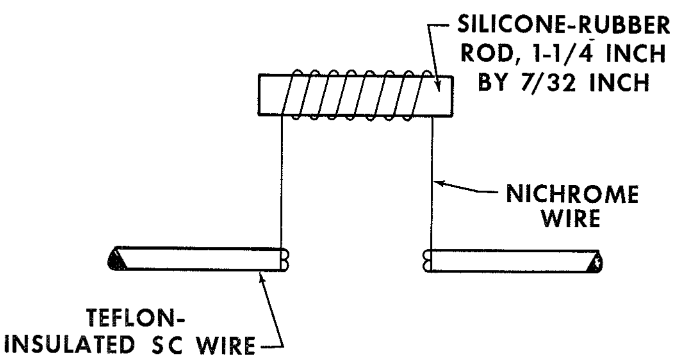
NASA-S-70-2142-X

TEST PHILOSOPHY

- SOURCE OF IGNITION INHERENT DUE TO ELECTRICAL SYSTEMS
  - PROGRAM WAS NOT AN EVALUATION OF IGNITION POSSIBILITIES
  - POSITIVE IGNITION TECHNIQUES WERE USED

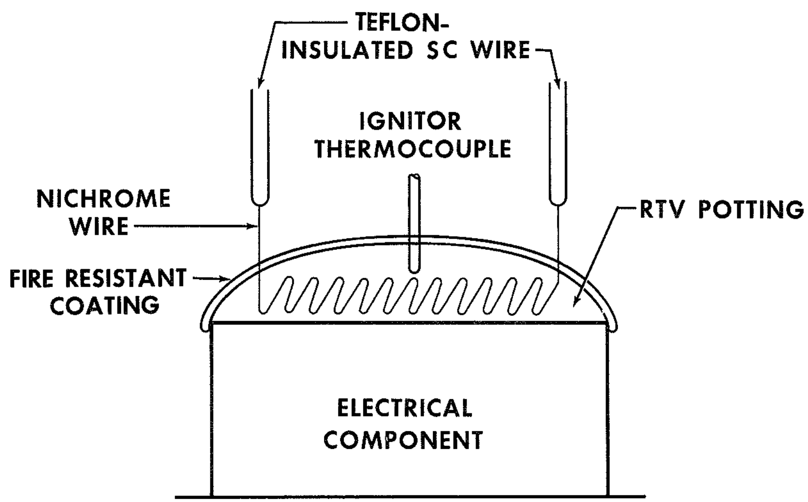
NASA-S-70-1611-X

EXTERNAL IGNITOR CONFIGURATION



NASA-S-70-1423-X

INTERNAL (HIDDEN) IGNITOR CONFIGURATION



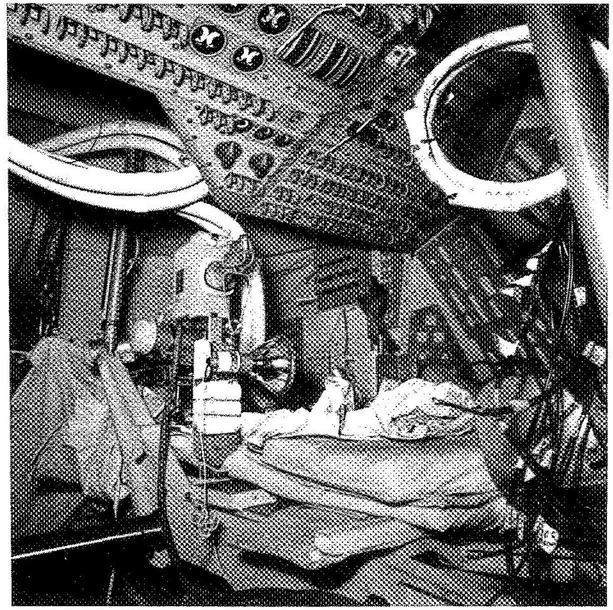
NASA-S-70-2139-X

GROUND RULES

- TRUE WORST-CASE CONFIGURATION
- SELECTED IGNITION POINTS
- TEST MONITORING
- TEST TERMINATION CONDITION

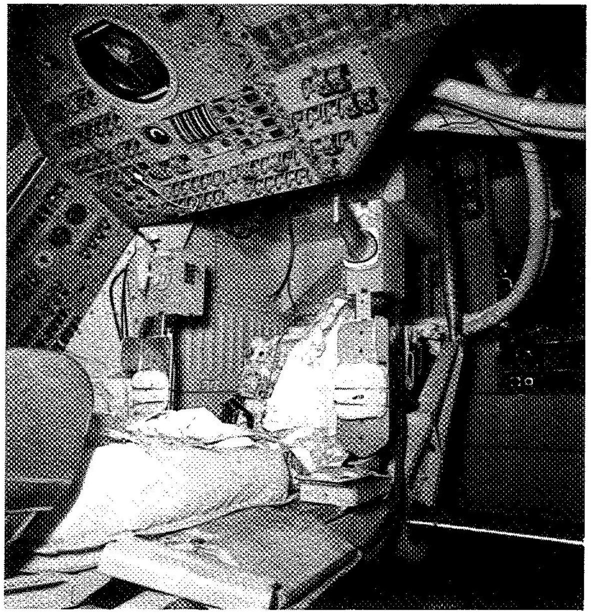
NASA-S-70-2109-X

RIGHT HAND SIDE OF COMMAND MODULE MOCKUP



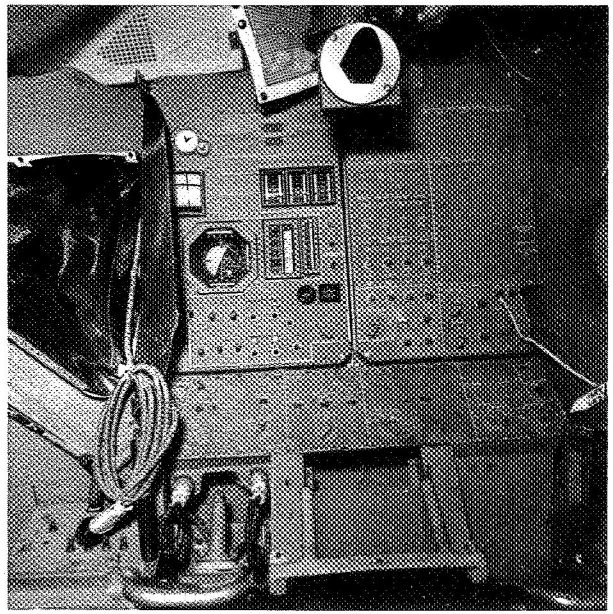
NASA-S-70-2101-X

LEFT HAND SIDE OF COMMAND MODULE MOCKUP



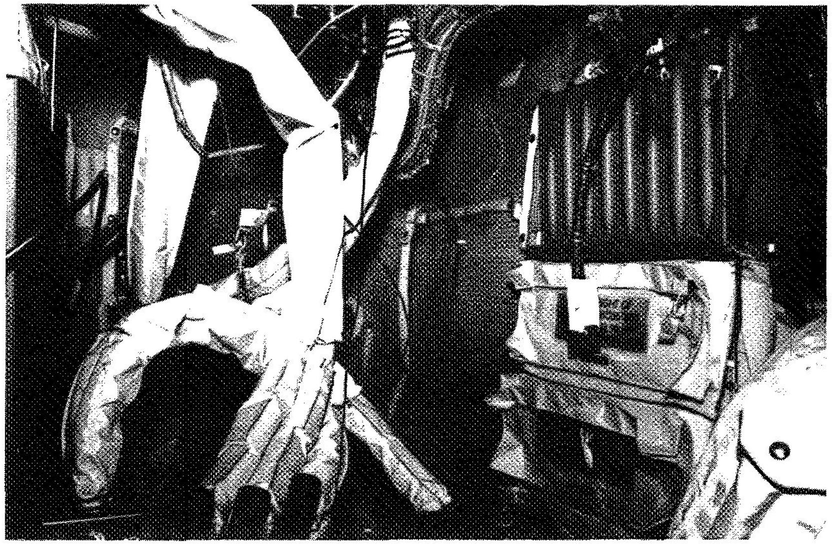
NASA-S-70-2108-X

LM MOCKUP LOOKING FORWARD



NASA-S-70-2104-X

LM MOCKUP - LOOKING AFT



NASA-S-70-2105-X

TEST MONITORING

- PRESSURE AND TEMPERATURE
- STILL PHOTOS
- COLOR MOVIES
- TV
- ASTRONAUT OBSERVER

NASA-S-70-2106-X

TEST TERMINATION RULES

- FIRE SELF-EXTINGUISHED (HOLD TEST CONDITIONS FOR 5 MINUTES)
- FLAME PROPAGATION BEYOND PREDETERMINED LIMITS (FORCED TERMINATION)
- EGRESS TIME
  - APPLICABLE TO LAUNCH ENVIRONMENTS ONLY
  - TRUE EGRESS TIME PLUS 50 PERCENT
  - TIME STARTED WHEN SMOKE FIRST OBSERVED
  - SUCCESSFUL EGRESS DEPENDENT ON FIRE LOCATION AND MAGNITUDE

NASA-S-70-2107-X

CRITERIA FOR SELECTION OF IGNITION LOCATIONS

- POTENTIAL PROPAGATION PATHS
- EVALUATE CHANGES
- PROXIMITY OF ALL KNOWN FLAMMABLES
- REPRESENTATIVE INSTRUMENTATION AND ELECTRICAL PANELS

NASA-S-70-1840-X

FLAMMABILITY TEST SUMMARY

LUNAR MODULE AND COMMAND MODULE

	LM TESTS	CM TESTS		
ENVIRONMENT	5.8 PSIA 100% O_2	6.2 PSIA 100% O_2	16.2 PSIA 60% O_2/ 40% N_2	16.2 PSIA 100% O_2
TOTAL TESTS	72	37	34	30
SELF EXTINGUISHED	65	34	28	15
REQUIRED TERMINATION	7	3	5	15
PERCENT TERMINATED	10	8	15	50
INSUFFICIENT EGRESS TIME			1	3
MARGINAL EGRESS TIME			1	4

NASA-S-70-2112-X

CONCLUDING REMARKS

- FULL-SCALE MOCKUP TESTS
  - COMPLEMENTED MATERIALS SCREENING AND COMPONENT TESTS
  - PROVIDED FINAL VERIFICATION
    - VERIFIED THAT THE CM AND LM WERE SAFE FOR THE PURE OXYGEN FLIGHT ENVIRONMENT
    - VERIFIED THAT THE CM IS SAFE FOR THE 60 PERCENT OXYGEN 40 PERCENT NITROGEN LAUNCH ENVIRONMENT

NASA-S-70-2111-X

CONCLUDING REMARKS (CONT)

- DEMONSTRATED VALUE OF SEVERAL DESIGN APPROACHES
  - ELIMINATE LONG PROPAGATION PATHS
  - USE OF NONFLAMMABLE COATINGS AND CONTAINERS
  - USE OF FIRE BREAKS
- PROPER MATERIALS AND DESIGN APPROACHES MINIMIZE THE NEED FOR REPETITIVE FULL-SCALE MOCKUP TESTS
- FULL-SCALE MOCKUP TESTING APPLICABLE TO AIRCRAFT, SURFACE, AND UNDERWATER VEHICLES

SESSION II

MATERIALS DEVELOPMENT

Session Chairman: Edward L. Hays

NONMETALLIC MATERIALS DEVELOPMENT

FOR SPACECRAFT APPLICATIONS

By Frederic S. Dawn
NASA Manned Spacecraft Center

ABSTRACT

The purpose of this paper is to present the specialized requirements of manned space flight in the category of nonmetallic materials, to give a brief history of materials development within the space program, to touch on the kinds of materials developed to date, and to describe a few of the new materials on the horizon. An overall view of the nonmetallic materials development work which has been conducted by NASA over the last several years is presented, and the properties and characteristics of selected materials are discussed. In addition, the paper considers a large variety of potential applications of flame-resistant materials developments for commercial, domestic, and military uses.

NASA-S-70-1695-X

SPACE & LUNAR SURFACE ENVIRONMENT

- PRESSURE — $\approx 10^{-14}$ mm Hg
- TEMPERATURE (LUNAR SURFACE)
  - UPPER — +250° F
  - LOWER — -250° F
- ELECTROMAGNETIC RADIATION — X-RAY, ULTRAVIOLET, VISIBLE, INFRARED
- SOLAR WINDS
- MICROMETEOROIDS

MATERIALS MUST WITHSTAND EXPOSURE WITHOUT FUNCTIONAL DEGRADATION

NASA-S-70-1704-X

APOLLO SPACECRAFT CABIN ENVIRONMENT

ENVIRONMENT	PRELAUNCH	POST LAUNCH
PRESSURE, PSIA (MAX)	16.5	6.2
TEMPERATURE, °F	70 ± 10	70 ± 10
REL HUMIDITY, PERCENT	30 ± 10	60 ± 10
OXYGEN, PERCENT	60	> 95
NITROGEN, PERCENT	40	0

MATERIALS MUST WITHSTAND EXPOSURE WITHOUT FUNCTIONAL DEGRADATION

NASA-S-70-2127-X

NONMETALLIC MATERIALS TEST CRITERIA

TEST	MAXIMUM LIMIT
TOTAL ORGANICS, μg/g	100
CO, μg/g	25
ODOR, RATING	2.5
FLAMMABILITY	
CATEGORY A	SELF EXTINGUISHING
CATEGORY B	0.3 IN/SEC

NASA-S-70-1700-X

TEST RESULTS ON TYPICAL APOLLO NONMETALLIC MATERIALS

MATERIALS	TOTAL ORGANICS, μg/g	CO, μg/g	ODOR
BETA	0	2.1	1.3
TEFLON	34.0	0.7	0.9
PBI	0.4	1.7	1.5
ASBESTON	1.3	1.0	1.7
NOMEX	1.0	0.4	0.7
VITON	0.3	0.4	0.8
FLUOREL	1.0	1.2	1.3
CNR	6.0	0.8	1.8
ASTRO VELCRO	2.0	0.2	1.7

NASA-S-70-2202-X

TEST RESULTS ON TYPICAL APOLLO NONMETALLIC MATERIALS

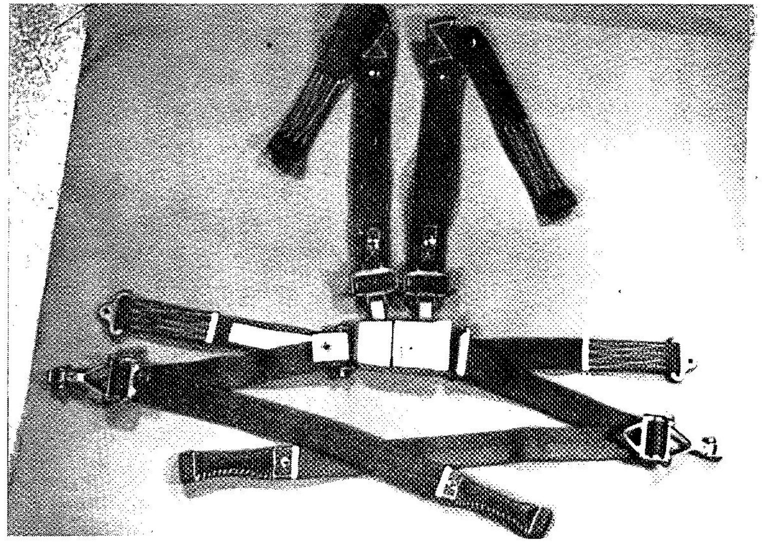
SILICONE IGNITOR, 100% O_2
BURN RATE, IN/SEC

MATERIALS	TOP IGNITION		BOTTOM IGNITION		
	16.5 PSIA	6.2 PSIA	16.5 PSIA	*16.5 PSIA	6.2 PSIA
BETA	NI	NI	NI	NI	NI
TEFLON	SE	SE	0.55	0.30	0.30
PBI	0.20	0.16	0.41	0.35	0.30
ASBESTON	SE	SE	SE	SE	SE
NOMEX	0.33	0.16	1.00	0.60	0.60
VITON	SE	SE	SE	SE	SE
FLUOREL	SE	SE	SE	SE	SE
CNR	SE	SE	SE	SE	SE
VELCRO**	0.02	0.01	0.50	0.37	0.35

* 60% O_2 40% N_2 **ASTRO VELCRO
SE = SELF EXTINGUISHING
NI = NO IGNITION

NASA-S-70-1693-X

POLYBENZIMIDAZOLE CREWMAN RESTRAINT HARNESS



NASA-S-70-1698-X

PROPERTIES OF FIBROUS MATERIALS

PROPERTIES	BETA	PBI	TEFLON	ASBESTON	NOMEX
TENSILE STRENGTH, G/DENIER	15	4.5	1.4	2.5 – 3.1	5.5
ELONGATION, %	4	12–13	15	2 – 3	17
SPECIFIC GRAVITY	2.45	1.34	2.1	2.10 – 2.80	1.38
SERVICE TEMPERATURE, °F	-300– +900	-65 – +800	-400 – +500	-200 – +2400	-65 – +500
THERMAL CONDUCTIVITY, BTU/FT^2/°F/HR/IN	4.97	0.9	1.7	0.59	0.9

NASA-S-70-1703-X

TYPICAL APPLICATIONS FOR FIBROUS MATERIALS

MATERIALS	TYPICAL APPLICATIONS
POLYBENZIMIDAZOLE (PBI)	HARNESSES, TETHERS, STRAPS, BELTS, CONTAINERS
TEFLON	FLIGHT COVERALL, ABRASION RESISTANT PATCHES FOR SPACE SUITS
ASBESTON	FLAME BARRIER OR THERMAL INSULATION
NOMEX	COMFORT LINER FOR APOLLO SPACE SUIT

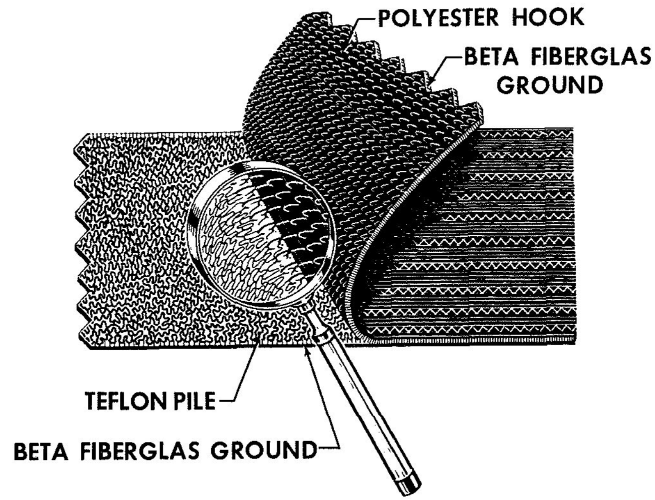
NASA-S-70-1699-X

PROPERTIES OF ELASTOMERIC MATERIALS

PROPERTIES	FLUOREL	VITON	CARBOXY NITROSO RUBBER
SPECIFIC GRAVITY	1.85	1.97	1.93
SERVICE TEMPERATURE, °F	-40 TO 400	-65 TO 400	-47 TO 375
TENSILE, STRENGTH PSI	1500-2500	1500-2500	1000-2200
ELONGATION, PERCENT	125-300	150-300	250-500
DUROMETER (SHORE A)	60-90	60-90	60-80
THERMAL CONDUCTIVITY, $BTU/FT^2/°F/HR/IN$	0.957	0.702	0.867

NASA-S-70-1706-X

ASTRO VELCRO



6-4

NASA-S-70-1701-X

FLAME PROPAGATION RATE OF VELCRO

BOTTOM IGNITION, IN/SEC

SILICONE IGNITOR

VELCRO TYPE (ENGAGED)	ENVIRONMENT: 6.2 PSIA 100% O_2	ENVIRONMENT: 16.5 PSIA 60% O_2/40% N_2
NYLON	1.66	1.66
ASTRO	0.35	0.37

NASA-S-70-1811-X

TEST RESULTS ON NEW MATERIALS

MATERIALS	TOTAL ORGANIC, μg/g	CO, μg/g	ODOR
DURETTE	0.6	3.0	0.2
POLYSULFONE	0.9	0.2	1.0
FL URETHANE	89.0	8.0	0.6
POLYQUINOXALINE	0.5	4.3	1.3
ASBESTOS FOAM	4.1	3.7	1.7
FYPRO	1.0	4.0	0.7

NASA-S-70-2203-X

TEST RESULTS ON NEW MATERIALS

SILICONE IGNITOR, 100% O_2
BURN RATE, IN/SEC

MATERIALS	TOP IGNITION		BOTTOM IGNITION		
	16.5 PSIA	6.2 PSIA	16.5 PSIA	*16.5 PSIA	6.2 PSIA
DURETTE	0.41	0.31	1.00	0.55	0.41
POLY-SULFONE	0.02	0.01	0.10	0.04	0.03
FL. URETHANE	SE	SE	-	SE	SE
POLYQUI-NOXALINE	SE	SE	0.02	SE	SE
ASBESTOS FOAM	NI	NI	NI	NI	NI
FYPRO	0.45	0.33	1.25	0.83	0.71

* 60% O_2 40% N_2
SE = SELF EXTINGUISHING
NI = NO IGNITION

NASA-S-70-1993-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

FIBROUS MATERIALS

MATERIALS	MILITARY
BETA	FIRE PROTECTIVE CLOTHING
PBI	PARACHUTES AND LINES
ASBESTON	BELTS AND STRAPS
NOMEX	TENTS AND TARPAULINS
DURETTE	
FYPRO	

NASA-S-70-1994-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

FIBROUS MATERIALS

MATERIALS	COMMERCIAL
BETA	THERMAL INSULATIONS
PBI	HOSPITAL AND INDUSTRIAL UNIFORMS
ASBESTON	VEHICLE UPHOLSTERY
NOMEX	PACKAGING, SEAT BELTS, TENTS,
DURETTE	CARGO COMPARTMENT LINERS
FYPRO	CARGO AND BOAT COVERS,
	CARPETS AND CURTAINS
	RACING CAR DRIVERS COVERALLS

NASA-S-70-1996-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

FIBROUS MATERIALS

MATERIALS	HOUSEHOLD
BETA	CLOTHING
PBI	CURTAINS, DRAPERIES
ASBESTON	BED SPREADS, BLANKETS
NOMEX	DECORATIVE PANELS
DURETTE	SEWING THREADS
FYPRO	MATTRESSES, SOFA TICKINGS
	TABLE CLOTHS
	UPHOLSTERY, CARPETS AND RUGS

NASA-S-70-1997-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

ELASTOMERIC MATERIALS

MATERIALS	MILITARY
FLUOREL	AIRCRAFT INTERIOR COATINGS
VITON	GAS MASKS
CNR	SURVIVAL EQUIPMENT
ASBESTOS FOAMS	COATINGS FOR CARGO COVERS
FLUORINATED SILICONE	SHIELDS FOR HAZARDOUS OPERATIONS
FLUORINATED URETHANE	TENTS

NASA-S-70-1998-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

ELASTOMERIC MATERIALS

MATERIALS	COMMERCIAL
FLUOREL	HEAT INSULATIONS, CEILING TILES,
VITON	WALL PANELS, FLOOR COVERINGS,
CNR	WIRE AND CABLE INSULATIONS
ASBESTOS FOAMS	AUTOMOTIVE PARTS AND ACCESSORIES
FLUORINATED SILICONE	WAREHOUSE FIREPROOF COATINGS
FLUORINATED URETHANE	FUEL PIPELINE INSULATIONS
	FURNITURE AND FIXTURE COVERS
	HOSPITAL EQUIPMENT
	MINE SAFETY APPLIANCES PARTS
	BUILDING INSULATIONS, PACKAGING,
	TOYS, FR COATINGS FOR HOTELS,
	HOSPITALS, SCHOOLS, PUBLIC BUILDINGS, MAIL BAG COATINGS

NASA-S-70-1999-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

ELASTOMERIC MATERIALS

MATERIALS	HOUSEHOLD
FLUOREL	FOAM PILLOWS AND MATTRESSES
VITON	DECORATIVE COATINGS FOR WALLS AND PANELS
CNR	CEILING TILES
ASBESTOS FOAMS	WALL PANELS
FLUORINATED SILICONE	FLOOR COVERINGS
FLUORINATED URETHANE	

NASA-S-70-1992-X

POTENTIAL APPLICATIONS OF FLAME-RESISTANT AEROSPACE MATERIALS

PAPER

COMMERCIAL & HOUSEHOLD	MILITARY
WALL PAPER	LOG BOOKS
DECORATIVE PANELS	FLIGHT MANUALS
DECORATIVE TILES	MAPS
NEWSPAPERS, CARD BOARDS	CHARTS
BOOKS, WRAPPING PAPERS	
LEGAL DOCUMENTS	

DEVELOPMENT AND APPLICATIONS OF FLUOREL

By Daniel E. Supkis
NASA Manned Spacecraft Center

ABSTRACT

The need for a nonflammable elastomer for use in the Apollo spacecraft is discussed. A brief development history of Fluorel, a copolymer of hexafluoropropene and vinylidene fluoride, is presented. The solubility of Fluorel and the usefulness of the Fluorel solution for conformable coating are discussed, and handling precautions are defined. Additives to and adhension of the Fluorel solution are treated briefly. Many Apollo spacecraft applications of Fluorel, with emphasis on use as a conformable coating, are illustrated. A more practical approach to future aerospace uses is examined. The versatility and the superior physical properties of Fluorel, when used in conjunction with other nonflammable materials, are discussed relative to potential applications in the commercial aviation, military, medical, transportation, and construction fields.

NASA-S-70-2328-X

FLUOREL COMPOUNDS QUALIFIED FOR CATEGORY A FLIGHT USE

(MOSITES RUBBER CO)

COMPOUND NUMBER	COMMENT
1059 (3M L-2231) GUM STOCK	USED IN HOSES, HEADRESTS, CABLE COATINGS
1062 LOW DENSITY CLOSED CELL SPONGE 1062C HIGH DENSITY CLOSED CELL SPONGE 1064J HIGH DENSITY OPEN CELL SPONGE	USED AS SHOCK ABSORBERS, SPACERS, EYE PIECE
1066 - FILM	USED AS AN ADHESIVE AND SURFACE COATING
1071 GUM STOCK 1076 GUM STOCK 1077 GUM STOCK 1079K GUM STOCK 1087JJ GUM STOCK	DEVELOPED FOR LOWER OPERATING TEMPERATURES AND GREATER FLEXIBILITY

NASA-S-70-2329-X

FLUOREL COMPOUNDS QUALIFIED FOR CATEGORY A FLIGHT USE

(RAYBESTOS - MANHATTAN INC)

COMPOUND NUMBER	COMMENT
L-3217 (3M L-2231) GUM STOCK	USED IN HOSES, HEADRESTS, CABLE COATINGS
L-3251-3 GUM STOCK	USED AS SPACE SUIT BOOT SOLE
L-3203-6 FILM	USED AS AN ADHESIVE AND SURFACE COATING
RL-3492 AND RL-3550 FILMS	BASIC L-3206-6 STOCK WITH ASBESTOS ADDED - USED AS FIREPROOF COATING

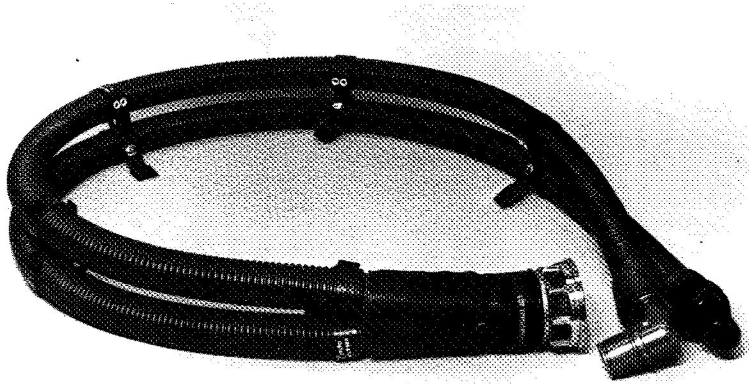
NASA-S-70-1541-X

FLUOREL APOLLO FLIGHT ITEMS

- OXYGEN UMBILICAL
- EYEGLASSES
- RELIEF TUBE ASSEMBLY
- BOOT SOLE AND HEEL
- FOAM PADS AS SPACERS IN RUCKSACK
- PRESSURE GARMENT ASSEMBLY GLOVES - COATED
- VACUUM SCREEN CAPS
- OXYGEN AND SMOKE MASK HOSES
- HEAD REST PADS
- CREWMAN COMMUNICATION UMBILICAL CABLE
- FLOODLIGHT GLARE SHIELD
- COATED CUFF CARDS, APOLLO 11
- COMMAND MODULE WINDOW GASKETS
- SUN SHADES - READOUT PANELS
- GUIDANCE AND NAVIGATION GASKET
- SUIT-HARNESS BEND-RELIEF BOOT

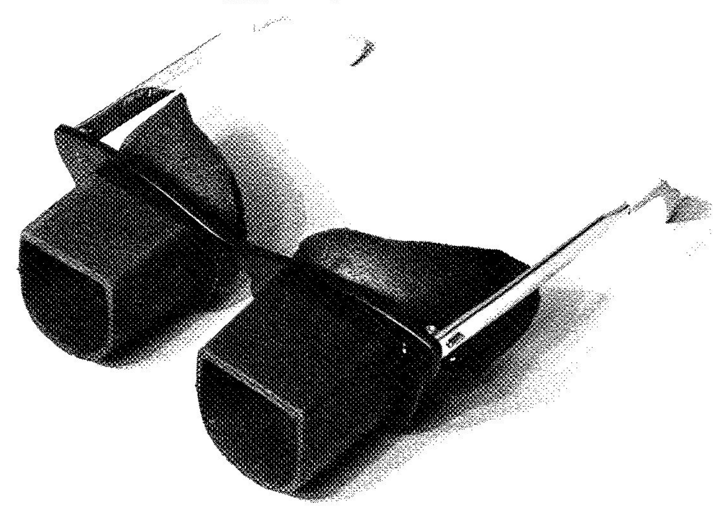
NASA-S-70-2151-X

FLUOREL OXYGEN UMBILICAL



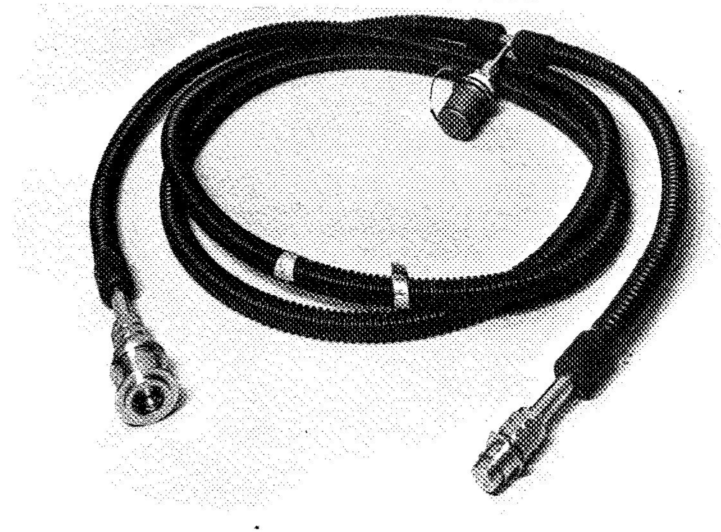
NASA-S-70-2150-X

FLUOREL 1064J EYEPIECES



NASA-S-70-2152-X

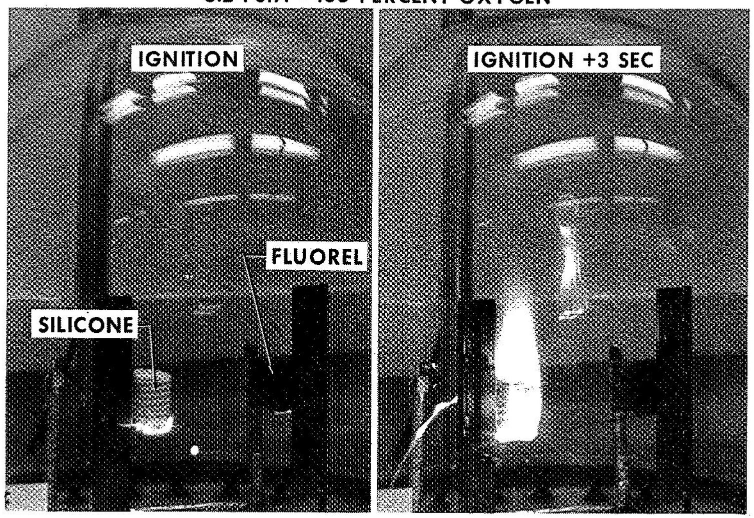
FLUOREL RELIEF TUBE



NASA-S-70-2149-X

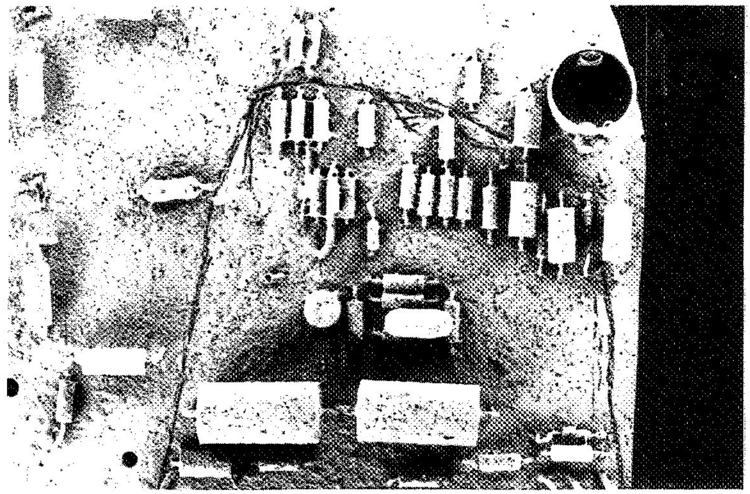
FLAMMABILITY TEST, SILICONE VS FLUOREL HOSE

6.2 PSIA - 100 PERCENT OXYGEN



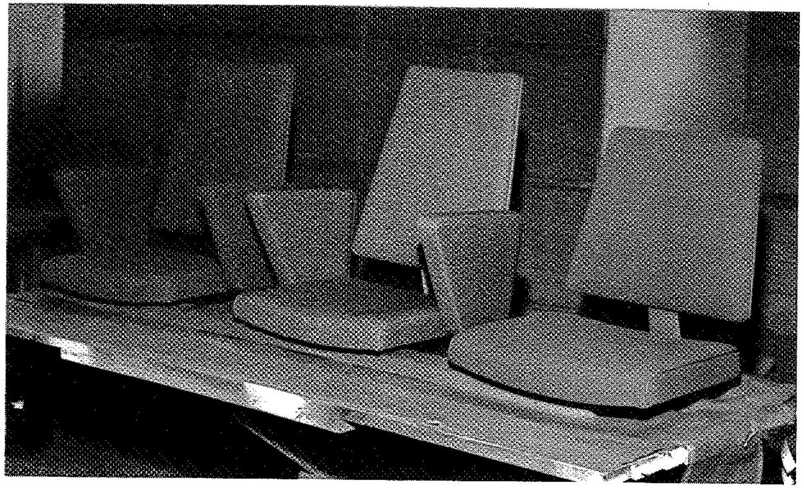
NASA-S-70-1544-X

ELECTRICAL PANEL FLUOREL CONFORMAL COATING



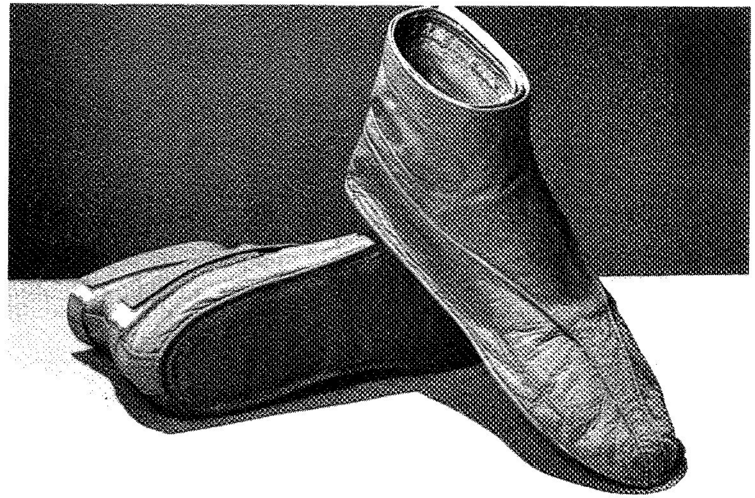
NASA-S-70-1534-X

UPHOLSTERY FIREPROOFED WITH FLUOREL



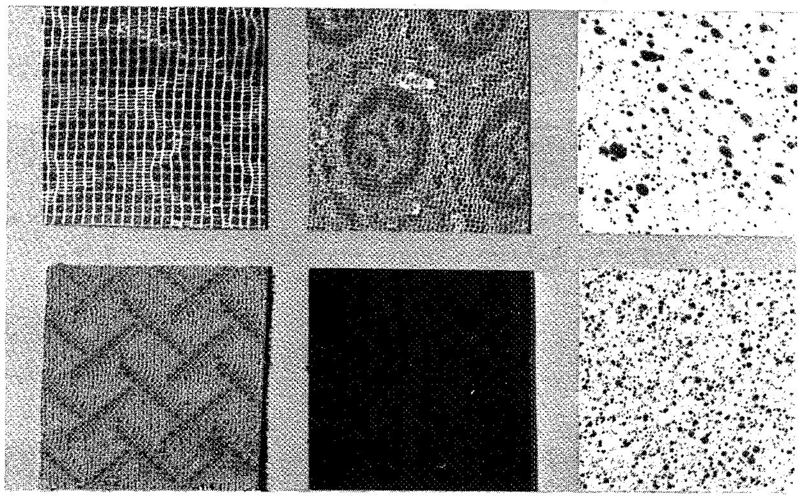
NASA-S-70-1527-X

FLUOREL COATED LEATHER BOOTS



NASA-S-70-1424-X

NONFLAMMABLE PANELING



DEVELOPMENT AND APPLICATION OF FLAME-RESISTANT POLYMERS AND COMPOSITES

By Dale G. Sauers
NASA Manned Spacecraft Center

ABSTRACT

This paper discusses the efforts and accomplishments of the aerospace industry in the areas of flame-resistant elastomers and structural composites. Elastomers discussed include carboxy nitroso rubber, fluorosilicones, and recently developed flame-resistant Viton elastomers. Flame-resistant Viton gum stocks and sprayable coatings that are effective in protecting flammable substrates in air and pure-oxygen environments are discussed. The principle structural composites discussed are polyimide and polyquinoxaline matrices with glass-fiber reinforcements. Data on other composite materials are provided. Possible industry applications for the flame-resistant elastomers and composites are discussed.

NASA-S-70-1808-X

TYPICAL PROPERTIES OF CARBOXY NITROSO RUBBER

PROPERTY	CURE AGENT	
	CHROMIUM TRIFLUOROACETATE	DICYCLOPENTADIENE DIOXIDE
TENSILE STRENGTH, PSI	1000 - 2000	600 – 1800
ELONGATION, PERCENT	250 - 800	150 – 1200
HARDNESS, SHORE A	35 - 80	35 – 80
COMPRESSION SET, PERCENT	15 - 30	10 – 15
FLAMMABILITY	NONFLAMMABLE	NONFLAMMABLE
OFFGASSING		
ODOR	ACCEPTABLE	-
CARBON MONOXIDE	ACCEPTABLE	-
TOTAL ORGANICS	ACCEPTABLE	-

NASA-S-70-2209-X

SELF-EXTINGUISHING VITONS WITH SILICONE IGNITOR - BOTTOM IGNITION

ENVIRONMENT		
6.2 PSIA, 100% O_2	16.5 PSIA, 100% O_2	16.5 PSIA, 60% O_2/40% N_2
238-46-2	238-012-1	238-46-2

SAMPLES 0.125 INCH THICK

NASA-S-70-2208-X

FLAMMABILITY PROPERTIES ALL-VITON ELASTOMER SPACECRAFT HOSES

ENVIRONMENT		
6.2 PSIA, 100% O_2	16.5 PSIA, 60% O_2/40% N_2	16.5 PSIA, 100% O_2
SELF EXTINGUISHING	SELF EXTINGUISHING	BURN RATE TOO SLOW TO MEASURE

NASA-S-70-2207-X

ADVANCED STRUCTURAL COMPOSITE MATERIALS

REINFORCEMENT FIBERS

ALUMINA	GRAPHITE
BORON	BERYLLIUM
BORON CARBIDE	SILICONE CARBIDE ON TUNGSTEN
BORON NITRIDE	
BORON ON TUNGSTEN	STAINLESS STEEL

MATRIX MATERIALS

POLYIMIDE	POLYIMIDEQUINOXALINE
POLYQUINOXALINE	POLYBENZIMIDAZOLE
POLYPHENYLQUIN-OXALINE	METALS

NASA-S-70-2211-X

POTENTIAL APPLICATIONS STRUCTURAL COMPOSITES

INDUSTRY	END ITEM
AIRCRAFT	AIR DISTRIBUTION SYSTEMS FIREWALLS ANTENNA SYSTEMS NACELLES DECORATIVE PANELING, OVERHEAD RACKS, AND PRINTED CIRCUITS
MARINE	VENT DUCTING CREW QUARTERS AND ENGINE ROOM STRUCTURES PLEASURE CRAFT
COMPUTER SCIENCE	COMPUTER STRUCTURES
AUTOMOTIVE	FIREWALLS
CONSTRUCTION	FIRE DOORS

DEVELOPMENT OF NONFLAMMABLE POTTING COMPONDS FOR SPACECRAFT USAGE

By Harry F. Kline
NASA Manned Spacecraft Center

ABSTRACT

This paper presents a progress report on the development of nonflammable potting compounds to meet the stringent requirements for adequate dielectric materials needed for space applications. Criteria for these materials are examined in some detail, with particular emphasis on flammability resistance and electrical properties. Results of the development of silicone room-temperature-vulcanizing materials, fluorocarbons, and brominated polyesters as aerospace encapsulating potting and conformal coatings are reported. These results are related to the flame resistance of numerous formulations and also to the corresponding electrical and mechanical properties. Applications in aerospace and industrial areas are suggested.

NASA-S-70-1639-X

THERMAL PROPERTIES

PROPERTY	REQUIREMENT	ENVIRONMENT
FLAMMABILITY	SELF-EXTINGUISHING	60% O_2 40% N_2
FLAMMABILITY	NO PROPAGATION TO ADJACENT COMPONENT	60% O_2 40% N_2
ORGANIC OFFGASSING	LESS THAN 100 $\mu g/g$ TOTAL ORGANICS, LESS THAN 25 $\mu g/g$ CARBON MONOXIDE	100% O_2 5 PSIA
ODOR	NO OBJECTIONABLE ODOR	100% O_2, 5 PSIA
VACUUM OUTGASSING AT 10^{-4} mm Hg AND 250° F	NO LOSS GREATER THAN .02 PERCENT/HR AFTER 24 HOURS	VACUUM

NASA-S-70-1636-X

MECHANICAL PROPERTIES

PROPERTY

- ELONGATION
- TEAR STRENGTH
- TENSILE STRENGTH
- SHRINKAGE
- COMPRESSION SET
- VISCOSITY
- ADHESION
- REPAIRABILITY
- SPECIFIC GRAVITY
- HARDNESS

NASA-S-70-1635-X

MANUFACTURING CHARACTERISTICS

CHARACTERISTICS	REQUIREMENT
APPLICATOR	INJECTION OR EXTRUSION GUN
CURE	>150° F; 7 DAYS MAX
SHELF LIFE	STABLE 6 MONTHS, AIR
REPAIRABILITY	REQUIRED REWORK POSSIBILITY
POT LIFE	1 HR

NASA-S-70-1634-X

ELECTRICAL PROPERTIES

PROPERTY	REQUIREMENT	TEST SPEC
DIELECTRIC CONSTANT	5.0	ASTM 150
POWER FACTOR	0.09	ASTM 150
DIELECTRIC STRENGTH VOLTS/MIL	500	ASTM D 749/ FTMS 406
VOLUME RESISTIVITY, OHM-cm	1×10^{12}	ASTM D 257
SURFACE RESISTIVITY, OHM-cm	1×10^{12}	ASTM D 257
ARC RESISTANCE, SEC	45	ASTM D 495/ MIL-C-5015
INSULATION RESISTANCE, MEGOHM	100K 77° F 750 212° F	MSFC-SPEC-202A
HIGH-POTENTIAL RESISTANCE	NO BREAKDOWN	MSFC-SPEC-202A
TEMPERATURE RESISTANCE, OHM-cm	1×10^9 FROM 0-250° F	MSFC-SPEC-202A

NASA-S-70-1637-X

FLAME-RESISTANT SILICONES

INGREDIENTS	COMPOUND				
	SG12	SG12D	SG12F1	SG12K1	SG12K1C
DIMETHYL SILOXANE RESIN	100	100	100	100	100
CURING AGENT	10	10	10	10	10
TETRABROMOPHTHALIC ANHYDRIDE	100	-	-	-	-
GLASS FRIT 1710	65	65	-	-	-
GLASS FRIT 7570	-	65	25	50	50
AMMONIUM PHOSPHATE	-	-	-	75	-
AMMONIUM CHLORIDE	-	-	-	-	75

VALUES SHOWN ARE 100 PARTS BY WEIGHT OF ELASTOMER TO CORRESPONDING PARTS BY WEIGHT OF OTHER INGREDIENTS

NASA-S-70-2115-X

SILICONE COMPOUNDS OXYGEN FLAMMABILITY DATA

60% O_2, 40% N_2

FORMULATION NO.	PRESS., PSIA	TEST RESULTS
SG12	16.2	PASSED
SG12D	16.2	PASSED (SIMULATED CONNECTOR)
SG12F1 / FTA-3	16.5	SUSTAINED COMBUSTION APPROXIMATELY 30 SECONDS (MIN)-MAXIMUM 200 SECONDS
SG12F1 / FTA-3	16.5	PASSED SILICONE IGNITOR
SG12K1C	16.5	PASSED SILICONE IGNITOR
SG12K1C	16.5	PASSED WIRE OVERLOAD TO IGNITION. FAILED WIRE OVERLOAD TO FUSION

NASA-S-70-2215-X

FLAME PROPAGATION RATE FIRE RESISTANT SILICONES

TEST ATMOSPHERE 6.2 PSIA O_2

COMPOUND	PROPAGATION RATE DOWNWARD, IN/SEC
SG12	.017
SG12D	.015
SG12F1/FTA-3	S E
SG12K1	.013
SG12K1C	.008
SG12K1C/FTA-3	S E
CONVENTIONAL SILICONE	.063

NASA-S-70-2189-X

SG12F1 PROPERTIES

TENSILE, PSI	628
ELONGATION, PERCENT	440
TEAR, LB/IN	52
RESISTANCE, AT 500 VOLTS, 60 H_z	>100 MΩ
DOWNWARD PROPAGATION 16.5 PSIA, 60% O_2, 40% N_2 (WITH FTA-3 SEAL COAT)	SE
UPWARD PROPAGATION 16.5 PSIA, 60% O_2, 40% N_2 (WITH FTA-3 SEAL COAT)	SE

NASA-S-70-2237-X

PROPERTIES OF FLUOROCARBON BASED POTTING COMPOUND (1015A) WITH SEALER COAT

PROPERTY	TEST RESULT
APPLICATION	CAN USE HYPODERMIC SYRINGE OR CAULKING GUN
REPAIR AND REWORK	CAN BE MECHANICALLY REMOVED - CAN BE PATCHED
TEMPERATURE RATING	INSULATION RESISTANCE
0°	0.82×10^{10}, OHMS
250° F	2.58×10^{10}, OHMS
MOISTURE RESISTANCE (AFTER HUMIDITY CYCLES)	3.5×10^{8}, OHMS

NASA-S-70-2238-X

PROPERTIES OF FLUOROCARBON BASED POTTING COMPOUND (1015A) WITH SEALER COAT (CONT)

PROPERTY	TEST RESULT
DIELECTRIC CONSTANT	1.42
POWER FACTOR	.019
DIELECTRIC STRENGTH	200 VOLTS/MIL
VOLUME RESISTIVITY	1.79×10^{12} OHM-cm
SURFACE RESISTIVITY	3.81×10^{12} OHM-cm
ARC RESISTANCE	123 SECONDS
HIGH POTENTIAL	NO BREAKDOWN
SPECIFIC GRAVITY	.36
FLAMMABILITY	SE IN 16.5 PSIA - O_2

NASA-S-70-2098-X

AEROSPACE APPLICATIONS FOR FIRE RESISTANT SILICONES AND FLUOROCARBONS

SILICONES

- POTTING ELECTRICAL COMPONENTS
- CONNECTORS
- PRINTED CIRCUIT BOARDS
- WIRE HARNESS TERMINATIONS
- SEALANT FOR INSTRUMENTS

FLUOROCARBONS

- SEAL COAT FOR ELECTRONICS
- COATING FOR FABRIC
- FIREPROOFING FOR HARNESS OR STRAPS

NASA-S-70-2187-X

POLYESTER CONFORMAL COATING (MRTA-5) ELECTRICAL TEST RESULTS (SUMMARY)

PROPERTY	RESULTS	
DIELECTRIC CONSTANT	4.78	
POWER FACTOR	.008	
DIELECTRIC STRENGTH (V/MIL)	400	
SURFACE RESISTANCE	4.05×10^{14} OHM-cm	
VOLUME RES, AMB	4.72×10^{14} OHM-cm	
ARC RES (SECONDS)	213	
HIGH POTENTIAL RESISTANCE 60 Hz/SEC	NO BREAKDOWN	
MOISTURE RESISTANCE	MIN OHMS	MAX OHMS
• AT 76° F	9.9×10^{6}	1.9×10^{10}
• AT 212° F	1.3×10^{7}	2.6×10^{10}
TEMPERATURE RESISTANCE, VOL RESISTIVITY AT 250° F	3.77×10^{13} OHM-cm	

NASA-S-70-2100-X

INDUSTRIAL APPLICATIONS FOR FIRE RESISTANT SILICONES AND POLYESTERS

- AIRCRAFT FIREWALLS
- CONFORMAL COATINGS ELECTRONIC COMPONENTS
- POTTING OF ELECTRICAL COMPONENTS
- ELECTRONIC COMPONENTS IN HYPERBARIC CHAMBERS
- COMMERCIAL TV ELECTRONIC EQUIPMENT

NEW MATERIALS FOR MANNED SPACECRAFT,

AIRCRAFT, AND OTHER APPLICATIONS

By Matthew I. Radnofsky
NASA Manned Spacecraft Center

ABSTRACT

While the overall objectives of fireproofing a spacecraft cabin and an aircraft interior are similar, there are some significant operational and design differences that merit consideration in the selection of materials. One of these differences is the fact that the spacecraft employs a closed environmental system, whereas the aircraft utilizes a semiclosed system. This makes considerations of odor and toxic offgassing much more critical for the spacecraft. In addition, spacecraft to date have operated with a 100-percent oxygen environment, whereas most aircraft operate with an air environment. This factor has limited the amount of materials which are acceptable for spacecraft usage since there are few useable materials that will not burn in oxygen. On the other hand, there are important considerations for selection of materials for aircraft that are of lesser importance to the spacecraft. Foremost among these are durability and aesthetic quality. In this area, functional utility for the duration of a single mission is basically all that has been required for the spacecraft. Aircraft, however, require nonmetallic materials that will withstand the rigors of repetitive usage and which are aesthetically pleasing. With the advent of longer space missions, the differences in these requirements for aircraft and spacecraft become smaller. Despite the noted differences in end-item usage, there are obvious and immediate applications of spacecraft nonmetallic materials for aircraft interiors, for uses in other types of vehicles, and for other commercial and domestic uses; this is particularly so amongst the more recently developed fire-resistant materials. This paper discusses recent fire-resistant nonmetallic-materials developments which should have widespread applicability. The presentation is accompanied by a descriptive film which vividly illustrates the excellent fire resistance of these new materials.

NASA-S-70-1665-X

FABRICS FOR WHICH SUMMARY DATA ARE AVAILABLE

- NYLON
- BETA 4190B/TEFLON
- BETA 4484/TEFLON
- TEFLON-BLEACHED T162-42
- TEFLON-NATURAL (TFE .250 IN. THICK)
- NOMEX-UNTREATED (H T 90-40)
- NOMEX-TREATED-$POCl_3$ Br
- NOMEX-TREATED-ADP/FLUOREL (L-3203-6)
- PBI-UNTREATED
- PBI-TREATED-$POCl_3$
- PBI-TREATED-(MONSANTO)
- DURETTE X-400
- DURETTE X-410
- DURETTE X-420
- NICKEL CHROMIUM (CHROMEL-R)
- STAINLESS STEEL (KARMA CLOTH)
- FYPRO

NASA-S-70-1664-X

FABRIC DATA AVAILABLE

- COMBUSTION RATES
- PHYSICAL CHARACTERISTICS
- ODOR/CO/TOTAL ORGANICS
- COST
- STATUS
- AVAILABILITY
- SUPPLIER

NASA-S-70-2233-X

COMPARATIVE FIREPROOF CHARACTERISTICS OF AIRCRAFT DECORATIVE PANELS

1002 — VINYL ON ABS WITH TEDLAR OVERLAY (21 MILS)

4000 — LAMINATED SCHEUFELEN PAPER WITH FLUOREL (21 MILS)

6000 — SCHEUFELEN PAPER COATED WITH BETA LACE AND SCRIM (36 MILS)

NASA-S-70-2234-X

COMPARATIVE CHARACTERISTICS OF AIRCRAFT DECORATIVE PANELS

MATERIAL	WEIGHT, OZ/YD	THICKNESS, IN.	PUNCTURE, LB
1002	20.4	.012	54
4000	18.7	.020	9.5
6000	25.6	.036	22.0

1002 - VINYL ON ABS WITH TEDLAR OVERLAY
4000 - LAMINATED SCHEUFELEN PAPER WITH FLUOREL
6000 - COATED WITH BETA LACE AND SCRIM

NASA-S-70-2235-X

COMPARATIVE CHARACTERISTICS OF AIRCRAFT DECORATIVE PANELS (CONT)

WAX PICK	FLEXIBILITY, GRAMS	BREAKING STRENGTH, LB
26	5.7	70
26	21.3	43
20A	49.0	118

NASA-S-70-1663-X

MATERIAL STAIN EVALUATION

STAINING AGENTS TESTED

- MAYONNAISE
- OIL
- BUTTER
- CATSUP
- WRITING INK
- MILK
- BOURBON
- NICOTINE
- ORANGE JUICE
- COFFEE
- MUSTARD
- ALCOHOL
- HAIR TONIC
- LIPSTICK
- COKE
- NAIL POLISH
- BALL POINT
- CRAYONS
- CLEANING AGENTS

NASA-S-70-1662-X

MATERIAL STAIN EVALUATION

MATERIALS TESTED

- ABS VINYL WITH TEDLAR OVERLAY
- VINYL ON ABS WITH TEDLAR OVERLAY
- FX 703 KEL-F
- KEL-F-3700 (SCHEUFELEN PAPER)
- KEL-F-5500 (SCHEUFELEN PAPER)
- LAMINATED SCHEUFELEN PAPER WITH FLUOREL
- SCHEUFELEN PAPER COATED WITH BETA LACE AND SCRIM
- BETA GLASS KEL-F FLUOREL (THICK)

FABRIC CHARACTERISTICS SUMMARY

Physical Test methods[a]	(12)	Combustion rates, (in/sec)					Physical characteristics												Outgassing			Cost	Status	Availability	Supplier
							(1)	(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)	(11)	(5)							
Fabric	Weight, oz/yd^2	Air	10 psia, 35% O_2, 65% N_2	6.2 psia, O_2	16.5 psia, O_2	16.5 psia 60% O_2/40% N_2	Elongation, %	Breaking strength (warp), lb/in.	Tear strength, g	Wear resistance, no. cycles	Folding endurance, no. cycles (c)	Stiffness, in-lb	Abrasion, no. cycles	Abrasion, no. cycles	Air permeability, $ft^3/ft^2/min$	Electrostatic charge, nC	Thermal conductivity, $cal/sec/cm^2/(°C/cm)$	Thickness, in.	Odor	Carbon monoxide, μg/g	Total organics, μg/g				
Nylon	6.9			0.78			22	350	>6400	174		0.002	2468	870	7.98	6.0	1.49×10^{-4}	0.0145	12	1.2	0.0003	$3/yd	Used for making mockups	2 to 3 wk del.	Stern & Stern
Beta 4190B	6.5	0	0	0.0	0	0	8.1	106	2400	148		0.003	198	85	0.5	2.0	1.69×10^{-4}	0.006				$6/yd		2 to 3 wk del.	Owens/Corning
Beta 4484/Teflon	6.1	0	0	0.0	0	0	8.9	142	>6400	151		0.003	125	1200	22.7	18.0	1.2×10^{-4}	0.008 0.009				$10/yd	In use as outer layer of PGA	2 to 3 wk del.	Owens/Corning
Teflon - bleached T162-42	8.7		0.29	0.13	0.435		67	59	5100	93		0.0002	584	600	4.8	20.0	2.1×10^{-4}	0.009	0.9	0.7	34.0	$30/yd	Apollo ICG fabric	4 wk del.	
Teflon - natural	16.9			0.21	0.725		56	172	5400	343		0.002	1075	1952	11.2	32.0	1.8×10^{-4}	0.018	1.7	4.2	9.0	$30/yd			E. I. DuPont
Nomex (H. T. 90-40)	6.2		0.121	0.63	1.00		40	325	>6400	689		0.001	943	260	4.9	8.0	1.58×10^{-4}	0.013	7	0.4	1.0	$8/yd	Was used as comfort liner of PGA		Stern & Stern
Nomex - treated, $POCl_3Br_2$	7.3			0.42			10	128	3000	353		0.004	450	227	10.9	0.06	1.6×10^{-4}	0.014				$6/yd treat.	Experimental	Nonproduction 3 mo lag	Dynatech
PBI - untreated	5.0			0.003	0.009		20	149	4600	206		0.004	629	143	98.5	40.0	3.0×10^{-5}	0.0135	5	2.4	3.0	$200/lb		4 wk del.	Celanese
PBI - treated, $POCl_3$	8.0	0		0.0			60	188	>6400	234		0.002	2481	1651	26.9	2.6	3.2×10^{-5}	0.017				$6/yd treat.	Experimental	Nonproduction 3 mo lag	Dynatech
PBI - treated, $POCl_3Br_2$	5.9			0.14			20	184	5700	721		0.002	1200	1500	38.7	2.4	4.8×10^{-5}	0.014							Monsanto
Durette X-400	6.2		S. E.[b]	0.31	0.813		30	138	5900	126		0.0003	467	116	89.1	2.0	1.3×10^{-4}	0.012		3.7	0.0	$25 to $50/yd	Being evaluated	4 to 6 wk del.	Monsanto
Durette X-410	5.0		S. E.[b]	0.29			14	200	3000	96		0.001	145	65	28.9	18.0	1.8×10^{-4}	0.0118	11	2.6	1.0		Experimental		Monsanto
Durette X-420	5.6			0.30			13.3	124	4100	93		0.002	100	350	43.4	0.01	2.0×10^{-4}	0.013					Experimental		Monsanto
Nickel chromium (Karma cloth or Chromel-R)	18.0	0	0	0.0	0	0		176	5400	869		0.008	2034	977	68.8	0.0	N/A	.0.010				$150/lb $1500/lb			Fabric Research Laboratory
FYPRO 5007/7	6.0	0	0.29	0.7		0.8	24	154	3800	836		0.003	217	41	49	12	2.0×10^{-4}	0.015	0.7	4.0	1.0	$8.50/yd	Commercial	2 to 3 wk del.	Travis Mills

[a]Physical test methods:

1. FED STD 191, Method 5104
2. FED STD 191, Method 5132
3. FED STD 191, Method 5302
4. ASTM-D 2176
5. FED STD 191, Method 5030
6. FED STD 191, Method 5202
7. FED STD 191, Method 5306 (C517 Wheel)
8. FED STD 191, Method 5304 (600 grit paper)
9. FED STD 191, Method 5450
10. Sweeney Test Method
11. Cenco-Fitch Test Method
12. FED STD 191, Method 5041

[b]Self-extinquished.

[c]All greater than 5000 cycles.

THE PERFORMANCE OF LIGHTWEIGHT PLASTIC

FOAMS DEVELOPED FOR FIRE SAFETY

By Richard H. Fish
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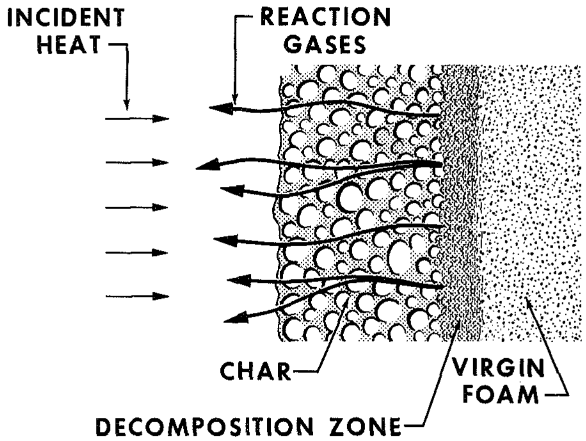
ABSTRACT

Research on the chemistry of ablation for protection of spacecraft during atmospheric entry has led to the development of a new class of fire-retardant materials, namely, lightweight plastic foams. The foams have been developed principally to protect aircraft structures and externally mounted fuel tanks from onboard fires in flight. Fire-retardant foams have been made from urethane, isocyanurate, and polybenzimidazole. The density of the foams ranges from 2 to 30 lb/cu ft. Addition of randomly placed quartz fibers to the urethane and isocyanurate foams increases the density of the foams and improves the stability of the char formed as a result of heat. For example, by adding fibers in a 10-percent concentration, the density of the urethane foam is tripled, and its fire-protection capability is increased fivefold. The fire-protection capability of the isocyanurate foam system is twice that of the urethane foam and is four times that of commercial isocyanurate fire-retardant foam. This paper describes the various fire-retardant materials and illustrates their performance when exposed to a fuel fire. The performance of the materials is compared wherever possible with presently available commercially developed products. Although the materials were developed primarily for aircraft use, a discussion is given of other possible areas of application.

NASA-S-70-2283-X

PYROLYSIS MECHANISM OF CHAR FORMING ABLATORS UNDER UNIDIRECTIONAL HEATING



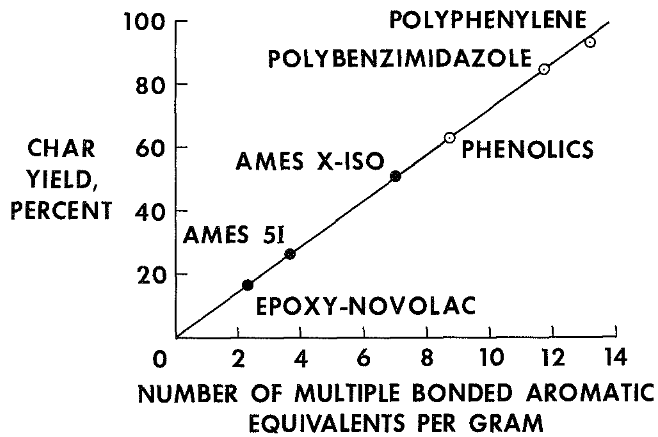
NASA-S-70-2302-X

FACTORS AIDING THERMAL PROTECTION

- HIGH RESISTANCE TO HEAT FLOW
  - LOW THERMAL CONDUCTIVITY
- PYROLYSIS GASES
  - COUNTERFLOW TO IMPEDE HEAT FLOW
  - HALOGEN RICH TO SUPPRESS FLAMES BY ACTING AS FLAME CHAIN SCAVENGERS
- HIGHLY CHARRED RESIDUE
  - LOW THERMAL CONDUCTIVITY
  - GOOD INTEGRITY - NO FISSURES

NASA-S-70-2296-X

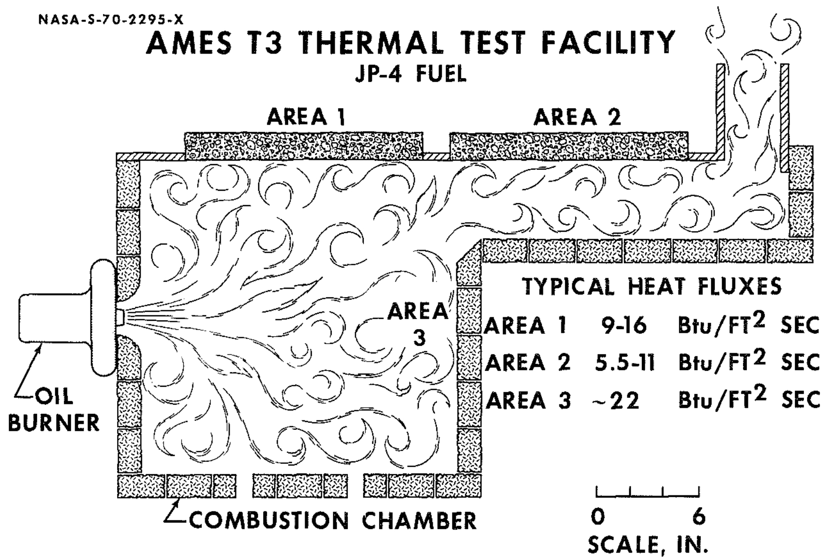
CORRELATION OF PRIMARY THERMOCHEMICAL CHAR YIELD WITH MOLECULAR STRUCTURE



NASA-S-70-2295-X

AMES T3 THERMAL TEST FACILITY

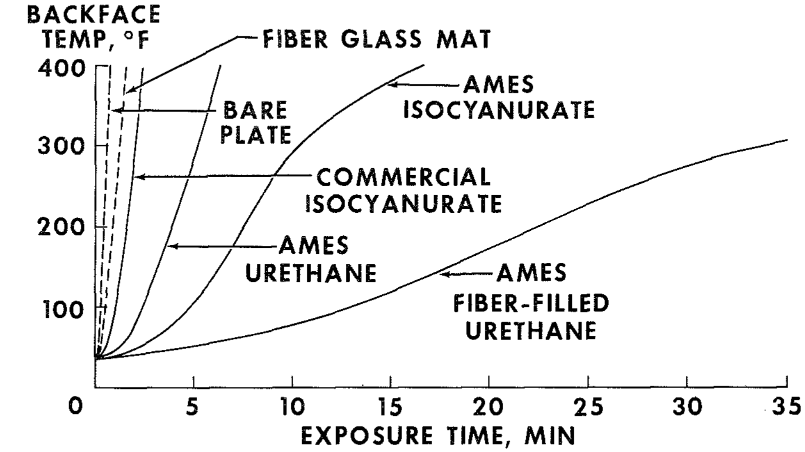
JP-4 FUEL



NASA-S-70-2291-X

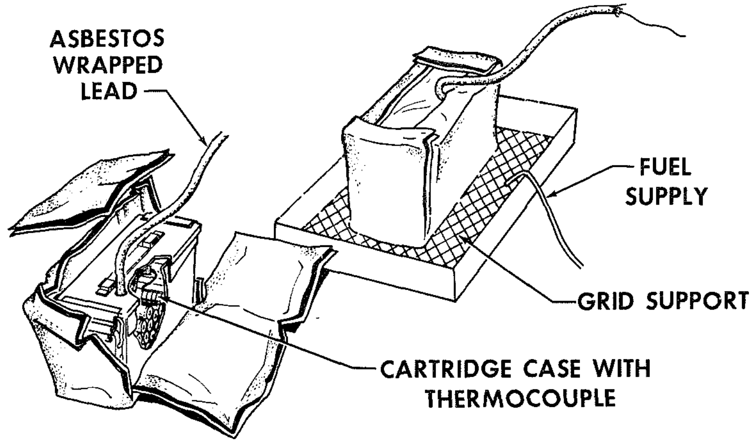
PERFORMANCE OF VARIOUS FIRE-RETARDANT FOAMS IN JP-4 FUEL FIRE

HEATING RATE = 10 Btu/FT^2 SEC



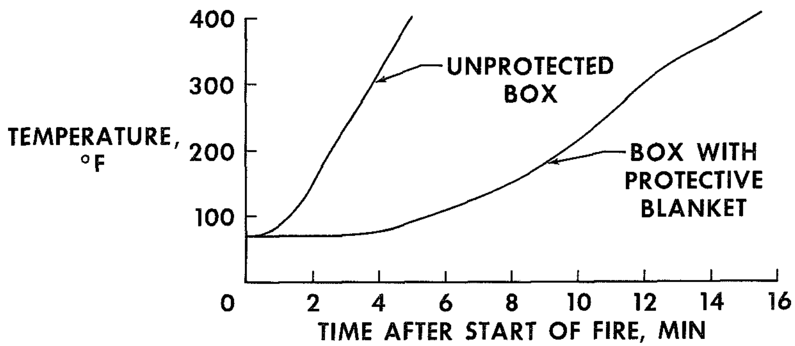
NASA-S-70-2289-X

TEST OF FOAM BLANKET TO PROTECT AMMUNITION BOX



NASA-S-70-2288-X

TIME-TEMPERATURE HISTORY OF .50 CAL CARTRIDGE IN AMMUNITION BOX JP-4 FUEL FIRE



NASA-S-70-2303-X

POTENTIAL APPLICATION OF AMES FOAMS

AREA	PROTECTION
MILITARY AIRCRAFT	FUEL TANK INCENDIARY PENETRATION
GENERAL AIRCRAFT	CRASH FIRES
JUMBO AIRCRAFT	CARGO HOLD FIRES
MINES	MINE STOPPING AND MINE-SHAFT REINFORCEMENT
SPACE SHUTTLE	CRYOGENIC INSULATION AND HEAT SHIELD
HOUSING	FIREWALLS AND TEMPORARY STRUCTURES

INTUMESCENCE: AN IN SITU APPROACH TO THERMAL PROTECTION

By G. M. Fohlen, J. A. Parker, S. R. Riccitiello, and P. M. Sawko
NASA Ames Research Center

ABSTRACT

The phenomenon of intumescence, the swelling of a substance upon the application of heat, has been used for many years in the form of surface coatings as a means of protecting fire-sensitive building materials. With regard to experience gained at the NASA Ames Research Center in the areas of polymer chemistry and ablation technology for thermal protection, intumescent systems that may serve to protect a variety of heat-sensitive components, such as fuels, explosives, structural materials, and even man, have been reexamined. In this paper, the evolution of intumescent coatings from the older carbohydrate-phosphoric acid systems, through the nitroaniline bisulfate salts originally used by NASA, to the newer nitroaniline-sulfonic acids, quinonedioxime-acid mixtures, and nitroanilinosulfones, is described. In the case of the nitroaniline derivatives, the intumescence is modeled as a thermal self-polymerization of the aromatic compounds passing through plastic states, being expanded by evolving gaseous products to form finely textured, low-density foams. These foams have low thermal conductivity, high emissivity, and good resistance to ignition. The gases evolved during the polymerization reaction and injected into the fire zone further serve as flame quenchers. The resulting polymeric foams are polyheterocyclic structures similar to polyquinoxalines or polyphenoxazines. The development of several useful coating systems to effect fire protection in a variety of applications is discussed. Potential applications ranging from the prevention of weapons cookoff to the improvement in the fire safety of building materials are illustrated in simulation tests.

NASA-S-70-2313-X

GENERAL SEQUENCE OF REACTIONS PRODUCING INTUMESCENCE

STABLE SOLID MONOMER OR PREPOLYMER — THERMAL POLYMERIZATION, > 392° F → HEAT STABLE POLYMER + EXPANDING GASES → (MELT PHASE)

FOAMING AND EXPANSION OF POLYMER IN DIRECTION OF APPLIED HEAT → FOAM + GAS

FOAM	GAS
LOW DENSITY	EXCESS GASEOUS SPECIES INJECTED INTO VAPOR PHASE
CLOSED CELL	CONVECTIVE PROTECTION
COHERENT	QUENCHING
THERMALLY AND OXIDATIVELY STABLE	FLAME SUPPRESSION

NASA-S-70-2314-X

INTUMESCENT REACTIONS OF NITRO SUBSTITUTED AROMATIC AMINES

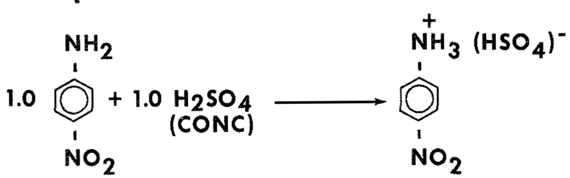
THERMAL POLYMERIZATION PROCESS OCCURS WITH:

- o-NITROANILINE
- p-NITROANILINE
- p-NITROACETANILIDE
- 5-NITROISATOIC ANHYDRIDE ETC

Δ > 392° F, CONCENTRATED SULFURIC OR POLYPHOSPHORIC ACID → SPONGY BLACK POLYMERIC FOAM + GAS

NASA-S-70-2312-X

SYNTHESIS AND CHARACTERIZATION OF INTUMESCENT INTERMEDIATE p-NITROANILINE BISULFATE

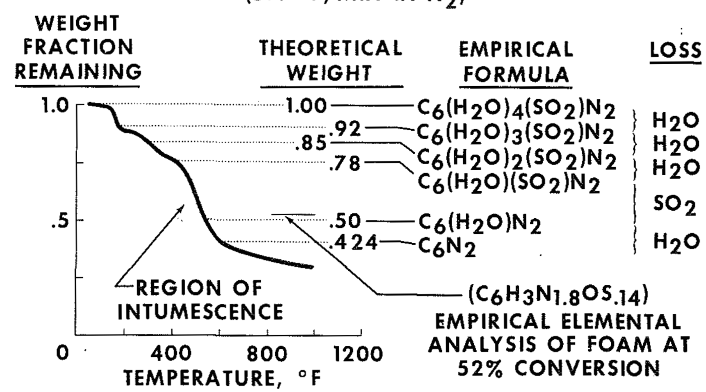


p-NITROANILINE		p-NITROANILINE BISULFATE
293° F	MELT POINT	392° F (DECOMP)
138	MOL WT	236 (CALCULATED)
		236 (MEASURED)
YELLOW SOLID	APPEARANCE	LT YELLOW SOLID
		(SOLUBLE IN ALCOHOLS, KETONES INSOLUBLE IN BENZENE, TOLUENE, ETHER)

NASA-S-70-2303-X

TYPICAL TGA OF p-NITROANILINE BISULFATE

($5.4°$ F/MIN IN N_2)



NASA-S-70-2315-X

ELEMENTAL ANALYSIS OF BLACK INTUMESCED POLYMERIC FOAM FORMED FROM p-NITROANILINE BISULFATE AT 482° F

C	H	N	S	O
59.65	2.51	20.77	3.64	13.43%

WHICH CALCULATES TO GIVE AN EMPIRICAL FORMULA:

$$C_6\,H_3\,N_{1.8}\,O_{1.0}\,S_{.14}$$

NASA-S-70-2318-X

STOICHIOMETRIC REACTION OF p-NITROANILINE BISULFATE

$$C_6H_8N_2O_6S \xrightarrow[]{\Delta \; 482°\,F} C_6H_3N_{1.8}OS_{.14} + H_2O + SO_2$$

MOL WT = 236   -5H -5O -S   FORMULA WEIGHT = 120.7

FOAM YIELD:

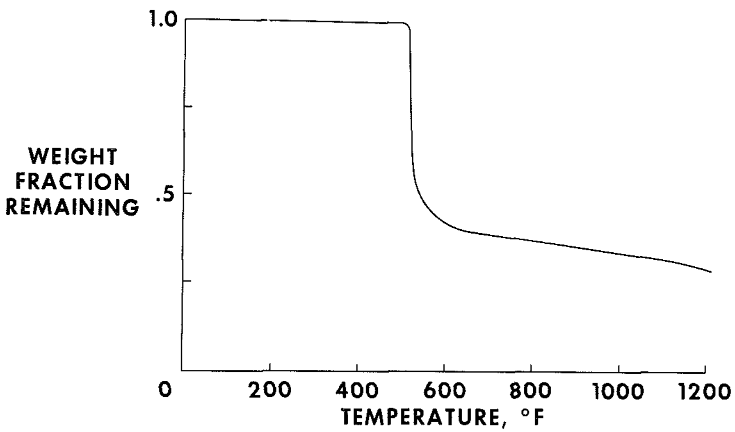
CALCULATED = 51.2 PERCENT

MEASURED = 51-54 PERCENT

NASA-S-70-2320-X

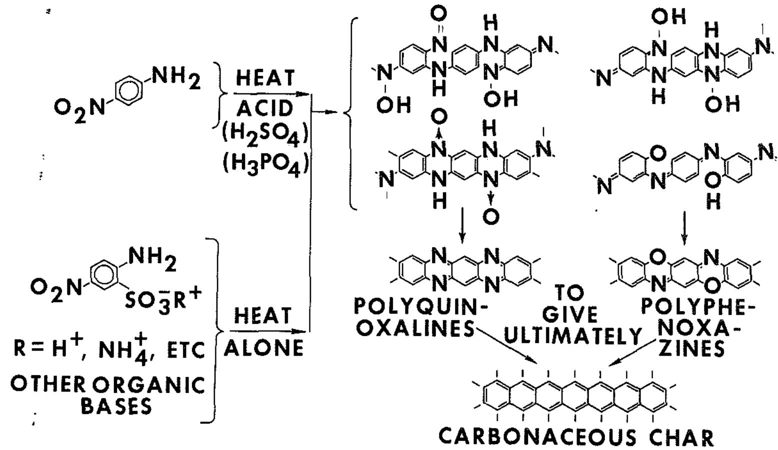
TGA OF p-NITROANILINE - o-SULFONIC ACID, AMMONIUM SALT

5.4° F/MIN IN N_2



NASA-S-70-2319-X

PROPOSED GENERALIZED MECHANISM FOR POLYMERIZATION



NASA-S-70-2316-X

VOID FILLING THERMAL PROTECTION COATING

FORMULATION NUMBER 341

	PARTS, WT
● PART A	
• NITROCELLULOSE, ETHANOL-WET (12% N)	8.0
• METHYL ETHYL KETONE	28.6
● PART B	
• p-NITROANILINE BISULFATE	43.7
• TOLUENE	19.7
• BUTYL ACETATE	19.7

NASA-S-70-2322-X

THERMAL PROTECTION COATING

FORMULATION NUMBER 410-1A

	PARTS, WT
PHENOLIC MODIFIED ACRYLONITRILE-BUTADIENE RUBBER SOLUTION	29.4
p-NITROANILINE BISULFATE	44.0
CYCLOHEXANONE	14.5
METHYL ETHYL KETONE	12.15

NASA-S-70-2317-X

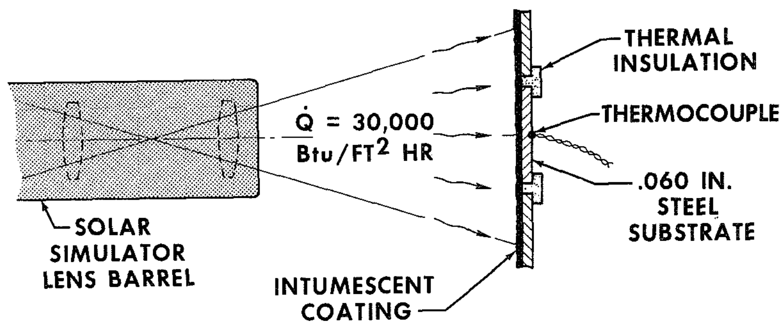
THERMAL PROTECTION COATING

FORMULATION NUMBER 45B3

	PARTS, WT
● PART A	
• POLYSULFIDE POLYMER	14.1
• AMMONIUM p-NITROANILINE-o-SULFONATE	57.0
• METHYL ETHYL KETONE	28.9
● PART B	
• EPOXY RESIN, LIQUID	14.1
• TOLUENE	14.7
● PART C	
• TRI (DIMETHYLAMINOMETHYL) PHENOL	2.8
• TOLUENE	2.8

NASA-S-70-2309-X

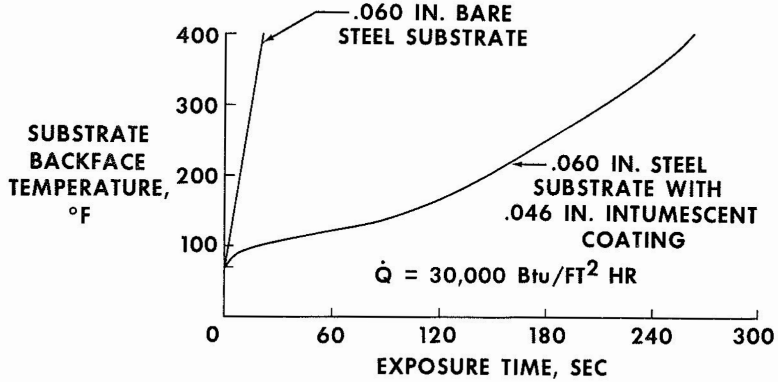
ARRANGEMENT FOR TESTS OF INTUMESCENT COATINGS IN SOLAR SIMULATOR BEAM



NASA-S-70-2310-X

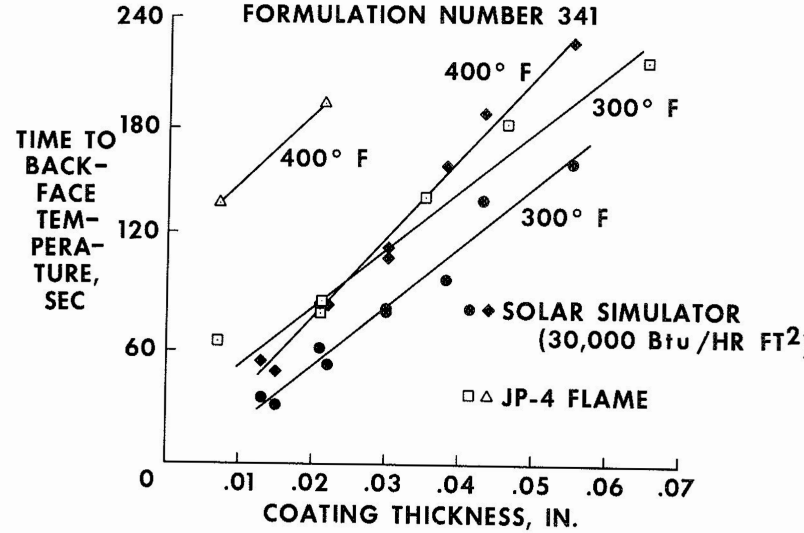
COMPARISON OF BARE STEEL AND INTUMESCENT COATED STEEL IN SOLAR SIMULATOR RADIATION TESTS

FORMULATION NUMBER 341



NASA-S-70-2321-X

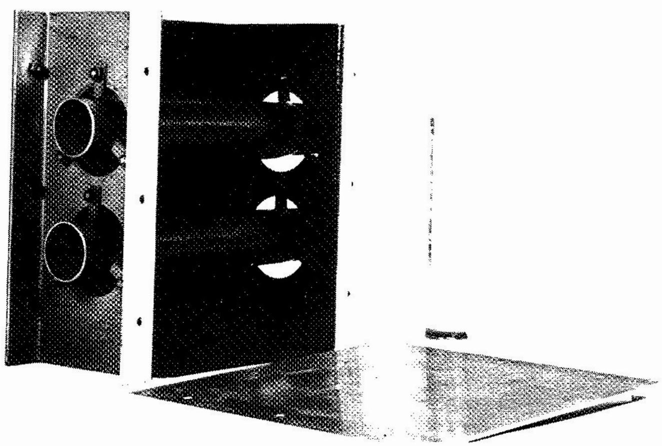
EFFECT OF INTUMESCENT COATING THICKNESS ON BACKFACE TEMPERATURE RISE



NASA-S-70-2307-X

TEST SETUP OF SIMULATED FUSELAGE SECTION COATED WITH VOID FILLING THERMAL PROTECTION COATING

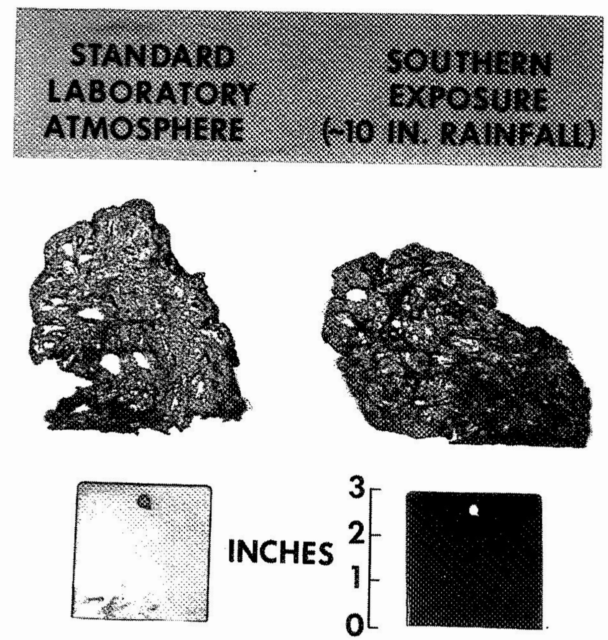
FORMULATION NUMBER 341



NASA-S-70-2308-X

INTUMESCENCE OF 45B3 COATING AFTER 90 DAY EXPOSURE TO OUTDOOR ENVIRONMENT

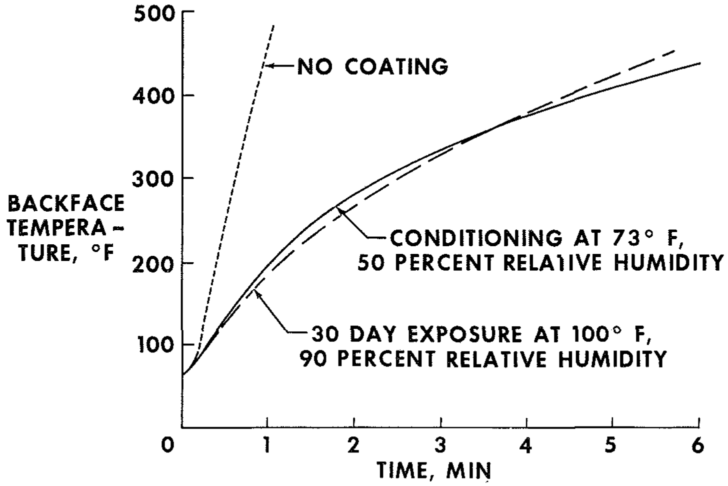
COATING THICKNESS =40 MILS



NASA-S-70-2311-X

FIRE-PROTECTIVE EFFECTIVENESS OF 45B3 INTUMESCENT COATING

HEATING RATE IN JP-4 FIRE = 10 Btu /FT2 SEC
80 MIL COATING ON 0.125 IN. STEEL SUBSTRATE



SESSION III

CONFIGURATION CONTROL AND MATERIALS APPLICATIONS

Session Chairman: Joseph N. Kotanchik

NONMETALLIC MATERIAL CONFIGURATION CONTROL

IN THE APOLLO SPACECRAFT

By M. W. Steinthal
NASA Manned Spacecraft Center

ABSTRACT

A program for control of nonmetallic materials used in and around the Apollo spacecraft was developed to minimize flammability and toxicity hazards. Engineering groups at spacecraft contractors facilities and at the Manned Spacecraft Center were designated to supply the materials technology and to conduct tests according to NASA Manned Spacecraft Center requirements. A coordinated materials effort was established at the NASA Kennedy Space Center by the assignment of materials engineers from the contractors and from the Manned Spacecraft Center to monitor materials used in and around the spacecraft at that site. All engineering documents that can add nonmetallic materials to or change the configuration of the spacecraft crew bay are reviewed and approved by the contractor and Manned Spacecraft Center materials-engineering personnel. Materials and configurations that do not meet the criteria and guidelines must be presented to the Manned Spacecraft Center configuration control board as deviations for disposition. A computer data system, Characteristics of Materials (called COMAT), was developed to record the use of nonmetallic materials. The Characteristics of Materials data system is jointly used by NASA and the Apollo spacecraft contractors for the storage and retrieval of usage, status, and characteristics data on nonmetallic materials used, or considered for use, on manned spacecraft. The usage data consist of an accounting of materials in terms of where they are used (assembly and spacecraft number), the quantity used (weight and surface area), and the functional application (adhesive, paint, etc.). The status data consist of evaluation of the material in its application in terms of specified limits for such elements as combustion rate, fire point, odor, carbon monoxide, et cetera. The characteristics data consist of selected elements of flammability and outgassing test data. This paper reviews the basic features of this management control system and discusses the utility and value of the attendant data storage and retrieval system.

NASA-S-70-1641-X

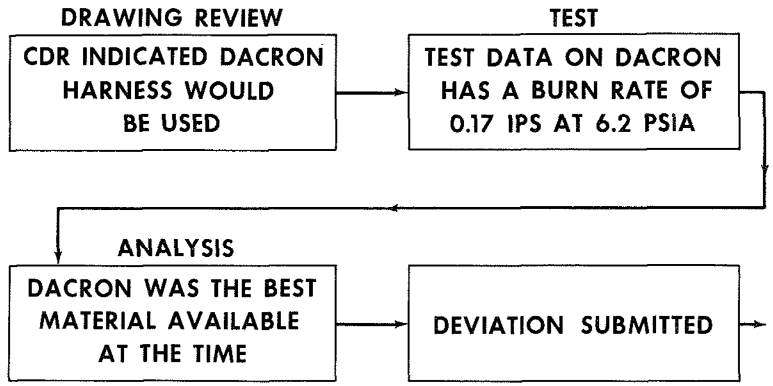
NONMETALLIC MATERIALS CONTROL

- IDENTIFICATION
  - CONTRACTOR FURNISHED EQUIPMENT
  - GOVERNMENT FURNISHED EQUIPMENT
  - GROUND SUPPORT EQUIPMENT
- TESTING
- DEVIATIONS
- DATA SYSTEM ACCOUNTING; CHARACTERISTICS OF MATERIALS (COMAT)
- VISUAL HARDWARE INSPECTIONS
- MAJOR MILESTONE REVIEWS
- CONTROL AT KENNEDY SPACECRAFT CENTER (KSC)
- CONCLUSIONS

NASA-S-70-2168-X

TYPICAL FLOW FOR A MATERIAL APPROVAL FOR USE

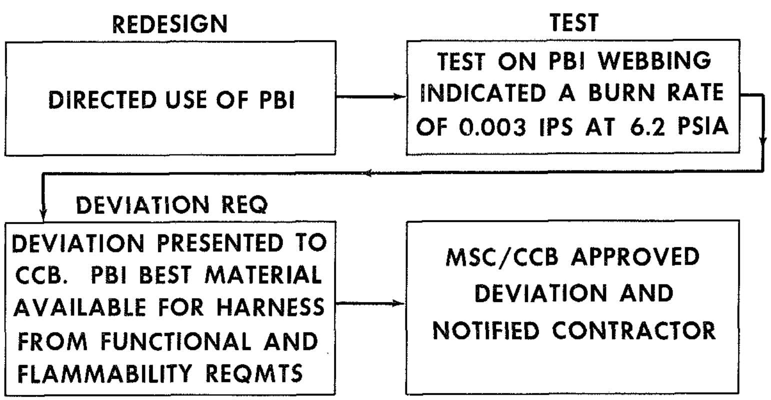
CREW RESTRAINT HARNESS



NASA-S-70-2169-X

TYPICAL FLOW FOR A MATERIAL APPROVAL FOR USE (CONT)

CREW RESTRAINT HARNESS



NASA-S-70-1640-X

DEVIATIONS

- THE FOLLOWING DATA ARE REQUIRED FOR NONMETALLIC MATERIALS DEVIATIONS
  - DRAWINGS, PHOTOGRAPHS AND SUPPORTING ILLUSTRATIONS
  - MATERIAL IDENTIFICATION AND LOCATION
  - WEIGHT AND SURFACE AREA
  - TEST DATA
  - RATIONALE FOR REQUESTING AND APPROVING THE MATERIAL USAGE

NASA-S-70-1644-X

CHARACTERISTICS OF MATERIALS (COMAT)

- THE COMAT DATA SYSTEM PROVIDES THE FOLLOWING:
  - INVENTORY AND STATUS ACCOUNTING SYSTEM
  - MANAGEMENT AID IN REVIEWING FLAMMABILITY AND OUTGASSING HAZARDS
  - MATERIAL CHANGE AND DEVIATION CONTROL
  - IDENTIFICATION OF MATERIAL CANDIDATES FOR PRIORITY TESTING
  - A COMMON DATA BANK OF MATERIALS TEST RESULTS

NASA-S-70-1645-X

MATERIALS ACCOUNTING SYSTEM

TRADE NAME	MFR	DETAIL PART	APPR	EVAL	WT, LB	AREA, IN^2	USAGE (CAT)
TEFLON, TFE	DuPONT	V36---	A	AAAA ---C	.052	8.1	B

OTHER DATA AVAILABLE

- PART NAME
- MAJOR ASSEMBLY DRAWING
- GENERIC IDENTIFICATION
- QUANTITY PER SPACECRAFT
- SPECIFICATIONS
- TEST DATA
- EVALUATION RATIONALE

NASA-S-70-2166-X

MATERIAL TEST DATA BY GENERIC IDENTIFICATION

SEQUENCE: TEST CHAMBER ENVIRONMENT, GENERIC ID, MANUFACTURER, MANUFACTURERS' DESIGNATION

TEST CHAMBER ENVIRONMENT: O_2

MFR	MFR'S DESIG	CHMB PRES	PROPG RATE	O_2 PRES	FLASH POINT

FIRE POINT	OD	CO	TO	TEMP	T R T T I C	TEST REP'T NUMBER

NASA-S-70-1643-X

MOST SIGNIFICANT BENEFITS TO BE REALIZED

- SOURCE OF FLAMMABILITY AND TOXICOLOGICAL DATA
- MATERIAL DESIGN USAGE INFORMATION
- TOOL FOR SAFETY IMPROVEMENT
- INFORMATION ON NEW MATERIALS APPLICATIONS

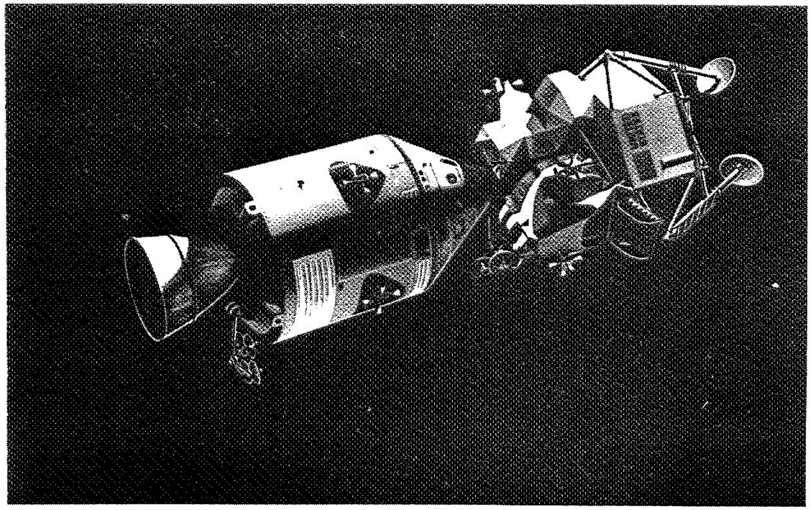
APOLLO SPACECRAFT NONMETALLIC MATERIALS APPLICATIONS

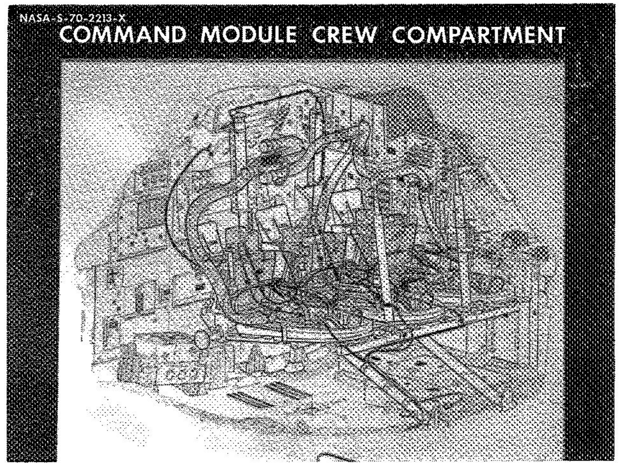
By Jerry W. Craig
NASA Manned Spacecraft Center

ABSTRACT

Several applications of nonmetallic materials in the Apollo spacecraft are reviewed. Significant applications of nonmetallic materials in both the lunar module and the command module crew compartments are emphasized. The materials and design techniques used in fabrication of electrical wire assemblies are discussed. Electrical-component panel materials and firesafety provisions are outlined. Modifications to electroluminescent crew displays are specified to achieve self-extinguishing flammability characteristics. Polyimide/fiber-glass laminates used for panel covers and containers are reviewed. Fire-extinguishment foam in a portable container shows excellent performance. The design techniques for crew couches and restraints are discussed. Superinsulation blankets, which consist of Mylar overwrapped with Kapton, are used in the service module and the lunar module and are nonflammable in air. Although there have been many Apollo Program nonmetallic materials developments and advances, the most significant value is the information on these materials and test methods that is now available for application in many other fields.

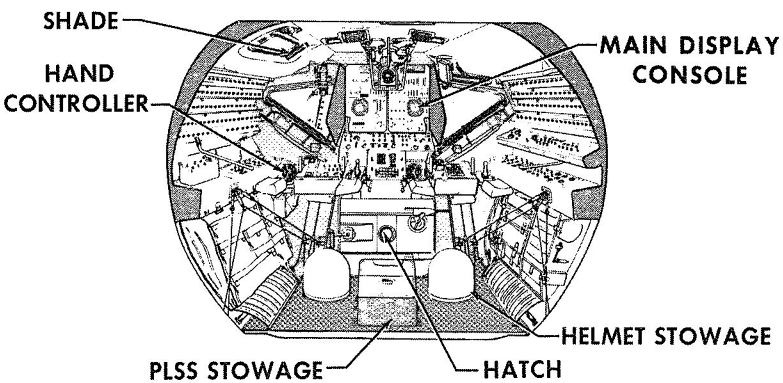
NASA-S-70-2214-X APOLLO COMMAND AND SERVICE MODULE DOCKED WITH LUNAR MODULE

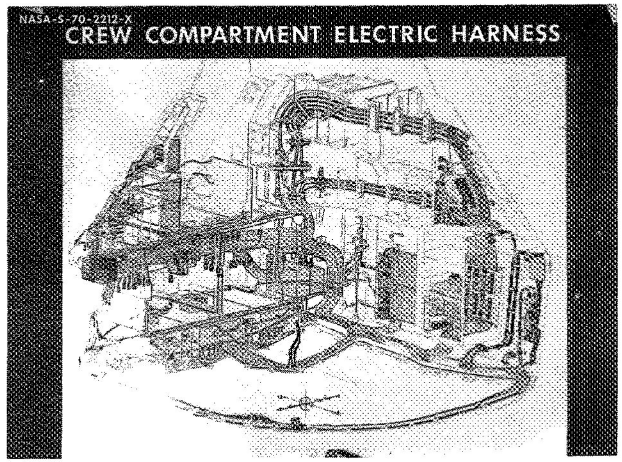




NASA-S-70-1973-X

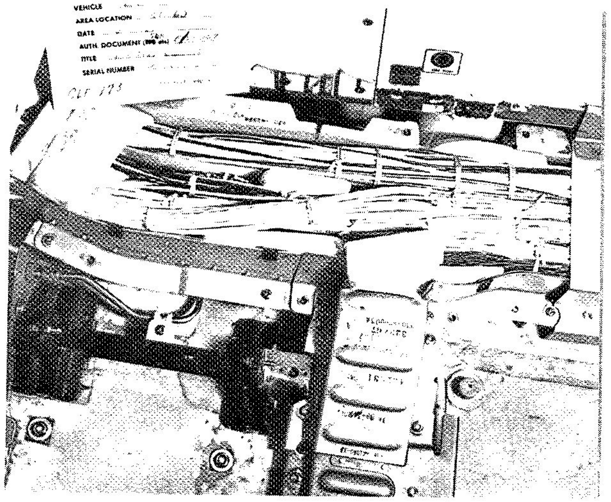
LM CREW COMPARTMENT





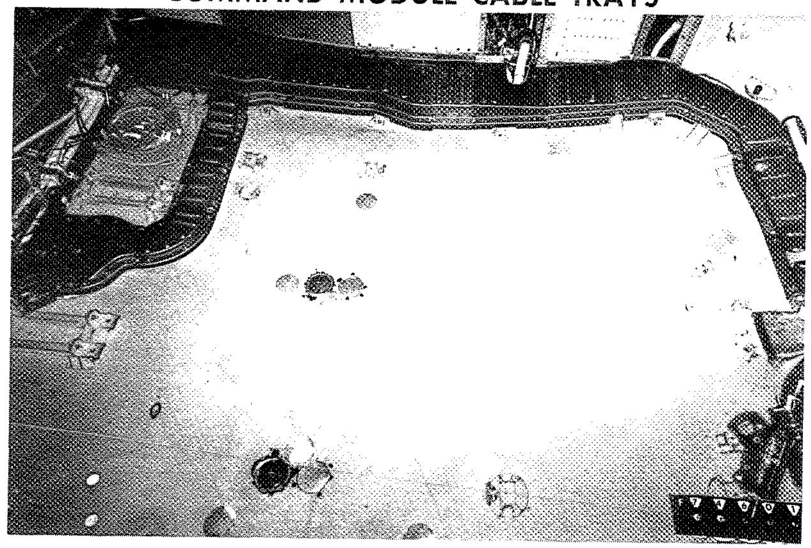
NASA-S-70-1932-X

**COMMAND MODULE
CABLE TRAY WITHOUT COVER**



NASA-S-70-1934-X

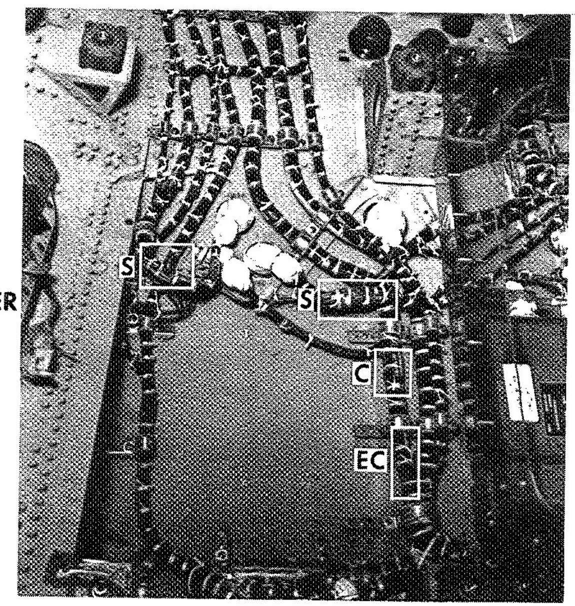
COMMAND MODULE CABLE TRAYS



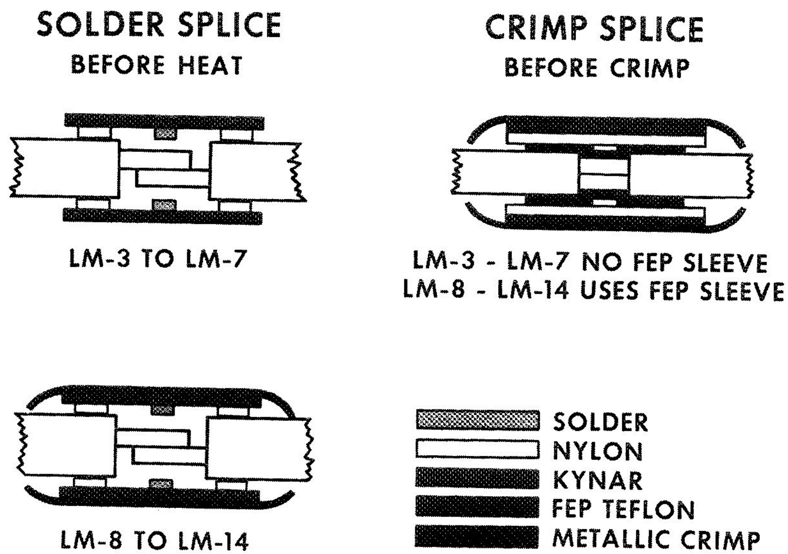
NASA-S-70-2363-X

LM CABIN WIRING

CRIMP AND SOLDER SPLICES AND END CAPS

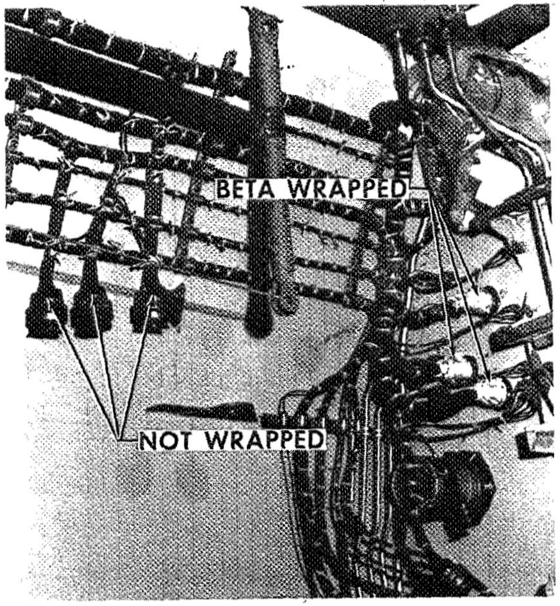


NASA-S-70-1959-X



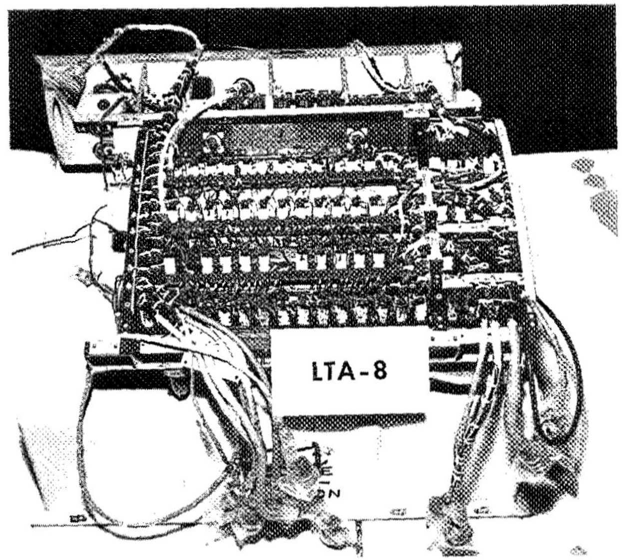
NASA-S-70-2364-X

LM CONNECTORS



NASA-S-70-1966-X

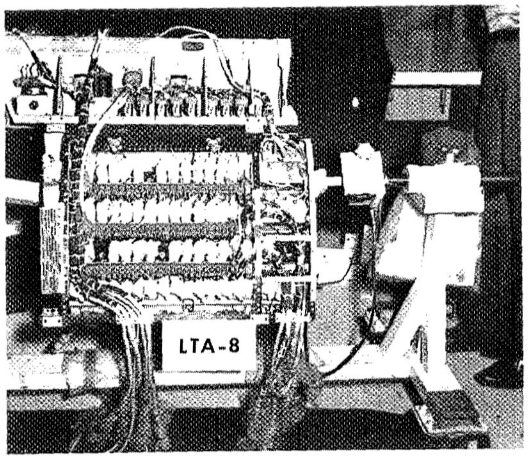
LUNAR MODULE CIRCUIT BREAKER PANEL



NASA-S-70-1967-X

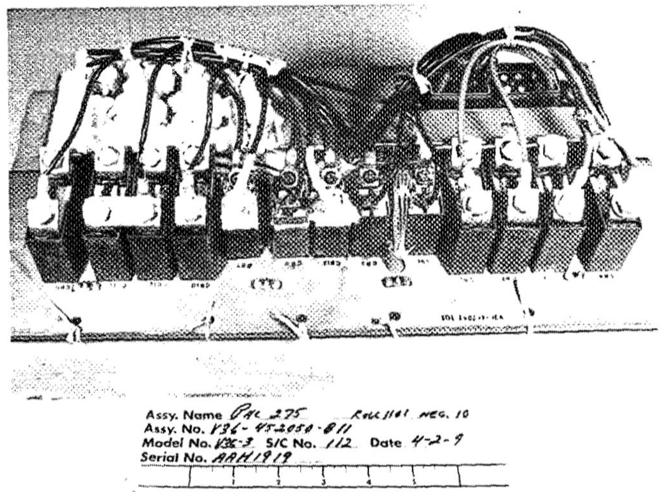
BETA BAGS

ON COATED LUNAR MODULE CIRCUIT BREAKER PANEL



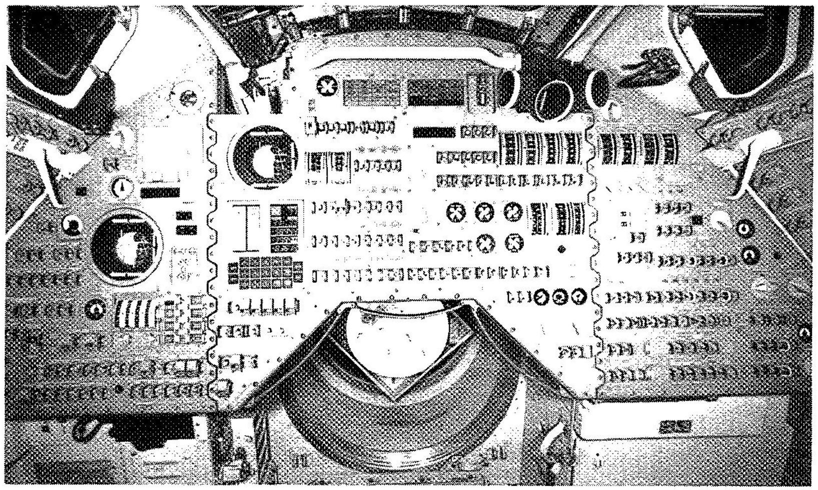
NASA-S-70-1944-X

SLEEVE CIRCUIT BREAKER PROTECTION



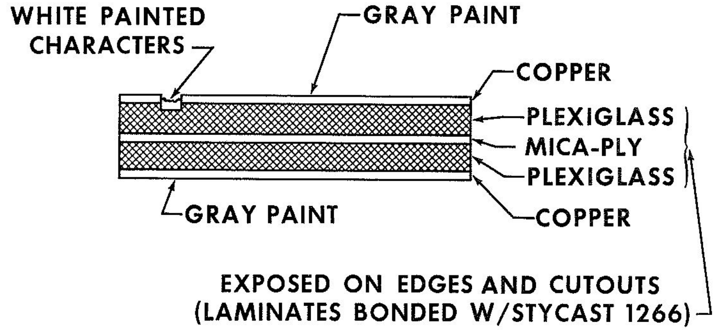
NASA-S-70-1949-X

COMMAND MODULE MAIN DISPLAY CONSOLE



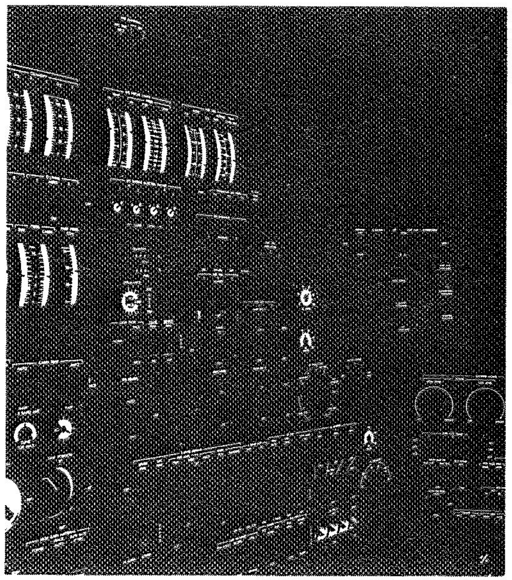
NASA-S-70-1951-X

ELECTROLUMINESCENT PANEL CONFIGURATION



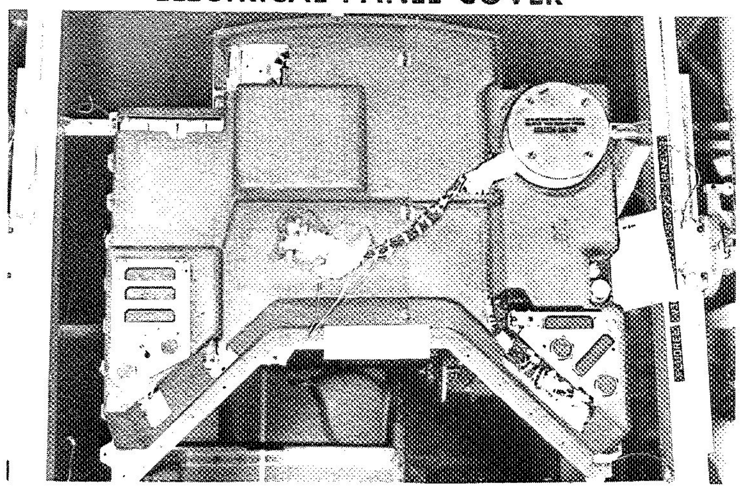
NASA-S-70-1935-X

COMMAND MODULE MAIN CONSOLE



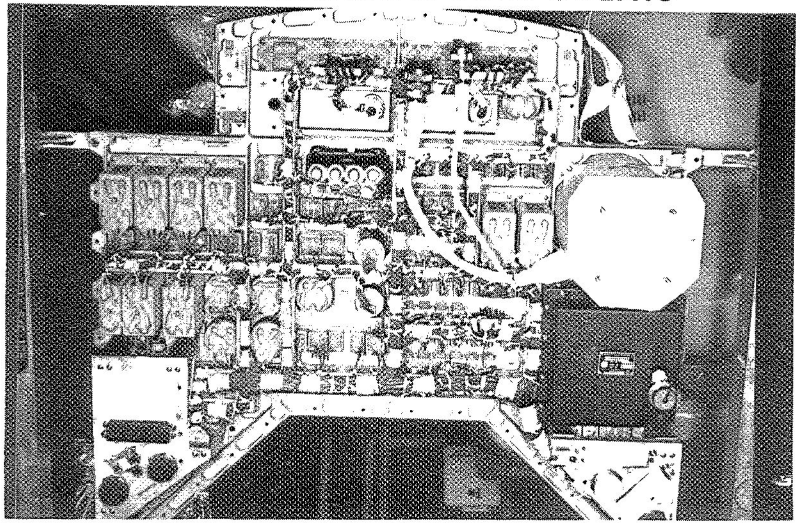
NASA-S-70-1947-X

ELECTRICAL PANEL COVER



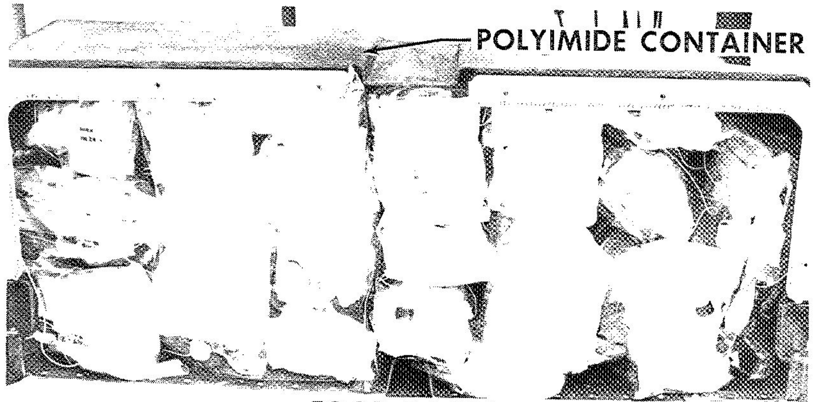
NASA-S-70-1945-X

COATED ELECTRICAL COMPONENTS



NASA-S-70-1940-X

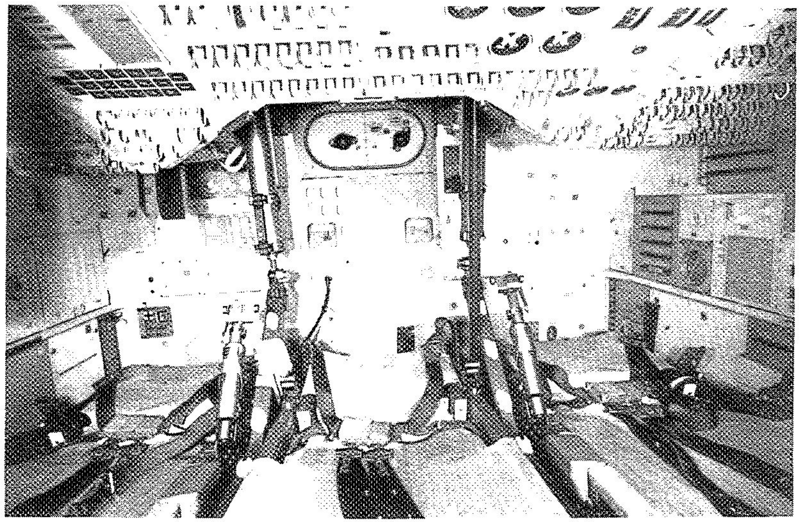
FOOD CONTAINER



FOOD PACKS
POLYETHYLENE-PRIMARY WRAP
KEL-F-OVERWRAP

NASA-S-70-1938-X

CREW COUCH AND RESTRAINT HARNESS

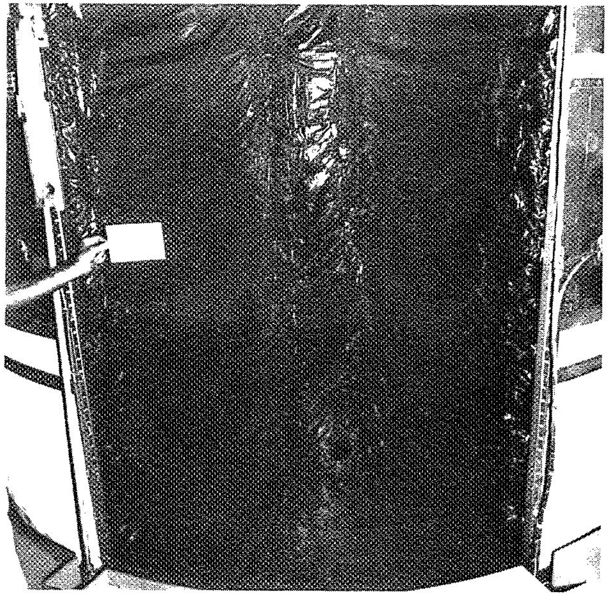


NASA-S-70-1954-X

COMMAND MODULE FIRE EXTINGUISHER

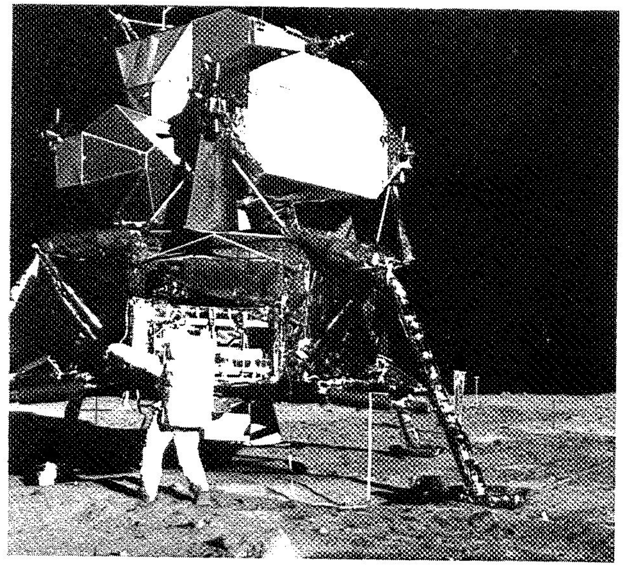
NASA-S-70-1956-X

SUPER
THERMAL
INSULATION
IN
SERVICE
MODULE



NASA-S-70-1964-X

LUNAR
MODULE ON
THE MOON
WITH SUPER
THERMAL
INSULATION



APOLLO APPLICATIONS OF BETA FIBER GLASS

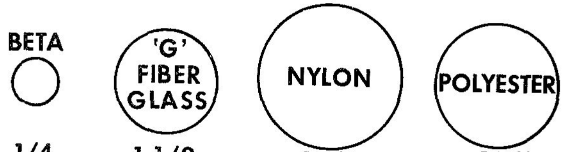
By Jack Naimer
NASA Manned Spacecraft Center

ABSTRACT

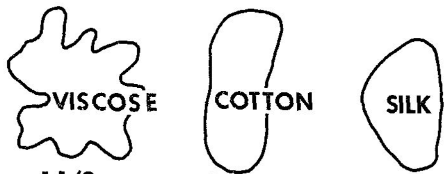
Beta fiber is a type of glass fiber that is characterized by an extremely fine fiber diameter (3.8 microns). Because of its excellent fire resistance in enriched oxygen atmospheres it is extensively used in the cabin areas of the Apollo spacecraft. The fine fiber diameter permits the fabrication of textile materials that have physical properties which are not obtainable in conventional glass fibers. This paper is a description of the development of a variety of textile materials from Beta fiber that are designed to meet specific performance requirements in the Apollo spacecraft. Where fire protection is required for flammables such as paper tissues, towels, and medical kit contents, Beta fabrics are combined with other fire-resistant materials to form composite layups that are fabricated into containers which provide protection from temperatures as high as 2500° F. Also, suggested applications to improve the fire safety of commercial aircraft, public transportation facilities, and homes are discussed. Research is continuing in an effort to devise new methods and approaches to improve performance characteristics.

NASA-S-70-1576-X

COMPARATIVE SIZE AND RELATIVE BENDING STIFFNESS OF FIBERS



	BETA	'G' FIBER GLASS	NYLON	POLYESTER
DENIER	1/4	1-1/2	1-1/2	1-1/2
DIA (MICRONS)	3.8	9.0	14	12
RELATIVE BENDING STIFFNESS	1	36	11	14



	VISCOSE	COTTON	SILK
DENIER	1-1/2	1-1/2	1.2
DIA (MICRONS)	16	16 × 6	14 × 8
RELATIVE BENDING STIFFNESS	7	8	7

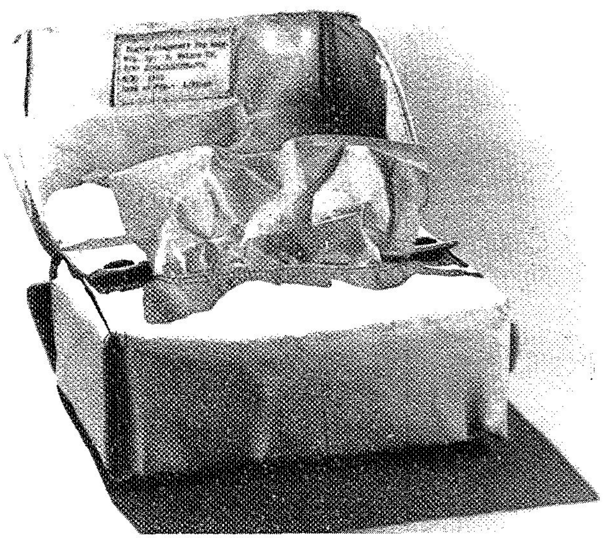
NASA-S-70-1574-X

PHYSICAL PROPERTIES OF BETA FIBER GLASS

CHARACTERISTIC	SINGLE FILAMENT	MULTIFILAMENT
BREAKING TENACITY, GRAMS PER DENIER	15.3	9.6
BREAKING ELONGATION, PERCENT	4.8	3.1
TENSILE STRENGTH, PSI	500,000	313,000
ELASTIC RECOVERY, PERCENT	100	100
AVERAGE STIFFNESS, GRAMS PER DENIER	320	310
SPECIFIC GRAVITY, GRAMS/cc	2.5	2.5
WATER ABSORBENCY, PERCENT 70° F, 65 PERCENT RELATIVE HUMIDITY	NONE	NONE

NASA-S-70-2441-X

TISSUE DISPENSER BAG



NASA-S-70-1575-X

BETA FIBER GLASS APOLLO APPLICATIONS

- 2 PASS BETA (DU PONT 95-049) TEFLON COATED
  - MEDICAL KIT
  - RUCKSACKS
  - TOWEL BAG
  - TISSUE DISPENSER
  - HELMET STOWAGE BAG
  - SUIT ACCESSORY KIT
  - LIFE VEST ASSEMBLY KIT
  - BACKPACK COVER
  - OXYGEN HOSE COVERS
- X4484 - BETA FABRIC, TEFLON COATED YARNS
  - OUTER LAYER OF SPACE SUIT
  - SPACECRAFT SHADES
- BETA MARQUISETTE
  - SPACER IN SUPERINSULATION OF SPACE SUIT

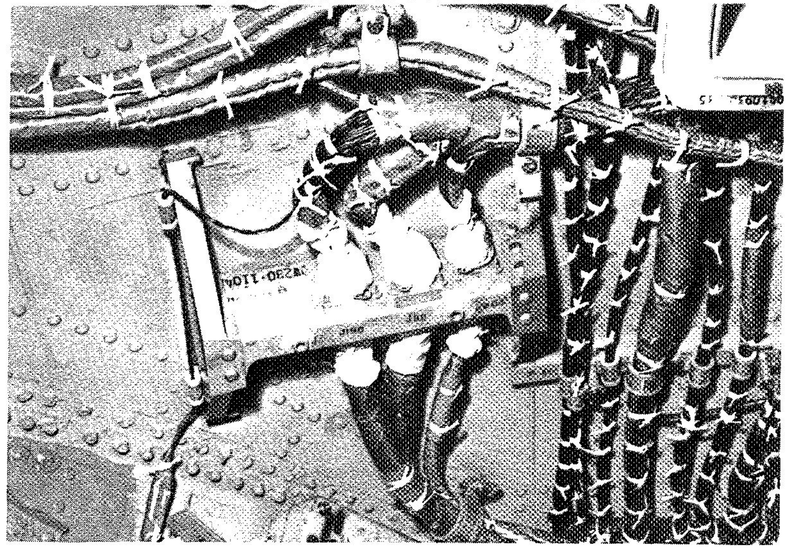
NASA-S-70 1577-X

BETA FIBER GLASS APOLLO APPLICATIONS (CONT)

- BETA CORDS AND WEBBINGS
  - USED AS ACCESSORIES ON CREW PROVISION AND SURVIVAL ITEMS
- BETA KNIT (FG-104)
  - NONFLAMMABLE SPACECRAFT INSULATION
- ASTRO-VELCRO
  - BETA IS USED FOR THE GROUND WEAVE
- BETA SCREEN PRINTS
  - MISSION EMBLEMS
  - NASA EMBLEMS
  - FLAGS
  - NAME PLATES

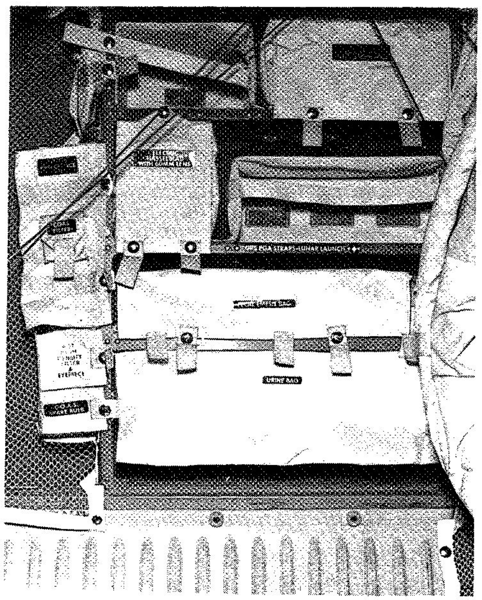
NASA-S-70-2113-X

BETA BAGS AS ELECTRICAL CONNECTOR PROTECTION



NASA-S-70-2114-X

BETA FABRIC CONTAINERS



NASA-S-70-1960-X

POTENTIAL USES OF BETA FIBER

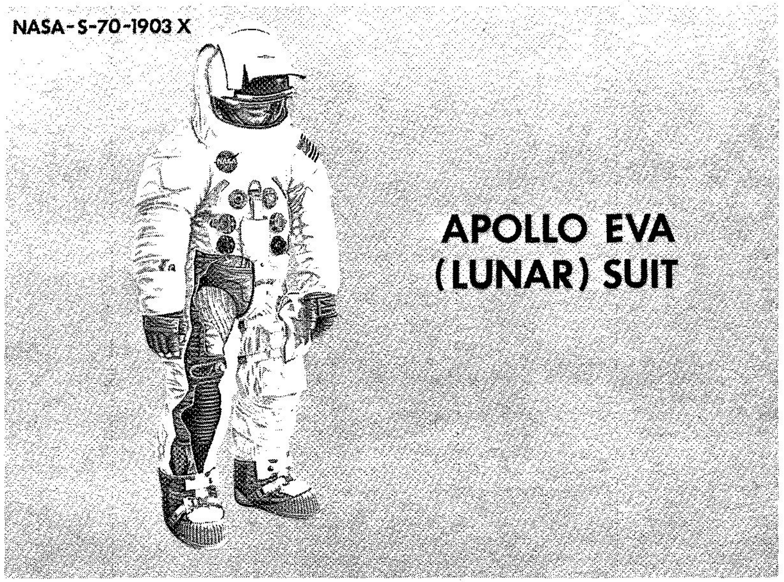
- PROTECTIVE WORK CLOTHING
  - MILITARY FLIGHT COVERALLS
  - FUEL AND AMMUNITION HANDLERS
  - FIRE FIGHTERS
- FLAME PROOF BEDDING FOR INSTITUTIONS, HOTELS, HOSPITALS
- WALL COVERINGS
- UPHOLSTERY
- FLOOR COVERINGS

THE APOLLO SPACE SUIT MATERIALS

By Frederic S. Dawn and Ralph L. Jarboe
NASA Manned Spacecraft Center

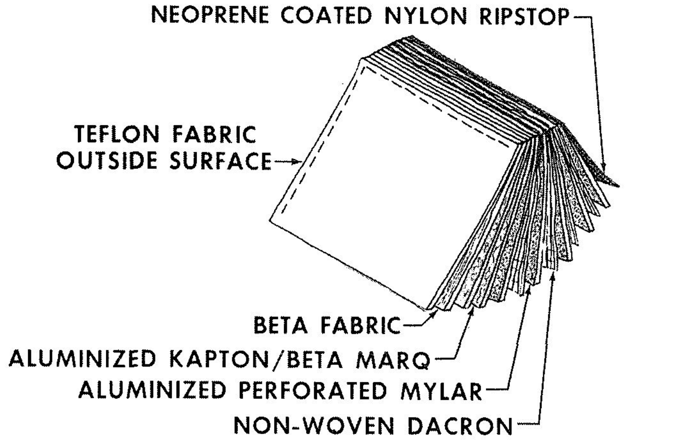
ABSTRACT

The Apollo lunar surface space suit is composed of several primary components such as the pressure garment assembly, the integrated thermal micrometeoroid garment, the liquid-cooled garment, the pressure garment boot, the lunar boot, the extravehicular boot, and the helmet with its various protective visors. Each of these components is basically a composite of a variety of nonmetallic materials (and some limited metal parts) each of which has specific functional requirements. This paper describes the various components of the space suit and considers the functional requirements for the various materials utilized, with special emphasis on the fire-resistance properties of these materials.



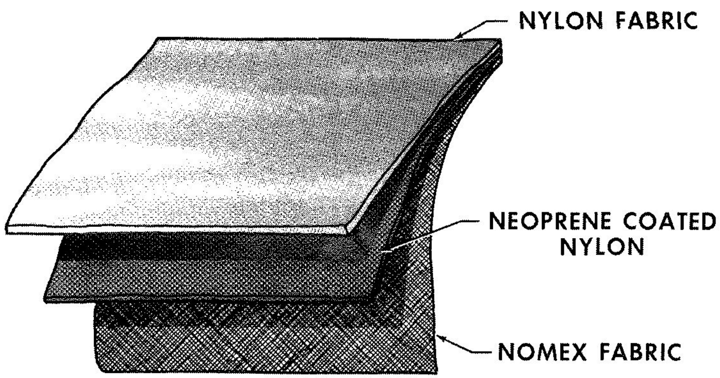
NASA-S-70-2118-X

THERMAL MICROMETEOROID GARMENT LAYUP



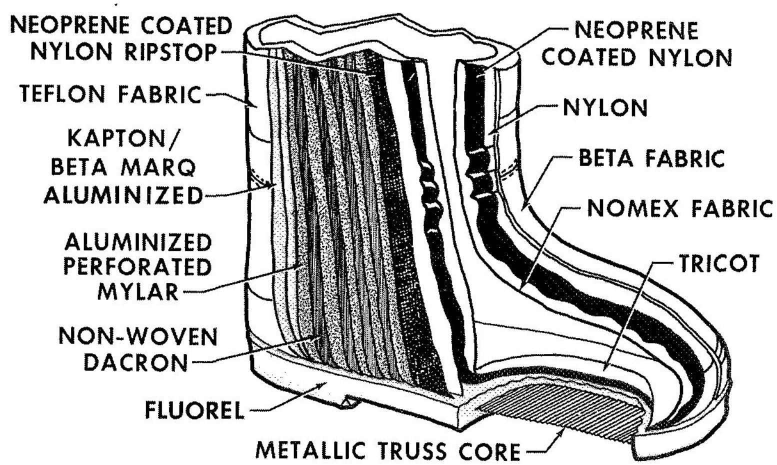
NASA-S-70-2117-X

PRESSURE GARMENT LAYUP



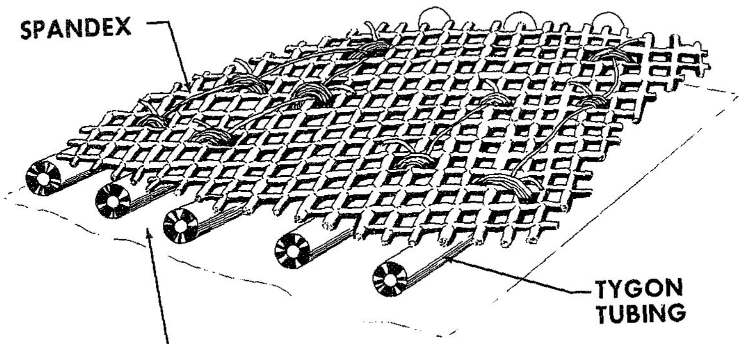
NASA-S-70-2116-X

PRESSURE GARMENT BOOT



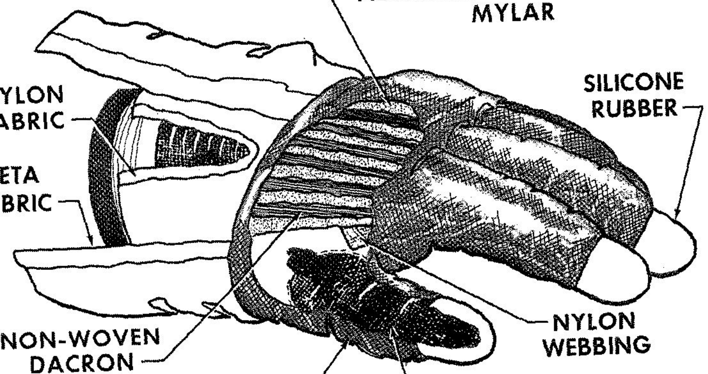
NASA-S-70-2120-X

LIQUID COOLING GARMENT CONSTRUCTION



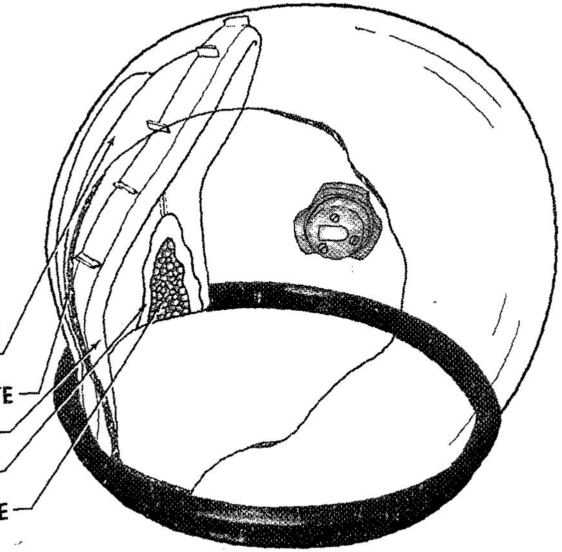
NASA-S-70-2121-X

EXTRAVEHICULAR GLOVE



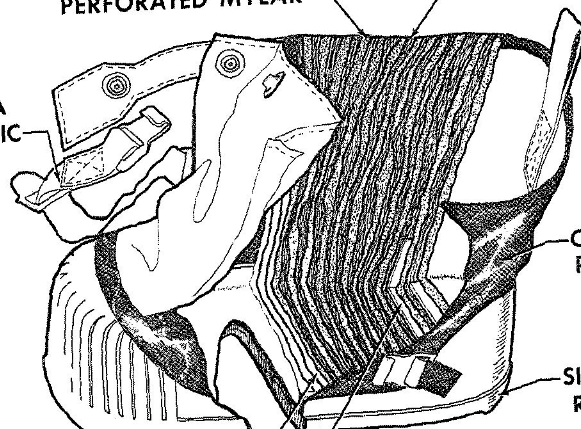
NASA-S-70-2119-X

HELMET



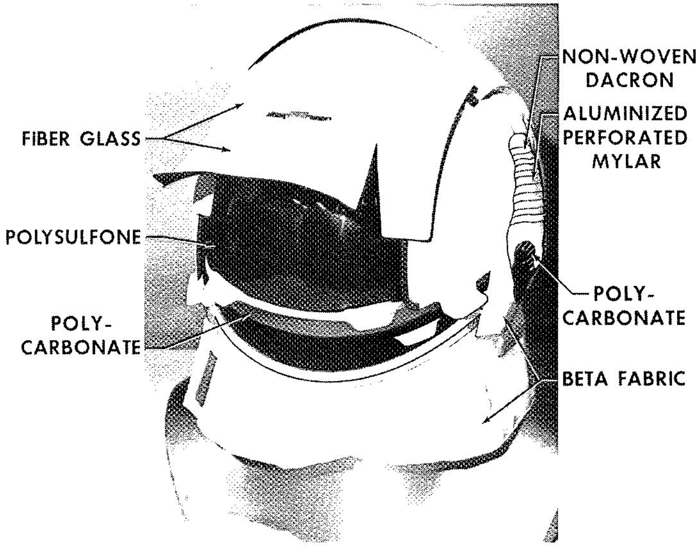
NASA-S-70-2122-X

LUNAR BOOT



NASA-S-70-2123-X

LUNAR EXTRAVEHICULAR VISOR ASSEMBLY



FIRE-SAFETY DESIGN OF A MOBILE QUARANTINE FACILITY

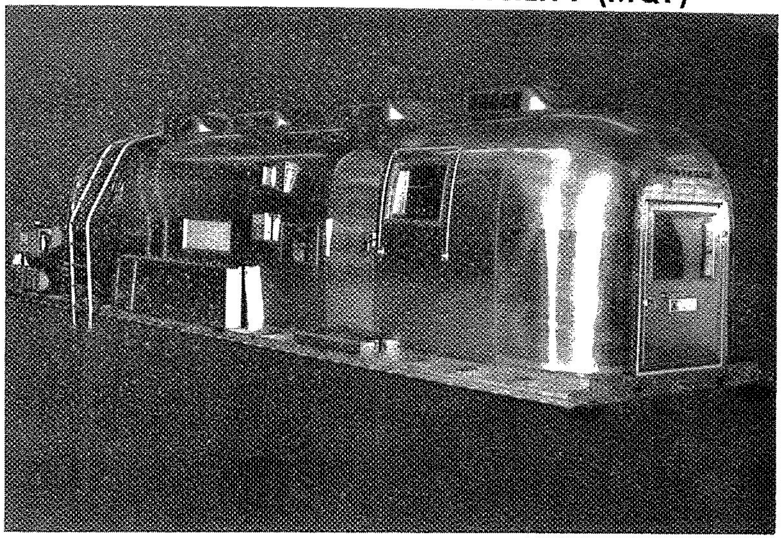
By Roderick S. Bass and John K. Hirasaki
NASA Manned Spacecraft Center

ABSTRACT

This paper discusses the approach taken by NASA in the design and construction of a Mobile Quarantine Facility to make it firesafe for manned operational purposes. In order that this facility be constructed with the greatest possible economy, it was decided to accept certain standard items of hardware used in the construction of commercial travel trailers and then to provide for subsequent fireproofing of these items. A base-line criterion was established that all fireproofing should meet or exceed the standards of commercial aviation practices as required by the Federal Aviation Administration. To meet this criterion, an evaluation program was initiated to investigate available fireproofing materials that could be applied to flammable substrates such as wooden panels. As a result of this evaluation program, Fluorel was selected because of its fire-retardant properties and because it could be applied to the flammable substrates by spray-application techniques. This Fluorel coating was applied to all wood, vinyl-coated wood, and fiberglass-reinforced plastic surfaces in the Mobile Quarantine Facility. Commercially available fire-retardant materials were chosen for such items as curtains, mattresses, upholstery, plumbing, and lavatory fixtures. In addition to these measures, the Mobile Quarantine Facility electrical system, auxiliary power unit, and fire-detection system incorporated design features to assure fire safety.

NASA-S-70-1568-X

MOBILE QUARANTINE FACILITY (MQF)



NASA-S-70-1563-X

STANDARD COMMERCIAL TRAVEL TRAILER MATERIALS

- BULKHEADS, DOORS AND FRAMING MATERIALS
  - WALNUT WOOD
  - OAK WOOD
  - VINYL-ON-WOOD
- BATHROOM FIXTURES
  - BATHTUB – FIBER-GLASS-REINFORCED PLASTIC
  - LAVATORY – FIBER-GLASS-REINFORCED PLASTIC
  - OTHER MOLDINGS – ACRYLONITRITE-BUTADIENE-STYRENE (ABS)
- MATTRESS
  - EXTERIOR TICKING – COTTON
  - INTERIOR – URETHANE FOAM

NASA-S-70-1564-X

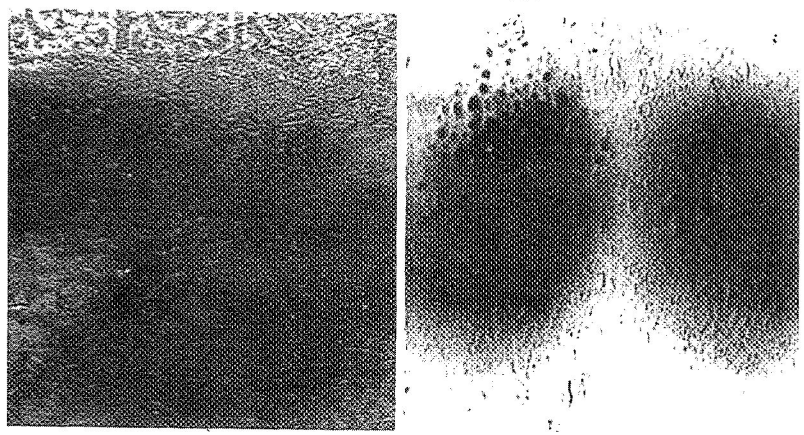
STANDARD COMMERCIAL TRAVEL TRAILER MATERIALS (CONT)

- SEATS – URETHANE FOAM
- CURTAINS – FIBER GLASS
- INTERIOR END SECTIONS – FIBER-GLASS-REINFORCED PLASTIC
- FLOOR – NYLON CARPET
- PLUMBING – ACRYLONITRITE-BUTADIENE-STYRENE (ABS)

NASA-S-70-1560-X

FLUOREL COATING - VINYL-ON-WOOD

FAA FLAMMABILITY TEST

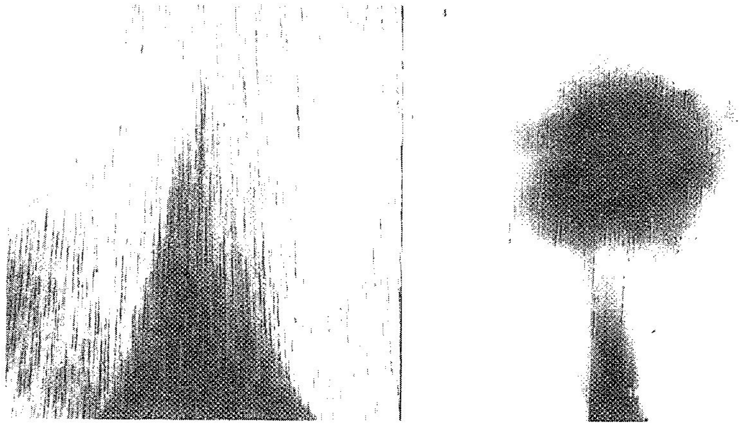


WITHOUT FLUOREL — WITH FLUOREL

NASA-S-70-1559-X

FLUOREL COATING ON PLYWOOD

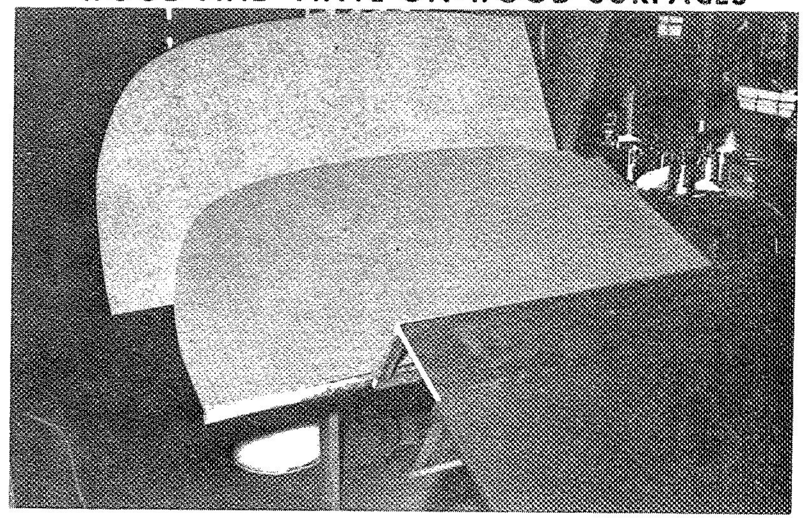
FAA FLAMMABILITY TEST



WITHOUT FLUOREL WITH FLUOREL

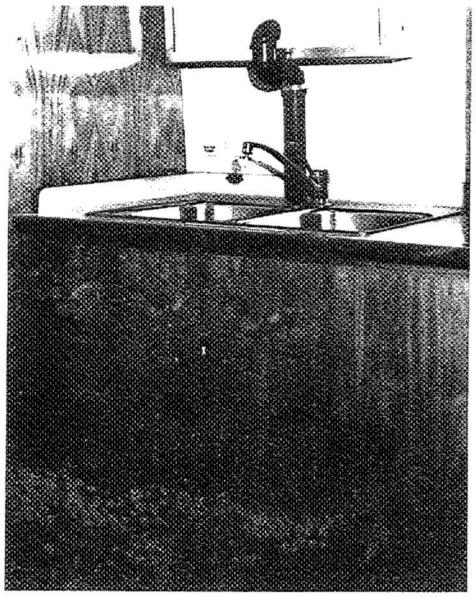
NASA-S-70-1570-X

FLUOREL APPLICATION ON WOOD AND VINYL-ON-WOOD SURFACES



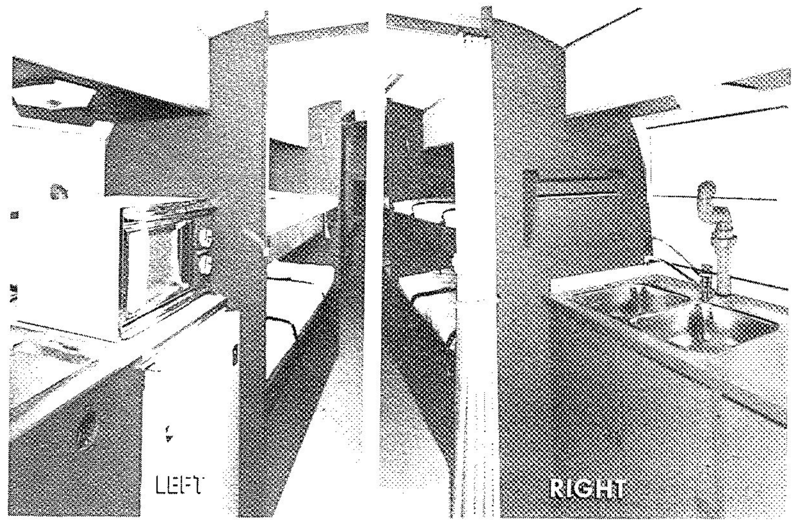
NASA-S-70-1556-X

GALLEY SHOWING ORIGINAL WOOD SURFACES



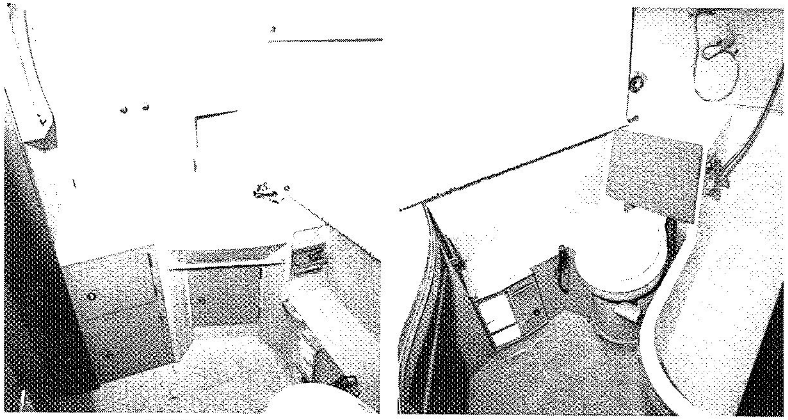
NASA-S-70-1557-X

GALLEY AND BUNK AREAS



NASA-S-70-1572-X

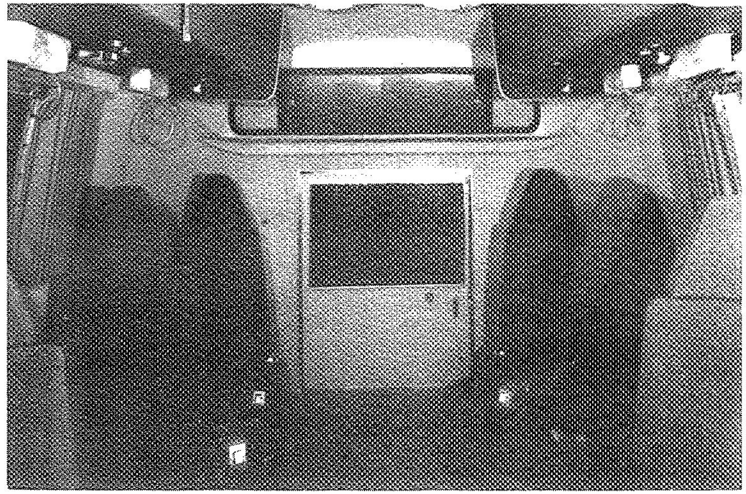
LAVATORY AREA



LEFT RIGHT

NASA-S-70-1569-X

LOUNGE AREA



NASA-S-70-1565-X

MATERIALS CHANGES MADE TO MEET FAA FLAMMABILITY REQUIREMENTS

- BULKHEADS, DOORS AND FRAMING MATERIALS
  - -*WALNUT WOOD WITH FLUOREL
  - -*OAK WOOD WITH FLUOREL
  - -*VINYL-ON-WOOD WITH FLUOREL
- BATHROOM FIXTURES
  - BATHTUB -*FIBER-GLASS-REINFORCED PLASTIC WITH FLUOREL
  - LAVATORY - FIRE RESISTANT PVC
  - OTHER MOLDINGS - FIRE RESISTANT PVC
- MATTRESS
  - EXTERIOR TICKING - FIRE RESISTANT POLYETHELENE
  - INTERIOR - FIRE RESISTANT URETHANE FOAM

*3-5 MILS COATING

NASA-S-70-1421-X

MATERIALS CHANGES MADE TO MEET FAA FLAMMABILITY REQUIREMENTS (CONT)

- SEATS - FIRE RESISTANT MATERIALS
- CURTAINS - COMB. VEREL MODACRYLIC, SARAN FLAT MONO-FILAMENT, AND VISCOSE RAYON
- INTERIOR END SECTIONS - *FIBER-GLASS-REINFORCED PLASTIC WITH FLUOREL
- FLOOR - ASBESTOS-VINYL TILE
- PLUMBING - FIRE RESISTANT PVC

• 3-5 MILS COATING

SUMMARY

- PRACTICAL APPLICATIONS OF ADVANCEMENT IN TECHNOLOGY
- APPLICATION OF FLUOREL
- OPERATIONAL USE OF MQF

PROTECTIVE CLOTHING UTILIZED AT THE KENNEDY SPACE CENTER

By Joel R. Reynolds
NASA Kennedy Space Center

ABSTRACT

The suit and suit material requirements for the Kennedy Space Center spacecraft close-out crew and astronaut rescue team are described in relation to the responsibilities and functions of these teams. Several years ago, the spacecraft close-out crew searched for a satisfactory garment material and selected Nomex, a member of the nylon family. The properties of Nomex and the results of tests are described which indicate that Nomex garments can withstand very short exposure to high-intensity heat and have heat-insulating properties which can protect the crews. It is noted that better performing flame-resistant materials are now available for use in lightweight fire-protection garments.

CONVENTIONAL
PROXIMITY FIRE
SUPPRESSION SUIT

ASTRONAUT RESCUE
TEAM
ALUMINIZED 'NOMEX'
FIRE SUPPRESSION SUIT

FIRE EXTINGUISHMENT IN HYPOBARIC

AND HYPERBARIC ENVIORNMENTS

By J. H. Kimzey
NASA Manned Spacecraft Center

ABSTRACT

Atmospheres of spacecraft and support equipment and problems of accidental fire in these atmospheres are discussed. A test program to determine the effectiveness of several fire extinguishants is reviewed. Open-cell foamed polyurethane is employed as the fuel in this program. Several extinguishants widely used for fires in air were ineffective or even detrimental in the oxygen-enriched test atmospheres, because they increased the burning rates. Gases such as Halon 1301, carbon dioxide, nitrogen, helium, and argon are included in this category. Water or water-based foams are shown to be effective. Data on the performance of water as a fire extinguishant in pure-oxygen atmospheres at 14.7 psia or less (hypobaric) and in air at pressures as great as 105 psia (hyperbaric) are presented and discussed.

NASA-S-70-2178-X

AEROSPACE ENVIRONMENT

- OXYGEN
  - 21, 60, AND 100 PERCENT
- PRESSURE
  - 3.5, 5, 14.7 AND 16.5 PSIA

NASA-S-70-1654-X

HALON 1301 TESTS IN APOLLO BOILERPLATE

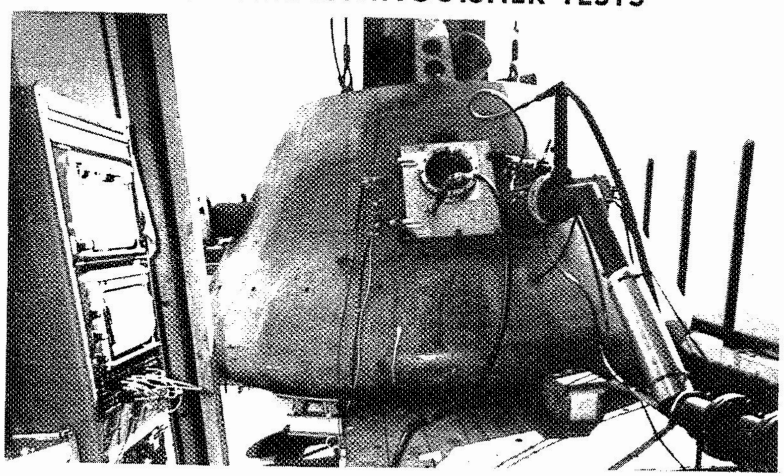
PRESSURE 14.7 PSIA

AMOUNT HALON 1301, LB	FUEL	OXYGEN, PERCENT	EXTINGUISHED
IGNITED IN OPEN TOP CONTAINER			
1.7	1	21	YES
1.7	2	24	YES
1.7	2	33	YES
1.7	2	82	NO
1.7	2	78	NO
1.7	2	79	NO
IGNITED ON FLAT BOARD			
1.7	2	82	NO
1.7	2	83	NO
3.5	3	81	NO
3.4	3	81	NO
4.0	3	80	NO

1 POLYSTYRENE FOAM
2 POLYURETHANE FOAM
3 COMPOSITE ASSORTMENT

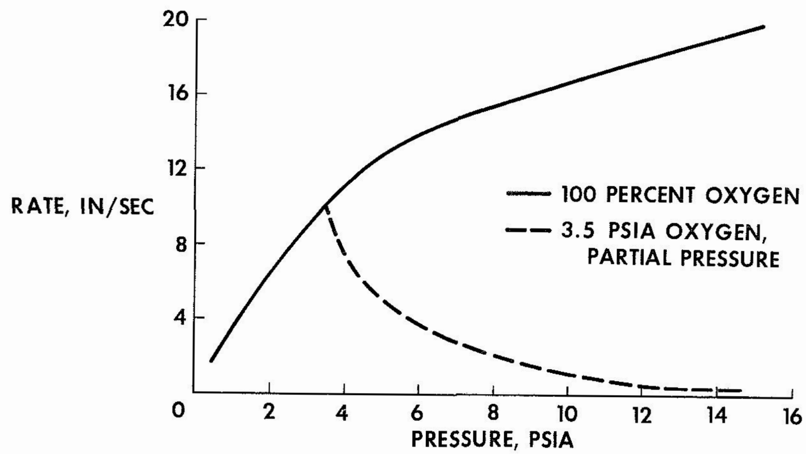
NASA-S-70-1650-X

APOLLO BOILERPLATE USED FOR FIRE EXTINGUISHER TESTS



NASA-S-70-1652-X

HORIZONTAL FLAME PROPAGATION RATE OPEN CELL POLYURETHANE FOAM



NASA-S-70-2182-X

RATING OF EXTINGUISHING AGENTS

POLYURETHANE FOAM FIRE IN OXYGEN (5 TO 16.2 PSIA)

GASSES	
HALON 1301 HELIUM NITROGEN ARGON CARBON DIOXIDE	INTENSIFIES BURNING
SOLIDS	
SODIUM BICARBONATE	INEFFECTIVE
POTASSIUM BICARBONATE	INEFFECTIVE

NASA-S-70-2181-X

RATING OF EXTINGUISHING AGENTS (CONT)

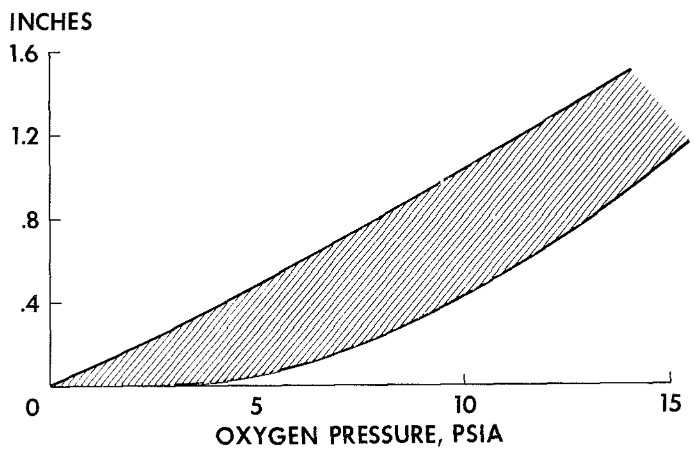
POLYURETHANE FOAM FIRE IN OXYGEN (5 TO 16.2 PSIA)

LIQUIDS	
WATER	GOOD
FOAM	GOOD
ETHYLENE GLYCOL SOLUTION	POOR
GEL SOLUTION*	EXCELLENT
VENT	
PUMPDOWN TO 0.12 PSIA IN 2 MIN	INEFFECTIVE

* WATER CONTAINING GEL (0.25 PERCENT), 300 TO 350 CENTIPOISE

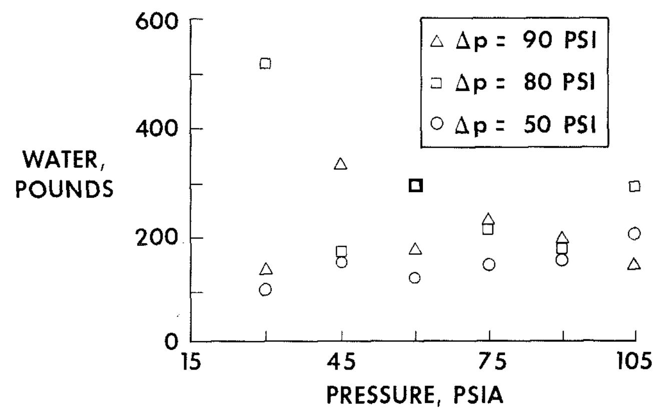
NASA-S-70-1497-X

EQUIVALENT THICKNESS OF WATER APPLIED TO EXTINGUISH POLYURETHANE FOAM FIRE IN OXYGEN



NASA-S-70-1651-X

WATER EXTINGUISHMENT IN HYPERBARIC CHAMBER (180 CU FT VOL) USING 27-1/2 PERCENT O_2



NASA-S-70-2179-X

OXYGEN TRANSPORT

- GASEOUS
  - AIRCRAFT
  - TRUCK
  - RAILROAD
  - PIPELINE
- LIQUID (VENTED CONTAINER)
  - AIRCRAFT
  - TRUCK
  - RAILROAD
- SOLID (VENTED CONTAINER)
  - AIRCRAFT
  - TRUCK

NASA-S-70-2180-X

OXYGEN-ENRICHED ATMOSPHERES

- AIRCRAFT
  - CABIN AND COCKPIT
- OCEANOGRAPHY
  - INCREASED PARTIAL PRESSURE
- MEDICAL
  - OXYGEN TENTS
  - HYPERBARIC CHAMBERS
- INDUSTRIAL
  - METALLURGY
  - CHEMICAL RAW MATERIAL
  - SEWAGE TREATMENT
- SPACE
  - SPACECRAFT
  - LUNAR VEHICLES
  - GROUND TRAINING EQUIPMENT
  - MISSILE SILOS

SESSION IV

SPECIAL TESTS

Session Chairman: H. Kurt Strass

MANNED SPACECRAFT ELECTRICAL FIRE SAFETY

By Anthony W. Wardell
NASA Manned Spacecraft Center

ABSTRACT

Of the possible ignition sources of fires in oxygen enriched atmospheres electrical ignition sources are the most probable. Of these electrical sources, electrical wire/cable is the most likely. The NASA approach to minimizing electrical wire/cable ignition hazards is discussed. The shortcomings of typical commercial wire/cable flammability test procedures are outlined. A new wire/cable electrical current overload flammability test is described, together with results to date. Many commonly used insulating and electrical system accessory materials are not firesafe for use in spacecraft oxygen enriched atmospheres. Accordingly, a list is given of materials that pass or fail the newly developed test. The effect of the wire/cable flammability test results on spacecraft configurations and the resultant design and procedural standards are discussed. "Spin-off" potential applications to the enhancement of electrical fire safety in commercial, residential, and airframe applications are enumerated.

NASA-S-70-1733-X

FIRE SAFETY GOALS

- MINIMIZE COMBUSTIBLES
- MINIMIZE IGNITION SOURCES

NASA-S-70-1732-X

IGNITION SOURCES

- ELECTRICAL
- HOT SURFACES
- OPEN FLAME
- HEATED GASES
- HIGH ENERGY IMPACT
- CHEMICAL
- ELECTROSTATIC SPARKS

NASA-S-70-1989-X

SPACE PROGRAM FIRES

LOCATION	DATE	O_2, PSIA	PROBABLE CAUSE
BROOKS AFB 2-MAN SIMULATOR (2 SUBJECTS)	1962	5	ELECTRICAL OVERLOAD
AIR CREW EQUIP-MENT LAB, PHILA (4 SUBJECTS)	1962	5	LIGHT FIXTURE ARCED
APOLLO ECS CHAMBER, TORRANCE, CALIF (UNMANNED)	1966	5	SHORT CIRCUIT OF STRIP HEATER
APOLLO 204 COMMAND MODULE (3 ASTRONAUTS) *	1967	16	WIRE SHORT CIRCUIT
BROOKS AFB 2-MAN SIMULATOR, (2 SUBJECTS) *	1967	5	LIGHT CORD SHORT CIRCUIT

* FATALITIES

NASA-S-70-1734-X

WIRE AND CABLE - MOST PROBABLE ELECTRICAL IGNITION SOURCES

- USER MAY TREAT WIRE AS 'RAW MATERIAL'
- WIRING IS VULNERABLE
- WIRING INTEGRITY IS DIFFICULT TO VERIFY
- CIRCUIT PROTECTIVE DEVICES MAY NOT BE 100 PERCENT EFFECTIVE
- WIRE INSULATIONS/ELECTRICAL ACCESSORY MATERIALS MAY IGNITE AND PROPAGATE FLAME

NASA-S-70-1735-X

NASA APPROACH TO MINIMIZE WIRE AND CABLE IGNITION HAZARDS

- INCREASED QUALITY CONTROL AT CONTRACTORS AND WIRE SUPPLIERS
- CHAFE GUARDS, WIRE TRAYS
- IN-PROCESS TEST AND INSPECTION
  - VISUAL INSPECTION
  - DIELECTRIC TESTS
- CIRCUIT BREAKER IMPROVEMENTS
- WIRE/CABLE ELECTRICAL OVERLOAD TEST
  - SCREENS CANDIDATE WIRE INSULATIONS
  - SCREENS CANDIDATE ELECTRICAL ACCESSORIES

NASA-S-70-2138-X

COMMERCIAL WIRE INSULATION FLAMMABILITY TESTS

SPECIMEN	IGNITION TECHNIQUE	ACCEPTANCE CRITERIA
	UNDERWRITERS' LABORATORIES	
HORIZONTAL SINGLE WIRE	TIRRILL BURNER 30 SEC	1 IN. PER MIN
VERTICAL SINGLE WIRE	TIRRILL BURNER FIVE 15-SEC EXPOSURES	10 IN. TOTAL 1 MIN MAX
	TYPICAL COMMERCIAL AIRCRAFT	
60 DEG SINGLE WIRE	BUNSEN BURNER 15 SEC AWG 30-18 30 SEC AWG 16-12	MEASURE AFTER-BURN TIME POST-TEST DIELECTRIC

NASA-S-70-1740-X

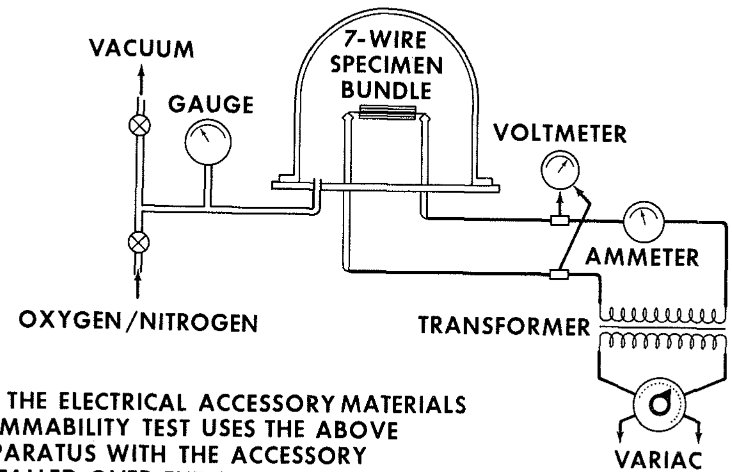
COMMERCIAL WIRE FLAMMABILITY TEST DEFICIENCIES

- ASSESSES ONLY THE WIRE INSULATION'S CONTRIBUTION TO AN ALREADY EXISTING FIRE
- COLD COPPER HEAT SINK
- SHORT FLAME EXPOSURE TIME
- FLAME PROPAGATION IS ACCEPTABLE

NASA-S-70-1741-X

NASA WIRE INSULATION FLAMMABILITY TEST

SCHEMATIC DIAGRAM OF APPARATUS



NOTE: THE ELECTRICAL ACCESSORY MATERIALS FLAMMABILITY TEST USES THE ABOVE APPARATUS WITH THE ACCESSORY INSTALLED OVER THE SPECIMEN BUNDLE

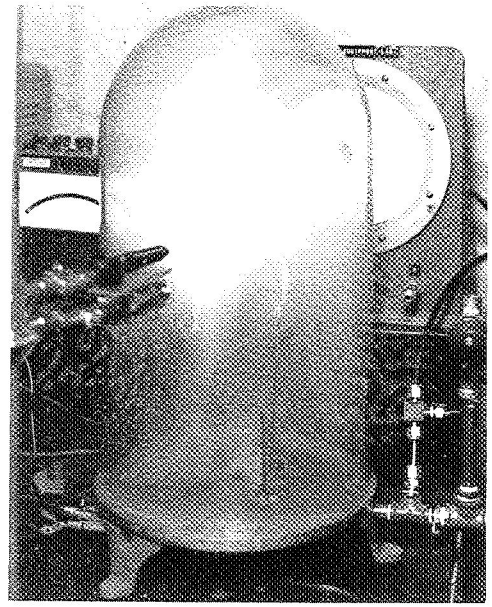
NASA-S-70-2137-X

NASA WIRE INSULATION FLAMMABILITY TEST

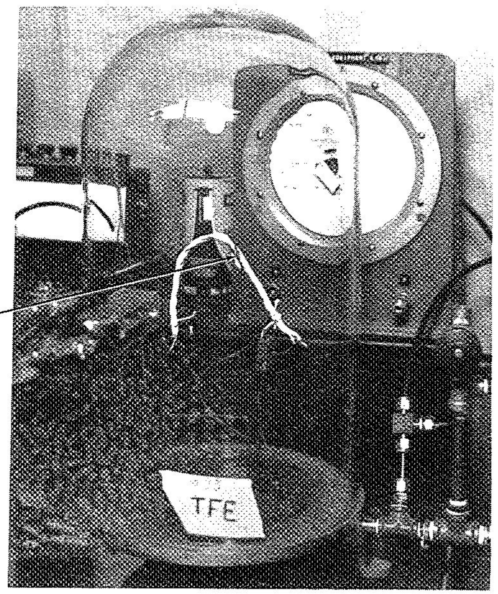
SPECIMEN	IGNITION TECHNIQUE	ACCEPTANCE CRITERIA
HORIZONTAL 7-WIRE BUNDLE	CURRENT OVERLOAD TO CONDUCTOR FUSION	NO FLAME PROPAGATION
ONE 'HOT' WIRE	80%-90% OF FUSION CURRENT	INSULATION INTEGRITY ON ADJACENT WIRES
	5 AMP STEPS EACH MINUTE	

NASA-S-70-1743-X

POLYOLEFIN BUNDLE BURNING IN 100 PERCENT OXYGEN AT 5 PSIA



NASA-S-70-1744-X



TEFLON BUNDLE BURNING

NOTE SMALL BLUE FLAME IN 100 PERCENT O_2 AT 5 PSIA

NASA-S-70-1736-X

UNACCEPTABLE ELECTRICAL MATERIALS IN OXYGEN-RICH ATMOSPHERES

- WIRE INSULATIONS
  - POLYOLEFIN
  - POLYVINYL CHLORIDE
  - SILICONE RUBBER
  - POLYVINYLIDENE FLUORIDE
- ELECTRICAL ACCESSORY MATERIALS
  - NYLON
  - POLYOLEFIN
  - VINYL
  - SILICONE
  - POLYVINYLIDENE FLUORIDE

NASA-S-70-1737-X

ACCEPTABLE ELECTRICAL MATERIALS IN OXYGEN-RICH ATMOSPHERES

- WIRE INSULATIONS
  - TEFLON TFE
  - TFE/ML
  - KAPTON/FEP*
- ELECTRICAL ACCESSORY MATERIALS
  - TEFLON TFE
  - FLUOREL
  - FIBER GLASS/ POLYIMIDE LAMINATE

*NOT ACCEPTABLE AS A SHIELDED ELECTRICAL CABLE JACKET MATERIAL

NASA-S-70-1738-X

RECOMMENDATIONS

- MATERIALS AND INSULATING SYSTEMS ACCEPTED BY NASA AS FIRE-SAFE IN SPACECRAFT OXYGEN ATMOSPHERES SHOULD BE CONSIDERED FOR USE IN COMMERCIAL, RESIDENTIAL, AND AIRFRAME APPLICATIONS
- UNREALISTIC BUNSEN BURNER TEST SHOULD BE REPLACED WITH AN ELECTRICAL OVERLOAD FLAMMABILITY TEST
- ELECTRICAL ACCESSORY MATERIALS SHOULD BE TESTED AS INSTALLED OVER AN ELECTRICAL OVERLOAD TEST SPECIMEN

NASA-S-70-1739-X

IMPACT OF NASA WIRE/CABLE FLAMMABILITY TEST

- GEMINI CABIN WIRING
- CM WIRING
- LM WIRING
- KAPTON/FEP CABLE 'BURNING REACTION' IN OXYGEN ENVIRONMENTS
- ELECTRICAL ACCESSORY MATERIALS
- NASA DESIGN AND PROCEDURAL STANDARDS

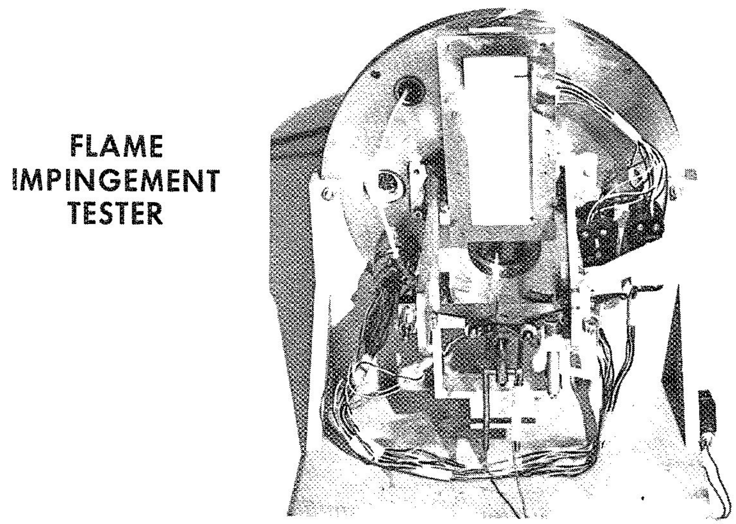
SPECIAL FLAMMABILITY TEST TECHNIQUES

By Dale G. Sauers
NASA Manned Spacecraft Center

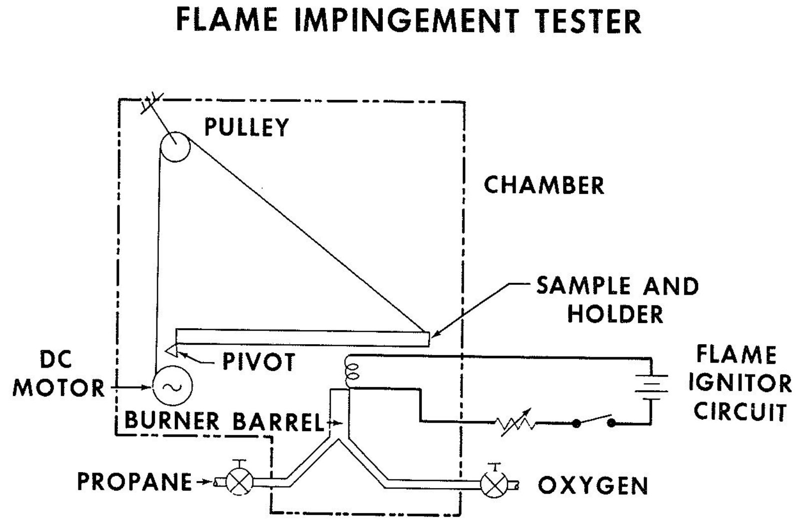
ABSTRACT

This paper discusses four new nonstandard test methods that have been developed to provide preliminary engineering data and to permit early prediction of end-item performance prior to full-scale-mockup flammability tests. The test methods discussed, all of which are operable in oxygen-enriched environments, are as follows: (1) flame impingement testing, which simulates a constant flame source and provides data on relative flammability and thermal performance; (2) short-circuit ignition testing, which evaluates the material in proximity to simulated electrical arcing; (3) polycarbonate-drip ignition testing, which evaluates the performance of materials exposed to falling flaming embers; and (4) flash-point/fire-point testing, which evaluates the performance of overheated materials in the presence of an electrical spark.

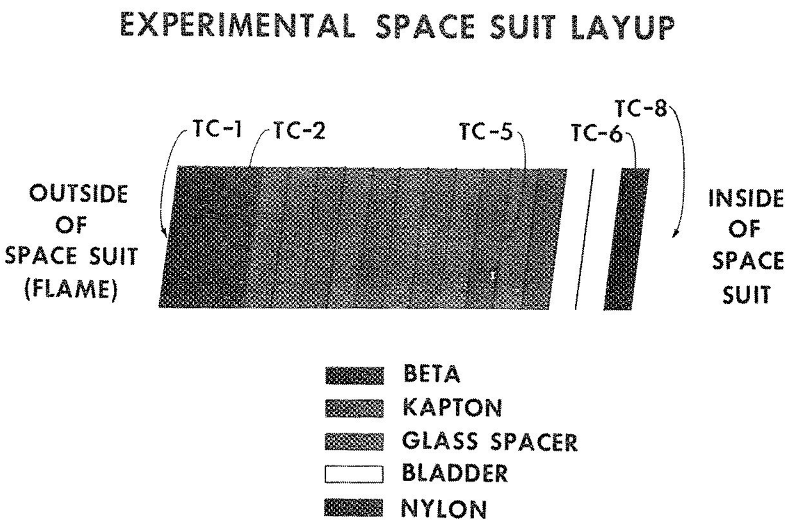
NASA-S-70-1621-X



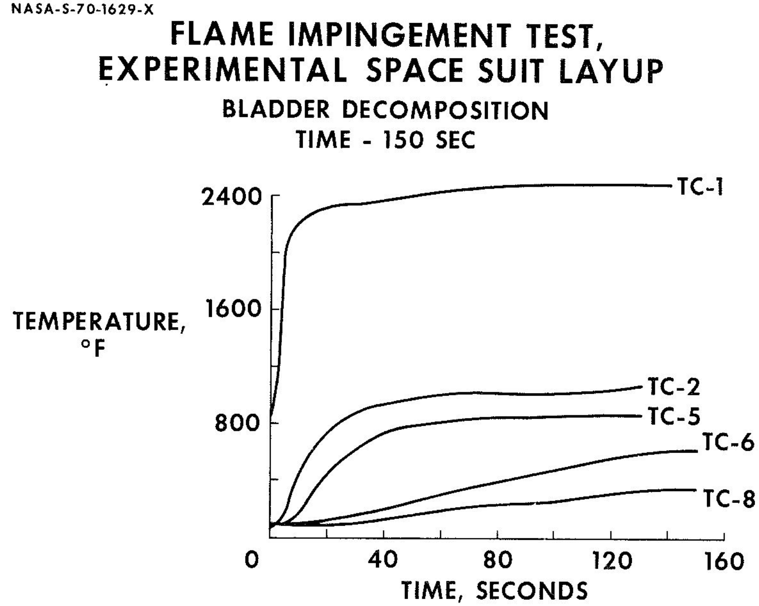
NASA-S-70-1624-X



NASA-S-70-1632-X

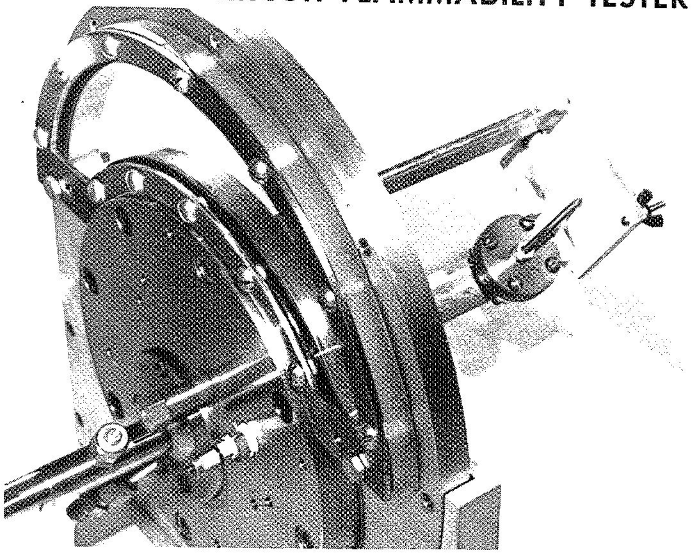


NASA-S-70-1629-X



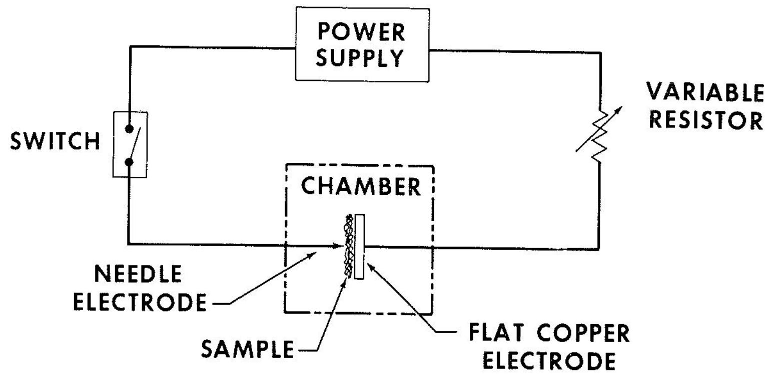
NASA-S-70-1619-X

SHORT CIRCUIT FLAMMABILITY TESTER



NASA-S-70-1625-X

ELECTRICAL SCHEMATIC SHORT CIRCUIT FLAMMABILITY TESTER



NASA-S-70-1627-X

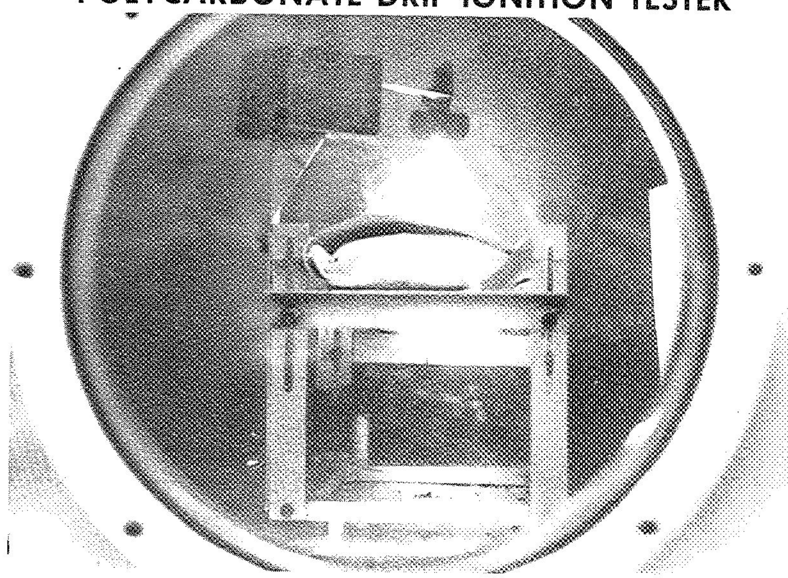
SHORT-CIRCUIT-CURRENT FLAMMABILITY TEST

95 PERCENT O_2, 28V DC OPEN CIRCUIT

MATERIAL	CHAMBER PRESSURE, PSIA	RESISTANCE, OHMS	MINIMUM CURRENT, AMPS
UNWASHED COTTON KNIT (GREEN)	19 6	21.5 15.5	1.3 1.8
CLEAN COTTON KNIT (GREEN)	19 6	25.5 10.8	1.1 2.6
UNWASHED COTTON KNIT (WHITE)	19 --	21.5 --	1.3 --
HUMAN HAIR	19 6	10 7.8	2.8 3.6
BIOINSTRUMEN-TATION INSULATION	19 6	8.25 4.3	3.4 6.5

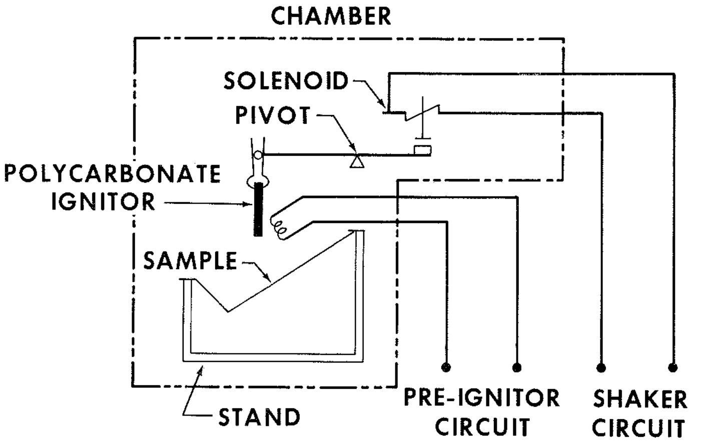
NASA-S-70-1615-X

POLYCARBONATE DRIP IGNITION TESTER



NASA-S-70-1630-X

POLYCARBONATE DRIP IGNITION TESTER



SPECIALIZED TESTING AND EVALUATION

OF SPACE-SUIT MATERIALS

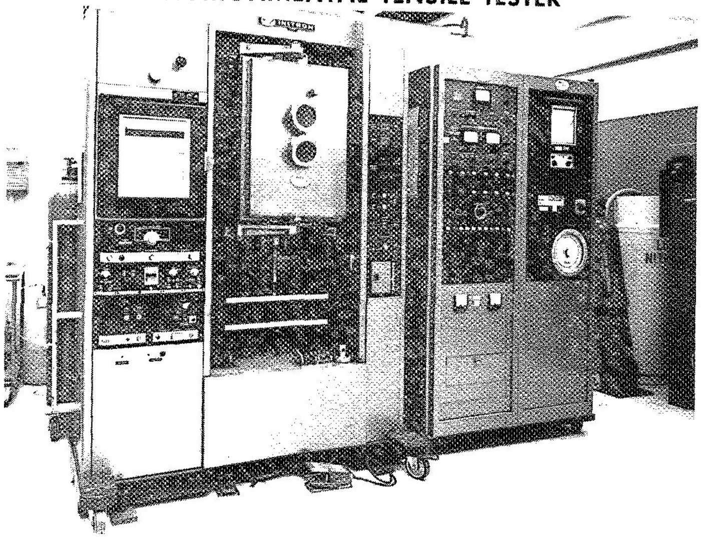
By Thomas J. Ballentine
NASA Manned Spacecraft Center

ABSTRACT

This paper describes the test program to assure that space-suit materials will perform adequately under space and lunar-environment conditions. The application of specialized test apparatus, along with standard test equipment, was necessary. Included in this paper are discussions of the methods used in determining material tensile properties, abrasion and wear resistance, and flexibility characteristics of the Apollo space suit. Test equipment — such as the helmet impact tester, the finger-flexing tester, the elbow/wrist-flexing tester, and the boot/ankle-flexing tester — used for the evaluation of space-suit components are discussed. Finally, the combined environment simulator that is designed to simulate the combined environmental characteristics of space and the lunar surface is described. Materials tested in this simulator are enumerated.

NASA-S-70-1720-X

ENVIRONMENTAL TENSILE TESTER



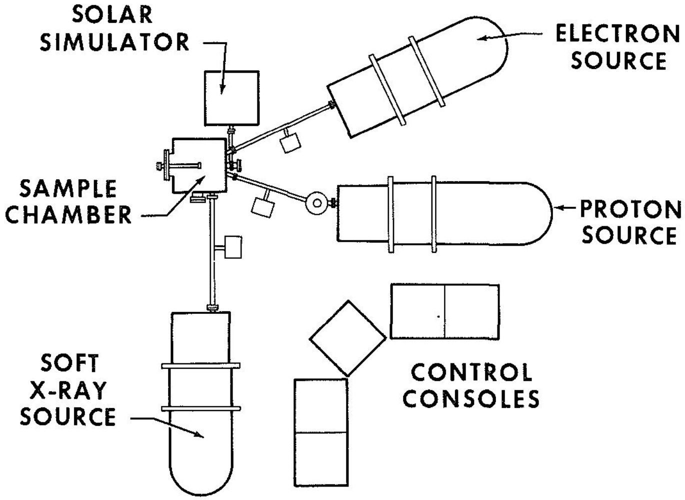
NASA-S-70-2097-X

SPECIAL TESTING APPARATUS

- ELBOW FLEXING TESTER
- BOOT/ANKLE FLEXING TESTER
- FINGER FLEXING TESTER
- FOLDING ENDURANCE TESTER
- ABRASION AND WEAR TESTER
- HELMET IMPACT TESTER

NASA-S-70-2190-X

COMBINED ENVIRONMENT SIMULATOR



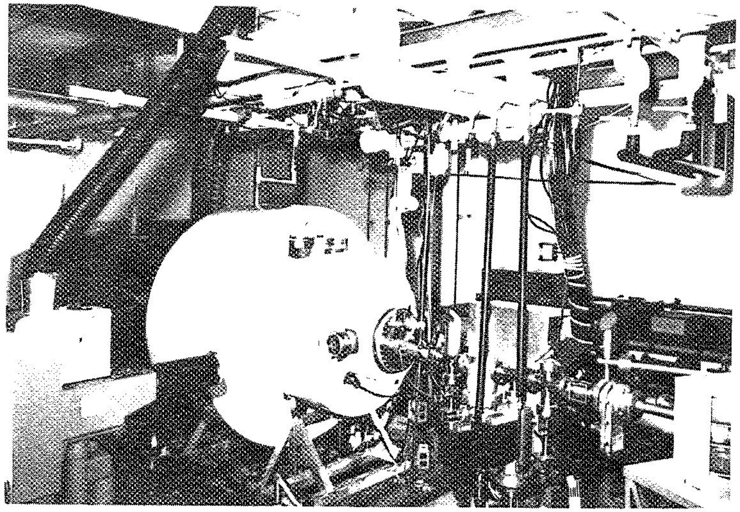
NASA-S-70-2096-X

FEATURES OF COMBINED ENVIRONMENT SIMULATOR

- VACUUM
  - 10^{-12} mm Hg
- TEMPERATURE
  - ±250° F
- ELECTROMAGNETIC RADIATION
  - INFRARED, VISIBLE, ULTRAVIOLET AND SOFT X-RAYS
- PARTICULATE FLUX
  - ELECTRONS AND PROTONS

NASA-S-70-1721-X

COMBINED ENVIRONMENT SIMULATOR



DEVELOPMENT OF AN OXYGEN IMPACT TESTING METHOD

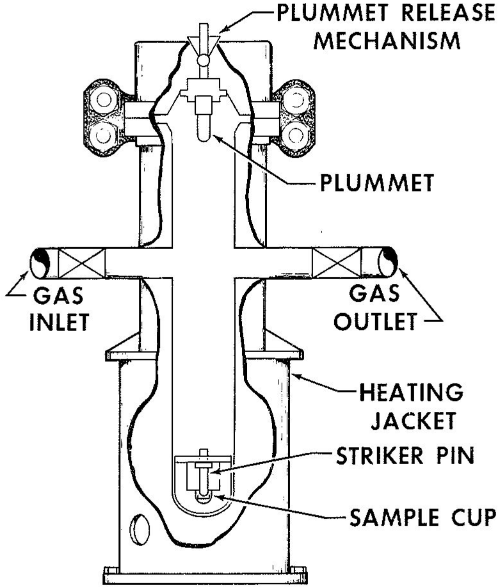
By Herschel H. Jamison
NASA Manned Spacecraft Center

ABSTRACT

It is well established that many materials which are satisfactory for use in air will ignite and burn in pure oxygen when subjected to mechanical impact. Because of this fact, various testing and screening methods have been proposed to evaluate the stability of materials to be used in oxygen systems. The most common method used is the Army Ballistics Missile Agency liquid-oxygen impact test, in which samples are immersed in liquid oxygen and then impacted by a falling plummet. This system has its limitations, however, for testing materials to be used in pressurized gas (as opposed to liquid oxygen). Because of these limitations, the need existed for an impact test method based on the testing of materials in gaseous oxygen. Since no satisfactory method was available, a program was initiated to develop a suitable test method. A system was conceived, equipment was designed and built, and procedures were developed for testing materials at temperatures up to 450° F and pressures up to 7500 psi in oxygen. Although the method is still in the evaluation and development stage, sufficient data have been gathered from the testing of Apollo spacecraft materials to conclude that the method will fill an important need.

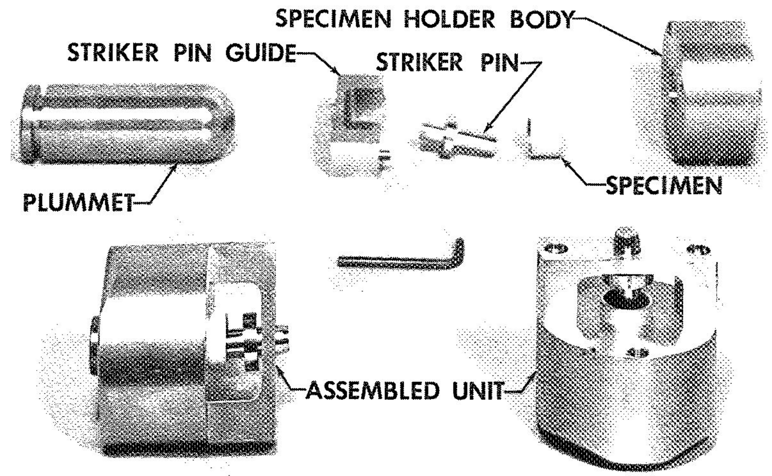
NASA-S-70-2154-X

SCHEMATIC OF TEST CHAMBER



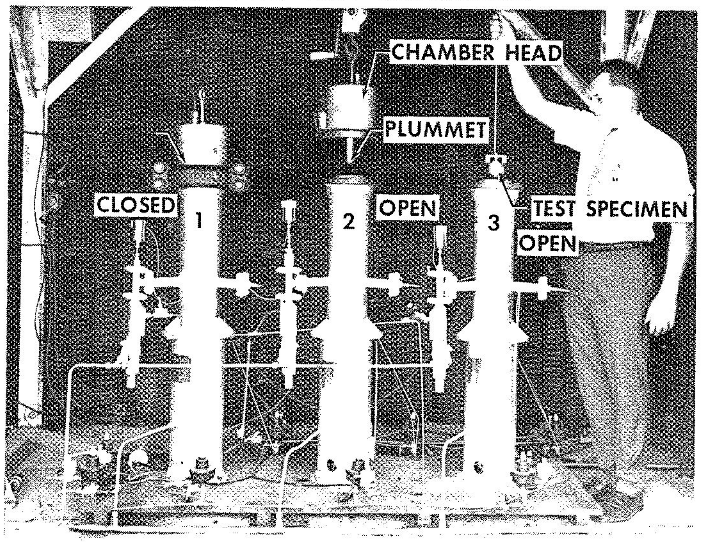
NASA-S-70-1491-X

SPECIMEN HOLDER ASSEMBLY AND PLUMMET



NASA-S-70-1492-X

IMPACT TEST CHAMBERS



NASA-S-70-1496-X

SUMMARY RESULTS OF IMPACT TESTS BY MATERIAL CLASS

MATERIAL CLASS	TYPES TESTED	TOTAL TESTS	PERCENT TESTS SHOWING NO COMBUSTION
FLUOROCARBON	9	181	100
SILICONE HYDROCARBONS	5	76	78
COMMON HYDROCARBONS	7	117	83
GREASES AND LUBRICANTS	6	108	91

NASA-S-70-2153-X

SUMMARY

- THIS IS A NEW TEST - NOT COMPLETELY PROVEN - TEST RESULTS TO BE CAREFULLY INTERPRETED
- TEST CONDITIONS APPROXIMATE USE CONDITIONS FOR MANY MATERIALS
- TEST SYSTEM IS HAZARDOUS
- TEST COVERS SIGNIFICANT AREA NOT PREVIOUSLY COVERED (HIGH PRESSURE GASEOUS OXYGEN)

ODOR TEST

By Leonard A. Schluter and David L. Pippen
NASA Manned Spacecraft Center

ABSTRACT

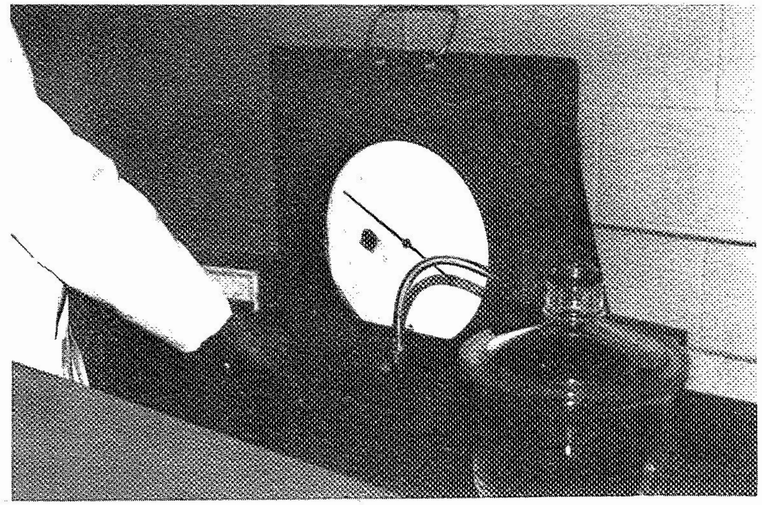
Manned space flight requires the confinement of personnel for extended periods of time with limited atmosphere purification systems available. Gaseous contaminants given off by materials such as fabrics, insulation, and adhesives can create nauseating and irritating odors. A material screening test was developed in which qualified personnel evaluate the odor characteristics of candidate spacecraft material. The odor test data provide design engineers with guidance in the selection and use of nonmetallic materials in the spacecraft. This paper presents the method employed at NASA in evaluating candidate materials for odor characteristics. The selection of odor panel members and the safety aspects of odor testing are discussed. Scoring methods and results of typical tests are included.

NASA-S-70-2436-X

THERMAL BAKEOUT

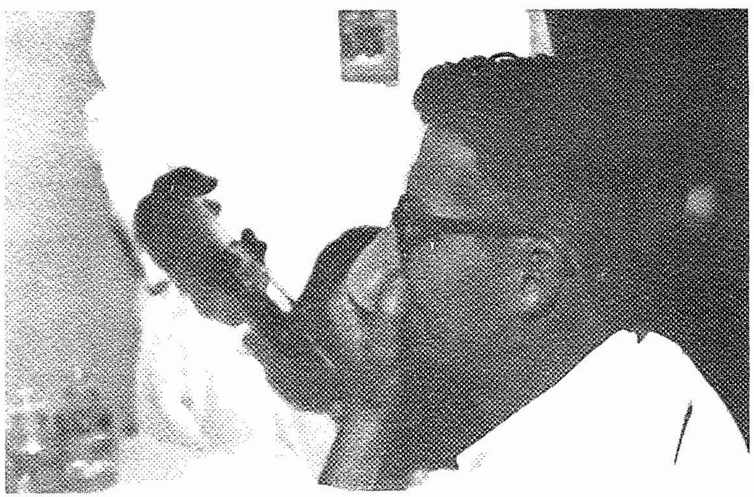
NASA-S-70-2435-X

CHARGING TO ATMOSPHERIC PRESSURE



NASA-S-70-2434-X

ADMINISTERING THE ODOR TEST



NASA-S-70-2438-X

ODOR EVALUATORS WORKSHEET

EVALUATOR	DATE	SHEET 1 OF 1
MARTENS, M.	25 MARCH 70	

SAMPLE NO.	NOT DETECTABLE (0)	BARELY DETECTABLE (1)	EASILY DETECTABLE (2)	OFFENSIVE (3)	IRRITATING (4)	TOTAL
1	X					
2		X				
3			X			

NASA-S-70-2439-X

ODOR TEST RATINGS

PANEL MEMBERS	ODOR SAMPLE CONCENTRATION		
	1 to 29 PARTS	1 to 9 PARTS	NO DILUTION
(1) PARKER, JOE	0	0	1
(2) TAYLOR, RONALD J	0	1	1
(3) HENDERSON, PARKER	0	0	1
(4) NEUMER, OSCAR	0	1	2
(5) SARABIA, DONALD	0	1	1
(6) SWITZER, GEORGE	0	1	1
(7) SHOCKLEY, KEN	0	0	0
(8) MARTENS, MARVIN	0	1	2
(9) FINNIE, M.W.	0	1	1
(10) GOGGIN, DONALD	1	1	2
TOTAL	1.0	7.0	12.0
AVG. RATINGS	0.1	0.7	1.2

DATE	TECH-TECH	CHECKED BY	STC ENG'RNG	Q. A.	OTHER

NASA-S-70-2437-X

TYPICAL ODOR TEST RESULTS

DILUTION	NONE	1:9	1:29
ALUMINA CEMENT	1.4	0.4	0.4
POTTING RESIN	2.0	1.2	0.6
KAPTON FILM	0.7	0.0	0.0
ION EXCHANGE RESIN	3.5	2.1	2.0

NOTE: THE ABOVE FIGURES ARE AVERAGE SCORES FOR THE DILUTIONS SHOWN.

NASA-S-70-2440-X

ODOR SCORE DISTRIBUTION FOR 1000 CANDIDATE MATERIALS

SCORE RANGE	% IN SCORE RANGE
0 – 0.4	6.3
0.5 – 0.9	13.6
1.0 – 1.4	26.5
1.5 – 1.9	29.9
2.0 – 2.4	15.7
2.5 – 2.9	6.7
3.0 – 3.4	.7
3.5 – 4.0	.6

TOXICOLOGY OF SPACECRAFT MATERIALS

By Elliot S. Harris
NASA Manned Spacecraft Center

ABSTRACT

It is essential that materials selected for use in spacecraft do not contribute noxious components to the atmosphere, which would endanger the performance or lives of the crew. It is equally important that in the event of accidental overheating or ignition, the materials selected have the lowest potential toxicity of thermal degradation products. To ensure that the materials were not toxic, those selected for use in the spacecraft were offgassed at 150° ± 5° F, and the effluvium was passed over growing rats and mice in a closed system for 7 days. Growth changes and histological evaluation were used as criteria for toxicity. Over 300 materials were evaluated in groups of 10 or more, and all were found to be acceptable. Special studies were performed on Scheufelen nonflammable paper and on a coated Beta-cloth jacket to evaluate potential skin and mucosal irritation. The nonflammable paper, although a potential mucosal irritant, tested satisfactorily; the coated jacket was irritating and, therefore, was not used.

NASA-S-70-2177-X

APPROACHES TO TOXICOLOGICAL EVALUATION

- MATERIALS OFFGASSING CHARACTERISTICS
- TEST VEHICLE ATMOSPHERIC ANALYSIS
- FLIGHT VEHICLE ATMOSPHERIC ANALYSIS
- ANIMAL TOXICITY OF MATERIALS EFFLUVIUM

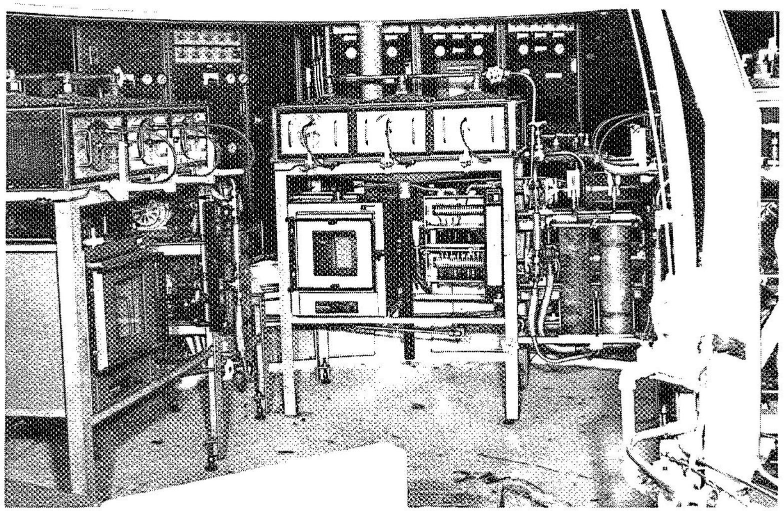
NASA-S-70-2176-X

ASSUMPTIONS FOR OFFGAS TEST

- MATERIALS OFFGAS SEVERAL COMPONENTS
- NO SINGLE COMPONENT WILL BE HIGHLY TOXIC
- NO ONE MATERIAL WILL BE EXCESSIVE

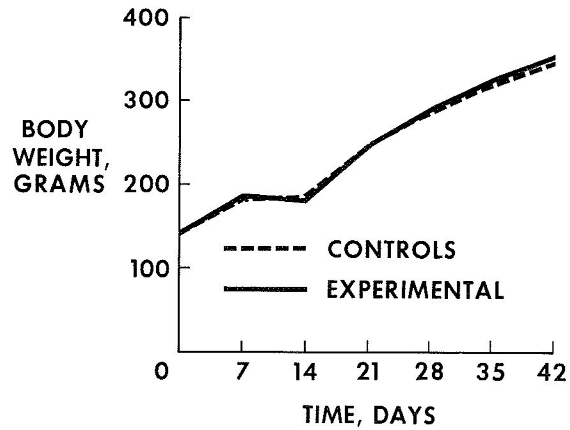
NASA-S-70-1774-X

OFFGASSING EXPOSURE SYSTEM



NASA-S-70-1659-X

MEAN GROWTH RATE OF MALE RATS



NASA-S-70-1661-X

MEAN RAT ORGAN WEIGHTS, GRAMS

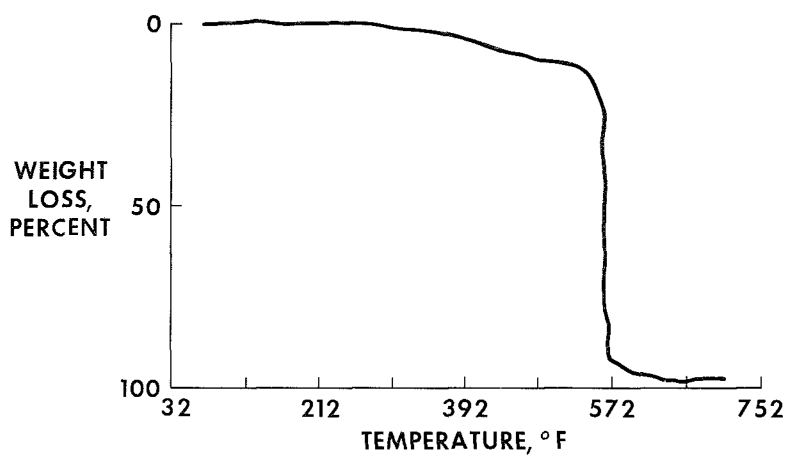
TEN RATS PER GROUP

	HEART	LUNG	LIVER	SPLEEN	KIDNEY
(2 WEEKS POSTEXPOSURE)					
CONTROLS	1.0	1.2	9.1	.7	1.8
EXPOSED	.9	1.3	9.0	.7	1.9
(4 WEEKS POSTEXPOSURE)					
CONTROLS	1.0	1.4	9.9	.8	2.1
EXPOSED	1.1	1.3	10.2	.8	2.2

NASA-S-70-1657-X

CARBOXYNITROSO RUBBER

THERMOGRAM



NASA-S-70-2175-X

NONFLAMMABLE PAPER

- SENSITIZATION
- IRRITATION
- TOXICITY

NASA — MSC
MSC 5858 .70