NASA WIRING FOR SPACE APPLICATIONS PROGRAM TEST RESULTS

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NASA Wiring for Space Applications Program

FY '94 - '95 Testing Activities
NASA JSC/WSTF

- ***Objective:*** Perform NASA specified testing for compatibility with enclosed spacecraft environments.

- ***Tests:*** Flammability: 30% O_2, 200°C
  Odor: 25.9% O_2, 50°C
  Aerospace Fluids Compatibility: N_2O_4, N_2H_4, $N_2H_3CH_3$
  Offgassing: 25.9% O_2, 50°C
  Thermal Vacuum Stability: 5 x 10^{-5} torr, 125°C, 24 hrs.

- ***Principal Investigators:*** Dr. Harry T. Johnson - NASA Laboratories Office
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Background

NASA Lewis Research Center Requested NASA Johnson Space Center White Sands Test Facility to Conduct Flammability, Odor, Offgassing, Thermal Vacuum Stability, and Compatibility Tests with Aerospace Fluids of Several Wire Insulations

Wire Insulations Evaluated:

- Partially Fluorinated Polyimide
- Extruded ETFE
- Extruded PTFE
- PTFE Tape
- PTFE/Kapton

Tests Performed:

- Per NHB 8060.1C
  - Flammability (Tests 1 and 4)
  - Odor (Test 6)
  - Compatibility with Aerospace Fluids (Test 15)
- Per NHB 8060.1B
  Offgassing (Test 7)
- Per SP-R-0022A (ASTM E 595)
  Thermal Vacuum Stability

Test 1 (Upward Flame Propagation)

Test Approach:

- Exposed Vertical Sample to Ignition Source That Provided 750 Calories for Approximately 25 s
- Three Samples Tested for Each Test Condition

Observations Made:

- Ignitability
- Burn Length
- Ignition of Wiring Insulation Material by Transfer of Burning Debris

Test Conditions:

30% Oxygen in Nitrogen at 10.2 psia

Results:

Materials	Sample Burn Length (cm)		
	1	2	3
Partially Fluorinated Polyimide	5.3	8.6	4.3
Extruded ETFE	18.3	5.8	8.9
Extruded PTFE	5.6	6.1	5.3
PTFE Tape	3.6	5.6	2.5
PTFE/Kapton	4.6	4.8	4.6

Note: Only the extruded ETFE insulated wire failed the test

Test 4 (Wire Insulation Flammability)

Test Approach:

- Oriented Wire Sample 15 Degrees to Vertical, Internally Heated Sample, and Exposed Sample to Ignition Source Providing 750 Calories for Approximately 25 s
- Tested Three Samples for Each Test Condition

Observations Made:

- Ignitability
- Burn Length
- Ignition of a Witness Material by Transfer of Burning Debris

Test Conditions:

- 30% Oxygen in Nitrogen at 10.2 psia
- Internal Wire Temperature 200 °C

Results:

Materials	Single Wire Burn Length (cm) for Samples Tested at 200 °C		
Partially Fluorinated Polyimide	2.5	3.3	4.1
Extruded ETFE	30.5	30.5	30.5
Extruded PTFE	3.0	3.3	3.6
PTFE Tape	3.3	3.6	3.3
PTFE/Kapton	1.5	2.5	2.0

Note: Only the extruded ETFE insulated wire failed the test.

Test 6 (Odor Assessment)

Test Approach:

- Subject Sample to Thermal Exposure for 72 Hours at 120 °F, 25.9% Oxygen at 11.9 psia
- Odor Panel Members Administered with at Least 30 cc of Gas from Sample Container

Odor Scale Rating	
Undetectable	0
Barely Detectable	1
Easily Detectable	2
Objectionable	3
Revolting	4

Results:

Material	Odor Rating*
Partially Fluorinated Polyimide	0.4
Extruded ETFE	1.4
Extruded PTFE	1.3
PTFE Tape	1.0
PTFE/Kapton	0.6

*Average Result of 5 Responses

Test 7 (Determination of Offgassed Products)

Test Approach:

- Subjected Sample to Thermal Exposure for 72 Hours at 120 °F, 25.9% Oxygen at 11.9 psia
- After Each Sample Container Was Cooled, Determined Identity and Quantity of Each Analyzable Offgassed Product

Maximum Amount of Material Used in Habitable Areas of Spacecraft Must Meet Toxic Hazard Index Requirement of ≤ 0.5

Material: Partially Fluorinated Polyimide

Component	Toxic Limit (µg/g)	Quantity (µg/g)
1-Methyl-2-Pyrrolidone	0.14	0.05
2-Butoxyethanol	34.68	0.005
2-Ethylhexanol	230	0.04
Acetaldehyde	6	0.02
Acetone	1018	0.03
Acetophenone	350	0.005
Benzaldehyde	247	0.005
Butene	7.17	0.005
Butyraldehyde	168.99	0.005
C10 Unsaturated aliphatic hydrocarbon	7.17	0.005
C6 Aldehyde	3.44	0.005

Test 7
(Determination of Offgassed Products), Cont'd

Material: Partially Fluorinated Polyimide - Cont'd

Component	Toxic Limit (µg/g)	Quantity (µg/g)
C8 Aldehydes	0.14	0.007
Carbon Monoxide	14	0.05
Decamethylcyclopentasiloxane	271.6	0.009
Dichloromethane	72	0.005
Ethyl alcohol	134	0.01
Hexamethylcyclotrisilozane	324	0.08
Isopropyl alcohol	215	0.02
Methyl alcohol	13	0.01
Methyl ethyl ketone	43	0.005
n-Butyl alcohol	173	0.005
n-Propyl alcohol	140	0.01

Material: Partially Fluorinated Polyimide - Cont'd

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Nonanal	42	0.007
Octamethylcyclotetrasiloxane	217.39	0.03
Styrene	60.9	0.005
t-Butyl alcohol	173	0.006
Toluene	86	0.01
Trimethyl silanol	57	0.005
Xylenes	315	0.005

Material: Extruded ETFE

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Acetaldehyde	6	0.02
Acetone	1018	0.02
Acrolein	0.04	0.03
Butene	7.17	0.40
C7 Ketone	33.68	0.006
Carbon monoxide	14	0.33
Cyclohexanone	86	0.01
Difluorodimethyl silane	0.14	0.06
Ethyl alcohol	134	0.005
Fluoroaliphatic hydrocarbons	0.14	0.06
Hexamethylcyclotrisiloxane	324	0.01

Test 7
(Determination of Offgassed Products), Cont'd

Material: Extruded ETFE - Cont'd

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Isobutane	339	0.009
Isobutyraldehyde	63.05	0.03
Isopropyl alcohol	215	0.005
Methyl alcohol	13	0.005
Methyl ethyl ketone	43	0.10
n-Butyl alcohol	173	0.005
n-Propyl alcohol	140	0.005
Octamethylcyclotetrasiloxane	217.39	0.02
Propionaldehyde	136	0.005
t-Butyl alcohol	173	0.06
Toluene	86	0.02
Trimethyl silanol	57	0.005

Material: Extruded PTFE

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Acetaldehyde	6	0.008
Acetone	1018	0.005
C10 Saturated and unsaturated aliphatic hydrocarbons	166.23	0.03
C5 Saturated aliphatic hydrocarbon	7.17	0.005
Carbon monoxide	14	0.05
Hexamethylcyclotrisiloxane	324	0.01
n-Butyl alcohol	173	0 005
n-Propyl alcohol	140	0.005
Octamethylcyclotetrasiloxane	217.39	0.01
Toluene	86	0.009
Trimethyl silanol	57	0.005

Test 7
(Determination of Offgassed Products), Cont'd

Material: Extruded ETFE

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Acetaldehyde	6	0.02
Acetone	1018	0.02
Acrolein	0.04	0.03
Butene	7.17	0.40
C7 Ketone	33.68	0.006
Carbon monoxide	14	0.33
Cyclohexanone	86	0.01
Difluorodimethyl silane	0.14	0.06
Ethyl alcohol	134	0.005
Fluoroaliphatic hydrocarbons	0.14	0.06
Hexamethylcyclotrisiloxane	324	0.01

Material: PTFE Tape

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Acetaldehyde	6	0.005
Acetone	1018	0.005
Allyl alcohol	1.43	0.009
alpha-Methylstyrene	17	0.006
Butene	7.17	0.005
C10 Saturated aliphatic hydrocarbons	7.17	0.02
C11-C13 Saturated and unsaturated aliphatic hydrocarbons	7.17	1.1
Carbon monoxide	14	0.05
Decamethylcyclopentasiloxane	271.6	0.008
Decane	333	0.04

Material: PTFE Tape - Cont'd

Component	Toxic Limit (µg/g)	Quantity (µg/g)
Dodecane	398.74	0.26
Ethyl alcohol	134	0.005
Hexamethylcyclotrisiloxane	324	0.06
Hexamethyldisiloxane	138.43	0.02
Methyl alcohol	13	0.005
n-Propyl alcohol	140	0.005
Octamethylcyclotetrasiloxane	217.39	0.03
Toluene	86	0.005
Trimethyl silanol	57	0.02
Undecane	436	0.26

Material: PTFE/Kapton

Component	Toxic Limit (µg/g)	Quantity (µg/g)
2-Phenyl-2-propanol	47	0.005
Acetaldehyde	6	0.005
Acetone	1018	0.005
Acetophenone	350	0.005
Allyl alcohol	1.43	0.005
alpha-Methylstyrene	17	0.005
C10 Saturated aliphatic hydrocarbon	7.17	0.005
C11-C12 Saturated and unsaturated aliphatic hydrocarbons	67	0.02
C8 Alcohol	0.14	0.005
Carbon monoxide	14	0.05

Test 7
(Determination of Offgassed Products), Cont'd

Material: PTFE/Kapton - Cont'd

Component	Toxic Limit (μg/g)	Quantity (μg/g)
Decamethylcyclopentasiloxane	271.6	0.01
Ethyl alcohol	134	0.005
Hexamethylcyclotrisiloxane	324	0.07
Isopropyl alcohol	215	0.005
Methyl alcohol	13	0.005
n-Propyl alcohol	140	0.005
Octamethylcyclotetrasiloxane	217.39	0.03
Trimethyl silanol	57	0.01

Test 15
(Reactivity of Materials in Aerospace Fluids)

Test Approach:

- During Phase I, Evaluated Gross Compatibility by Exposing Material to Fluid at Ambient Temperature for 2 Hours
- During Phase II, Exposed Material to Fluid for 48 Hours at Maximum System Temperature c. 160 °F (Whichever Was Higher)
- Observed Pressure Rise, Fluid Composition, and Material Changes When Compared with Reference Material Exposed to Same Fluid

Test 15
(Reactivity of Materials in Aerospace Fluids), Cont'd

Immersion Data in Liquid Phase of Dinitrogen Tetroxide

Material	Gas Pressure (psia)		Material Changes	Fluid Visual Changes
	Sample	Reference		
Partially Fluorinated Polyimide	ND	ND	Partial Dissolution	None
Extruded ETFE	128	128	White to Yellow	None
Extruded PTFE	125	126	Lettering Disappeared	None
PTFE Tape	126	128	White to Slight Orange	None
PTFE/Kapton	125	127	Brown to Orange	None

Immersion Data in Liquid Phase of Dinitrogen Tetroxide

Material	Posttest Fluid Analysis (Non-volatile Residue), mg	
	Sample	Reference
Partially Fluorinated Polyimide	ND	ND
Extruded ETFE	6.5	2.7
Extruded PTFE	16.7	9.1
PTFE Tape	1.3	1
PTFE/Kapton	ND	0.7

Test 15
(Reactivity of Materials in Aerospace Fluids), Cont'd

Immersion Data in Liquid Phase of Hydrazine

Material	Gas Evolut. Rate (sccm/hr/cm² x 10E4) Sample	Reference	Material Changes	Fluid Visual Changes
Partially Fluorinated Polyimide	ND	ND	Complete Degradation	Brown, Particulate
Extruded ETFE	15	8	White to Grey	None
Extruded PTFE	16	9	None	None
PTFE Tape	29	8	White to Slight Yellow	Yellow
PTFE/Kapton	32	6	Brown to Yellow	Yellow

Immersion Data in Liquid Phase of Hydrazine - Posttest Fluid Analysis

Material	Purity (%)	CO_2 (ppm)	Non-Volatile Residue (mg)	Chloride (µg)	Fluoride (µg)
Partially Fluorinated Polyimide	ND	ND	ND	ND	ND
Reference	ND	ND	ND	ND	ND
Extruded ETPE	99.7	10	0.6	12	48
Reference	99.7	10	0.8	37	ND
Extruded PTFE	99.7	10	0.7	35	4.6
Reference	99.7	10	0.9	35	2.3
PTFE Tape	99.7	10	35.1	44	ND
Reference	99.8	9	1	44	ND
PTFE/Kapton	99.7	9	1.2	41	ND
Reference	99.7	9	0.5	41	ND

Test 15
(Reactivity of Materials in Aerospace Fluids), Cont'd

Immersion Data in Liquid Phase of Monomethylhydrazine

Material	Gas Evolut. Rate (sccm/hr/cm² x 10E4) Sample	Reference	Material Changes	Fluid Visual Changes
Partially Fluorinated Polyimide	ND	ND	Complete Degradation	Brown
Extruded ETFE	2	1	White to Light Yellow	Light Yellow
Extruded PTFE	1	1	None	None
PTFE Tape	2	1	White to Yellow	Yellow
PTFE/Kapton	1	2	Brown to Brown/Yellow	Yellow

Immersion Data in Liquid Phase of Monomethylhydrazine - Posttest Fluid Analysis

Material	Purity (%)	CO_2 (ppm)	Non-Volatile Residue (mg)	Chloride (µg)	Fluoride (µg)
Partially Fluorinated Polimide	ND	ND	ND	ND	ND
Reference	ND	ND	ND	ND	ND
Extruded ETFE	99.7	5	0.7	6.9	160
Reference	99.7	2	0.3	4.6	ND
Extruded PTFE	99.8	4	0.1	2.3	ND
Reference	99.8	3	0.3	4.6	ND
PTFE Tape	99.7	2	49.1	6.9	ND
Reference	99.7	2	0.3	6.9	ND
PTFE/Kapton	99.7	2	27.8	6.9	2.3
Reference	99.7	2	0.3	2.3	ND

- PFPI was very reactive to Hydrazine and MMH, others slightly reactive

- Pictures of pre- and post-test samples will be printed in the final test report

VCM Test

Total Mass Loss and Collected Condensable Materials from Outgassing in a Vacuum Environment

Test Approach:

- Conditioned Sample for 24 Hours at 23 °C and 50% RH
- Weighed Conditioned Sample and Exposed Sample to Vacuum for 24 Hours (At Least 5 x 10E-5 Torr) and 125 °C
- Condensed Portion of Vapors on Preweighed Collector Maintained at 25 °C
- Posttest Collector and Sample Weight Measurements Yielded Weight Loss and Collected Volatile Condensable Material
- Further Conditioning of Sample for 24 Hours at 23 °C and 50% RH and Weighing Yielded Water Vapor Recovery Values

VCM Test, Cont'd

Results:

Material	Weight Loss (%)	VCM (%)	WVR (%)
Partially Fluorinated Polyimide	3.44	0.00	0.40
Extruded ETFE	0.31	0.01	0.04
Extruded PTFE	0.01	0.00	0.01
PTFE Tape	0.29	0.00	0.18
PTFE/Kapton	0.35	0.00	0.26

Note: All materials passed the VCM requirement. Only the partially fluorinated polyimide failed the weight loss requirement.