

FLAMMABILITY, ODOR, OFFGASSING, THERMAL VACUUM STABILITY, AND
COMPATIBILITY WITH AEROSPACE FLUIDS OF WIRE INSULATIONS

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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:

- PTFE Teflon, 12 AWG
- PTFE Teflon, 20 AWG
- Kapton, 12 AWG
- Kapton, 20 AWG
- Teflon/Kapton Hybrid, 12 AWG
- Teflon/Kapton Hybrid, 20 AWG

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 a Witness Material by Transfer of Burning Debris

Test Conditions:

30% Oxygen in Nitrogen at 10.2 psia

Results:

Materials	Burn Length (cm)		
	Sample 1	Sample 2	Sample 3
PTFE Teflon, 12 AWG	0	0	0
PTFE Teflon, 20 AWG	8.1	7.6	6.4
Kapton, 12 AWG	0	0	1.0
Kapton, 20 AWG	0.3	5.8	0
Teflon/Kapton Hybrid, 12 AWG	0.3	1.0	1.0
Teflon/Kapton Hybrid, 20 AWG	1.0	3.8	3.8

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 Temperatures at 125 and 200 °C

Results:

Materials	Single Wire Burn Length (cm)					
	Samples Tested at 125 °C			Samples Tested at 200 °C		
PTFE Teflon, 12 AWG	2.5	2.5	3.0	3.6	3.3	2.3
PTFE Teflon, 20 AWG	2.0	3.8	4.1	4.8	4.1	4.3
Kapton, 12 AWG	0	0	0	1.0	0.8	0.8
Kapton, 20 AWG	4.1	3.8	4.3	4.1	4.6	4.1
Teflon/Kapton Hybrid, 12 AWG	1.3	0	0	0	0	0
Teflon/Kapton Hybrid, 20 AWG	3.0	2.8	2.5	2.5	4.1	2.5

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*
PTFE Teflon, 12 AWG	0.8
PTFE Teflon, 20 AWG	1.0
Kapton, 12 AWG	0.8
Kapton, 20 AWG	0.4
Teflon/Kapton Hybrid, 12 AWG	0.4
Teflon/Kapton Hybrid, 20 AWG	0.2

*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

Material: Teflon, 12 AWG

Component	Toxic Limit ($\mu\text{g/g}$)	Quantity ($\mu\text{g/g}$)
C10-C11 Saturated and Unsaturated Aliphatic Hydrocarbons	186.29	0.05
Carbon Monoxide	40.9	0.32
Fluoroaliphatic Hydrocarbons	0.14	0.007
Octamethylcyclotetrasiloxane	217.39	0.005

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

Material: Teflon, 20 AWG

Component	Toxic Limit ($\mu\text{g/g}$)	Quantity ($\mu\text{g/g}$)
C10-C11 Saturated and Unsaturated Aliphatic Hydrocarbons	186.29	0.07
C12 Saturated Aliphatic Hydrocarbon	7.17	0.005
Carbon Monoxide	40.9	0.23
Decamethylcyclopentasiloxane	248	0.005
Fluoroaliphatic Hydrocarbons	0.14	0.006
Hexamethylcyclotrisiloxane	324	0.005
Octamethylcyclotetrasiloxane	217.39	0.006
Xylenes	124	0.02

Material: Kapton, 12 AWG

Component	Toxic Limit ($\mu\text{g/g}$)	Quantity ($\mu\text{g/g}$)
Acetaldehyde	77.1	0.005
Carbon Monoxide	40.9	0.17
Hexamethylcyclotrisiloxane	324	0.009
Naphthalene	15.05	0.005
Octamethylcyclotetrasiloxane	217.39	0.005
Toluene	108	0.005
Trimethyl silanol	2.58	0.005

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

Material: Kapton, 20 AWG

Component	Toxic Limit ($\mu\text{g/g}$)	Quantity ($\mu\text{g/g}$)
Acetaldehyde	77.1	0.01
Acetone	1018	0.02
C10 Aromatic Hydrocarbon	0.14	0.008
C8 Ether	167.03	0.005
C9 Saturated Aliphatic Hydrocarbon	7.17	0.005
Carbon Monoxide	40.9	0.17
Hexamethylcyclotrisiloxane	324	0.009
Isopropyl Alcohol	140	0.007
Methyl Alcohol	74.9	0.005
Octamethylcyclotetrasiloxane	217.39	0.006
Trimethyl silanol	2.58	0.01

Material: Teflon/Kapton, 12 AWG

Component	Toxic Limit ($\mu\text{g/g}$)	Quantity ($\mu\text{g/g}$)
Acetaldehyde	77.1	0.007
C11 Saturated and Unsaturated Aliphatic Hydrocarbons	17.2	0.01
C9 Aromatic Hydrocarbon	21.5	0.005
Carbon Monoxide	40.9	0.05
Chlorobenzene	65.7	0.005
Hexamethylcyclotrisiloxane	324	0.005
Octamethylcyclotetrasiloxane	217.39	0.005
Toluene	108	0.007

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

Material: Teflon/Kapton, 20 AWG

Component	Toxic Limit ($\mu\text{g/g}$)	Quantity ($\mu\text{g/g}$)
Acetaldehyde	77.1	0.04
Acetone	1018	0.04
Acrolein	0.16	0.005
C10 Saturated Aliphatic Hydrocarbons	7.17	0.02
C11-C12 Saturated and Unsaturated Aliphatic Hydrocarbons	7.17	0.15
C6 Aldehyde	3.44	0.01
C7 Aldehyde	0.14	0.007
C9 Aldehyde	0.14	0.009
Carbon Monoxide	40.9	0.05
Chlorobenzene	65.7	0.005
Decamethylcyclopentasiloxane	248	0.005
Ethyl Alcohol	134	0.005
Hexamethylcyclotrisiloxane	324	0.005
Methyl Alcohol	74.9	0.02
Methyl Ethyl Ketone	84.3	0.02
Nitromethane	71.5	0.02
Octamethylcyclotetrasiloxane	217.39	0.005
Tetrachloroethylene	48.6	0.005
Toluene	108	0.01
Trimethyl silanol	2.58	0.01
Unidentified Component	0.14	0.009

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 or 160 °F (Whichever Was Higher)
- Observed Pressure Rise, Fluid Composition, and Material Changes When Compared with Reference Material Exposed to Same Fluid

Immersion Data in Liquid Phase of Dinitrogen Tetroxide

Material	Gas Pressure (psia)		Material Changes	Fluid Visual Changes
	Sample	Reference		
PTFE Teflon, 12 AWG	133	132	None	None
PTFE Teflon, 20 AWG	135	133	None	None
Kapton, 12 AWG	141	131	Yellow to Brown	None
Kapton, 20 AWG	157	132	Rough, Friable	Particulate
Teflon/Kapton Hybrid, 12 AWG	132	131	White to Light Pink	None
Teflon/Kapton Hybrid, 20 AWG	132	130	White to Light Pink	None

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

Immersion Data in Liquid Phase of Dinitrogen Tetroxide

Material	Posttest Fluid Analysis (Non-volatile Residue), mg	
	Sample	Reference
PTFE Teflon, 12 AWG	2.1	1.0
PTFE Teflon, 20 AWG	2.0	1.2
Kapton, 12 AWG	1.4	1.7
Kapton, 20 AWG	21	1.5
Teflon/Kapton Hybrid, 12 AWG	1.5	1.5
Teflon/Kapton Hybrid, 20 AWG	0.6	0.5

Immersion Data in Liquid Phase of Hydrazine

Material	Gas Evolut. Rate (sccm/hr/cm ² x 10E4)		Material Changes	Fluid Visual Changes
	Sample	Reference		
PTFE Teflon, 12 AWG	EQ	EQ	None	None
PTFE Teflon, 20 AWG	EQ	EQ	None	None
Kapton, 12 AWG	7.1	3.7	Yellow to Brown Rough, Tacky	Brown and Opaque, Particulate
Kapton, 20 AWG	--	--	Gray to Yellow Rough, Tacky, Friable	Brown and Opaque, Particulate
Teflon/Kapton Hybrid, 12 AWG	EQ	EQ	White to Yellow	Yellow
Teflon/Kapton Hybrid, 20 AWG	EQ	EQ	White to Yellow	Yellow

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

Immersion Data in Liquid Phase of Hydrazine - Posttest Fluid Analysis

Material	Purity (%)	CO ² (ppm)	Non-Volatile Residue (mg)	Chloride (μ g)	Fluoride
PTFE Teflon, 12 AWG	99.7	6	0.1	18.4	2.3
Reference	99.7	6	ND	13.8	ND
PTFE Teflon, 20 AWG	99.6	3	0.6	9.2	ND
Reference	99.6	2	1.0	4.6	ND
Kapton, 12 AWG	99.8	1	110	18.4	6.9
Reference	99.8	6	0.5	9.2	ND
Kapton, 20 AWG	99.6	2	91	69	2.3
Reference	99.6	2	0.3	11.5	2.3
Teflon/Kapton Hybrid, 12 AWG	99.6	4	34	9.2	2.3
Reference	99.6	1	0.1	6.9	ND
Teflon/Kapton Hybrid, 20 AWG	99.6	3	37	9.2	2.3
Reference	99.6	1	0.1	9.2	ND

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 $5 \times 10E-5$ 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

Results:

Material	Weight Loss (%)	VCM (%)	WVR (%)
PTFE Teflon, 12 AWG	0.06	0.03	0.05
PTFE Teflon, 20 AWG	0.04	0.02	0.02
Kapton, 12 AWG	0.80	0.01	0.60
Kapton, 20 AWG	1.02	0.07;0	0.71
Teflon/Kapton Hybrid, 12 AWG	0.26	0	0.20
Teflon/Kapton Hybrid, 20 AWG	0.30	0.01	0.23