N95- 16056

30140
p. 20

109641

NEW INSULATION CONSTRUCTIONS FOR AEROSPACE WIRING APPLICATIONS

PROGRAM MANAGER: GEORGE SLENSKI
WL/MLSA
WPAFB OH 45433-6533

BACKGROUND:

- WIRING HAS BECOME AN IMPORTANT AIRCRAFT SYSTEM
  - HIGH COST DRIVER FOR ACQUISITION AND LOGISTICS
  - INCREASED RELIANCE ON AVIONICS
  - FLY-BY-WIRE SYSTEMS
- ISSUES RAISED CONCERNING THE PRIMARY INSULATION IN USE (KAPTON)
  - HANDLING CHARACTERISTICS
  - ENVIRONMENTAL AND FLUID COMPATIBILITY
  - SUSCEPTIBLE TO FLASHOVER
- ISSUES RAISED CONCERNING ALTERNATIVE INSULATIONS (X-LINKED TEFZEL)
  - SUSCEPTIBLE TO CHAFING
  - THERMAL STABILITY
  - SMOKE GENERATION
  - CONDUCTOR CORROSION

AIR FORCE WIRING POLICY

- 81381 WILL NO LONGER BE THE WIRING OF FIRST CHOICE
  - NEW SYSTEMS
  - MODIFICATIONS
  - REWIRING
- NO ALTERNATE WIRING RECOMMENDED
- SELECT WIRING BASED ON SYSTEM REQUIREMENTS
  - PERFORMANCE
  - MAINTENANCE

PROGRAM SUPPORT

- PROGRAM COORDINATED AND PERIODICALLY REVIEWED WITH GOVERNMENT AND INDUSTRY
  - AFSC, AFLC, ASD
  - NAVY-NAVAIR, NRL, NAC
  - FAA, NASA
  - SAE, NEMA
- BROAD INDUSTRY PARTICIPATION
  - FIVE AIRCRAFT COMPANIES
  - NINE WIRE MANUFACTURERS
  - THREE MATERIALS SUPPLIERS

New Insulation Constructions
Purpose

- Determine by Comprehensive Testing and Analysis if There Are New Insulation Constructions That Have Better Balance of Properties Than M22759/XL ETFE and M81381

- If New Insulation Constructions Are Identified That Possess Improved Balance of Properties, Identify Relative Costs, Processability Concerns, Material Availability, Multiple Sources and Environmental Impact to Manufacture

New Insulation Constructions
Program Contract Requirements

- Establish Performance Tests. Identify Weighting Factors for Each Test. Describe Minimum Performance Criteria
- Select 10 Candidate Insulations for Screening. Identify and Perform Screening Tests
- Select 4 Candidates from Screening Tests. Identify and Conduct Performance Tests
- Perform Assembly, Handling, Installation, Repair, and Chemical/ Thermal Tests on Best Candidate(s)
- Prepare and Provide Preliminary Specification(s) to Customer
- Prepare a Final Report on All Program Activities Including Recommendations to Customer for Replacement of Present Insulations
- Conduct Periodic Briefings
  - February 1989 - St. Louis
  - October 1990 - St. Louis
  - April 1991 - St. Louis

Test Plan

- Screening Tests (15)
  - 10 Candidates Plus M81381/7, /9, /11 and M22759/44, /33, /43
  - Testing by MCAIR
- Full Performance Tests (28)
  - 4 Selected Candidates Plus M81381 and M22759
  - Testing by MCAIR, DAC and DuPont
- Additional Testing
  - 270 Vdc Dry Arc Propagation Tests
  - Assembly, Handling and Repair Evaluations
  - Thermal and Chemical Stability Test by McDonnell Douglas Research Laboratory
  - Round Robin Tests

Wire and Cable Constructions Requested

Primary Wire

- 26 AWG* Thin Wall (5.8 mil)
- 22 AWG Thin Wall (5.8 mil)
- 22 AWG Thick Wall (8.6 mil)

Twisted Pair, Shielded and Jacketed

- 22 AWG Thin Wall
- 26 AWG* Thin Wall

Note: Not All Constructions Are Tested in Every Test

*26 AWG to Be CS95 Beryllium Copper Alloy

Construction Requirements

- Weight within M81381 Specs
- Diameter within M81381 Specs
- Silver Plated Conductor
- CS95 Alloy for 26 AWG Constructions
- Multiple Sources
- Production Quantity Capable

Insulation Candidates Provided for WRDC/MCAIR Test Program

	1st Layer	2nd Layer	3rd Layer/Topcoat
Barcel	2919 50% OL	Unsintered 0.002 in. PTFE Tape, Butt Wrap	
Brand Rex	XL ETFE 0.001 in. Tape, 50% OL	616 50% OL	XL ETFE 0.001 in. Tape, 50% OL
Champlain	2919 0.0035 in. Wall, 50% OL	Extr XL ETFE 0.0035 in. Wall	
DuPont	New Polyimide/ Fluoropolymer Tape, 0.0012 in. Thick, 50% OL	Same	Fluoropolymer
Filotex	PFTE Extrusion	616 0.0025 in. 53% OL Min	PFTE Topcoat 0.0008 in.

Insulation Candidates Provided for WRDC/MCAIR Test Program

	1st Layer	2nd Layer	3rd Layer/Topcoat
Gore	0.0015 in. PTFE Tape 0.003 in. Wall, 50% OL	0.0015 in. HSCR PTFE 0.003 in. Wall, 50% OL	
Tensolite	200AJ919, 0.0005 in. PTFE 0.001 in. H, 0.0005 in. PTFE 0.004 in. Wall, 50% OL	0.0015 in. PTFE Tape 0.003 in. Wall, 50% OL	
Thermatics	Mod PTFE Tape 0.0017 in. Thick, 50% OL	TPT Tape, (Mod PTFE, H, Mod PTFE), 0.00125 in. Thick, 50% OL	Mod PTFE Tape 0.0008 In. Thick 50% OL
NEMA #2	PTFE Tape 0.001 in. Thick, 0.0015 in. Wall	616 0.0024 in. Thick, 50% OL	PTFE Tape 0.001 in. Thick, 0.0018 in. Wall
NEMA #3	616 0.0024 in. Thick, 50% OL	Extr XL ETFE 0.004 in. Wall	

Performance Requirements

- Combat Damage
- Electrical
- Environmental
- General
- Marking
- Mechanical
- Thermal
- Weight and Dimensional

Weight Factor
Per Individual Test

	Low	Moderate	High
• Probability of Occurrence	1	2	3
• Frequency of Occurrence	1	2	3
• Seriousness of Failure	1	3	5

- Add, then Divide by 2
- Max = 5.5
- Min = 1.5

Statistical Analysis

- Best Score = 0.0
- Deviation from 0.0 Is Determined by:

$$Zn = (|X_b - X_n|)/S$$

Zn = Numerical Score
Xb = Best Test Result
Xn = Candidate Test Result
S = Unbiased Standard Deviation

$$S = \sqrt{\frac{\Sigma(Xn - \bar{X})^2}{n-1}}$$

$\bar{X}$ = Average Candidate Test Result
n = Number of Candidates

Screening Tests

Test	Document	Weight*
Finished Diameter	S - 901	4.2
Finished Weight	S - 902	4.2
Workmanship	S/M - 3.1.4	3.0
Stiffness and Springback	S - 708	4.2
Dry Arc Resistance	S - 301	5.5
Flammability	S - 801	4.3
Toxicity	B0482	5.0
Fluid Immersion	S - 601	4.5
Verification of Retained Properties: Heat Aged (1000 Hrs at 200°C)		
- Abrasion	S - 701	5.5
- Dynamic Cut Through	S - 703	4.5
- Flex Life	B0482	5.5
- Notch Propagation	S - 707	5.0
- Voltage Withstand	S - 510	5.5
- Insulation Resistance	S - 504	4.5
- Examine Product	S/M - 3.1.4	3.0

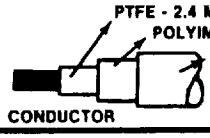
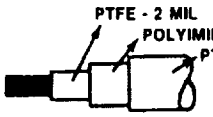
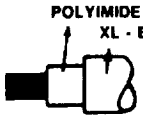
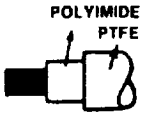
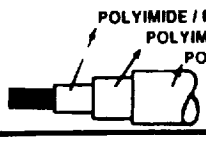
* Avg = 4.6

S - SAE AS4373
S/M - SAE AS4372 Proposed B0482 - MCAIR Wire Test for MOD

Screening Test Results

	Overall WTD	Overall UNWTD	22 TN WTD	22 TK WTD	26 TN WTD	SJ Cable WTD
Filotex	1 6.52	1 6.15	1 6.25	2 6.90	4 8.23	No Test
Thermatics	2 7.23	2 7.16	4 9.11	1 6.68	1 7.16	6 8.45
NEMA #3	3 8.59	4 8.89	5 9.47	5 8.98	2 7.40	8 9.68
Gore	4 9.05	3 8.57	2 8.63	6 9.75	5 8.46	10 13.48
M81381/7/9/11	5 9.22	5 9.29	3 8.90	4 8.84	3 8.06	1 1.11
Tensolite	6 9.59	6 9.62	3 8.90	9 12.06	7 9.01	9 12.20
Champlain	7 9.92	8 9.82	8 10.78	7 10.51	8 9.06	3 4.34
Barcel	8 9.94	7 9.78	9 12.00	3 8.36	9 10.02	4 6.65
NEMA #2	9 10.97	10 11.21	7 10.71	8 10.83	11 12.75	11 16.57
M22759/44/33/43	10 11.18	9 10.89	6 9.78	11 13.16	10 12.34	5 8.24
Brand Rex	11 13.96	12 14.02	11 17.23	10 12.07	6 8.95	7 9.01
DuPont	12 14.19	11 13.66	10 15.01	12 16.69	12 14.40	2 4.31

SELECTED WIRE INSULATIONS FOR FULL PERFORMANCE EVALUATION

MATERIAL CONSTRUCTION (2.6 GA.)	WIRE DIAMETER (MILS)	WEIGHT / 1000 FT. (LBS)	PERCENTAGE POLYIMIDE / FLUOROPOLYMER
 FILOTEX	29.6	1.27	36 / 64
 THERMATICS	29.7	1.33	33 / 67
 NEMA	31.0	1.32	31 / 69
 TENSOLITE	33.8	1.55	28 / 72
 MIL-W-81381/9	34	1.30	69 / 31

PTFE - POLYTETRAFLUOROETHYLENE
FEP - FLUORINATED ETHYLENE PROPRYLENE
XL - ETFE - CROSS - LINKED ETHYLENE - TETRAFLUORO ETHYLENE COPOLYMER
NEMA - NATIONAL MANUFACTURER'S ELECTRICAL ASSOCIATION

Full Performance Tests

Test	Document	Weight*
Dielectric Constant	S - 501	2.0
Corona Inception and Extinction	S - 502	3.3
Surface Resistance	S - 506	2.2
Time/Current to Smoke	S - 507	3.3
Wet Arc Tracking	S - 509	3.2
Wire Fusing Time	S - 511	3.2
Forced Hydrolysis	S - 602	3.5
Humidity Resistance	S - 603	4.5
Weight Loss/Outgassing	S - 604	2.2
Weathering Resistance	S - 606	3.5
Wicking	S - 607	3.5
Abrasion	S - 701	5.2
Cold Bend	S - 702	3.3
Dynamic Cut Through	S - 703	4.8
Flex Life	S/M - 3.9.6	4.7

S - SAE AS4373, April 1989 S/M - SAE AS4372, Proposed

Full Performance Tests

Test	Document	Weight*
Insulation Impact Resistance	A - D256	3.1
Insulation Tensile Strength	S - 706	3.2
Notch Propagation	S - 707	5.0
Smoke Quantity	S - 803	4.3
Thermal Index	S - 804	4.0
Thermal Shock	S - 805	4.0
Wire Surface Markability	DMS 2325	3.8
Crush Resistance	A - D3032	3.0
Aging Stability - SJ Cable	M - 4.5.10	3.0
Jacket Wall Thickness - SJ Cable	F - 1018	3.3
Verification of Retained Properties	S - 805	5.5
Wire-to-Wire Rub	DAC Procedure	5.2
Dry Arc Prop - Large Guage, Thermal Age	BSI No. 43	5.5
270 VDC Dry Arc Prop - No Protection	S - 301	-
270 VDC Dry Arc Prop - w/Protection	CuDust	-
270 VDC Dry Arc Prop - Large Guage, Inorganic (NP)	CuDust	-

S - SAE AS4373, April 1989
M - MIL-C-27500G
BSI - British Standards Institute
DMS - Douglas Materials Specification
A - ASTM
F - Federal Standard 228
DAC - Douglas Aircraft Co.
NP - No Protection

Avg = 3.8

Overall Screening and Full Performance Test Results

	Overall WTD	Overall UNWTD	22 TN WTD	22 TK WTD	26 TN WTD	SJ Cable WTD
Filotex	1 8.22	2 8.42	2 8.50	2 9.53	2 9.13	* *
Tensolite	2 8.23	1 7.43	1 7.57	4 10.16	3 9.32	1 7.15
M81381/7/9/11	3 9.21	3 8.69	3 8.79	1 7.93	1 6.90	2 8.65
Thermatics	4 9.39	4 9.43	5 10.38	3 9.55	5 10.22	4 8.86
NEMA #3	5 10.48	5 9.92	4 10.02	5 11.20	4 9.35	5 9.93
M22759/44/33/43	6 11.38	6 10.73	6 11.59	6 12.48	6 12.42	3 8.81

* No SJ Cable Was Provided for Screening Tests

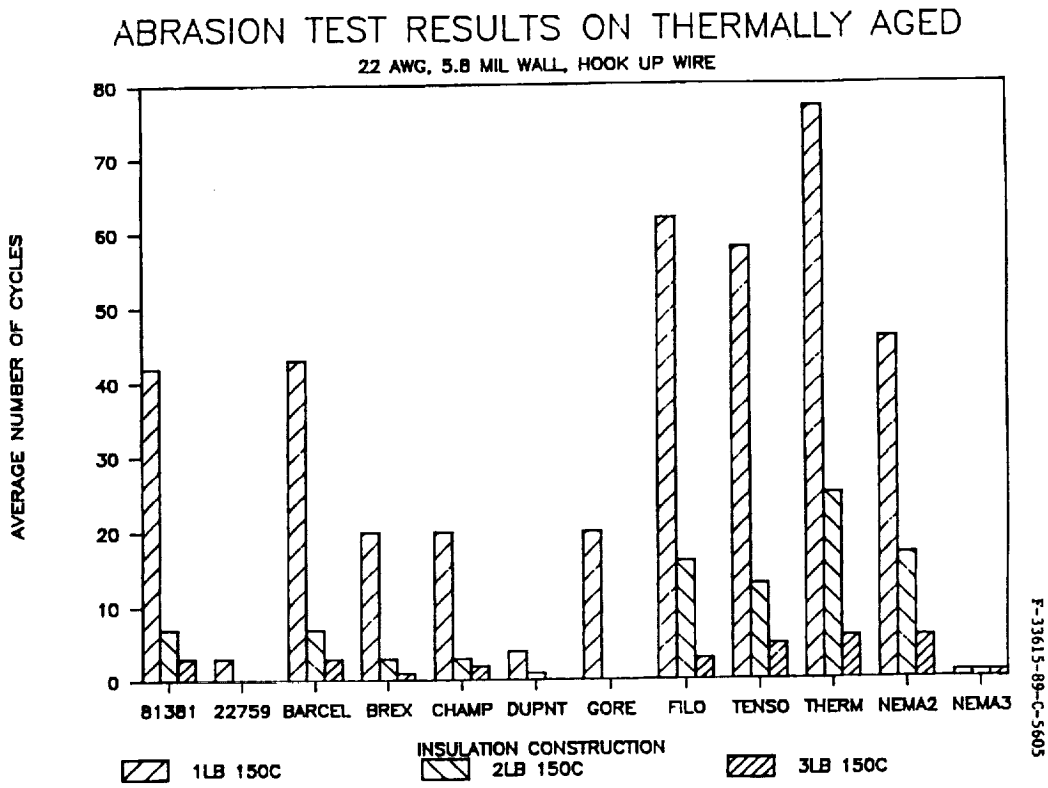
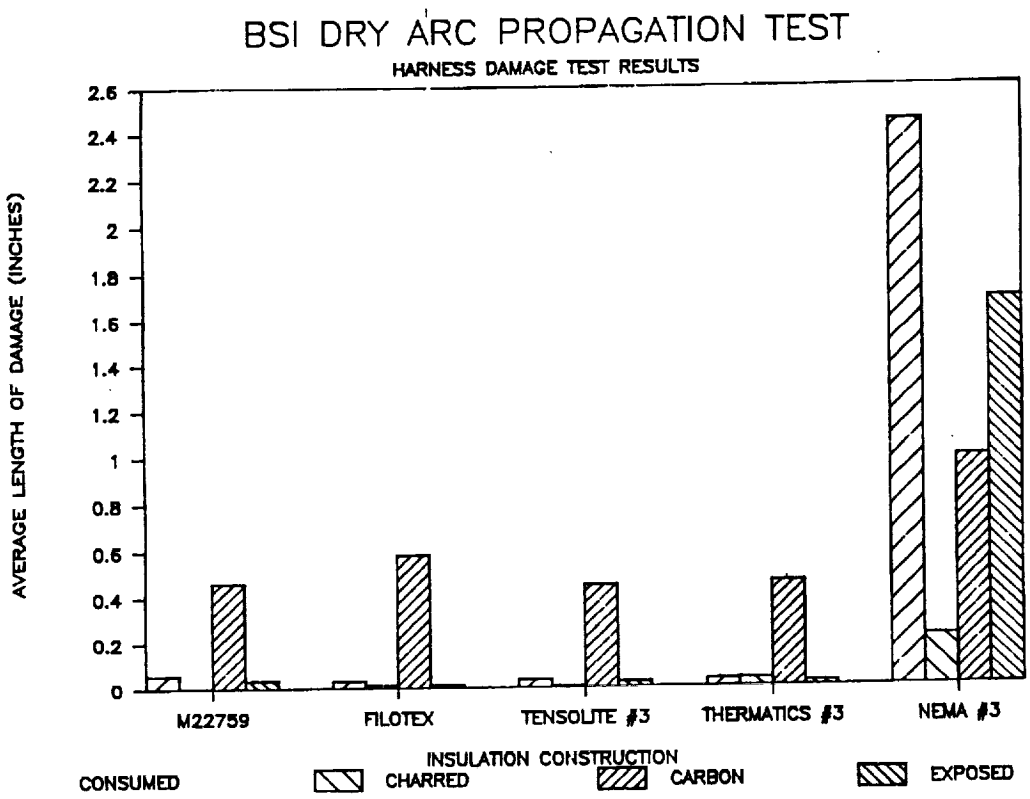


FIGURE 3.17 - ABRASION TEST RESULTS ON THERMALLY AGED, 22AWG, 5.8 MIL WALL, HOOK UP WIRE AT 150°C



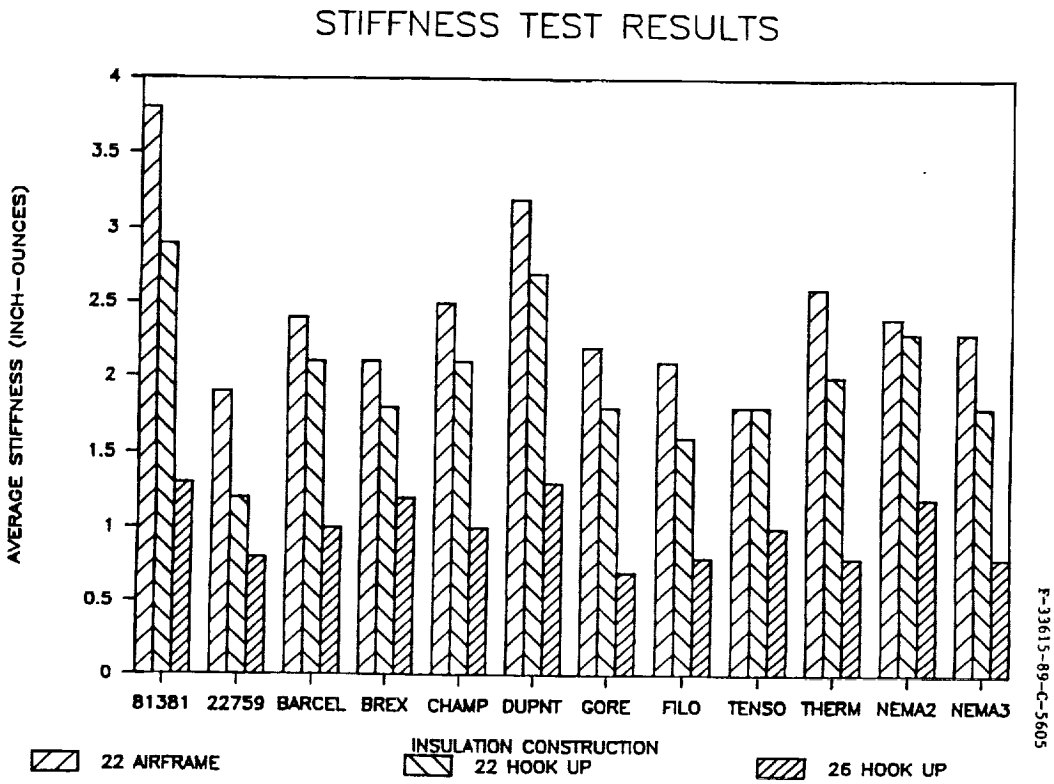


FIGURE 3.35 - STIFFNESS TEST RESULTS

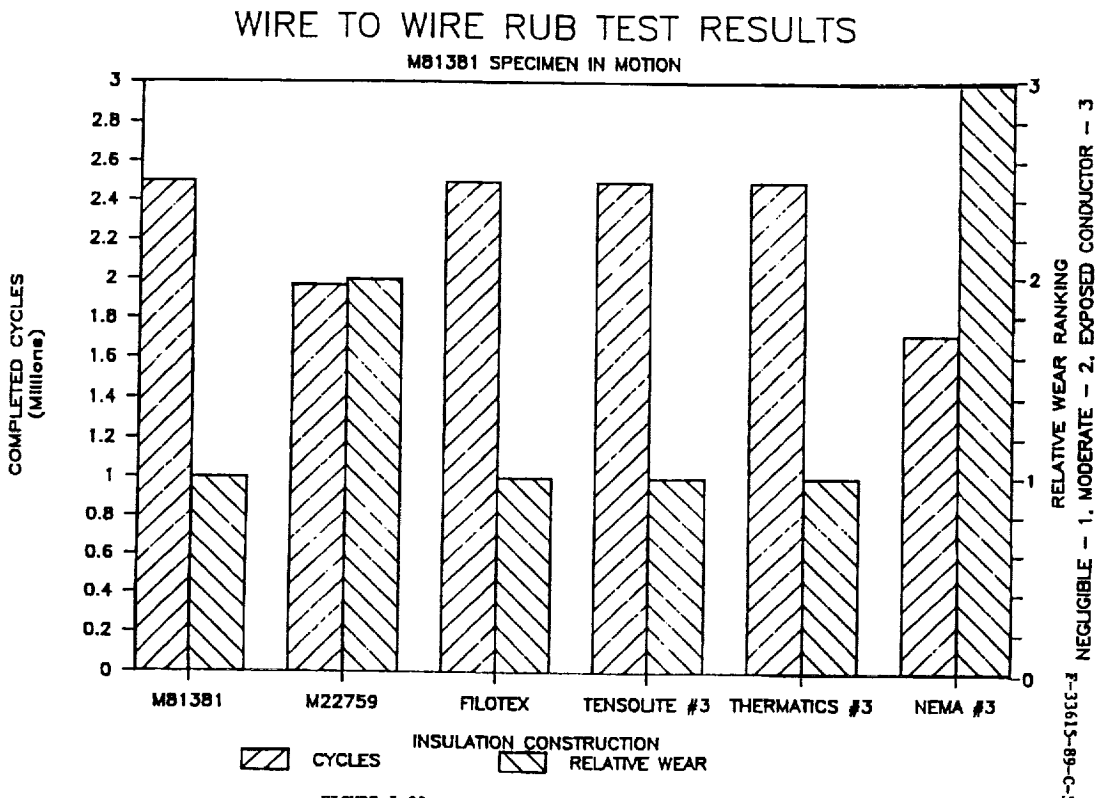


FIGURE 5.82 - WIRE TO WIRE RUB TEST RESULTS, M81381 SPECIMEN IN MOTION

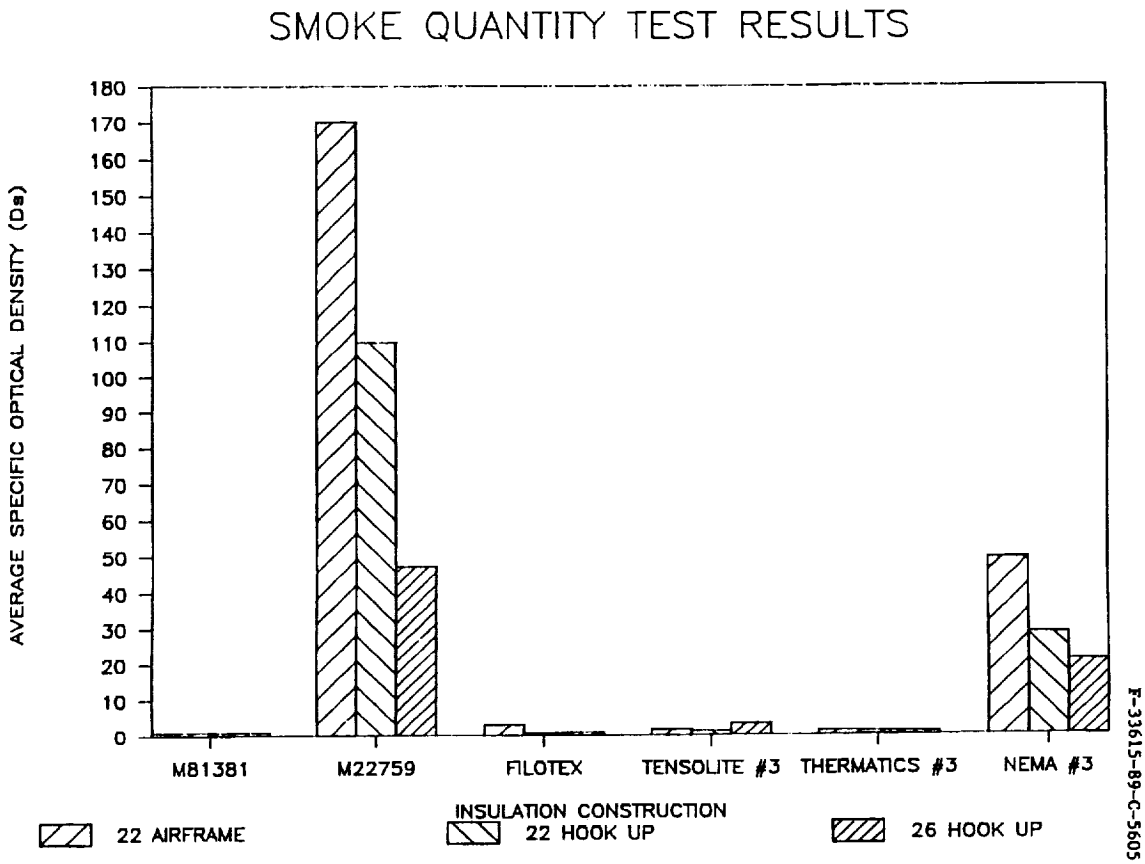


FIGURE 5.91 - SMOKE QUANTITY TEST RESULTS

Assembly, Handling and Repair Specimens Tested

- M22759/33/44 — 22 Thin, 26 Thin; 22 SJ, 26 SJ
- Filotex — 22 Thin, 26 Thin; 22 SJ, 26 SJ
- Tensolite — 22 Thin, 26 Thin; 22 SJ, 26 SJ

Assembly, Handling and Repair
Test Results

- Filotex
  - Best Performer
  - Most Flexible, Easiest to Handle
  - Difficulty During Shield Splice
- Tensolite
  - Wire Stiffness Aids in Connector Insertion and Harness Twisting
  - Some Tendency Toward Coiling in Layout

Candidate Performance Review

Standing

1) Filotex, 2) Tensolite, 3) Thermatics, 4) NEMA 3

Rationale For Preferred Choice

- Filotex Used NPC on 100 Series Wire to Meet MCAIR Test Start Deadline
- Filotex Has Indicated the 200 Series Wire Using SPC Is Not Capable of Being Poduced in Their Production Facility. Many Insulators are Uncomfortable with Production of 0.002" Extruded PTFE
- Tensolite Diameter and Weights Do Not Fall Within the M81381 Diameter and Weight Guidelines Established. Since USAF/MCAIR Are Discussing a Direct Replacement of M81381 in F-15's with the Preferred Construction, Tensolite's Diameter and Weight Would Create Problems

Diameter and Weight Specification Comparisons

	22 AWG, 8.6 mil		22 AWG, 5.8 mil		26 AWG, 5.8 mil	
Construction	Diameter Specification	Weight Specification	Diameter Specification	Weight Specification	Diameter Specification	Weight Specification
Tensolite	.047 - .049	3.2	.045 - .047	3.0	.035 - .037	1.6
M81381	.045 - .049	3.0	.041 - .044	2.8	.031 - .034	1.3
M22759	.050 ± .002	3.2	.043 ± .002	2.8	.032 ± .002	1.4

4 Draft Sheets Prepared

LWC Light Weight (Thin Wall) Copper
Similar to M22759/44

LWA Light Weight (Thin Wall) Alloy
Similar to M22759/33

NWC Normal Weight (Thick Wall) Copper
Similar to M22759/43

NWA Normal Weight (Thick Wall) Alloy
Similar to M22759/35

Cost Observations/Predictions

Estimates Ranged from
Comparable with M81381 Up to
a 25% Increase Over M81381

Conclusions

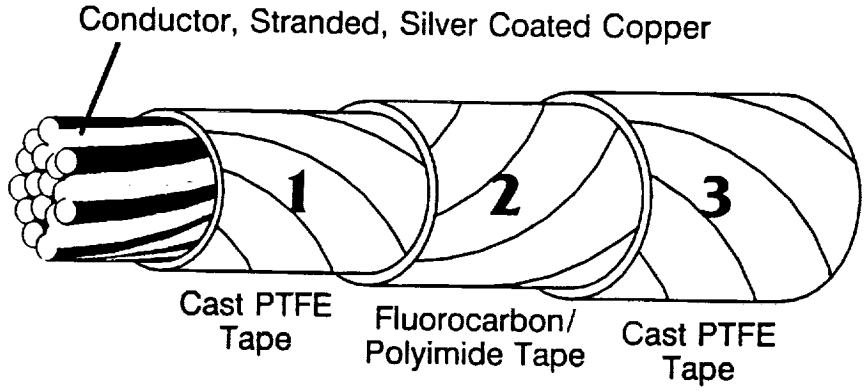
- Two Candidates Performed Better than Both Baseline Constructions, and the Other Two Performed Better than M22759
- Three Out of Four Candidates Demonstrated NO Arc Propagation Characteristics In Our Evaluations
- NEMA #3 and Thermatics Candidates Met All Program Requirements (ie: Multi Source, Weight and Dimensional Equivalent to M81381, and Production Capability)
- Filotex and Tensolite Are Excellent Performers if Program Requirements Allow Use of Nickel Plated Conductor (Filotex) or Larger Wire (Tensolite)

Cost Observations/Predictions

Estimates Ranged from
Comparable with M81381 Up to
a 25% Increase Over M81381

Military Specification Sheet

Wire, Electric, PTFE, Fluorocarbon/Polyimide, PTFE Insulated, Lightweight, Silver Coated Copper Conductor, 200°C, 600 Volts



BENEFITS

- PROVIDES THIN WALL AND LIGHT WEIGHT WIRE INSULATIONS FOR AEROSPACE USE
  - DIRECT REPLACEMENT FOR M81381 WIRING
  - MANUFACTURABLE BY MORE THAN ONE SOURCE
- INCREASED MAINTAINABILITY
  - IMPROVED FLEXIBILITY OVER M81381
  - LASER MARKABLE
- INCREASED RELIABILITY
  - FLASHOVER (ARC TRACKING) RESISTANT
  - IMPROVED ENVIRONMENTAL RESISTANCE OVER M81381
- IMPROVED PERFORMANCE
  - HIGHER TEMPERATURE CAPABILITY OVER M81381 AND M22759
  - IMPROVED MECHANICAL PROPERTIES OVER M22759

TECHNOLOGY TRANSITION PLAN PROGRAM DELIVERABLES

- PREPARE PRELIMINARY WIRE SPECIFICATIONS
  - AFLC/2750 AND NAVY WILL INCORPORATE AT LEAST TWO CONSTRUCTIONS INTO M22759
  - AT LEAST TWO MANUFACTURERS WILL BE QUALIFIED TO THE SPECIFICATIONS
- PROVIDE TEST DATA TO SUPPORT THREE NEW CONSTRUCTIONS
  - THERMATICS - PTFE/KAPTON/PTFE, AG PLATING
  - TENSOLITE - KAPTON/PTFE, AG PLATING
  - FILOTEX - PTFE/KAPTON/PTFE, NI PLATING

TECHNOLOGY TRANSITION PLAN
FOLLOW-ON ACTIVITIES

- MONITOR PROGRAMS USING NEW INSULATIONS
  - TENSOLITE-TYPE WIRING CHOSEN BY BOEING FOR NEW PRODUCTION AIRCRAFT
  - THERMATICS-TYPE WIRING CHOSEN FOR THE EUROPEAN FIGHTER AIRCRAFT
- FLIGHT TEST NEW WIRING CONSTRUCTIONS

Amendment #1

270 Vdc Dry Arc Resistance/ Fault Propagation

Measure the Resistance of the Insulation to Arc Propagation as a Result of a 270 Vdc Power System Short

- Method 301 of SAE AS4373 as a Guide. Backplates and One Harness Clamp Were Grounded. No Insulation Resistance Test and *No Circuit Protection*
- 20 Wires Per Harness of a 43 ± 1 Inch Length (22 and 26 Gauge, Thin Wall)
- 270 Vdc, 30 kW, Westinghouse Generator

Amendment #1 Results

All of the Tested Insulation Constructions Exhibited Some Degree of Arc Propagation in Unprotected 270 Vdc Circuits

Amendment #1 Conclusions

Insulation Is Not a Viable Means of Inhibiting an Arc at 270 Vdc; Other Circuit Protection Devices Must Be Examined

Amendment #2

270 Vdc Dry Arc Propagation

Repeat the 270 Vdc Dry Arc Propagation Tests with Power Controllers Protecting the Harness

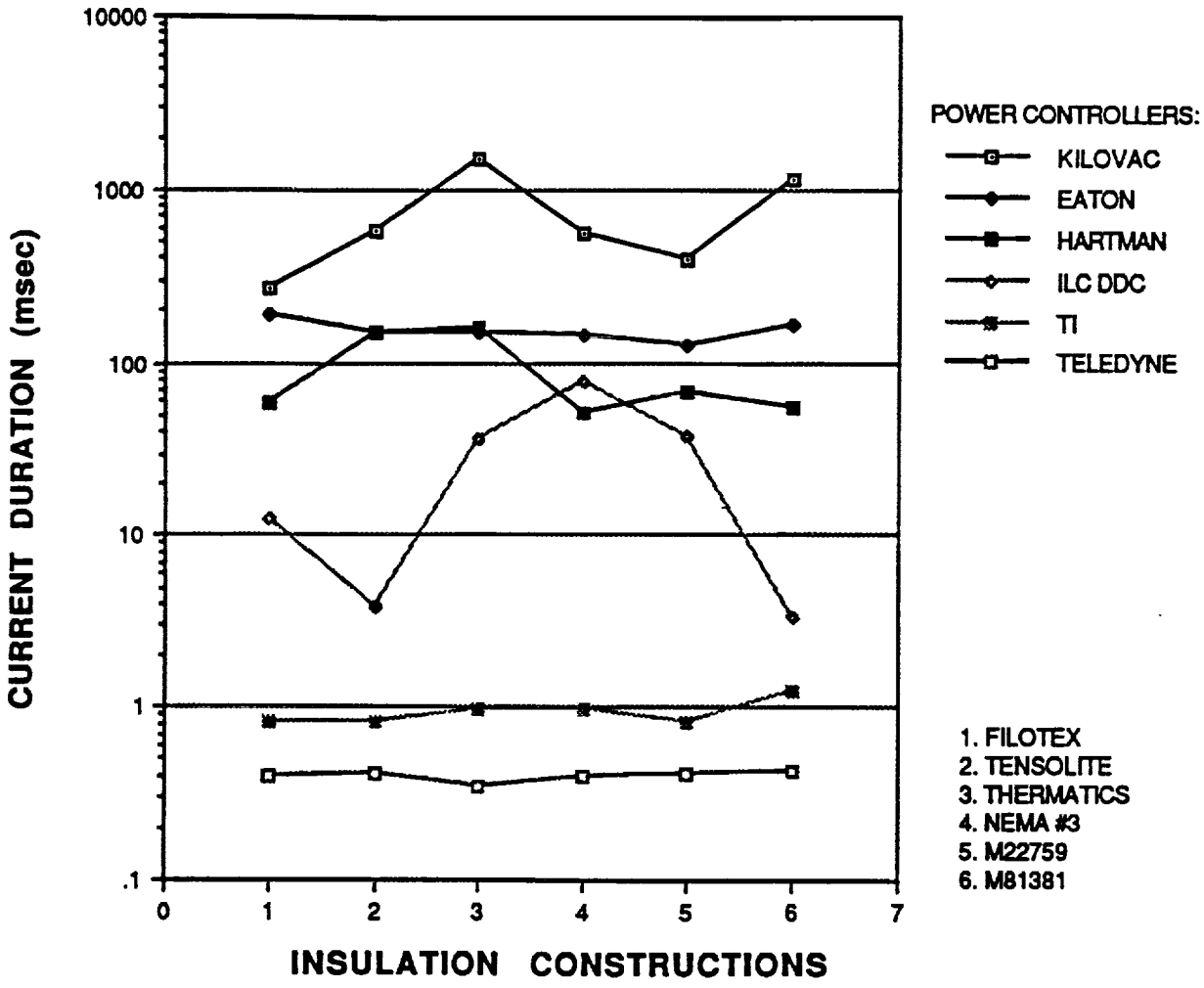
- 48 ± 1 Inch Harness of 22 AWG Thin Wall Wire (Tested with Four Low Amperage Power Controllers)
- 48 ± 1 Inch Harness of 12 AWG Thick Wall Wire (Tested with Two High Amperage Power Controllers)
- 48 ± 1 Inch Harness of Inorganic Insulation (with No Circuit Protection)
- 7 Wire Harness
- Copper Dust Shorting Method

Amendment #2

270 Vdc Dry Arc Propagation Test Power Controller Suppliers

Supplier	Rated Amperage	Harness Gauge
Eaton Corporation	40A	12 AWG
Hartman	40A	12 AWG
ILC Data Device Corp	15A	22 AWG
Kilovac	15A	22 AWG
Teledyne Solid State	5A	22 AWG
Texas Instruments	10A	22 AWG

AMENDMENT #2 RESULTS



Amendment #2 Conclusions

Circuit Protection Devices Are Required to Protect 270 Vdc Interconnect Systems from Arc Propagation. There Are Protection Devices Available which Sufficiently Limit Arc Propagation

omit

AEROSPACE WIRE AND CABLE

Presentation for NASA
Lewis Research Center
July 24, 1991

by
E. I. du Pont de Nemours & Co., Inc.
Dr. David H. Berkebile

AEROSPACE WIRE & CABLE SUPPLIERS

- DuPont is a Supplier of Materials
  (DuPont is not a wire vendor or processor)

- Wire Processors (such as Teledyne Thermatics) manufacture and sell Wire and Cable.

- Distributors (such as A.E.Petsche) also are vendors of aerospace wiring.

- DuPont sells Teflon®, Tefzel®, Kapton®, Nomex®, Kevlar®, Dacron®, & Liquid H. Nearly all of the polymer systems that are used in aerospace wiring systems.

DU PONT POLYMERS

Alcryn® Melt Processible Rubber
Elvaloy® Resin Modifiers
Elvax® Resins
Hypalon® Synthetic Rubber
Hytrel® Polyester Elastomer
Kapton® Polyimide Film
Kevlar® Aramid Fiber
Mylar® Polyester Film
Neoprene Synthetic Rubber
Nomex® Aramid Fiber
Nordel® Hydrocarbon Rubber
Polyethylene Resins
Surlyn® Ionomer Resins
Teflon® Fluorocarbon Resins (FEP, PFA, TFE)
Tefzel® Fluoropolymer Resins
Vamac® Ethylene Acrylic Elastomer
Zytel® Nylon Resin

AEROSPACE WIRE & CABLE SELECTION

- Many excellent aerospace wire constructions are available.

- Appropriate engineering selections depend upon understanding the actual end use requirements and their relative importance.

- Using a single performance criteria a wire could be designed for almost any demand. (bullet-proof, very flexible, very small, light weight, arc propagation resistance, high abrasion abrasion resistance, excellent fuel resistance, etc., etc., etc.)

- However, you can't have it all at once !!

→ → → → → Increased toughness → → → → →

PTFE ETFE XL-ETFE POLYIMIDE

← ← ← ← ← Increased flexibility ← ← ← ← ←

There is no perfect insulation

COMPARISON OF CHOICES

	RELATIVE RANKING			
MAJOR CONCERNS	1	2	3	4
ARC PROPAGATION RES.(AC)	TEF	TFZ	XTZ	KAP
FLEXIBILITY	TEF	TFZ	XTZ	KAP
WEATHERABILITY (UV,H_2O,O_2)	TEF	TFZ	XTZ	KAP
CHEMICAL INERTNESS	TEF	TFZ	XTZ	KAP
HYDROLYSIS RESISTANCE	TEF	TFZ	XTZ	KAP
NOTCH SENSITIVITY	TEF	TFZ	KAP	XTZ
THERMAL LIFE	TEF	KAP	XTZ	TFZ
FLAMMABILITY	TEF	KAP	TFZ	XTZ
LOW SMOKE	KAP	TEF	TFZ	XTZ
COLD FLOW (CREEP @ TEMP)	KAP	XTZ	TEF	TFZ
ABRASION/CUT-THRU	KAP	XTZ	TFZ	TEF
WEIGHT	KAP	XTZ	TFZ	TEF
SPACE	KAP	XTZ	TFZ	TEF

CODES		TYPICAL MIL SPECS
TEF = TEFLON● PTFE	- - - - -	22759/12
KAP = KAPTON●	- - - - -	81381/7
TFZ = TEFZEL●	- - - - -	22759/17
XTZ = CROSSLINKED TEFZEL●	- - - - -	22759/34

NEW HYBRIDS CHOICES

MAJOR CONCERNS	RELATIVE RANKING 1	2	3	4
ARC PROPAGATION RES.(AC)	TEF	TFZ ■	XTZ	KAP
FLEXIBILITY	TEF	TFZ ■	XTZ	KAP
WEATHERABILITY (UV,H_2O,O_2)	TEF ■	TFZ	XTZ	KAP
CHEMICAL INERTNESS	TEF	TFZ ■	XTZ	KAP
HYDROLYSIS RESISTANCE	TEF	TFZ ■	XTZ	KAP
NOTCH SENSITIVITY	TEF	TFZ ■	KAP	XTZ
THERMAL LIFE	TEF ■	KAP	XTZ	TFZ
FLAMMABILITY	TEF ■	KAP	TFZ	XTZ
LOW SMOKE	KAP ■	TEF	TFZ	XTZ
COLD FLOW (CREEP @ TEMP)	KAP ■	XTZ	TEF	TFZ
ABRASION/CUT-THRU	KAP ■	XTZ	TFZ	TEF
WEIGHT	KAP ■	XTZ	TFZ	TEF
SPACE	KAP ■	XTZ	TFZ	TEF

■ = HYBRIDS OF TEFLON TFE & KAPTON (T/K/Ts)

CODES		TYPICAL MIL SPECS
TEF = TEFLON® PTFE	- - - - -	22759/12
KAP = KAPTON®	- - - - -	81381/7
TFZ = TEFZEL®	- - - - -	22759/17
XTZ = CROSSLINKED TEFZEL®	- - - - -	22759/34

DESIGN CONSIDERATIONS

- Weight and size requirements
- Human exposure vs equipment only
- Internal vs external
- Low earth orbit vs deep space
- Signal vs Power
- Exposed vs protected & not exposed
- AC vs DC power

DUPONT WOULD LIKE THE OPPORTUNITY
TO ASSIST IN THE APPROPRIATE USE
OF MATERIALS IN WIRING SYSTEMS
FOR SPACE APPLICATIONS

David Berkebile (302) 999-3623

Mike McCord (302) 996-8546

omit

WIRE AND CABLE DESIGN FOR SPACE APPLICATIONS - NEW IDEAS

Bruce Pike
Teledyne Thermatics

PHYSICAL CONSIDERATIONS

- Temperature Characteristics
- Flexibility
- Strength and Toughness
- Size and Shape
- Flame Response

FLAT CABLE CHARACTERISTICS

- Planar Flexibility
- Size and Shape
- Cables and Conductors

ELECTRICAL CONSIDERATIONS

- Signal versus power applications
- Data Transmission
- EMI

CONDUCTORS

- Conductivity versus Strength
- Downsizing

	CONDUCTIVITY (% IACS)	BREAK STRENGTH (kPSI)
Copper	100	35
Aluminum	62	10
PD 135	88	58
Stainless Steel	20	60
CS 95	62	95

FLAT CABLE CONSTRUCTIONS

- Lamination
- Woven
- Extrusion

SEVERE TEMPERATURE APPLICATIONS

- Fire Zone
- Circuit Integrity
- Thermocouple

DATA CABLES

. Token Ring	150 Ohm
. Data Buss	70 Ohm
. FDDI	

EMI

- Reciprocity Theorem

EMI FIXES

- Low Noise
- Filter Line
- Flat Shields
- Foil and Braid

COMPOSITE INSULATION SYSTEMS

- Weight and Size
- Tailored to Application
- Proven