

USAF/WL ROBUST 300 °C WIRE INSULATION SYSTEM PROGRAM STATUS

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 p. 10

ROBUST 300°C WIRE INSULATION SYSTEM

PROGRAMMATICAL INFORMATION

- WRIGHT LABORATORY PROGRAM MANAGER: JOHN NAIRUS (WL/POOC-1)
- TRW PROGRAM MANAGER: WING WONG\* (SPACE & ELECTRONICS GROUP)
- KEY NON-TRW PROGRAM PARTICIPANTS

<u>COMPANY</u>	<u>ROLE</u>
LAWRENCE TECHNOLOGY AND TELEDYNE THERMATICS	FILM ELECTRICAL PROPERTY TESTING WIRE TESTING WIRE QUALITY TESTING
MCDONNELL AEROSPACE - ST. LOUIS	DETAILED WIRE TESTING
POLY-MATERIALS	POLYIMIDE POLYMER PREPARATION
REXHAM	CONTINUOUS FILM PREPARATION

\*PREVIOUSLY MANAGED BY ROBERT J. JONES

## ROBUST 300°C WIRE INSULATION SYSTEM

### OBJECTIVE

THE OBJECTIVE OF THIS PROGRAM IS TO IDENTIFY, DEVELOP, AND DEMONSTRATE AN OPTIMUM WIRE INSULATION SYSTEM CAPABLE OF CONTINUOUS OPERATION AT 300°C WHICH POSSESSES A COMBINATION OF SUPERIOR ELECTRICAL (AC OR DC), MECHANICAL, AND PHYSICAL PROPERTIES OVER KAPTON® DERIVED INSULATIONS DESCRIBED IN MIL-W-81381 AND THOSE HYBRID MATERIALS COMMONLY KNOWN AS TKT CONSTRUCTIONS.

## ROBUST 300°C WIRE INSULATION SYSTEM

### TASK 1 - FILM/ADHESIVE CANDIDATE SCREENING

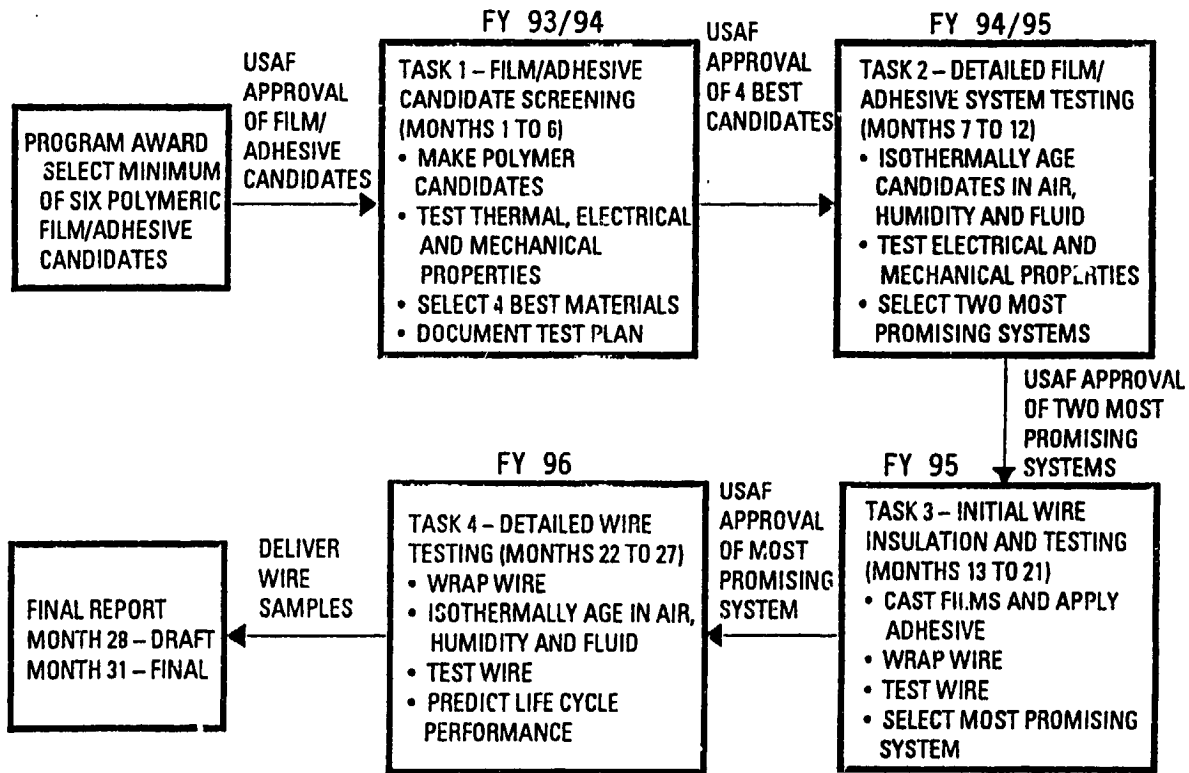
- SHALL BALANCE VARYING AMOUNTS OF FLUORINE CHARACTER FOR CANDIDATE POLYMERS AGAINST EXPECTED (OR KNOWN) EFFECTS OF THERMAL-MECHANICAL AND ELECTRICAL PROPERTIES.
- SHALL MAKE AND TEST A MINIMUM OF SIX FILM AND ADHESIVE CANDIDATES TAILORED TO CONTRIBUTE THEIR BEST PROPERTIES TO A SUPERIOR 300°C WIRE INSULATION SYSTEM.

### SUBTASKS

- FILM/ADHESIVE SAMPLE PROCUREMENT/PREPARATION
  - PPFI (4-BDAF/PMDA FORMULATION)
  - FPE 265
  - AFR700B
  - FM680-1
  - MODIFIED AFR700
- DATABASE PROPERTY DETERMINATION
  - DYNAMIC MECHANICAL ANALYSIS FOR GLASS TRANSITION TEMPERATURE
  - TENSILE STRENGTH
  - TENSILE LAP SHEAR STRENGTH FOR FILM/ADHESIVE SYSTEM
  - ELECTRICAL PROPERTIES (DIELECTRIC PROPERTIES, BREAKDOWN VOLTAGE AND DRY ARC TRACK)

# ROBUST 300°C WIRE INSULATION SYSTEM

## PROGRAM LOGIC DIAGRAM



# ROBUST 300°C WIRE INSULATION SYSTEM

## TASK 1 - Results

Material		Kapton	FPE-265	PFPI	AFR700B	FM680-1	Mod. AFR
Tg (G' Knee)		340 C	333 C	350 C	375 C	368 C	265 C
Tensile Strength (ksi)							
	RT	28.6	11.5	11.5			
	250C	17.3(60%)	4.2 (37%)	7.0 (61%)			
	300C	11.6(41%)	2.8 (24%)	2.9 (25%)			
Dielectric Constant							
RT	.4KHz	3.46	3.07	2.08			
	1KHZ	2.45	3.1	2.08			
300C	.4KHz	2.89	2.82	1.91			
	1KHz	2.88	2.82	1.91			
Dissipation Factor							
RT	.4KHz	0.0045	0.0057	0.0028			
	1KHZ	0.0051	0.0115	0.0011			
300C	.4KHz	0.0051	0.0017	0.001			
	1KHz	0.0044	0.0017	0.0008			
Breakdown (kV/mil)							
RT	AC	7.3	6.3	6.3			
RT	DC	9.9	11.4	10.4			

System		PFPI/AFR	PFPI/Cytec 680	FPE/AFR	FPE/Cytec
Lap Shear (ksi)					
	RT	1.55	1.52	0.92	1.78
	300 C	1.00(65%)	.58 (38%)	.20 (22%)	.33 (19%)

( ) Percentage of Strength Retention Compared to RT

## ROBUST 300°C WIRE INSULATION SYSTEM

### Approved Task 2 Film/Adhesive System Candidates Contract F33615-93-C-2367, Robust 300°C Wire Insulation System

Polymer/Adhesive System Candidate	Selection Rationale
PFPI <sup>(1)</sup> /AF-R-700B	<ul style="list-style-type: none"><li>• Demonstrated excellent potential for service at 300°C with glass transition temperature (by DMA, G' Knee) in excess of 320°C</li></ul>
FPE 265/AF-R-700B	<ul style="list-style-type: none"><li>• Demonstrated acceptable bonding capability with tensile lap shear testing at RT and 300°C</li></ul>
PFPI/Cytec 680-1 <sup>(2)</sup>	<ul style="list-style-type: none"><li>• Eliminate modified AF-R-700 as adhesive due to low glass transition temperature (260°C), lack of lap shear strength at 300°C and marginal processability</li></ul>
FPE 265/Cytec 680-1	

<sup>(1)</sup> 4 BDAF/PMDA formulation

<sup>(2)</sup> Extracted resin from Cytec 680-1 film adhesive

## ROBUST 300°C WIRE INSULATION SYSTEM

### TASK 2 - DETAILED FILM/ADHESIVE SYSTEM TESTING

- EMPLOY THE FOUR PROMISING POLYMERIC FILM AND ADHESIVE CANDIDATES RECOMMENDED AT THE CONCLUSION OF TASK 1 UPON AIR FORCE APPROVAL.
- SUBJECT THE COMBINATIONS OF EACH TO THE BONDING, AGING, AND TESTING NECESSARY TO FULLY ASSESS THEIR POTENTIAL. A MINIMUM OF ONE PROMISING SYSTEM WILL BE SELECTED AND RECOMMENDED TO USAF FOR ASSESSMENT ON WIRE IN TASK 3.

### SUBTASKS

- SAMPLE BONDING
  - BONDING PROCESS DEVELOPMENT BY TRIAL AND ERROR APPROACH
- SAMPLE AGING
  - AIR-AGING AT 300°C FOR 1000 HOURS
  - IMMERSION IN CLEANING SOLVENT DS-108 AT ROOM TEMPERATURE FOR 168 HOURS
  - EXPOSURE TO 90°C/95% RH CONDITION FOR 1000 HOURS
- SAMPLE TESTING
  - WEIGHT CHANGE
  - PHYSICAL CHANGE
  - ELECTRICAL PROPERTIES

### Task 2 Isothermal Aging Studies - Results

Test A. Effect of Air - Aging at 300°C on Four Most Promising Insulation Systems

Aging Duration (Hours)	Percent Weight Loss on Air Aging By Candidate Film/Adhesive System <sup>a),b)</sup>			
	PFPI/AFR700B	PFPI/Cytec 680-1	FPE/AFR700B	FPE/Cytec 680-1
24	1.3	1.2	1.8	5.6
48	1.2	1.3	2.2	6.7
120	1.6	1.6	3.9	10.0
264	2.3	2.1	8.6 <sup>c)</sup>	18.2 <sup>c)</sup>
528	3.7	2.9	21.6	50.0
768	5.0	3.6	27.0	65.6
1000	6.2	4.6	28.5	70.7

<sup>a)</sup>Test sample dimensions approximately 1.25-inch wide x 1.25-inch long x .005-inch thick consisting of selected adhesive (thickness = .002-inch) laminated between two polymeric films (each = .0015-inch thick)

<sup>b)</sup>Average of 2 samples

<sup>c)</sup>Onset of severe sample darkening/curling

# ROBUST 300°C WIRE INSULATION SYSTEM

## Task 2 Isothermal Aging Studies - Results

Test B. Effect of Cleaning Solvent DS-108 Aging at 25° on Four Most Promising Insulation Systems

Aging Duration (Hours)	Percent Weight Gain on Aging By Candidate Film/Adhesive System <sup>a),b)</sup>			
	PFPI/AFR700B	PFPI/Cytec 680-1	FPE/AFR700B	FPE/Cytec 680-1
24	0.9	7.4	2.1	8.0
48	0.9	3.3	1.4	4.8
120	2.5	7.5	2.2	6.7
168	2.7	6.3	1.8	5.4

<sup>a)</sup> Test sample dimensions approximately 0.5-inch wide x 1.0-inch long x .005-inch thick consisting of selected adhesive (thickness ~ .002-inch) laminated between two polymeric films (each ~ .0015-inch thick)

<sup>b)</sup> Average of 2 samples, except for FPE/Cytec 680-1

## Task 2 Isothermal Aging Studies - Results

Test C. Effect of Humidity - Aging at 90°C/95% RH on Four Most Promising Insulation Systems

Aging Duration (Hours)	Percent Weight Loss (-) or Weight Gain (+) on Aging By Candidate Film/Adhesive System <sup>a),b)</sup>			
	PFPI/AFR700B	PFPI/Cytec 680-1	FPE/AFR700B	FPE/Cytec 680-1
24	-0.9	-0.1	+1.1	-1.6
48	-0.9	-0.1	+1.0	-2.1
120	-0.9	-0.1	+1.1	-2.6
264	-0.9	-0.1	+1.0 <sup>c)</sup>	-2.8 <sup>c)</sup>
528	-0.9	-0.1	+1.2	-2.4
768	-0.8	-0.1	+0.1	-3.3
1000	-0.7	-0.1	+0.3	-3.3

<sup>a)</sup> Test sample dimensions approximately 1.25-inch wide x 1.25-inch long x .005-inch thick consisting of selected adhesive (thickness ~ .002-inch) laminated between two polymeric films (each ~ .0015-inch thick)

<sup>b)</sup> Average of 2 samples

<sup>c)</sup> Onset of severe sample darkening

## **ROBUST 300°C WIRE INSULATION SYSTEM**

### **TASK 2 - RESULTS**

- **FPE FILM IS NOT A 300°C MATERIAL**
- **PFPI/AFR700B AND PFPI/CYTEC 680 DEMONSTRATED EXCELLENT THERMAL-OXIDATIVE STABILITY. BOTH SYSTEMS SHOWED ESSENTIALLY IDENTICAL DEGRADATION IN AIR-AGING AT 300°C FOR 1000 HOURS.**
- **BOTH SYSTEMS ALSO DEMONSTRATED EXCELLENT RESISTANCE TO 90°C AGING IN 95% RH.**
- **FILM SAMPLES BONDED WITH AFR700B ARE MORE RESISTANT TO THE ATTACK BY DS-108 CLEANING SOLVENT THAN THOSE WITH CYTEC 680-1.**

**CONCLUSION: PFPI/AFR700B SYSTEM IS THE TOP CANDIDATE FOR TASK 3.**

### **TASK 3 - INITIAL WIRE INSULATION & TESTING**

- **EMPLOY THE MOST PROMISING FILM/ADHESIVE INSULATION SYSTEM(S) RECOMMENDED AT THE CONCLUSION OF TASK 2 UPON AIR FORCE APPROVAL.**
- **SUBJECT THE SYSTEM(S) TO CASTING, INITIAL WIRE WRAPPING, AND INSULATED WIRE TESTING NECESSARY TO FULLY ASSESS POTENTIAL.**

#### **SUBTASKS**

- **FILM PREPARATION/PROCUREMENT**
  - **FILM CASTING AT REXHAM**
  - **COATING CONTINUOUS FILM WITH ADHESIVE AT TRW**
- **INITIAL WIRE WRAPPING**
- **INITIAL INSULATION TESTING**



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### REXHAM FILM CASTING PROCESS OVERVIEW

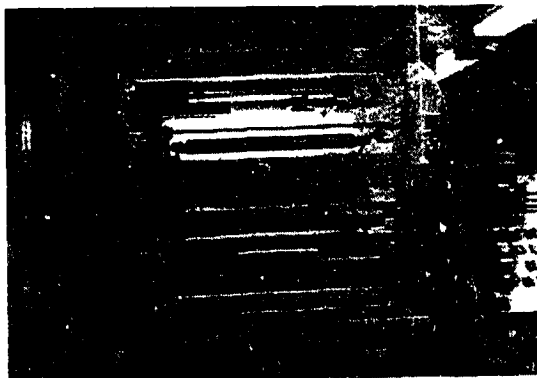
<b>SOLVENT:</b>	<b>N-METHYL PYRROLIDONE (NMP)</b>
<b>PFPI VARNISH SOLID LOADING:</b>	<b>14.8% BY WEIGHT</b>
<b>SPEED:</b>	<b>10 FEET PER MINUTE</b>
<b>CASTING SUBSTRATE:</b>	<b>5-MIL X 18-INCH X 5000 FEET MYLAR FILM</b>
<b>DRYING OVEN LENGTH:</b>	<b>40 FEET</b>
<b>DRYING OVEN TEMPERATURE (4 ZONES):</b>	<b>ZONE 1 = 250°F; ZONE 2 = 300°F; ZONE 3 &amp; 4 = 350°F</b>
<b>HIGH QUALITY PFPI FILM PRODUCED:</b>	<b>2 ROLLS OF ~ 1-MIL X 12-INCH X 400-FEET</b>



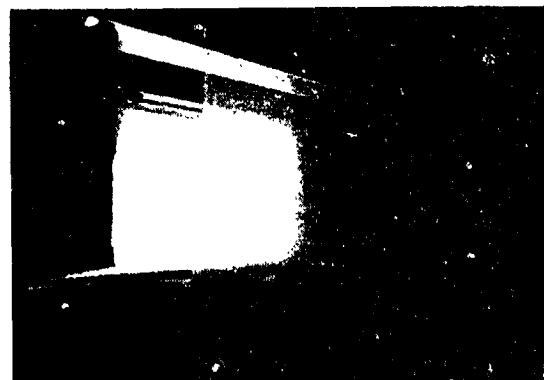
Casting Solution Preparation



Cast PFPI Film



Control Panel



Drying Oven

## **ROBUST 300°C WIRE INSULATION SYSTEM**

### **CONCLUDING REMARKS**

- **AFR700B DEMONSTRATED TO BE A 300°C STABLE ADHESIVE MATERIAL**
- **PFPI (4-BDAF/PMDA)/AFR700B SHOWN AS THE TOP CANDIDATE FOR 300°C WRAPPED INSULATION SYSTEM**
- **SUCCESSFUL CASTING OF PFPI RESIN VARNISH INTO CONTINUOUS FILM**
- **COATING OF THIN LAYER OF AFR700B ON CONTINUOUS PFPI FILM IS IN PROGRESS**