Development of a New Flammability Test for Aircraft Ducting

Federal Aviation Administration

Presented to: The Fifth Triennial International Aircraft Fire and Cabin Safety Research Conference

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Outline

DEVELOPMENT FRAMEWORK

- Initiating
- Planning
- Executing
- Monitoring & Control
- Closing

Initiating

BACKGROUND

- The FAA initiated efforts to improve the fireworthiness of hidden areas in the aircraft (T/A Insulation) in 1995 after several incidents involving the thermal-acoustic insulation.

- Systems of interest in the hidden area includes thermo/acoustic insulation, aircraft ducting, wiring, etc.

- Aircraft ducting is currently certified using “12-second Vertical Bunsen Burner test (12VBB, Title 14 Code of Federal Regulations Part 25, Appendix F Part I (a)(ii))

- In 1997, FAA Technical Center concluded that the 12VBB test did not produce consistent results and it is not a good indicator of flammability characteristics.

SwissAir MD-11 Accident Investigation Reconstruction, 1998

Initiating

BACKGROUND (CONT.)

- In 2004, as part of the project baseline, the aircraft ducting materials were re-tested with the 12VBB test. They all passed the test.
- That same year, Intermediate-scale fire tests results showed that the 12VBB test was unable to properly predict the fire propagation performance of ducting materials when subjected to a realistic fire scenario.
- The FAA, in conjunction with the IAMFTWG (Stakeholders), chartered a project with a scope to develop a new test procedure to evaluate aircraft ducting materials.

Initiating

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Current FAA Test: 12-sec Vertical Bunsen Burner

Intermediate-Scale Fire Test: New Fire Threat

Outline

DEVELOPMENT FRAMEWORK

- Initiating
- Planning
- Executing
- Developed Test
- Test Method Validation
- Final Words

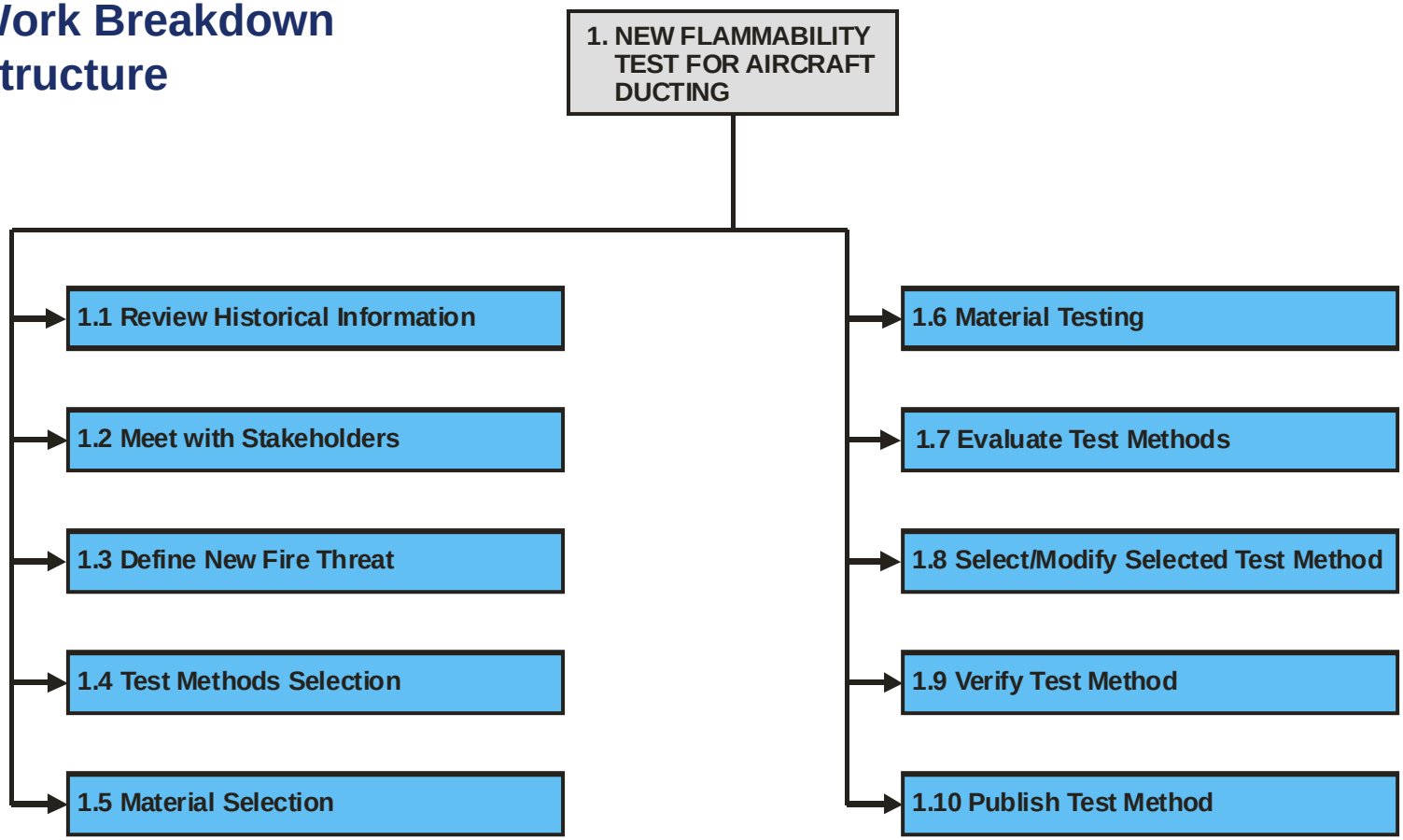
Planning

OBJECTIVE

Develop a fire test method for aircraft ducting that could adequately discriminate between poorly performing materials and fire worthy materials when exposed to a realistic fire scenario.

Planning

Work Breakdown Structure



Planning

- **SCHEDULE**
  - Project Initiated: April 2005
  - Project Due Date: Sep 2007
- **QUALITY**
  - Systems/instrumentation calibrations
  - Measurements
- **COMMUNICATIONS PLAN**
  - Formal & Informal Presentations IAMFTWG
- **HR PLAN**
  - Responsibility Assignment Matrix
- **RISK PLAN**
- **PROCUREMENT PLAN**

Executing

1.1 REVIEWED HISTORICAL INFORMATION

- Title 14 Code of Federal Regulations Part 25, Appendix F Part I(a)(4) – "12-seconds Vertical Bunsen Burner Test"
- Report DOT/FAA/CT-89/15 – "Aircraft Material Fire Test Handbook," September 1990
- Report DOT/FAA/AR-97/58 – "Evaluation of Fire Test Methods for Aircraft Thermal Acoustical Insulation," September 1997
- Report DOT/FAA/AR-99/44 – "Development of Improved Flammability Criteria for Aircraft Thermal Acoustic Insulation," September 2000
- Report DOT/FAA/AR-01/117 – "A Microscale Combustion Calorimeter," February 2002

Executing

1.2 Meet with Stakeholders

- Task group formed under the International Aircraft Materials Fire Test Working Group

AIRBUS, BOEING, BOMBARDIER, DAHER (Au service du progrès industriel), degussa. (creating essentials), Flexfab, Gulfstream (A General Dynamics Company), HSH, JEHIER, JM Johns Manville, senior, SOLVAY, Triumph Group, Inc., ZODIAC, & Others…

Executing

1.3 Define New Fire Threat

- Report DOT/FAA/AR-99/44 – “Development of Improved Flammability Criteria for Aircraft Thermal Acoustic Insulation,” September 2000
- Fire Threat: 101.6 by 101.6 by 228.6-mm Urethane Foam Block (Density: 16.02 kg/m^3)
- Environment:
  - ✓ Sea Level
  - ✓ Narrow-body and Wide-body attic
  - ✓ Insulation blankets in attic
  - ✓ Quasi-Std Ambient Temperature

1.4 Test Methods Selection

MEASUREMENT	MATERIAL TEST METHOD					
	12-Sec Vertical Bunsen Burner	Intermediate-Scale	OSU Heat Release	Smoke	Microscale Combustion Calorimeter	Radiant Heat Panel
Fire Propagation	●	●				●
Burn Area		●				
After Flame Time	●	●				●
Drip Flame Time	●					
Total Heat Release			●		●	
Heat Release Rate			●		●	
Onset Temperature					●	
Combustion Temperature					●	
% Char					●	
Smoke Density				●		

Executing

1.5 Material Selection

- Materials tested included most of the non-metal aircraft ducting materials:
  - ✓ Thermosetting (TS)
  - ✓ Thermoplastics (TP)
  - ✓ Combination/Composite TS/TP (Flexible)
  - ✓ Films
  - ✓ Tapes
  - ✓ Hook & Loop
  - ✓ Insulation/Fire Protection Jackets

Executing

1.6 Material Testing

- Material Fireworthiness Determination:
  - ✓ High ignition temperature
  - ✓ Low total heat release
  - ✓ Low heat release rate
  - ✓ Low smoke emission
- Used OSU heat release, smoke and microscale combustion calorimeter test methods to determine material properties.
- Materials ranked
- Results used to predict fire propagation performance during the intermediate-scale testing, radiant heat panel test and development of new test method.

1.6 Material Testing (Cont.) – Material Fireworthiness Ranking

Best

Worst

12 VBB Material	Final Rank
R	1
U	2
X	3
Y	3
H	4
P	4
O	5
N	6
T	6
K	7
Q	8
B/AB	9
F	10
G	11
M	12
W	13
C	14
V	15

* Ranking based on FAA's 12-seconds Vertical Bunsen Burner tests.

MATERIAL	FINAL RANK
O	1
R	2
T	3
P	4
U	5
V	6
D	6
W	7
F	8
M	9
G	10
Q	11
H	12
B	13
AD	14
AW	15
X	15
Y	16
K	17
Coated Taped N	17
N	18
Taped N	19
C	20

* Ranking based on Microscale Combustion Calorimeter & NBS smoke tests.

Executing

1.6 Material Testing (Cont.)

- Aircraft ducting materials were tested using the intermediate-scale fire test to expose them to the new fire threat (“standard”).
- Fire Threat: 101.6 by 101.6 by 228.6-mm Urethane Foam Block (Density: 16.02 kg/m^3)
- An 243.8 cm (varied) aircraft duct place inside the attic of a 304.8 cm long aircraft fuselage section.
- Wide-body and narrow-body attic tested.
- Attic are instrumented with thermocouples and calorimeters.
- Fire was initiated 30 seconds after data acquisition system was activated.
- Test ended after fire self-extinguished (ignition source or duct, the one with the longest period)

1.6 Material Testing (Cont.)

Best

Worst

MATERIAL	FINAL RANK
O	1
R	2
T	3
P	4
U	5
V	6
D	6
W	7
F	8
M	9
G	10
Q	11
H	12
B	13
AD	14
AW	15
X	15
Y	16
K	17
Coated Taped N	17
N	18
Taped N	19
C	20

* Ranking based on Microscale Combustion Calorimeter & NBS smoke tests.

Intermediate-Scale Test Results

- Self-extinguished within 3 min without significant duct damage (<15%)
- Burned for a long period of time (AFT> 9 min)
- Burned a significantly portion of the duct (>90%) in less than 6 minutes

Note: Materials D, G & AW had low onset temperatures that allows for ignition at lower temperatures than the other materials with the green dot. AW also has very high specific heat release and heat release rate.

1.7 Evaluate Test Methods

MEASUREMENT	MATERIAL TEST METHOD					
	12-Sec Vertical Bunsen Burner	Intermediate-Scale	OSU Heat Release	Smoke	Microscale Combustion Calorimeter	Radiant Heat Panel
Fire Propagation	●	●				●
Burn Area		●				
After Flame Time	●	●				●
Drip Flame Time	●					
Total Heat Release			●		●	
Heat Release Rate			●		●	
Onset Temperature					●	
Combustion Temperature					●	
% Char					●	
Smoke Density				●		

Current small-scale test measures:

- Fire Propagation (Burn Length)
- After flame time
- Drip flame time

Radiant heat panel test measures:

- Fire Propagation (Flame Propagation)
- After Flame Time

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1.7 Evaluate Test Methods (Cont.)

- Selected the radiant heat panel test (FAR25.856) for evaluation
- RHP is currently used to certify t/a insulation
- It was developed using the new fire threat
- Procedure:
  - Condition sample (318mm x 584mm) & calibrate radiant panel to 1.7 Watts/cm^2
  - Ignite propane pilot (127mm long)
  - Place secured sample on the sliding platform holder
  - Push sliding platform into radiant heat panel/pilot chamber
  - Impinge pilot on sample for 15 seconds
  - Remove pilot and record flame propagation and after flame time
  - Acceptance criteria: flame propagation <= 5.08cm, after flame time <= 3 seconds

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1.8 Select/Modify Selected Test Method

- After a series of test evaluations, the RHP test method had to be modified.
- To achieve correlation to Intermediate-Scale Fire test, the following issues were addressed:
  - Thermo-Mass Balance (1-min pre-heat)
  - Acceptance Criteria (A-FT increased)
  - Sample Size (Reduced)
  - Radiant Panel Heat Setup (Reduced)
- After addressing issues, the new RHP test procedure was re-evaluated and verified.
- *See next page for the New Flammability Test for Aircraft Ducting*

Executing

EQUIPMENT:

Vertical Bunsen Burner Test Apparatus

(FAR 25.853 or Handbook)

Radiant Heat Panel Test Apparatus

(same as FAR 25.856)

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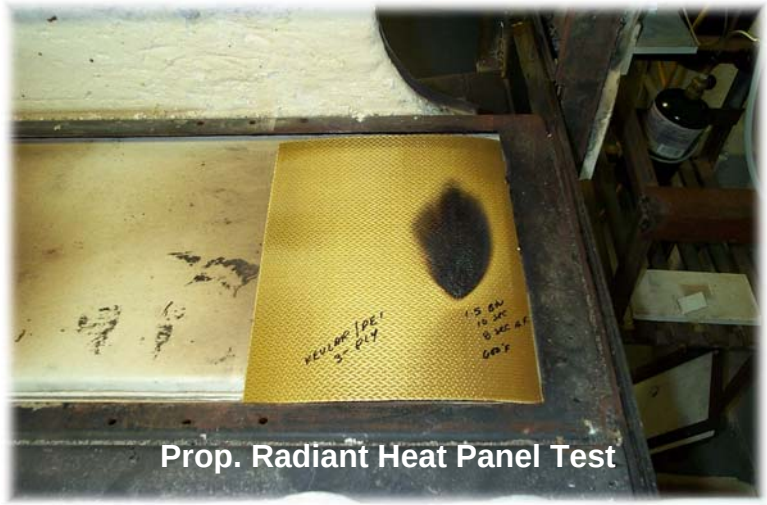
SPECIMEN:

Vertical Bunsen Burner Test

- 6.98cm x 30.42cm (unless actual size smaller)
- Test maximum and minimum thickness
- If thickness > 1.27cm, test material at 1.27cm
- Test flat sheet (t< 0.32cm) if sample smaller than size of specimen



Prop. Radiant Heat Panel Test

- 21.59cm x 27.94cm (unless actual size smaller)
- Test maximum and minimum thickness
- If thickness > 1.27cm, test material at 1.27cm
- Test flat sheet (t< 0.32”) if sample smaller than size of specimen
- Fire Blocking Jacket, hook & loop, tapes, etc.

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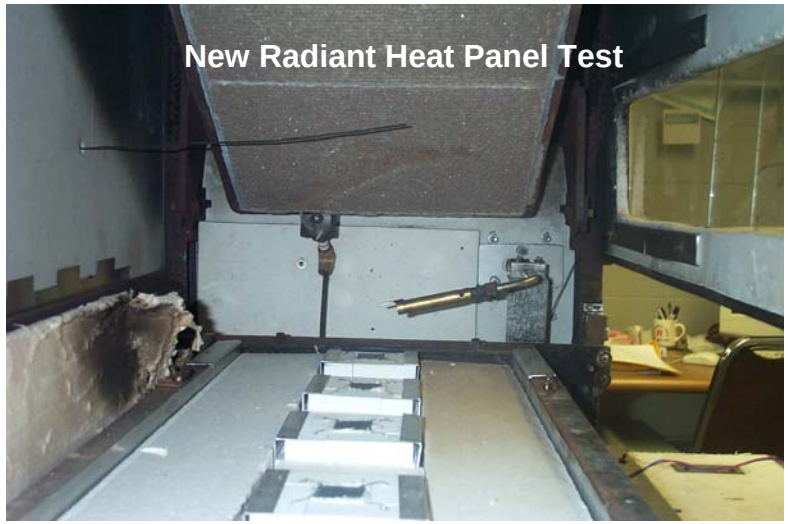
FIRE THREAT:

• Methane Pilot Flame (Inner cone = 2.22cm & tip of flame = 3.81cm)



• 1.13 W/cm^2 Radiant Heat (1 min Exposure)

• Propane Pilot Flame (blue inner cone = 1.90cm, overall flame length = 12.70cm long)

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TEST PROCEDURE:

Vertical Bunsen Burner Test

- Impinge the pilot burner flame on the sample for 12 seconds
- Maintain sample in chamber until flames are self-extinguished or after flame time > 15 seconds
- Record after flame time, burn length, and drip flame time

- Expose sample to 1.13 W/cm^2 radiant heat for 1 minute
- After the 1 minute exposure, impinge the pilot burner flame on the sample for 15 seconds
- Maintain sample in chamber until flames are self-extinguished or after flame time > 45 seconds
- Record after flame time and burn length

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ACCEPTANCE CRITERIA

Vertical Bunsen Burner Test

- Burn Length <= 8”
- Flame Time <= 15 sec
- Drip Flame Time <= 3 sec

New Radiant Heat Panel Test

- Burn Length <= 2”
- After Flame Time <= 45 sec
- Fire Blocking Jacket, tapes or hook and loop shall not shrink away

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12-Sec Vertical Bunsen Burner Test
(Passed Current Test)

New Flammability Test For Aircraft Ducting
(14.5 cm, Exp. > 45 sec, Failed new test)

Material C

Executing

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Material AV B.L = 4.4 cm, A.F.T. = 11 sec), passed

Monitoring & Control

1.9 Verify Test Method (Scope Verification)

MATERIAL	FINAL RANK	ISFT	New RHP
O	1		
R	2		
T	3		
P	4		
U	5		
V	6		
D	6		
W	7		
F	8		
M	9		
G	10		
Q	11		
H	12		
B	13		
AD	14		
AW	15		
X	15		
Y	16		
K	17		
Coated Taped N	17		
N	18		
Taped N	19		
C	20		

Intermediate-Scale Test Results

- Self-extinguished within 3 min without significant duct damage (<15%)
- Burned for a long period of time (AFT> 9 min)
- Burned a significantly portion of the duct (>90%) in less than 6 minutes

New RHP Test Results

- Passed Test
- Failed Test

1.9 Verify Test Method (Scope Verification, Cont.)

MATERIAL: O (PASSED)

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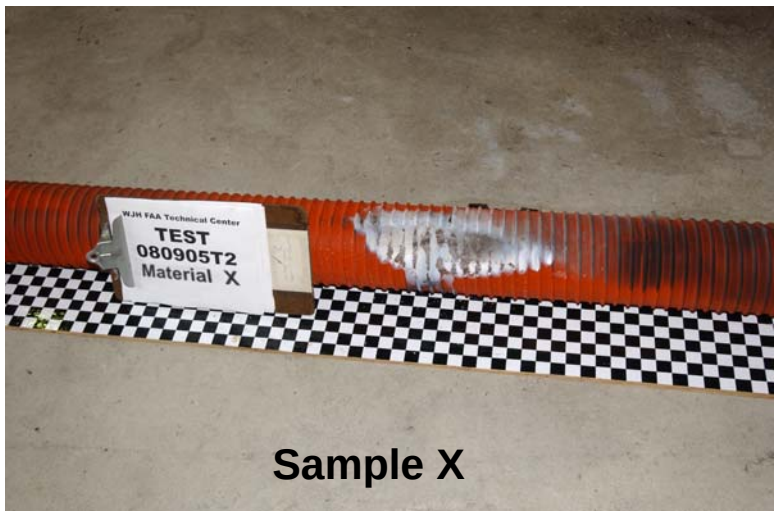
Tested at 1BTU/ft2 Radiant Heat

1.9 Verify Test Method (Scope Verification, Cont.)

MATERIAL: X (PASSED)



Sample X

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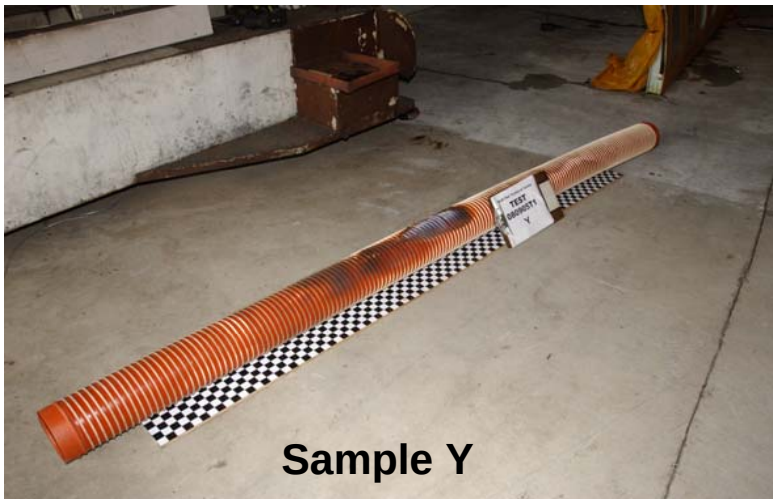
Tested at 1BTU/ft2 Radiant Heat

1.9 Verify Test Method (Scope Verification, Cont.)

MATERIAL: Y (PASSED)



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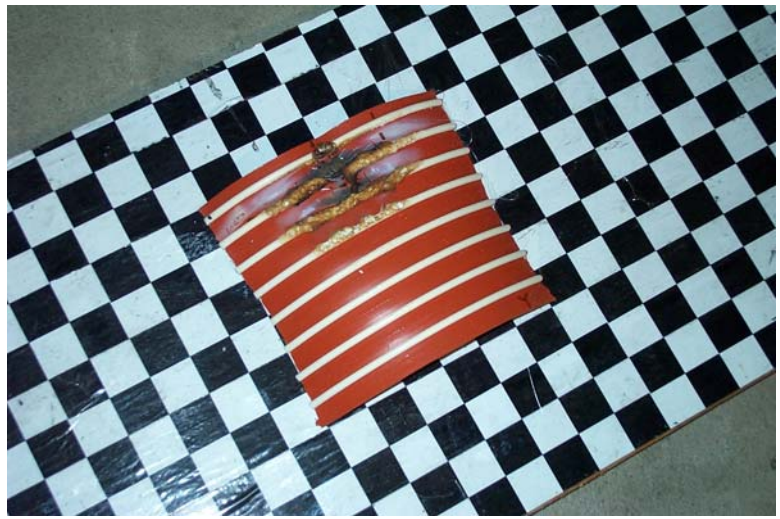
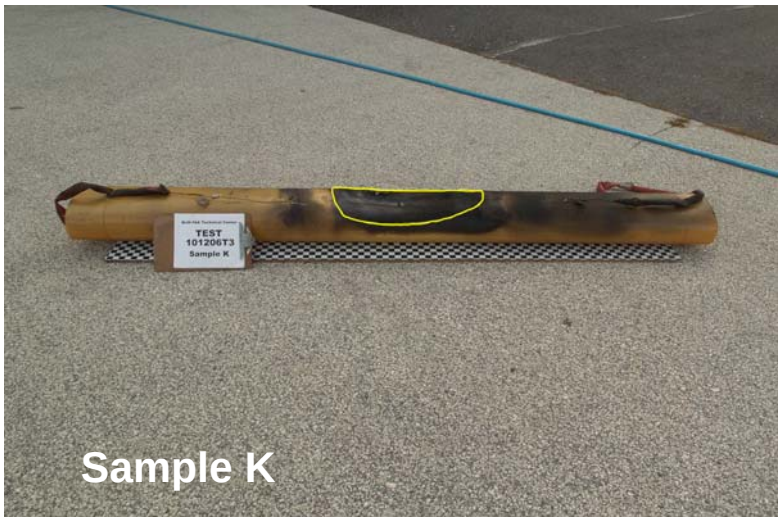


Tested at 1BTU/ft2 Radiant Heat

1.9 Verify Test Method (Scope Verification, Cont.)

MATERIAL: K (PASSED)



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Tested at 1BTU/ft2 Radiant Heat

1.9 Verify Test Method (Scope Verification, Cont.)

MATERIAL: D (FAILED)

T_i = <300 ºC
IST Burning Time = N/A minutes
IST Burned Area = N/A cm^2
IST Peak Temperature = N/A ºC

RP Burned Length = 16 cm
RP After Flame = >40 seconds
OSU Peak Heat Released = 66 kW/m^2
OSU Total Heat Released = 30 kW/m^2
Smoke Density = 4.5

1.9 Verify Test Method (Scope Verification, Cont.)

MATERIAL: AW (FAILED)

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Tested at 1BTU/ft2 Radiant Heat

T_i = 488 ºC
HRR = 427 W/g
IST Burning Time = 8.5 minutes
IST Burned Length = 64.8 cm
IST Peak Temperature = 1409 ºC
IST Peak Heat Release Rate = 64 kW/m^2

RHP Burn Length = 7.5 cm
RHP After Flame Time > 50 seconds

MATERIAL: COATED/TAPED N (FAILED)

Sample Coated N

T_i = N/A
IST Burning Time = 40 minutes
IST Burned Area = 4985 cm^2
IST Peak Temperature = 766 ºC

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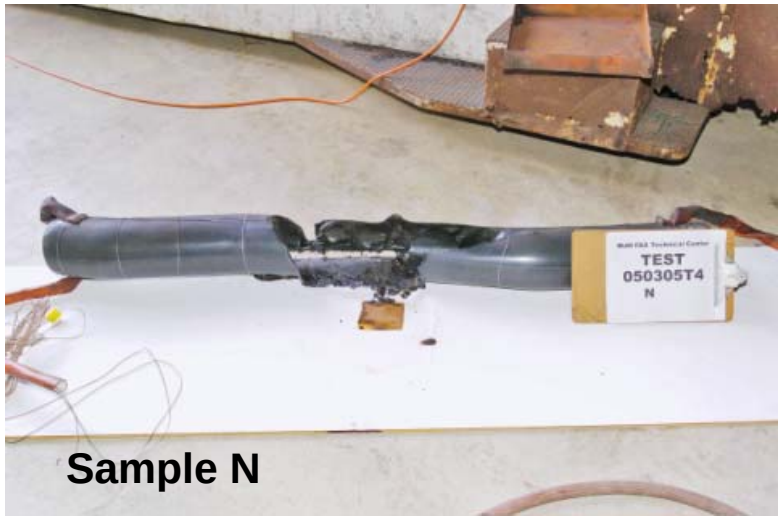
RP Burned Length = 9.7 cm
RP After Flame = >40 seconds
OSU Peak Heat Released = N/A
OSU Total Heat Released = N/A
Smoke Density = N/A

Monitoring & Control

MATERIAL: N (FAILED)



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T_i = 358 ºC
IST Burning Time = 30 minutes
IST Burned Area = 1752 cm^2
IST Peak Temperature = 708 ºC

RP Burned Length = 16 cm
RP After Flame = >40 seconds
OSU Peak Heat Released = 179 kW/m^2
OSU Total Heat Released = 114 kW/m^2
Smoke Density = 176

MATERIAL: C (FAILED)

=

Tested at 1BTU/ft2 Radiant Heat

Closing

1.10 Publish Test Method

- Draft report was created to document project and deliver new test protocol
- Draft report under FAA internal editing
- Draft report submitted to project sponsor in September 2007 for review

Closing

Questions?