LESSONS LEARNED:

Use of Microscale Combustion Calorimetry in the Development of a New Radiant Heat Panel Test for Aircraft Ducting

Federal Aviation Administration

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Outline

LESSONS LEARNED:

- Background
- Lesson 1: Thermo-Mass Balance
- Lesson 2: Radiant Heat Panel Setting
- Lesson 3: Screening Tool

Background

BACKGROUND

- The FAA initiated efforts to improve the fireworthiness of hidden areas in the aircraft (T/A Insulation) in 1995 after several fire 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.
- In 2004, as part of the project baseline, the aircraft ducting materials were re-tested with the 12VBB test. They all passed the test.

SwissAir MD-11 Accident Investigation Reconstruction, 1998

Background

BACKGROUND (CONT.)

- 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.
- In 2007, after hundreds of material tests, a modified version of the radiant heat panel test (FAR 25.856) was selected as the best candidate to replace the 12VBB test to certify aircraft ducting.

Background

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Current FAA Test: 12-sec Vertical Bunsen Burner

Material: Glass/Epoxy/Polyurethane

Background

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Intermediate-Scale Fire Test: New Fire Threat

Material: Glass/Epoxy/Polyurethane

Background

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Improved Radiant Heat Panel Test for Aircraft Ducting – Glass/Epoxy & Polyurethane Foam: Sample C

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Lessons Learn 1

Lessons Learn 1: Thermo-Mass Balance

- MSCC was used to determine if there was some difference in material composition between two given samples or if it was just a thickness difference.
- Two different samples of Kevlar/Epoxy were tested with the FAR25.856 radiant heat panel test: one was a 2-plies composite and the other a 4-plies composite.
- The 2-plies sample was failing significantly the flame propagation of the test, while the 4-plies sample was within the pass criteria.
- The MSCC results indicated that the difference was merely a thickness difference.
- A one-minute heat-soak period was added to the test to balance the temperature between the top and bottom surfaces of the specimens.

Lessons Learn 1

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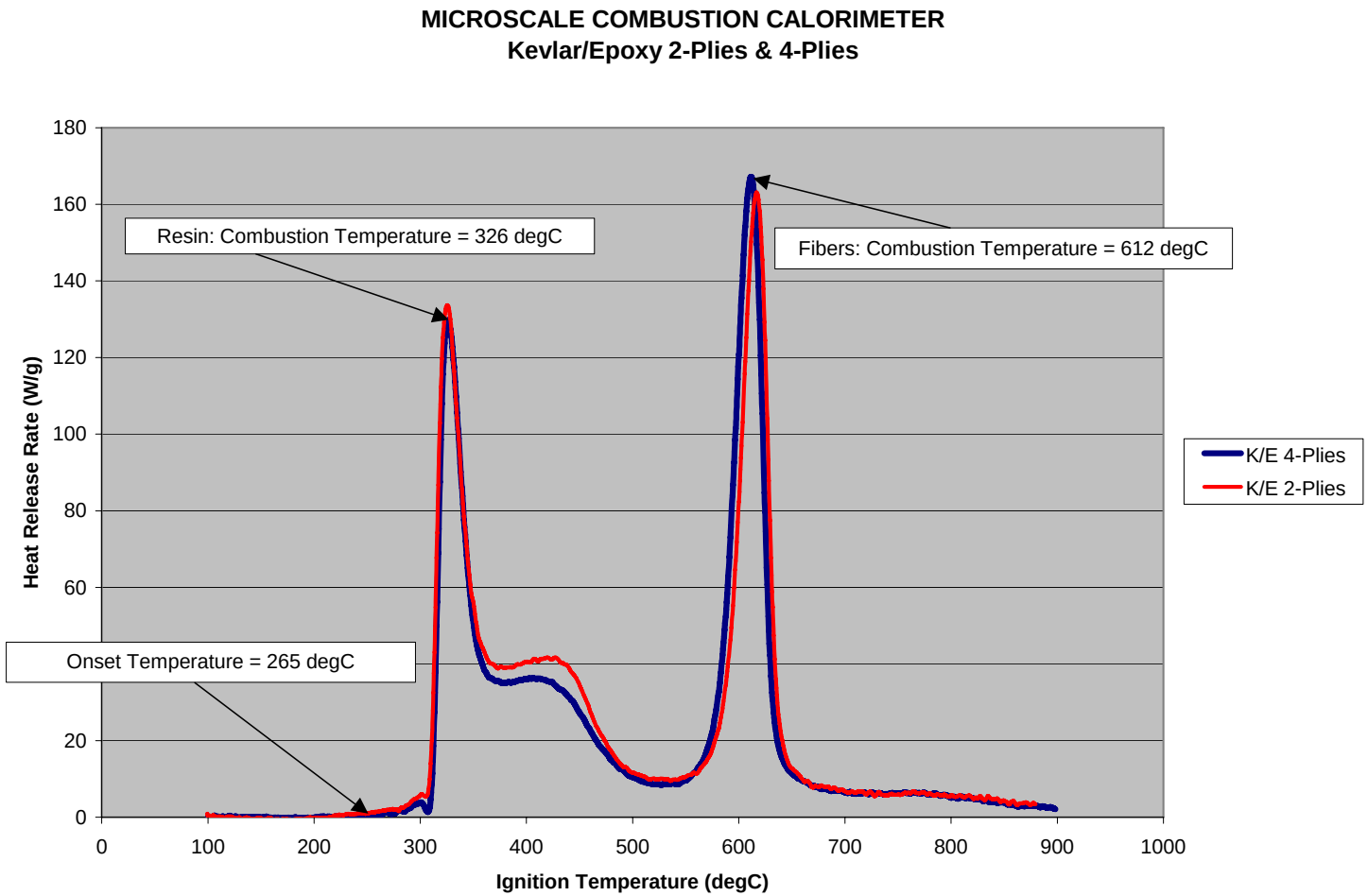
FAR25.856 Radiant Heat Panel Test of K/E 2-Plies & K/E 4-Plies

Lessons Learn 1: Thermo-Mass Balance



Lessons Learn 1

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1-Minute heat-soak added to radiant heat panel test. Sample K/E 4 Plies

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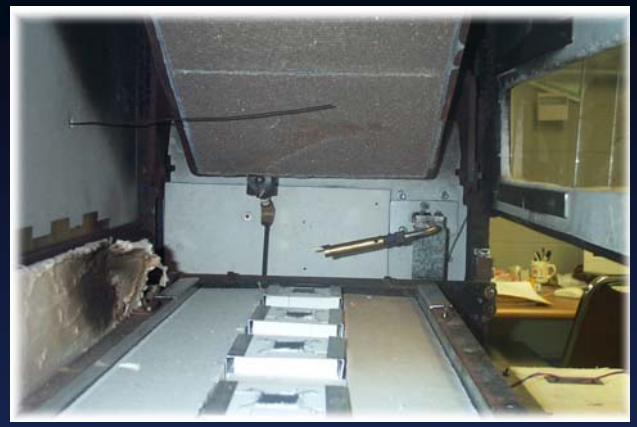
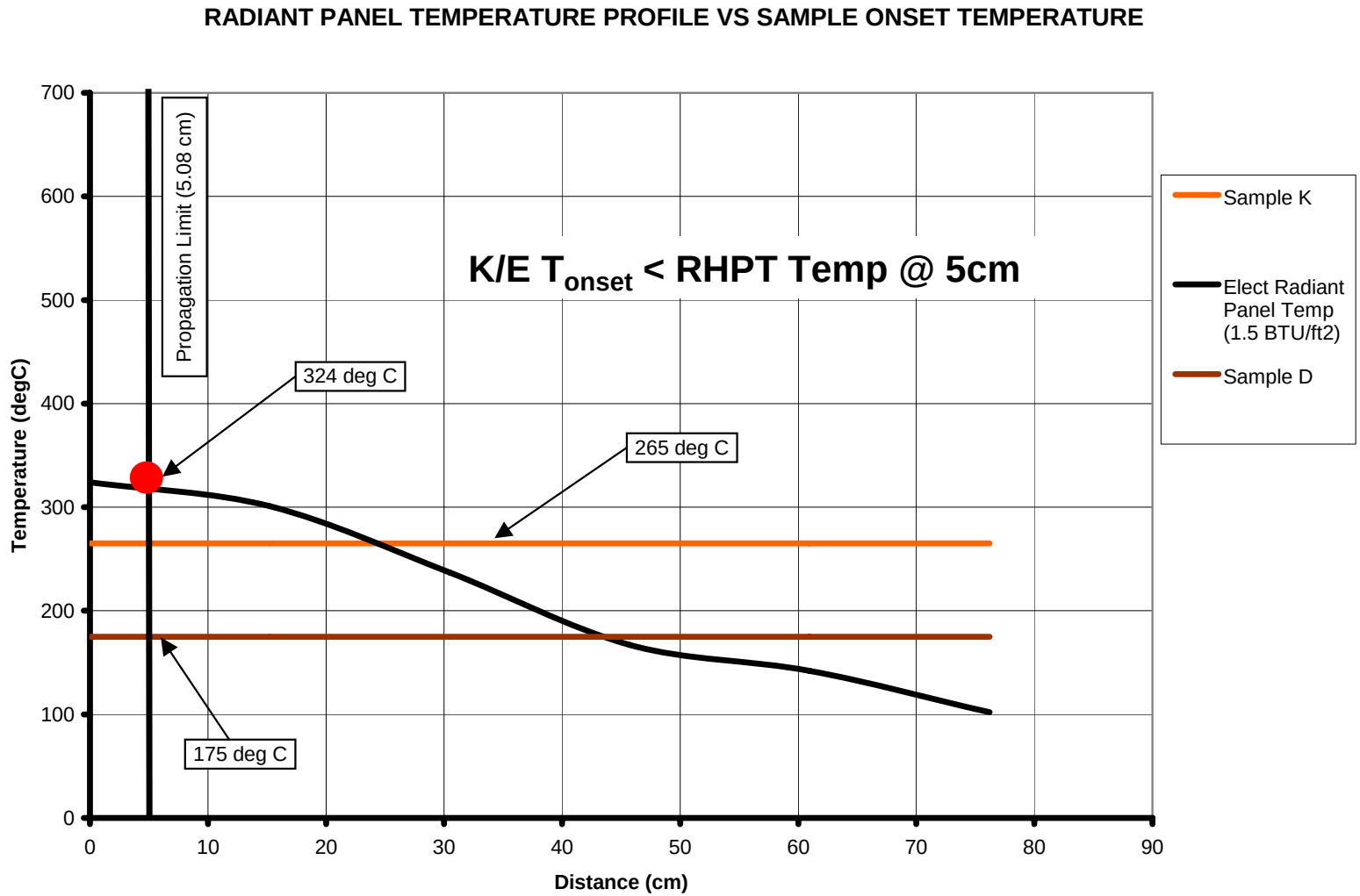
Lessons Learn 2

Lessons Learn 2: Radiant Heat Panel Setting

- MSCC was also used during the determination of the correct radiant heat panel setting.
- The intermediate-scale fire test results showed that Kevlar/Epoxy performed in an acceptable manner: self-extinguished within 3 minutes and burned area < 15% of total area.
- The modified radiant heat panel test, on the other hand, was failing the Kevlar/Epoxy samples.
- The radiant heat panel temperature gradient, along the specimen tray, was measured.
- The onset temperature of Kevlar/Epoxy was determined using MSCC
- The material onset temp must be greater than the radiant heat panel temperature at the 5.08 cm mark to have a chance of passing the test.

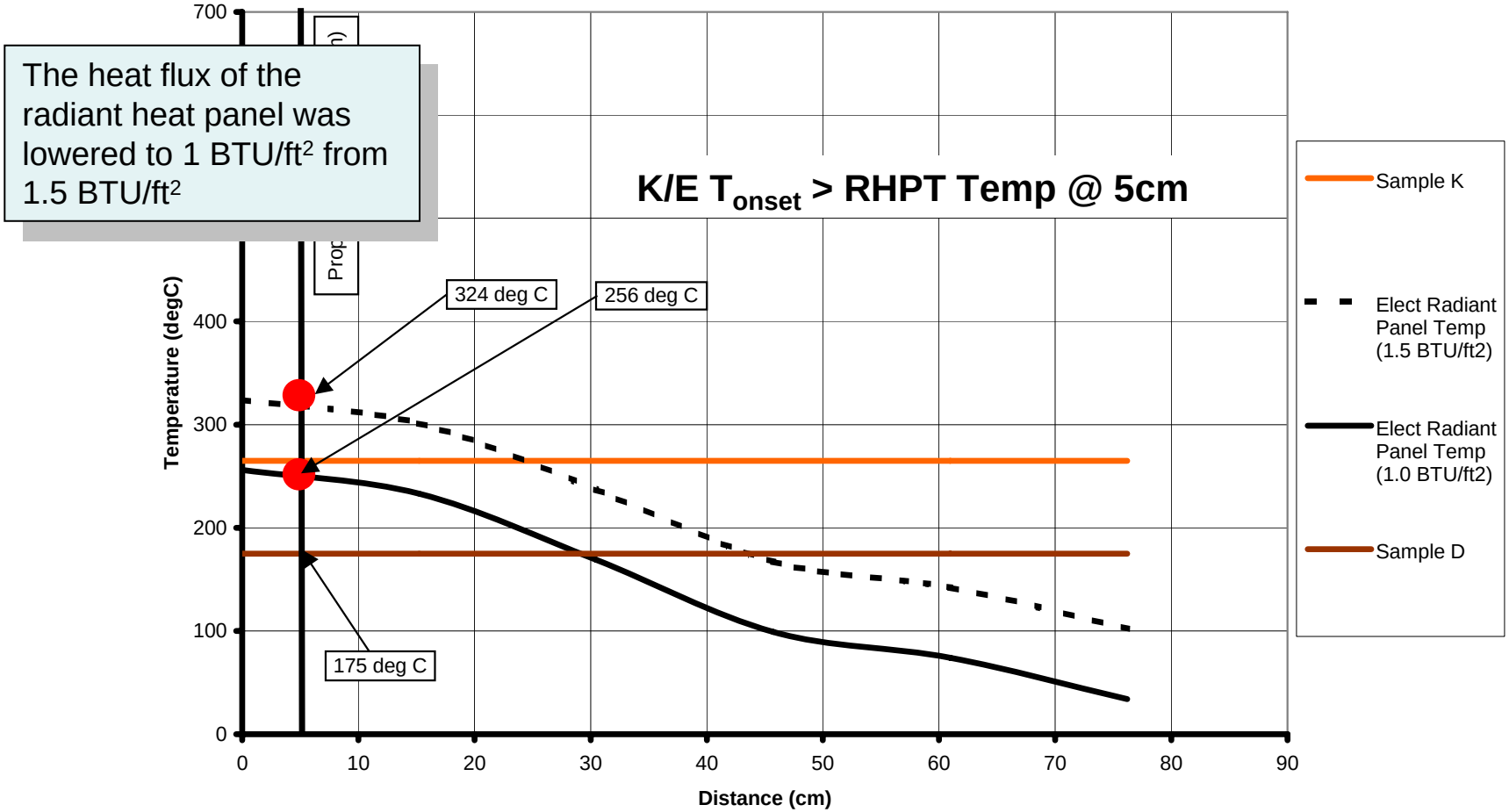


Lessons Learn 2



Lessons Learn 2

The heat flux of the radiant heat panel was lowered to 1 BTU/ft^2 from 1.5 BTU/ft^2



Lessons Learn 2

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Kevlar/Epoxy tested with new Radiant Heat Panel Test (1 BTU/ft2).
Passes test: Burn Length = 3.8cm, After-Flame Time = 14 secs

Lessons Learn 2

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Sample D tested with new Radiant Heat Panel Test (1 BTU/ft2).
Failed Test: Burn Length = 9.70cm, After-Flame Time > 50 secs

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Lessons Learn 3

Lessons Learn 3: Screening Tool

Determine Fireworthiness of Materials

- One of the first activities listed on the project's work breakdown structure was to determine the "fireworthiness" of the different ducting materials.
- The results were to be ranked and used to predict performance during the intermediate-scale fire test and fire propagation test.
- Several aircraft fire test methods were used: OSU heat release, NBS smoke, and microscale combustion calorimetry.
- Combinations of some of these tests were used to determine when the material would ignite, how much heat would they produce, at what rate, and how much smoke would they produced.

Lessons Learn 3

Lessons Learn 3: Screening Tool

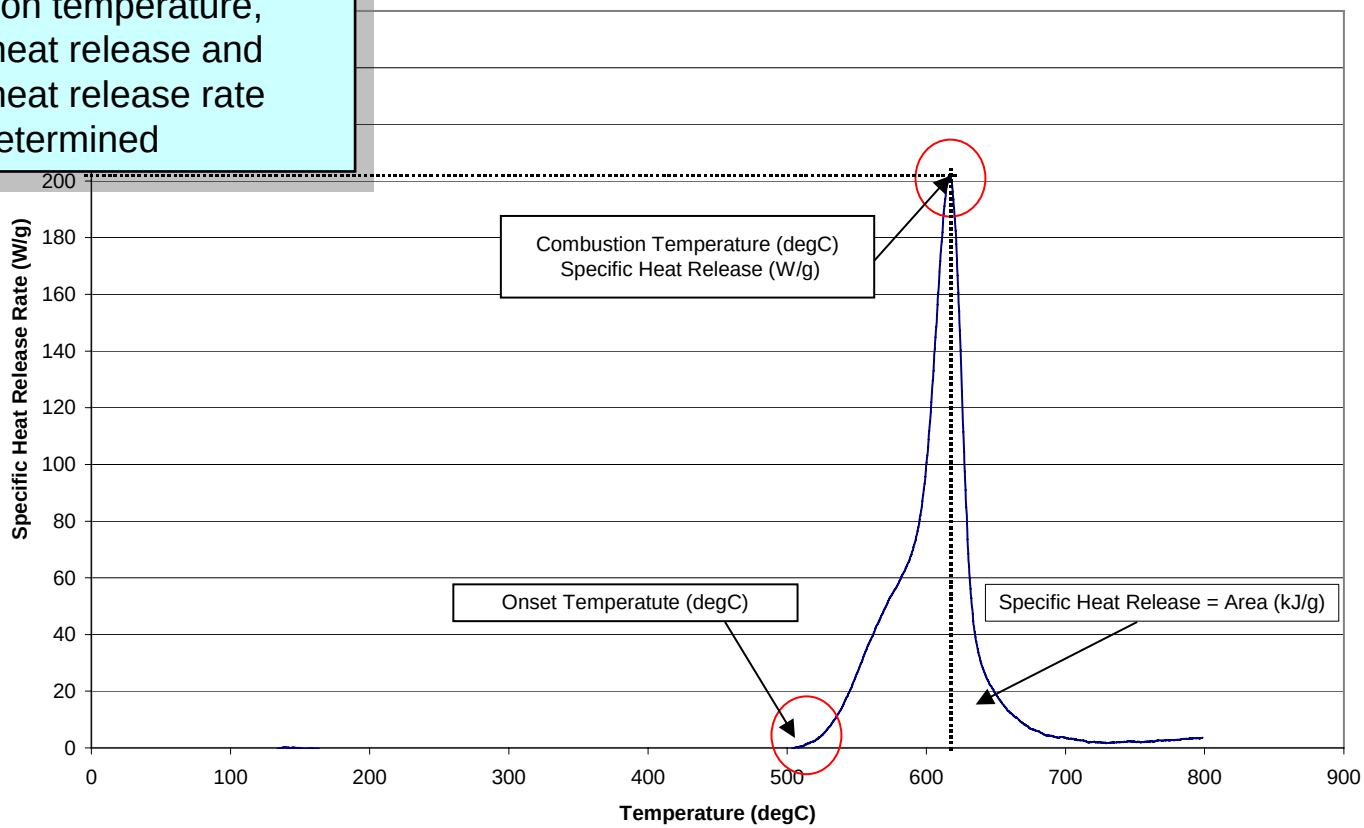
Aircraft Fire Test Methods Selection

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				●		

Best combination to answer the questions were: NBS smoke & MSCC tests)

Lessons Learn 3

From this test result chart, the onset temperature, combustion temperature, specific heat release and specific heat release rate can be determined



Lessons Learn 3

Lessons Learn 3: Screening Tool

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 (T_o, T_c, SHR, HRR) & NBS smoke tests (D_s).

Example:

N = Nylon

W = PEI

C = Aircraft duct (glass/epoxy and polyurethane)

Lessons Learn 3

Lessons Learn 3: Screening Tool

Intermediate-Scale Fire Test (ISFT)

- Aircraft ducting materials were tested using the ISFT 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 was 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)

Lessons Learn 3

Lessons Learn 3: Screening Tool

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 (>50%) 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.

Lessons Learn 3

Lessons Learn 3: Screening Tool

New Fire Propagation Test

• The aircraft ducting materials were also tested with the improved radiant heat panel test (RHPT) to validate it.

• Procedure:

- Calibrated equipment and apparatus according to FAR 25.856 with the exception of the radiant heat panel setting; heat panel calibrated to 1.13 W/cm^2

- Placed material specimen on test apparatus sliding tray

- Heated material for 1 minute

- After the 1-minute preheat, impinged pilot flame for 15 seconds

- Allowed material to burn until it self-extinguished or time exceeded 45 seconds

- Acceptance Criteria: Burn Length <= 5.08cm, After-Flame Time <= 45 seconds

Lessons Learn 3

Lessons Learn 3: Screening Tool

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 (>50%) in less than 6 minutes

New RHP Test Results

- ● Passed Test
- ● Failed Test

Lessons Learn 3

Lessons Learn 3: Screening Tool

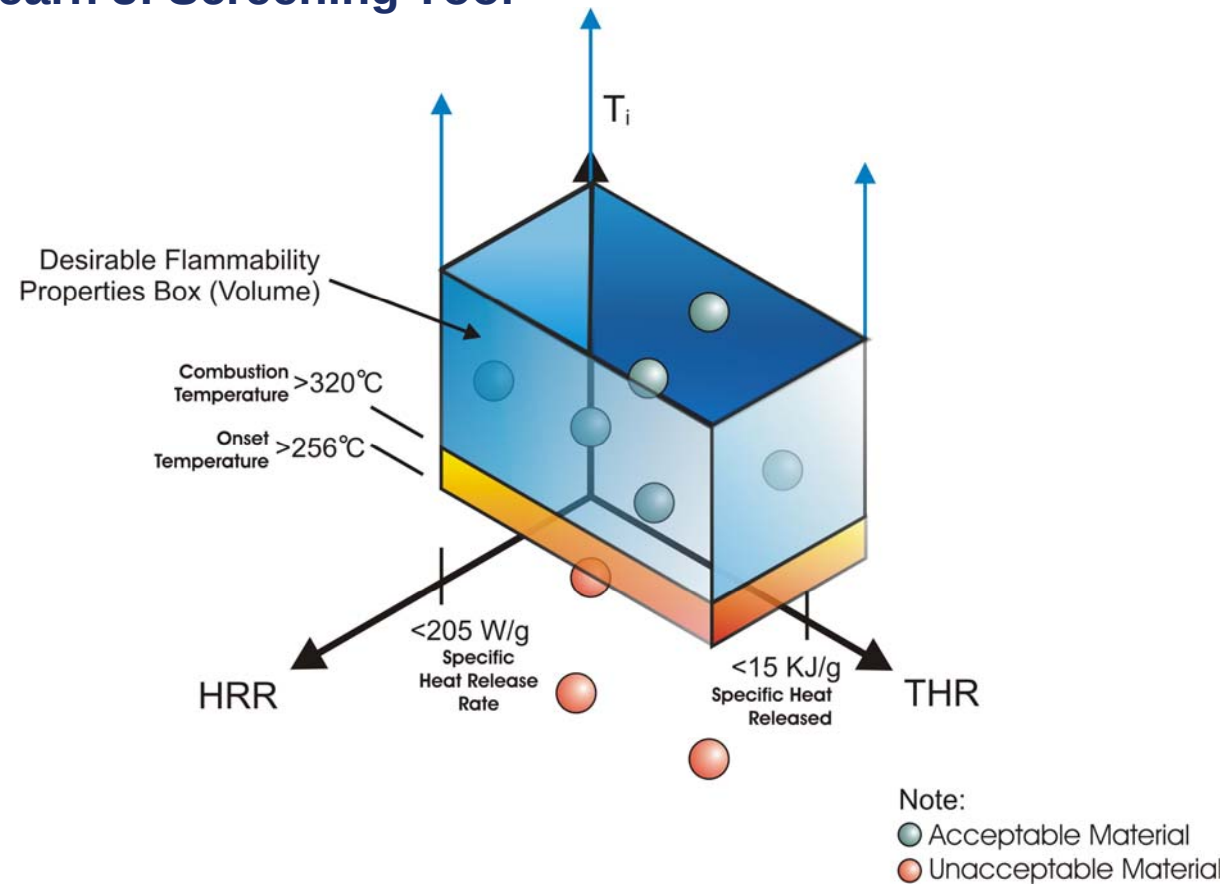
- The aircraft ducting materials that performed well during the ISFT and the new RHPT had the following flammability characteristics:
  - Onset Temperature > 256 °C
  - Combustion Temperature > 320 °C
  - Specific Heat Release < 15 kJ/g
  - Specific Heat Release Rate < 205 W/g

Note: there were a few composite materials that performed well in the ISFT and new RHPT that had one of its materials with flammability characteristics outside this envelop. The way they were configured prevented fire propagation beyond the threshold.

- These flammability characteristics may be used to screen materials to be considered in aircraft ducting applications.

Lessons Learn 3

Lessons Learn 3: Screening Tool



Questions?