COMPOSITE MATERIAL FIRE FIGHTING

Presented to: International Aircraft Materials Fire Test Working Group
Atlantic City, New Jersey, USA

Presented By: John C. Hode
SRA International

Date: Wednesday, October 21, 2009

Composite Aircraft Fire Fighting

THE BIG QUESTION:

Do composite skinned aircraft require more agent to control external fire and facilitate evacuation?

Must first evaluate if composite materials used for aircraft construction will continue to burn after exposing pool fire is extinguished.

Representative Incident
Air China at Japan Naha Airport, August 19, 2007

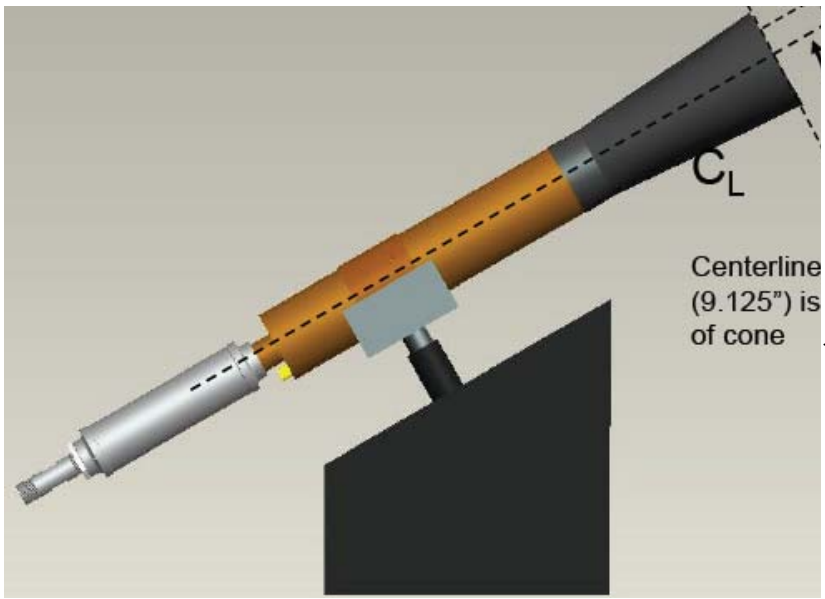
External Fire Control Defined

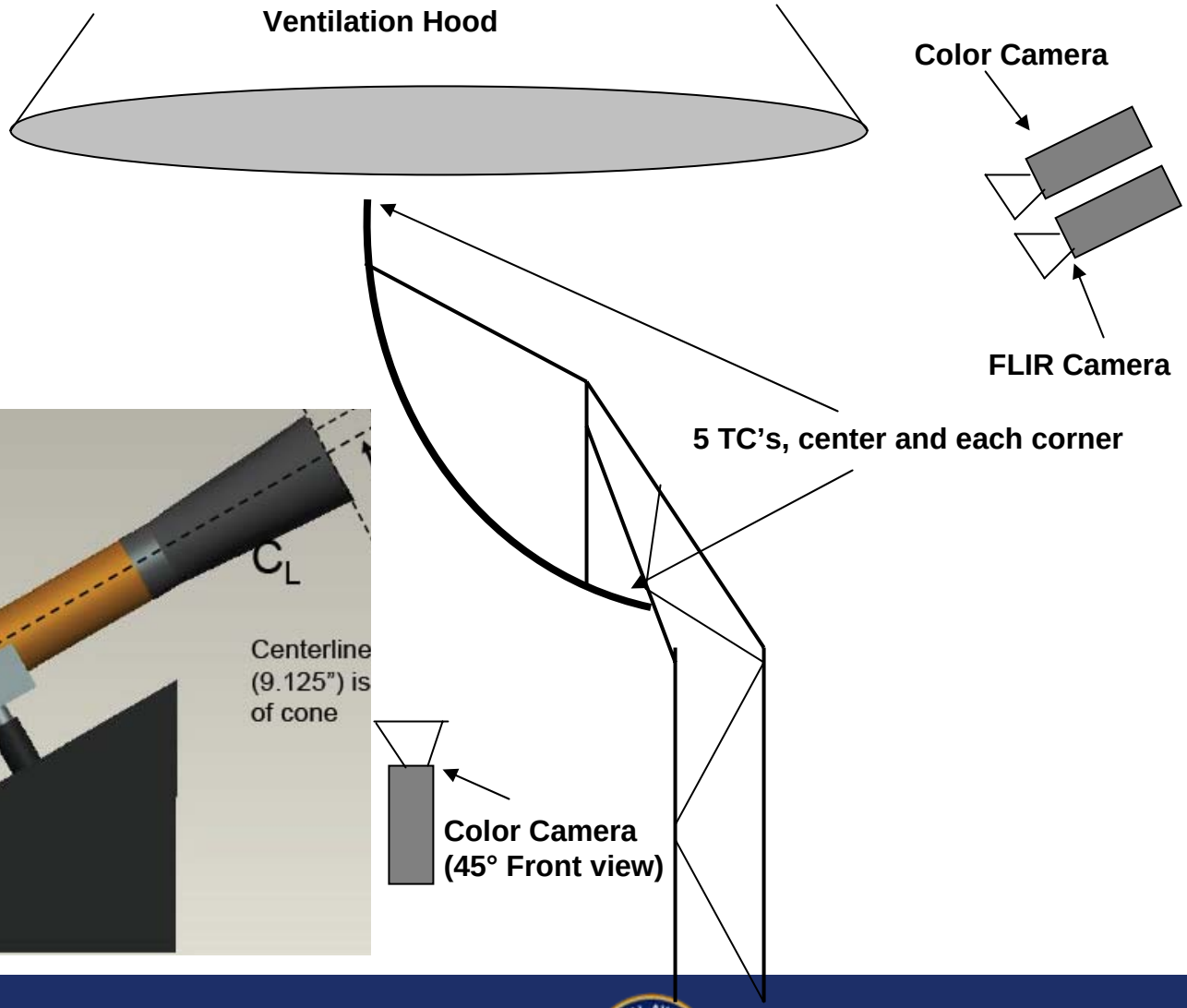
- **Extinguishment of the body of external fire**
  - Our question: Will the composite skin continue to burn after the pool fire is extinguished, thereby requiring the fire service to need more extinguishing agent in the initial attack?
- **Cooling of the composite skin to below 300°F**
  - Our question: How fast does the composite skin cool on its own and how much water and foam is needed to cool it faster?
    - 300°F is recommended in the basic ARFF training.
    - Aircraft fuels all have auto ignition temperatures above 410°F. This allows for some level of a safety factor.

Actual Test Set-up

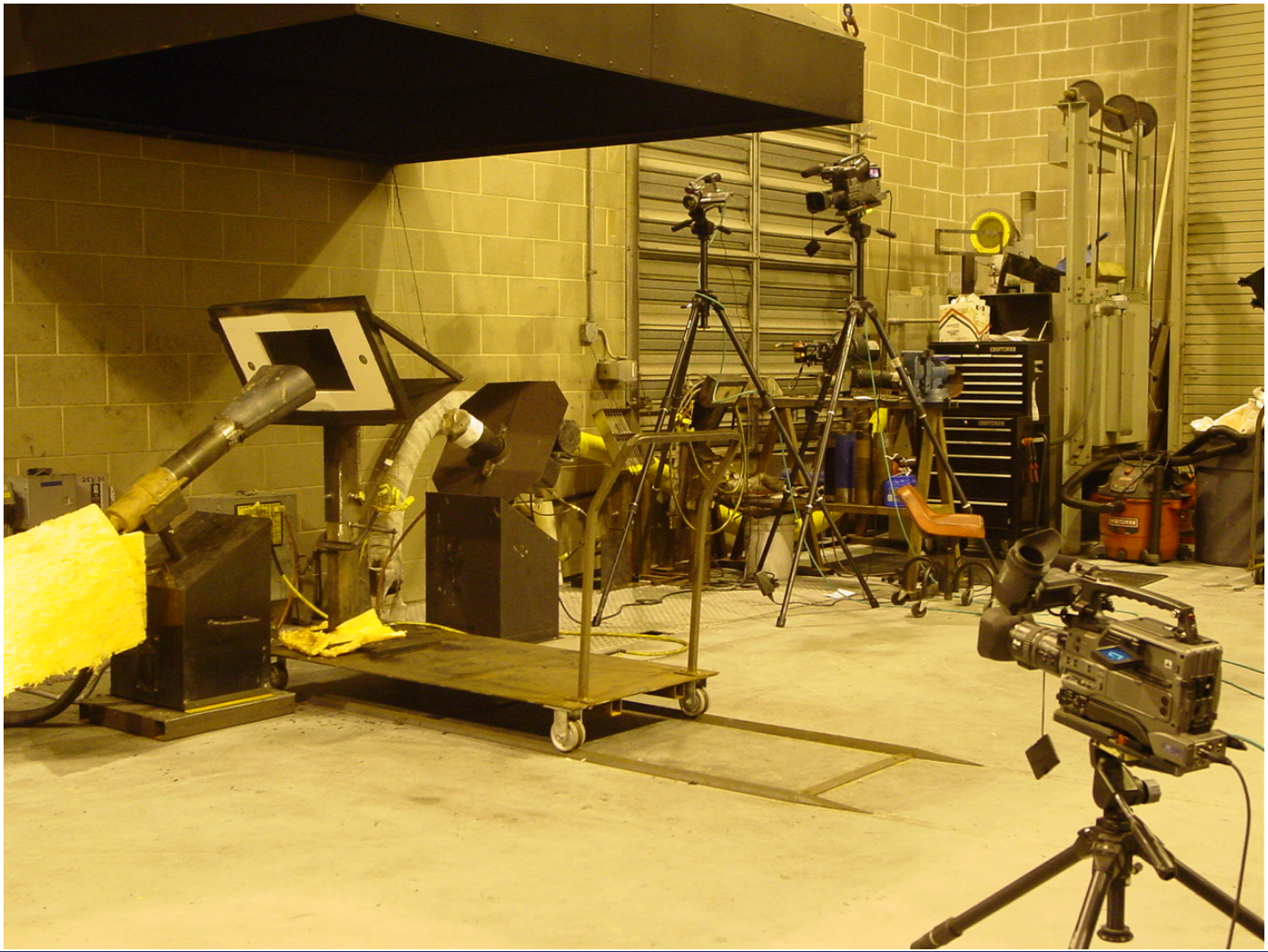
- **Sample oriented to the burner in the same manner as insulation blanket samples.**
- **Thermocouples (TC) fixed to back at each of the four corners and center of the sample.**
- **Forward Looking Infrared (FLIR) video camera placed at rear of sample to correlate with TC data.**
  - FLIR camera captures still color & IR images every 20 seconds in addition to the running video.
- **Color video camera positioned adjacent to FLIR camera to capture the same view. Second color video camera set at 45° to the front face of the sample**

Actual Test Set-up

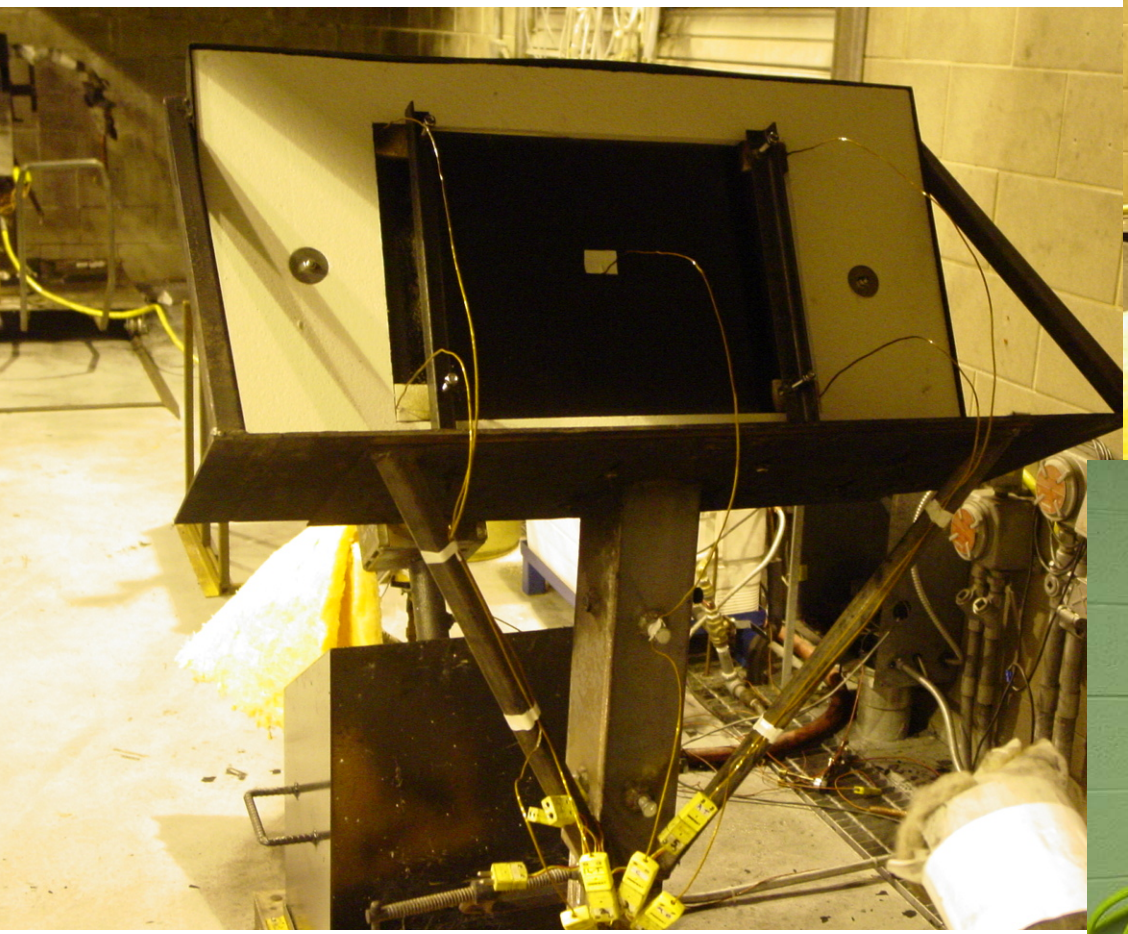


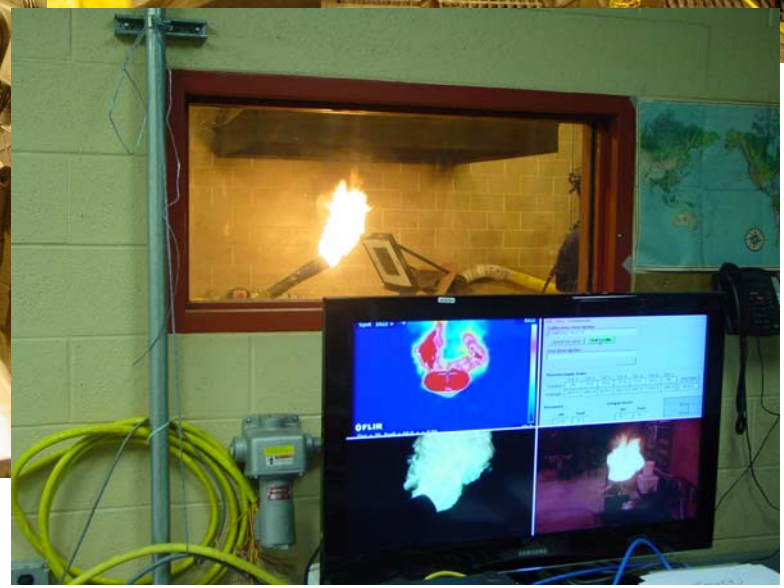


Actual Test Set-up



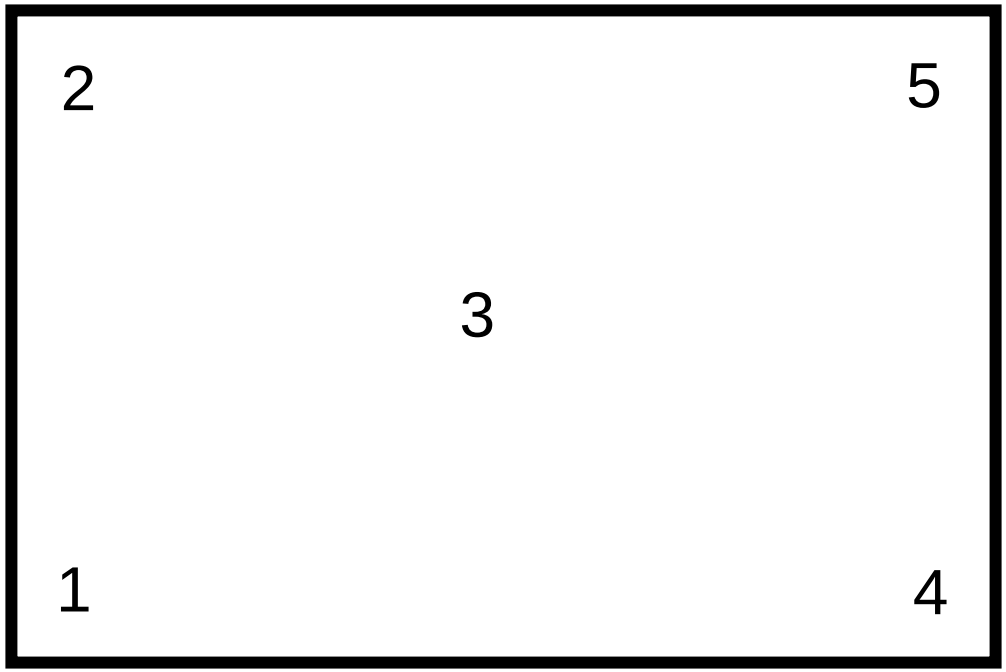
Actual Test Set-up





Actual Test Set-up

Thermocouple Positions



Testing in Two Stages

First stage:

Determine if self-sustained combustion or smoldering will occur.

Second stage:

Determine how much fire agent is needed to extinguish visible fire and cool the material sufficiently to prevent re-ignition.

We are conducting First Stage testing currently.

It was decided to vary the exposure times of First Stage tests.

- Intervals used: 10, 5, 3, 2, & 1 minutes

Material Being Used Currently

- **Air Force carbon fiber composite**
  - Flat panels, 12 inches by 18 inches
  - Unidirectional prepreg; Cytec 5208/T-300, 16 plies, (0, 90, +45, -45)S2
  - 350°F cure, Tg 410°F
- **Panels built at Ogden ALC in the composite shop.**
  - Made for F-16 composite repair training.
- **No consistent data on resin content is available. An attempt has been made to clarify this issue through testing.**
  - Microscale Combustion Calorimeter testing done to help assess epoxy percentage.
  - ASTM test being conducted to determine ‘as built’ fiber/resin volumes

MCC and FTIR Testing

- **Microscale Combustion Calorimeter (MCC) evaluation of panels provided the following;**

SAMPLE	HEAT RELEASE CAPACITY, J/g-K	MAX HEAT RELEASE RATE, W/g	TOTAL HEAT RELEASE, kJ/g	TEMPERATURE of PEAK, °C	CHAR, %
BOEING PANEL	100	95	7	417	70
AIR FORCE PANEL	165	163	12.5	410	50

(Data is the average of 3 tests)

- **Fourier Transform Infrared (FTIR) Spectroscopy showed the epoxies used in both panels are similar**

MCC and FTIR Testing

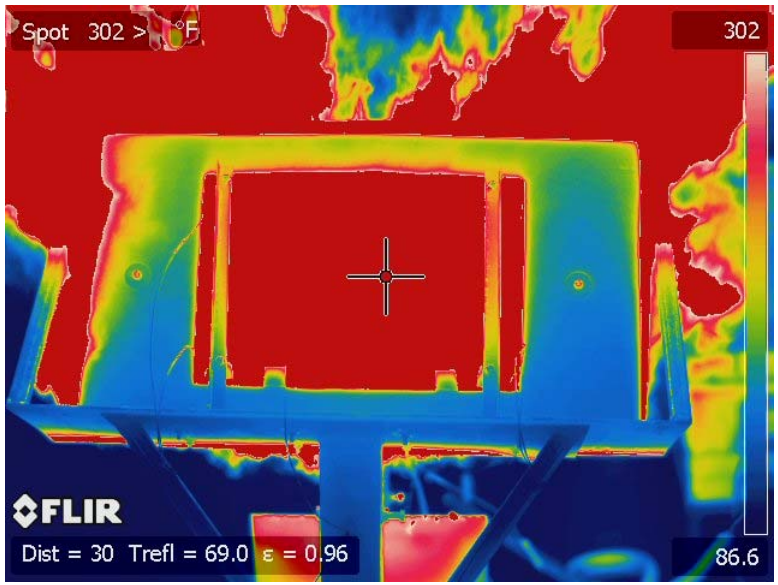
So what does this mean?

- **MCC comparison to Boeing Specification panel shows the Air Force panel has similar resin composition but higher resin content.**
- **More epoxy = more available fuel.**
- **50% Char of the Air Force panels shows they have less than 50% fiber.**

The Air Force panels are a worse case scenario since normal fiber/epoxy percentages in structural aircraft carbon composite are on the order of 55-65% fiber.

First Stage Testing

- **The first several tests identified necessary adjustments to refine our methodology.**
  - Attachment of thermocouples
  - Method to secure panel in place
  - Placement of thermocouples
  - FLIR camera settings



Test 2, FLIR set to low temp. scale


Test 1, Holder Failure

Test 10 Video

Test 12 Video

Results

- **The center thermocouple is used as the representative of the panel temperature (TC 3)**
- **Based on thermocouple data, the average temperature on the backside has been 653.1°F in a range from 599.8°F to 720.8°F.**
- **This is less than half of the burner temperature. (about 1800°F)**
- **Shorter pre-burn times seem to reach a max panel temperature *after* exposure.**

Three Minute Pre-burn Tests

TEST	TC MAX PANEL TEMP	TIME TO MAX PANEL TEMP
7	691.8	3:16
8	650.6	3:17
10	720.8	3:18

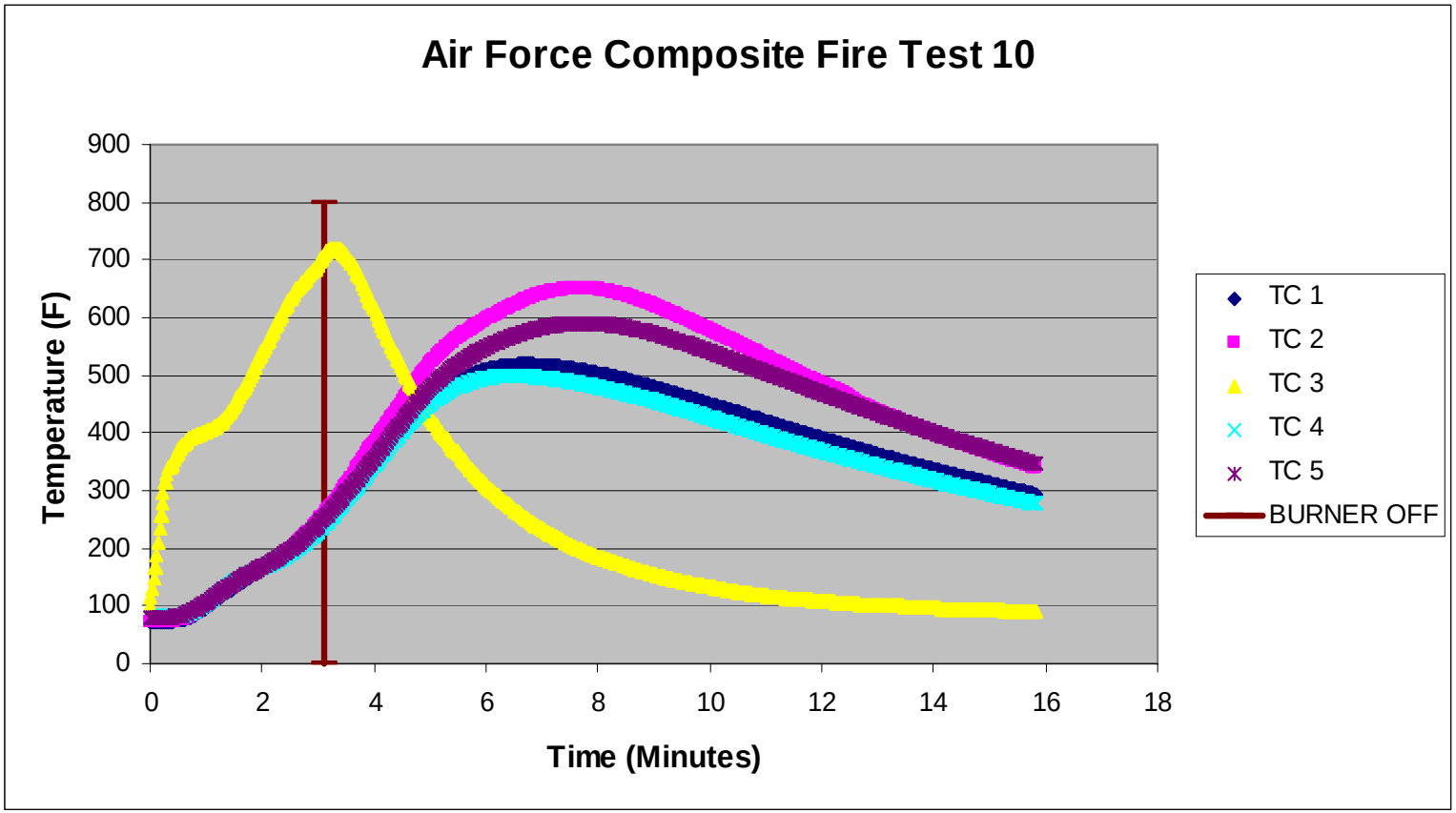
Two Minute Pre-burn Test

TEST	TC MAX PANEL TEMP	TIME TO MAX PANEL TEMP
11	616.2	2:19

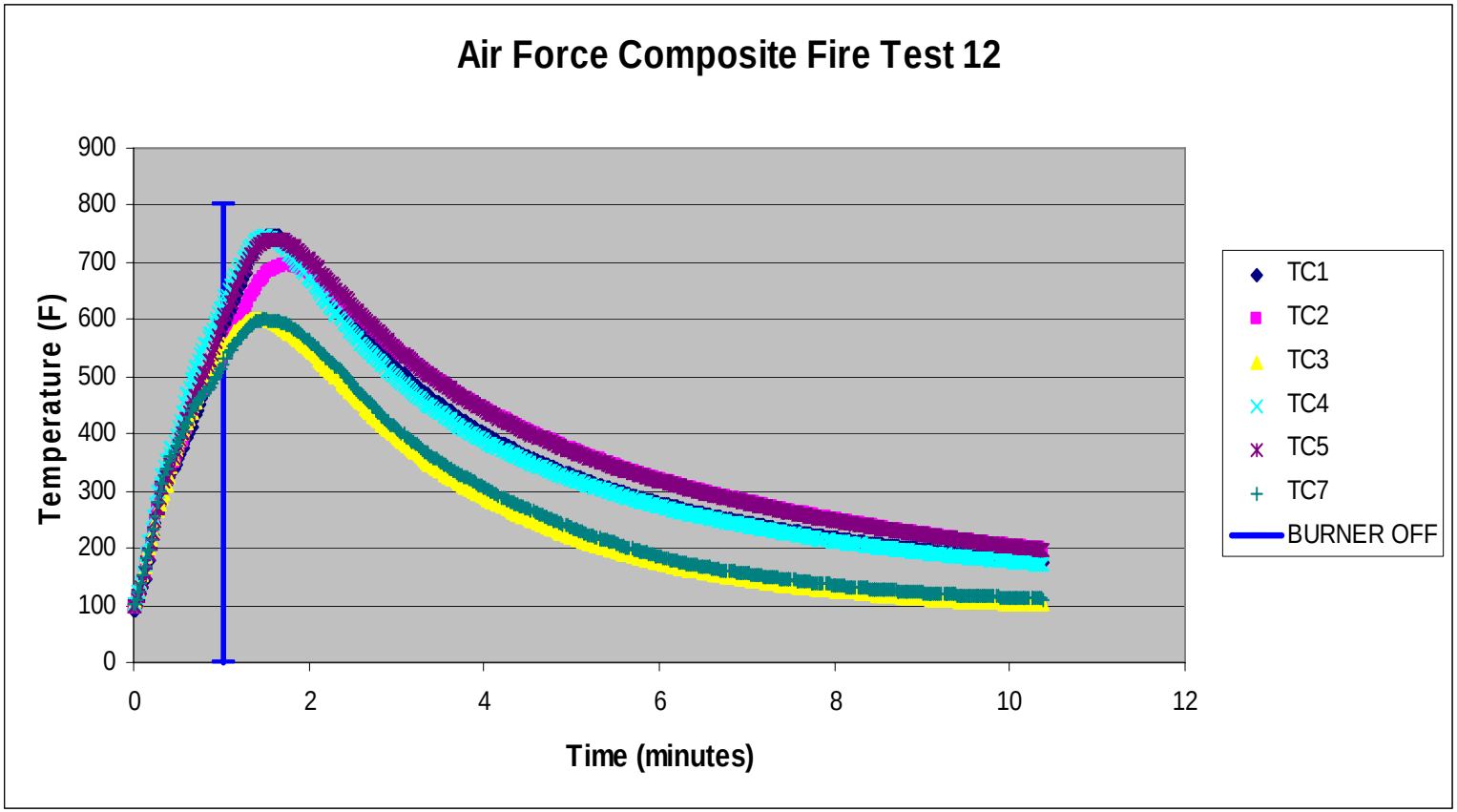
One Minute Pre-burn Test

TEST	TC MAX PANEL TEMP	TIME TO MAX PANEL TEMP
12	602.3	1:25

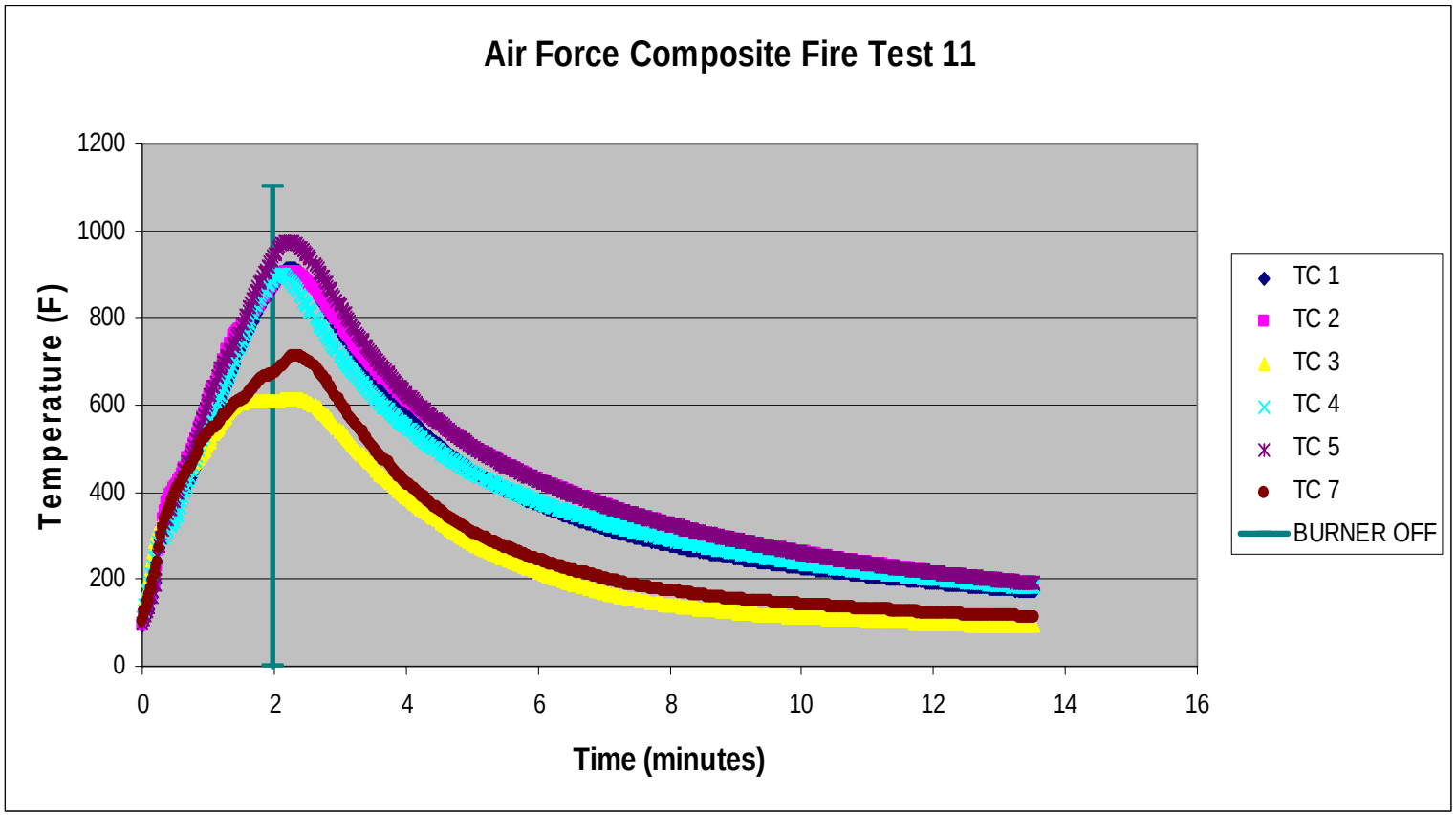
Results


Air Force Composite Fire Test 10
Temperature (F)
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
Time (Minutes)
TC 1
TC 2
TC 3
TC 4
TC 5
BURNER OFF

Results

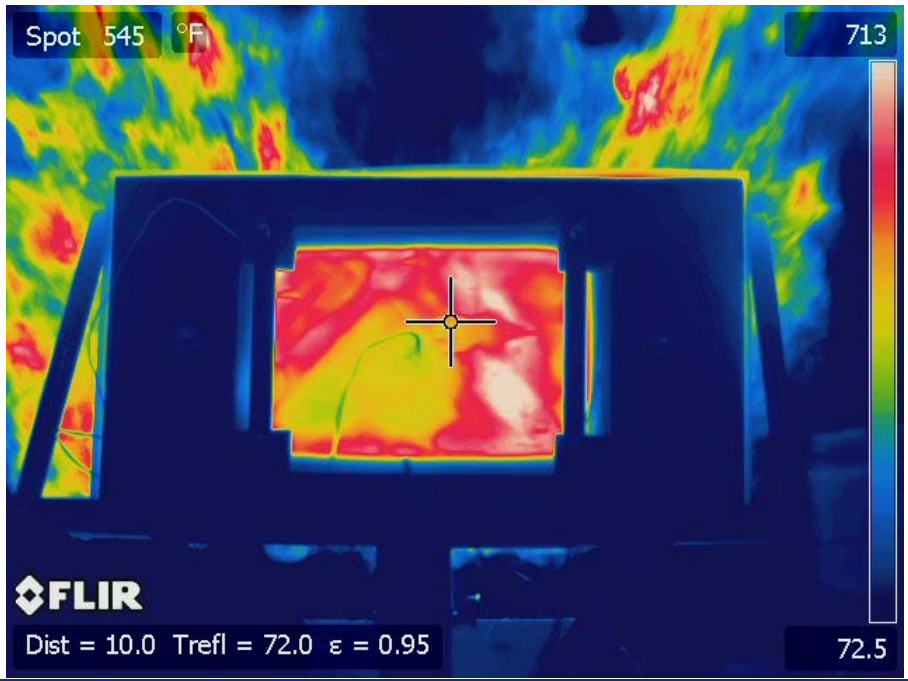

Air Force Composite Fire Test 12
Temperature (F)
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
Time (minutes)
TC1
TC2
TC3
TC4
TC5
TC7
BURNER OFF

Results

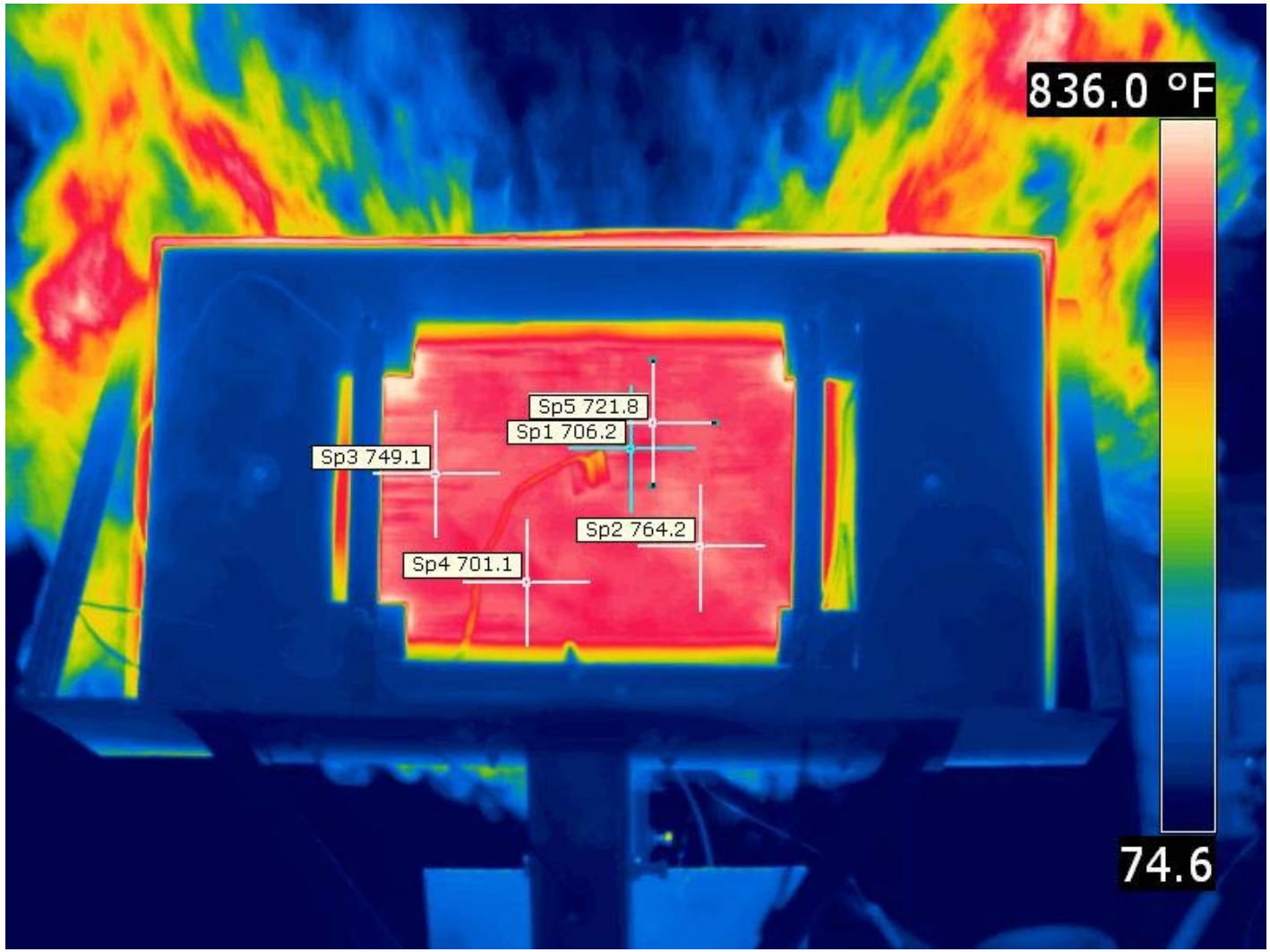

Air Force Composite Fire Test 11
Temperature (F)
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
Time (minutes)
TC 1
TC 2
TC 3
TC 4
TC 5
TC 7
BURNER OFF

Results

- **FLIR images show panel surface is not one uniform temperature as the temperature increases.**
- **As the panel cools, FLIR shows the temperatures balance out.**
- **FLIR seems to correspond well with thermocouple data, however temperatures across the entire panel can vary widely.**



Temperatures Across Panel



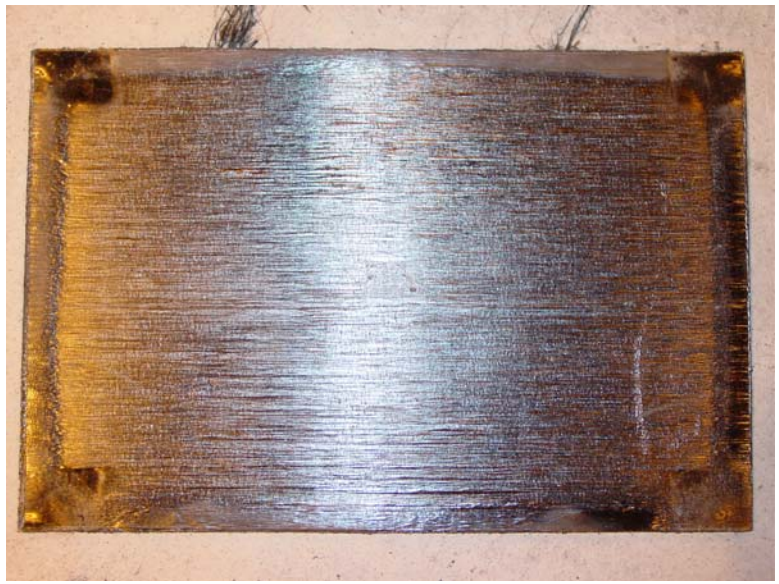
Results

- **Longer exposure times inflicted heavy damage on the panels.**
  - Longer exposures burned out almost all of the resin.
  - Backside has “hard crunchy” feel.
  - Edges however, seem to have most of the resin intact. Edge area matched 1 inch overlap of Kaowool.

Test 6, 10 minute exposure

Front (fire side)

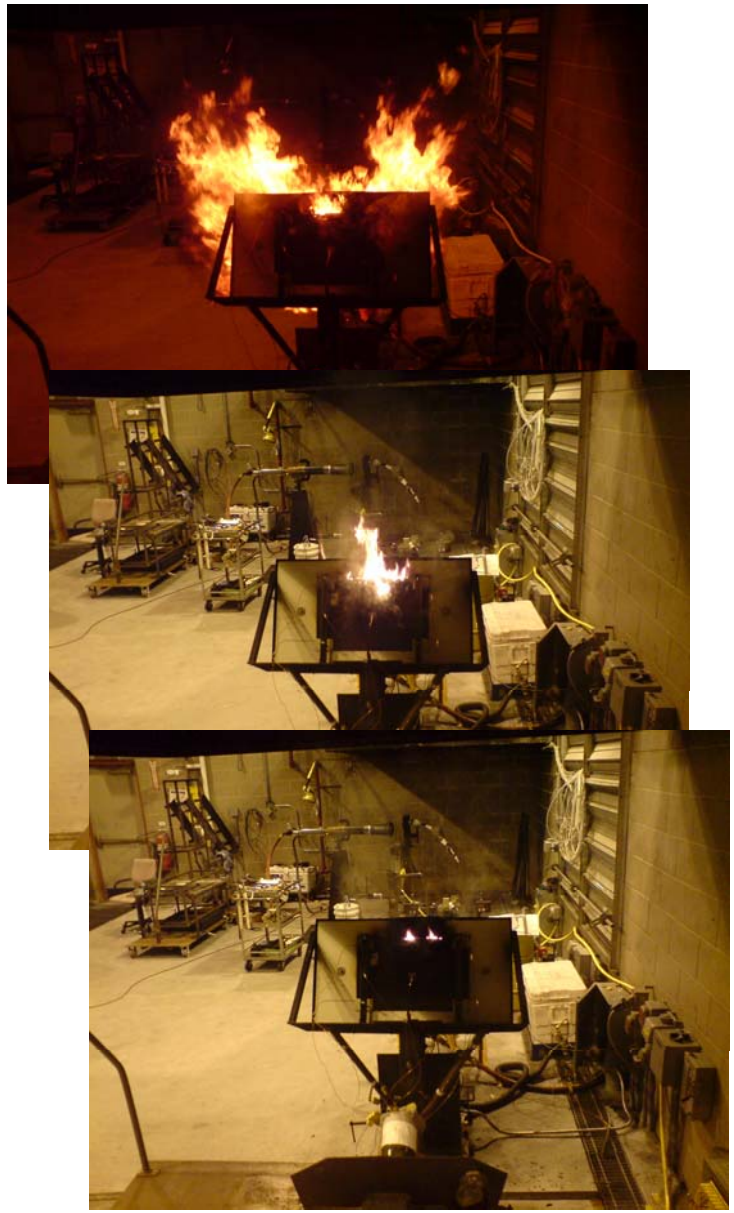
Edge View



Back (non-fire side)

Current Results

- **Shorter pre-burns showed some flaming combustion after exposure.**
  - 1 minute pre-burn seemed to offer the most post-exposure burning.
    - Continued burning for 1:17 min
  - Separate Air Force testing currently underway has shown a similar result at 1 minute.
  - However only 1 test, Test 12, has been conducted by us with 1 minute pre-burn.
  - Test 12 had flame initiate on the back top of the panel due to a crack in the Kaowool board.
  - Post-exposure the panel was burning on both the front and back sides which may account for why slight propagation of flame was noted on back.



Moving Forward

- **Need to perform more repetitions at various intervals; 10 min, 1 min particularly.**
- **Will perform at least 2 tests with the addition of a fan to simulate wind driven conditions.**
  - Fan speed measured at 11.5 mph at 4 ft distance.
- **Use longer panels that are only partially exposed during the pre-burn.**
- **Simple geometries, (T-type form).**
- **Simulate assembly and hidden areas.**

Participation welcome