Development of a Lab-Scale Flame Propagation Test for Composite Fuselages

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Introduction

- **With the increased use of non-traditional materials for modern aerospace applications, fire test methods must be continually updated and re-evaluated in order to maintain a high level of passenger safety**
  - Application of fire tests to modern materials
  - Re-evaluation of pass/fail criteria
  - Introduction of new safety threats with new materials
  - Develop new standards or test methods to address these issues
- **Composite materials (carbon fiber-epoxy) are being used in places where aluminum was traditionally used**
  - Fuselage skin
  - Structural members – stringers and formers
  - Seat frames
  - Fuel tanks
- **There is a need to evaluate the fire properties of these materials to ensure there is not a decreased level of safety**

Composite Fuselage

- **There is a need to evaluate the fire properties of a composite fuselage**
  - Burnthrough
  - Toxicity
  - In-flight burnthrough
  - Flame propagation
- **This objective of this study is to determine whether a composite fuselage will pose a flame propagation hazard**
  - Identify potential scenarios where a threat may be present
  - Evaluate threat with full or intermediate scale test
  - Analyze results to determine if there is an increased risk
  - Use full/intermediate scale test results to develop a lab-scale test for future certification purposes

Evaluation of Flame Propagation Risk

- An intermediate scale test was performed using the foam block fire source
- Different configurations of the fire source, thermal acoustic insulation, and composite panel were attempted
- Test results indicated that the material being evaluated did not present a flame propagation hazard
- Other composites or composites of varying thicknesses may pose a threat

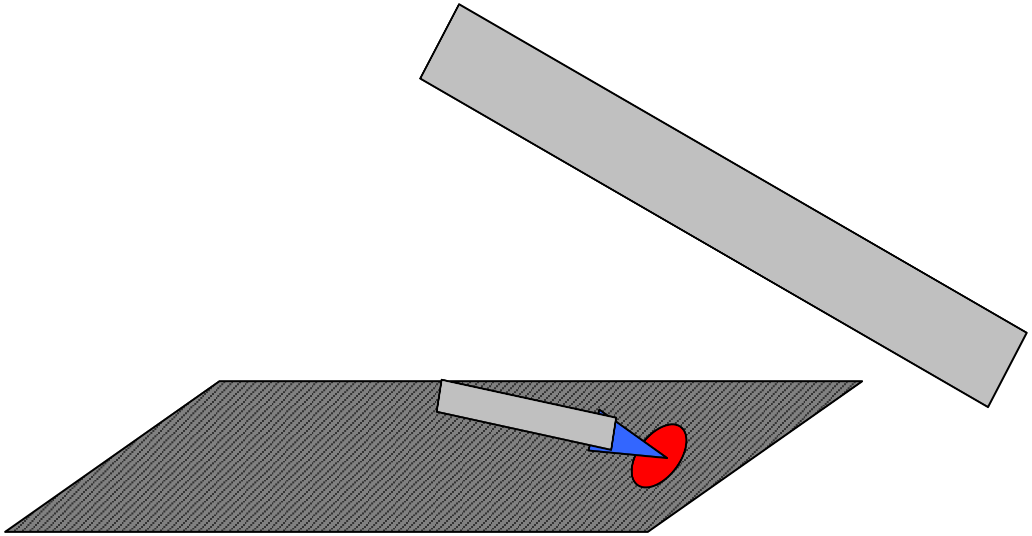
Development of Lab-Scale Test

- **Use the results from previous intermediate scale test as a baseline for a “pass”**
  - The intermediate scale test results were used to certify that specific material for use in aircraft
  - The intermediate scale test will not suffice for certification, however, as it is a large test and takes time and money to perform
  - Certification tests must be performed when varying the material (different epoxies, thicknesses, etc.)
  - The lab scale test must provide the same discretion as the intermediate scale test, but be more efficient to perform
- **Radiant Panel Test Apparatus**
  - The radiant panel test is very useful for evaluation flame propagation tendencies for materials
  - The test is a “surface” test, as radiant heat and the burner impingement are applied to the material surface
  - Material thickness and thermal conductivity play a large role in this test
  - Test parameters must be adjusted to account for composite materials of varying thicknesses (warm-up time, flame exposure time, radiant heat energy, etc.)
  - Task here is to determine if the radiant panel test will be useful for evaluating the flame propagation threat of composite materials

Preliminary FAATC Measurements

- **BMS 8-276, 0.125” thickness, 20” x 9.5”**
- **Radiant Panel Test, configured for 25.856(a)**
  - 1.5 BTU/ft^{2}s at zero position
    1. 15 sec. pilot flame application
       - Result: No propagation, no after flame
    2. 4 min. pre-heat, 30 sec. pilot flame application
       - Result: No propagation, no after flame
    3. Turned sample 180°, 30 sec. pilot flame application (~6 min pre-heat)
       - Result: 3 sec. after flame, no propagation
    4. Re-applied flame for 1 min
       - Result: 6 sec. after flame, no propagation
    5. Damaged Panel, 15 sec. pilot flame application
       - 19 sec. after flame, no propagation
    6. Pilot flame applied to rear edge of panel, 15 sec pilot flame application
       - Result: >15 sec. after flame, no propagation

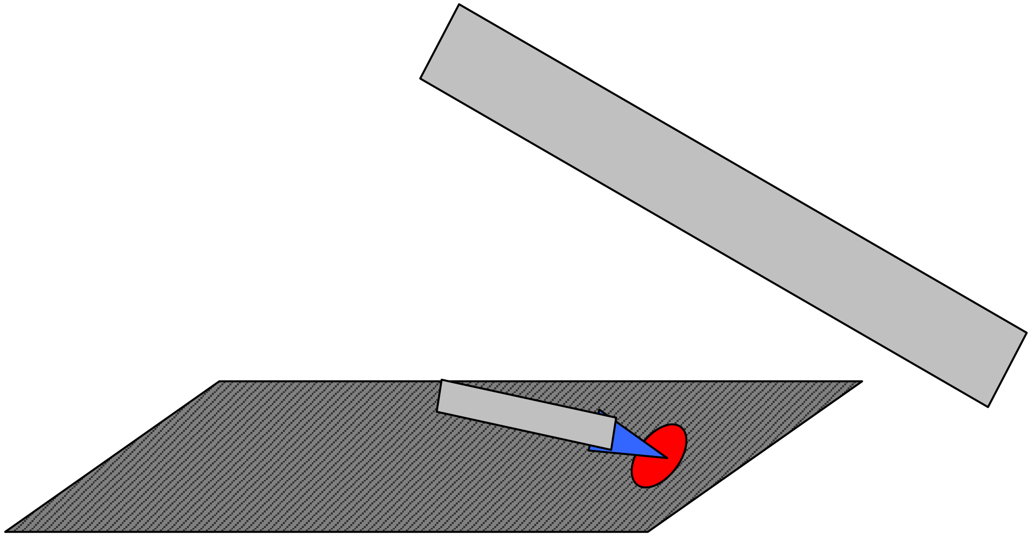
Configuration 1



15 sec. flame application

No propagation or after flame

Configuration 2



4 min. pre-heat

30 sec. flame application

No propagation or after flame

Configuration 3&4

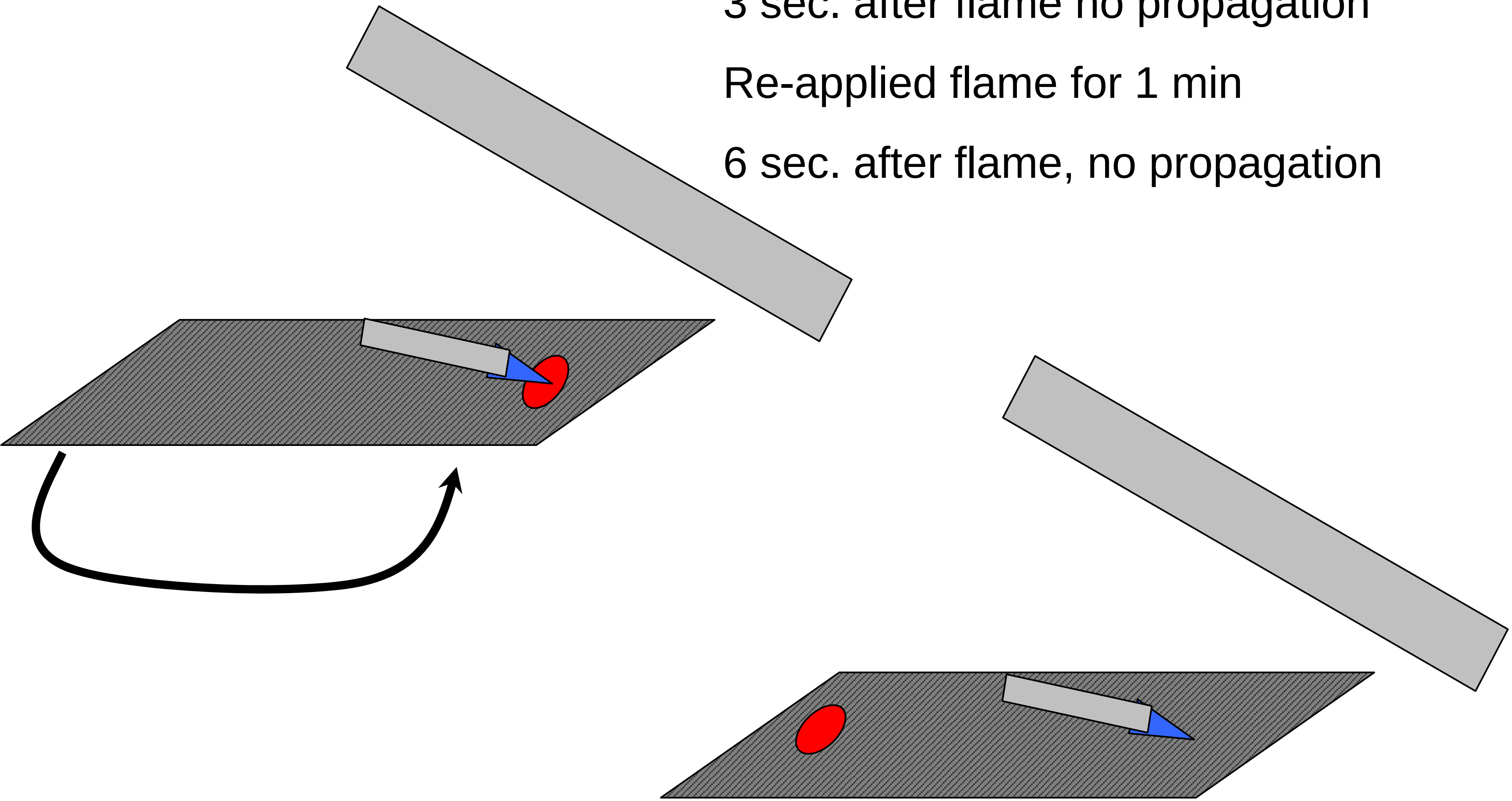
Rotated sample 180°, -> ~6 min pre-heat

30 sec. flame application

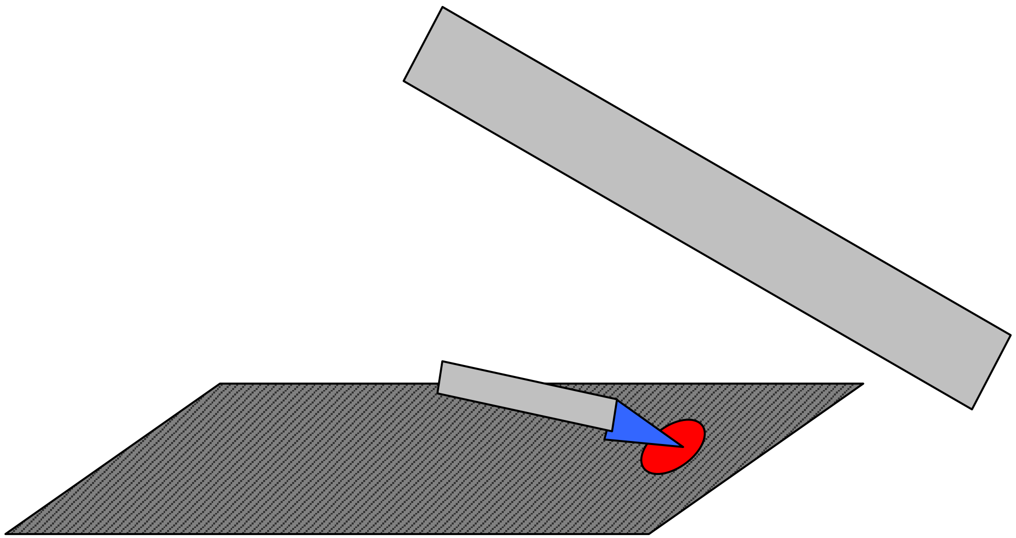
3 sec. after flame no propagation

Re-applied flame for 1 min

6 sec. after flame, no propagation



Configuration 5

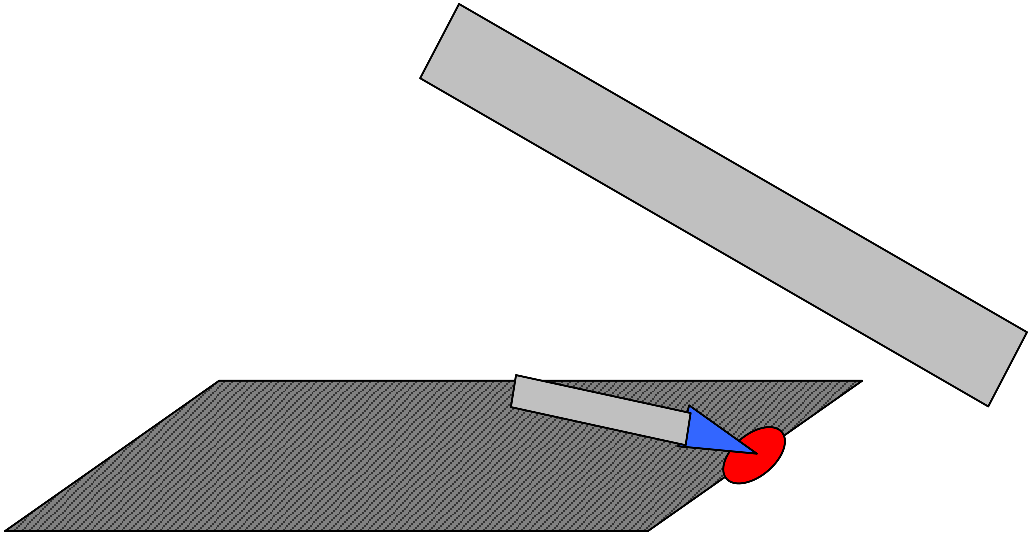


Damaged Panel

15 sec. flame application

19 sec. after flame, no propagation

Configuration 6



Pilot flame applied to edge

15 sec. flame application

>15 sec. after flame, no propagation

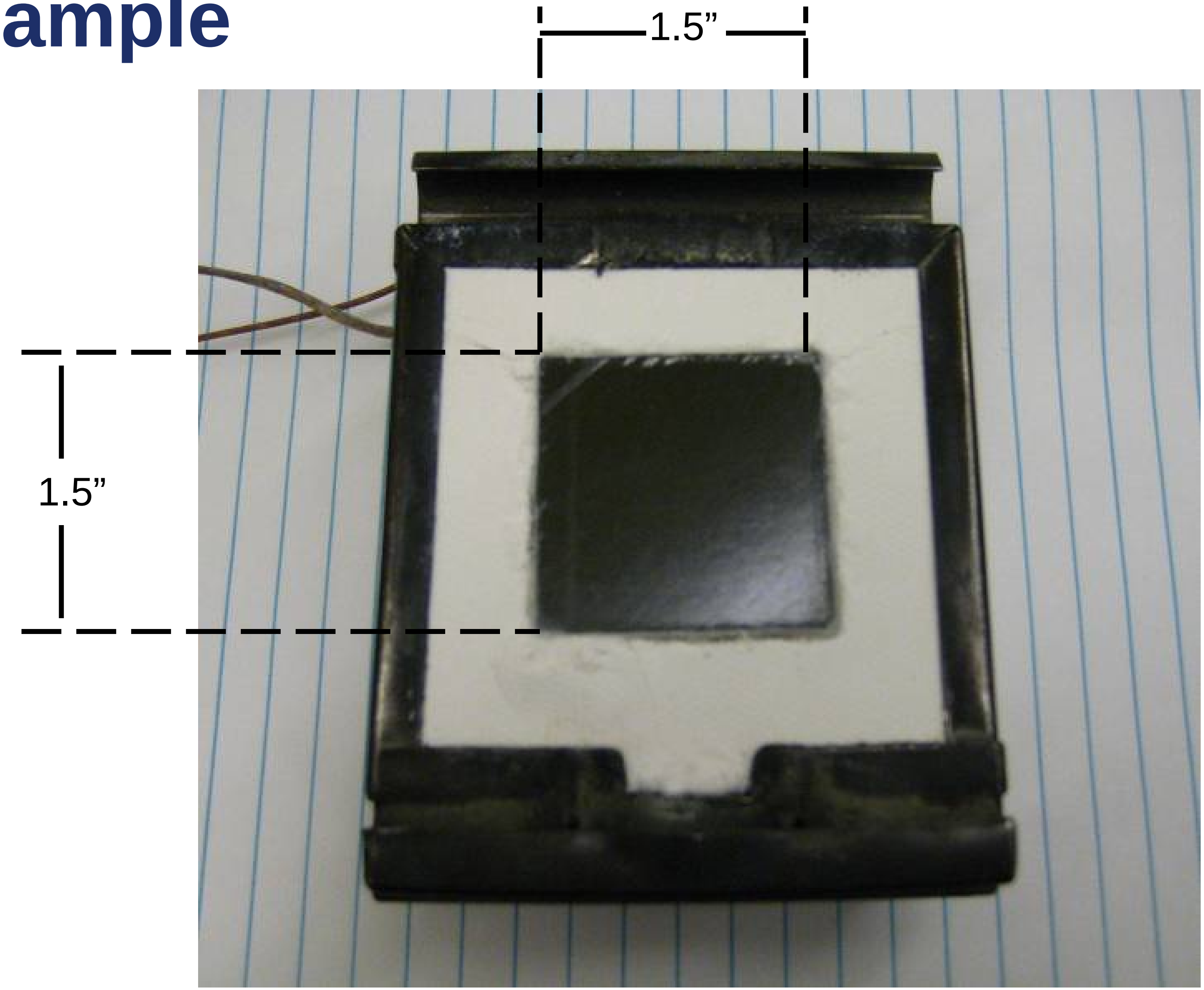
Summary of Initial Testing

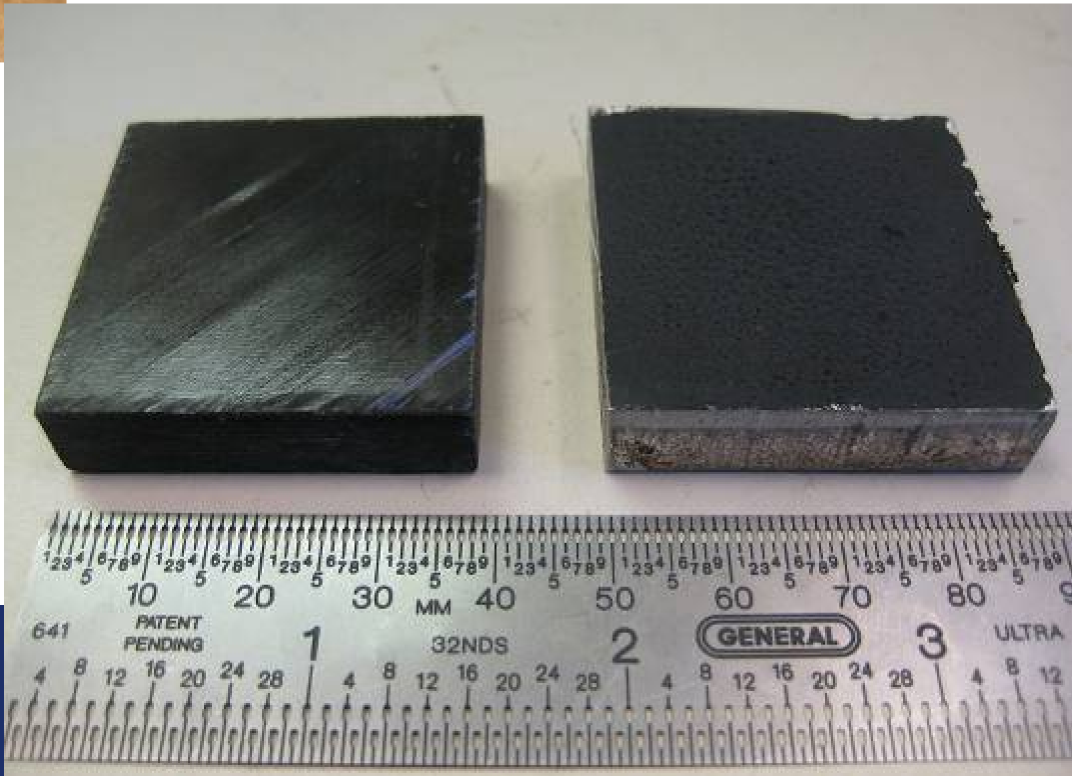
- **Results:**
  - Test conditions for 25.856(a) are not severe enough to produce any result
  - 4 minute pre-heat not sufficient to produce any result
  - ~6 minute pre-heat was able to produce short after flame
  - Delamination and damage to panel caused significant after flame
  - Application of flame to edge of panel caused significant after flame
  - After flame seems to behave like a candle, where fuel is drawn to the flame through the panel like a candle
  - Combustible gases seem to escape through the edges, which causes after flame at the edge
  - Sample frame should be constructed to completely block off the edges and only allow for surface to be exposed

Recent Work – HT Measurements

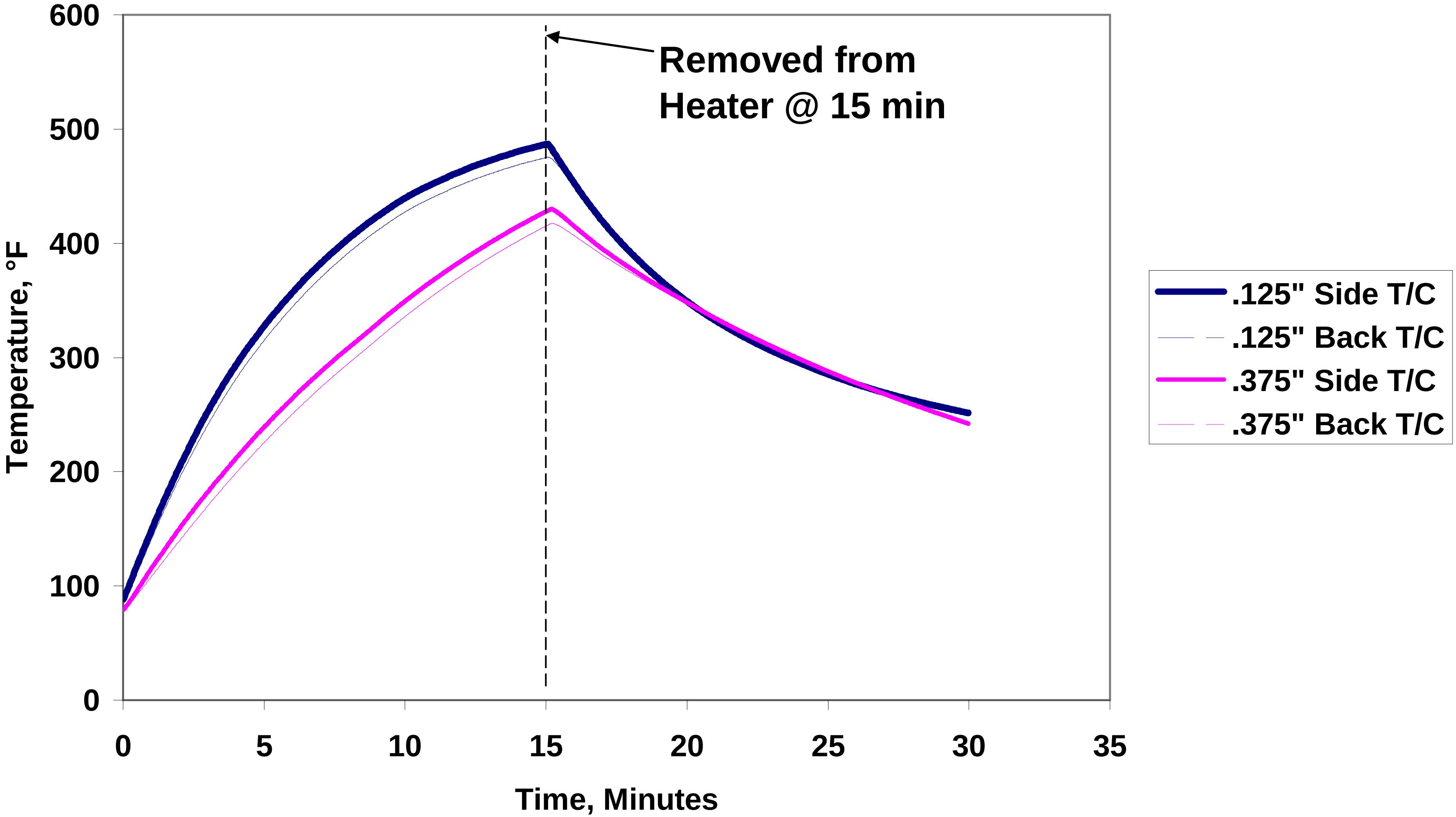
- If a radiant panel test is to be used for testing composites, then the sample surface emissivity will be a critical property in the test
- Also, if a pre-heat time is to be used to test samples of various thicknesses, then the emissivity will play a role in transferring heat from the top surface through the material
- Measurements were made on samples of aluminum and composite of the same dimensions to study the transfer of radiant heat from the exposed surface to the back surface of the sample

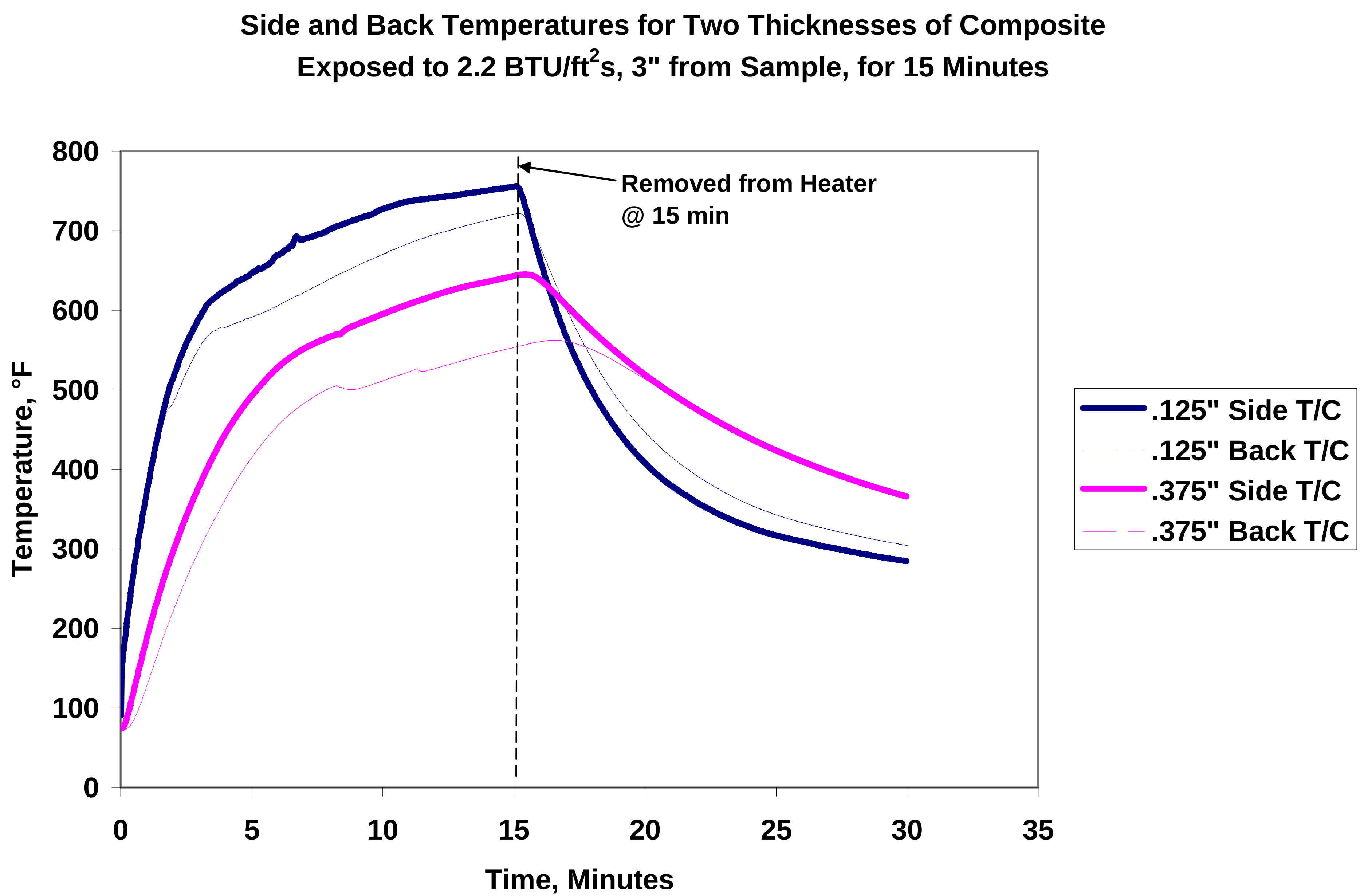
Sample



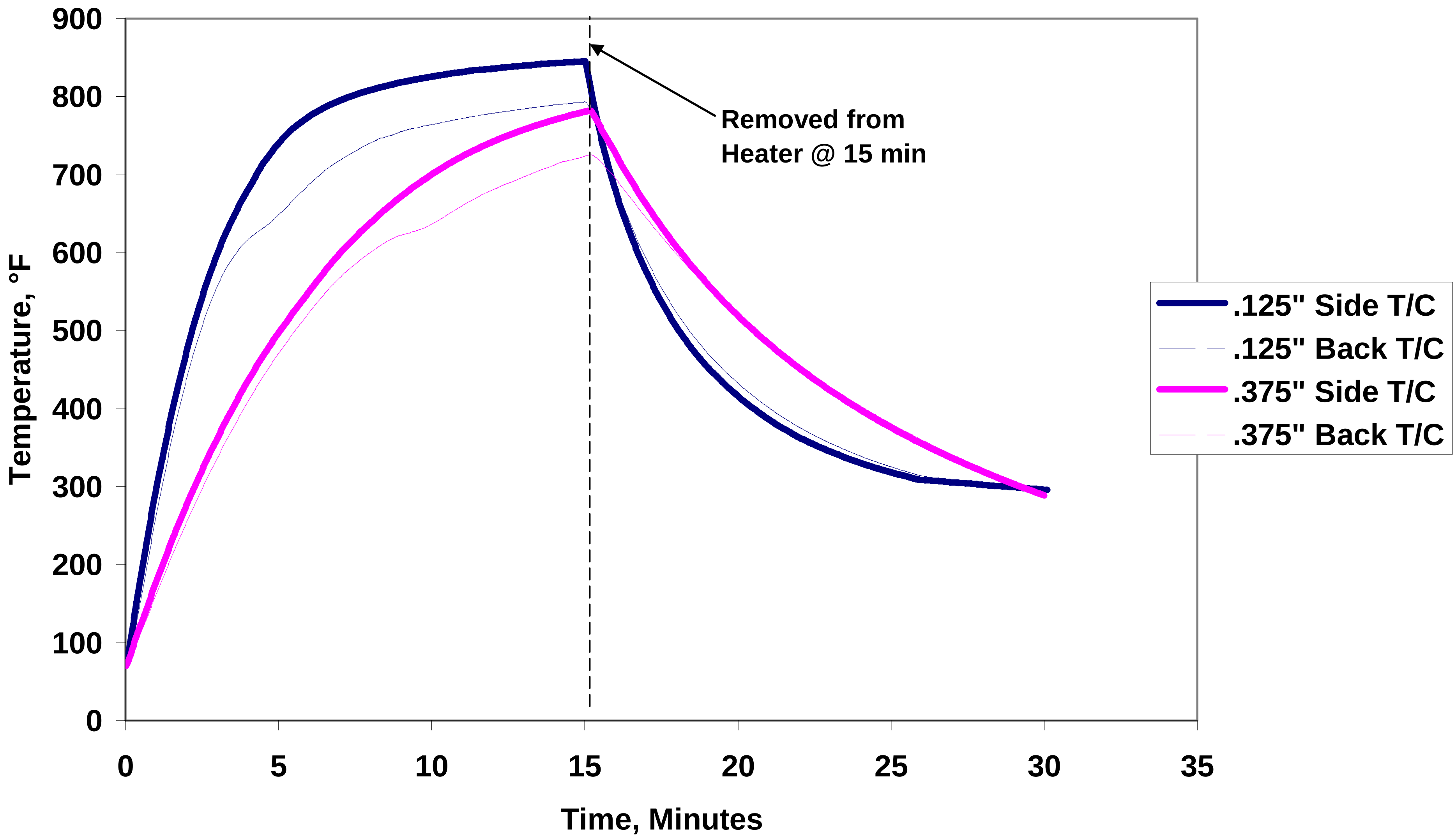

641
PATENT
PENDING
MM
32NDS
GENERAL
ULTRA

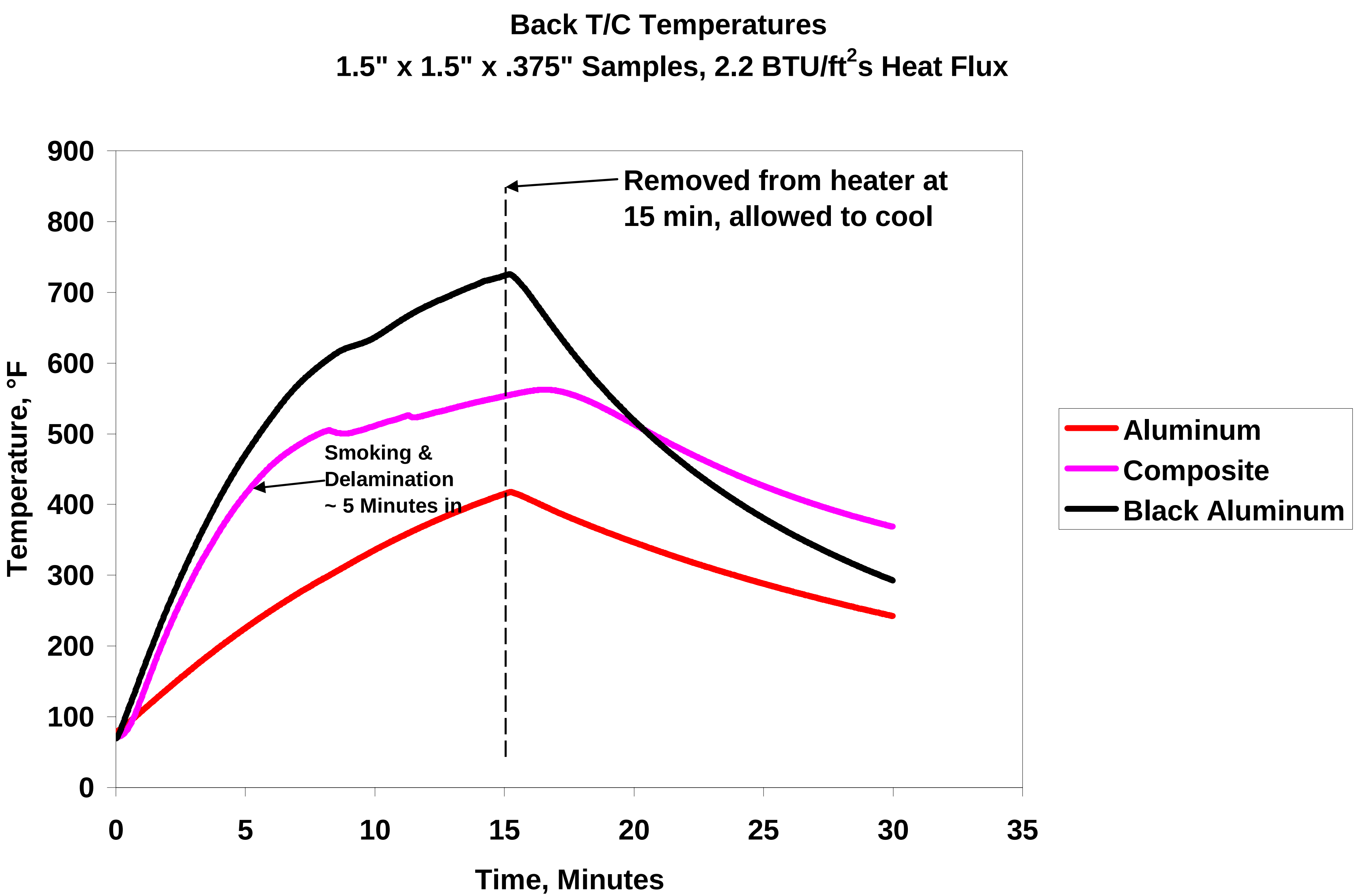
Side and Back Temperatures for Two Thicknesses of Aluminum Exposed to 2.2 BTU/ft^{2}s, 3" from Sample, for 15 Minutes

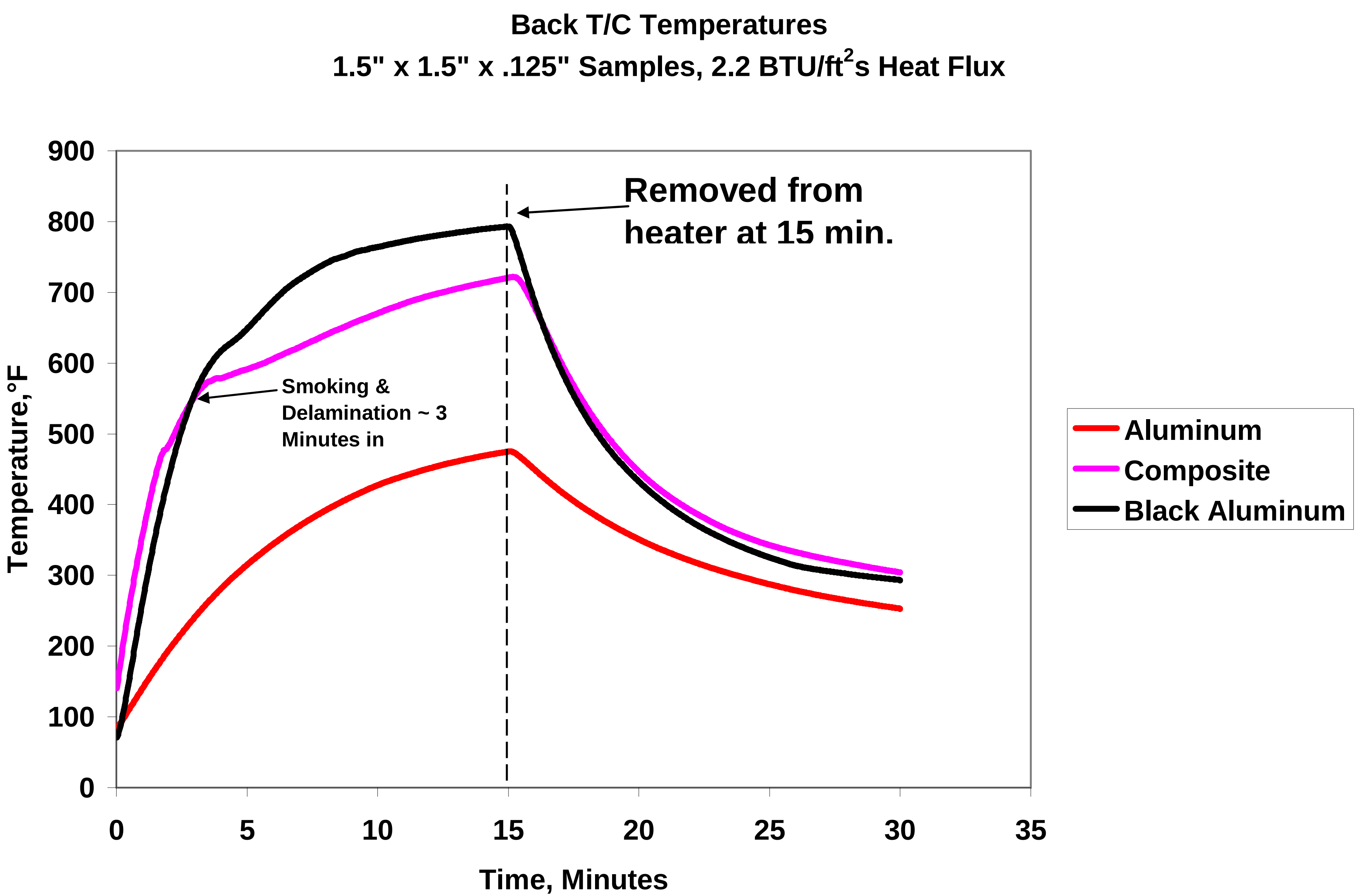



Side and Back Temperatures for Two Thicknesses of Composite
Exposed to 2.2 BTU/ft²s, 3" from Sample, for 15 Minutes
Removed from Heater
@ 15 min
Temperature, °F
Time, Minutes
0
100
200
300
400
500
600
700
800
0
5
10
15
20
25
30
35
.125" Side T/C
.125" Back T/C
.375" Side T/C
.375" Back T/C

Side and Back Temperatures for Two Thicknesses of Black Aluminum Exposed to 2.2 BTU/ft^{2}s, 3" from Sample, for 15 Minutes




Back T/C Temperatures
1.5" x 1.5" x .375" Samples, 2.2 BTU/ft2s Heat Flux
Removed from heater at
15 min, allowed to cool
Smoking &
Delamination
~ 5 Minutes in
Temperature, °F
Time, Minutes
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
35
Aluminum
Composite
Black Aluminum


Back T/C Temperatures
1.5" x 1.5" x .125" Samples, 2.2 BTU/ft2s Heat Flux
Removed from heater at 15 min.
Smoking & Delamination ~ 3 Minutes in
Temperature, °F
Time, Minutes
Aluminum
Composite
Black Aluminum
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
35

Analysis of Results

- **Heat transfer observations:**
  - Aluminum is a good conductor of heat, and quickly disperses absorbed heat through the sample thickness
  - The composite sample quickly heats up, but the rate at which the temperature increases changes, perhaps due to charring and delamination on front surface
  - Black aluminum absorbs more heat than unpainted aluminum and composite, and readily transfers the heat away from the exposed surface

- **Application of observations to fire testing**
  - If, after intermediate scale tests have been performed, a radiant panel test is chosen for determining the resistance of non-traditional fuselage materials to flame propagation, consideration should be given to the exposed surface emissivity
  - If the test material is a poor conductor, then the absorbed heat will remain near the exposed surface, causing off gassing of constituents and perhaps flaming combustion when exposed to a pilot flame
    - If the same material had a lower emissivity surface, then the amount of heat absorbed will be less, perhaps making the sample less likely to propagate a flame
  - If the test material is a good conductor, absorbed heat will disperse through the material, perhaps making the surface less likely to propagate a flame
    - If the same material had a higher emissivity surface, then the amount of heat absorbed will be higher, perhaps making it more likely to propagate a flame

Status

- **Work is in the initial phase right now**
- **Initial work will involve tooling with the radiant panel and different composite material plaques to observe how the material behaves in this test**
  - Vary sample size, thicknesses, surface emissivity
  - Vary radiant heat and flame exposure times
- **Gather samples of different composite materials for intermediate and lab scale tests**
- **Perform intermediate and lab scale tests, change test parameters such that the intermediate and lab scale results correlate**

Questions or Comments?

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