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

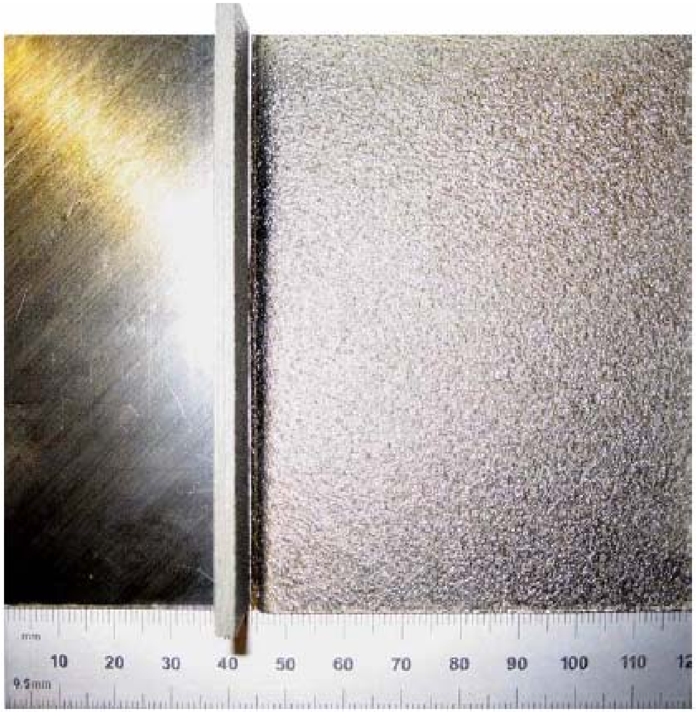
- **Use the results from previous intermediate scale test as a baseline for a "pass"**
  - The intermediate scale test results were used to certify that specific material for use in aircraft
  - The intermediate scale test will not suffice for certification, however, as it is a large test and takes time 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

Previous Work on Composites

- **FAA Report DOT/FAA/AR-07/57 (Quintiere et al.) entitled "*Flammability Properties of Aircraft Carbon-Fiber Structural Composite*"**
- **Investigated a material manufactured by Toray Composites America to meet Boeing Material Specification 8-276**
- **Key objective was to investigate the heating and burning properties of the material with various methods**
  - Cone calorimeter
  - Microscale combustion calorimeter
  - Thermogravimetric analysis
  - Differential scanning calorimeter
  - Flame spread apparatus
  - Thermal conductivity apparatus
  - OSU and smoke chamber

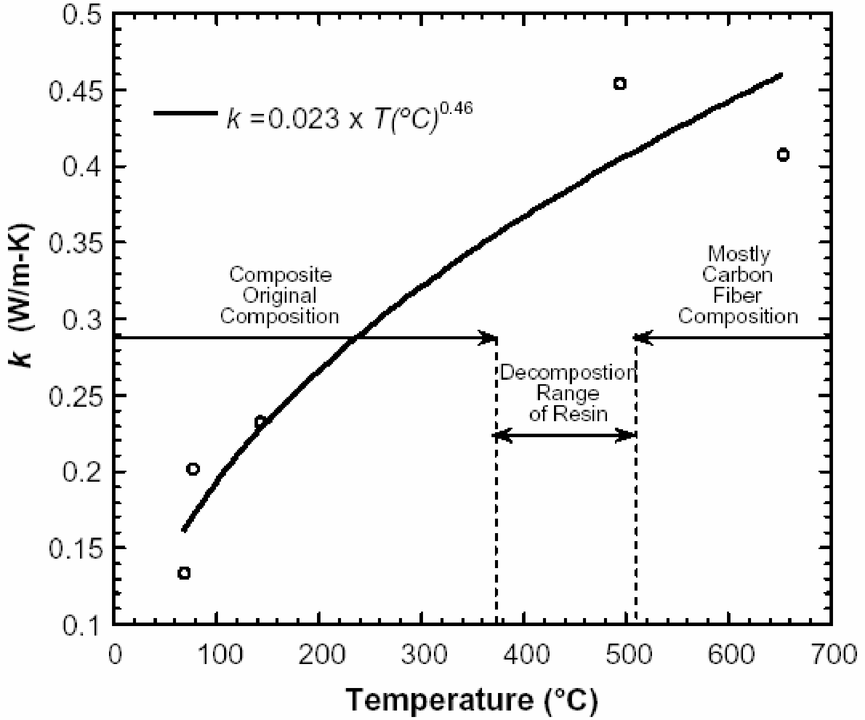
Material Details

- **Toray Composites, BMS 8-276**
  - [-45, 0, 45, 90]2s 16 plies
  - Material is composed of carbon fibers (7µm dia.) and resin
  - 3.2 mm thick (0.125 in.)
  - Density = 1530 kg/m^3 (95.5 lb/ft^3
  - 60% by volume carbon fibers
  - Resin density = 1220 kg/m^3 (76 lb/ft^3)
  - Typical char fraction of resin ~ 25%



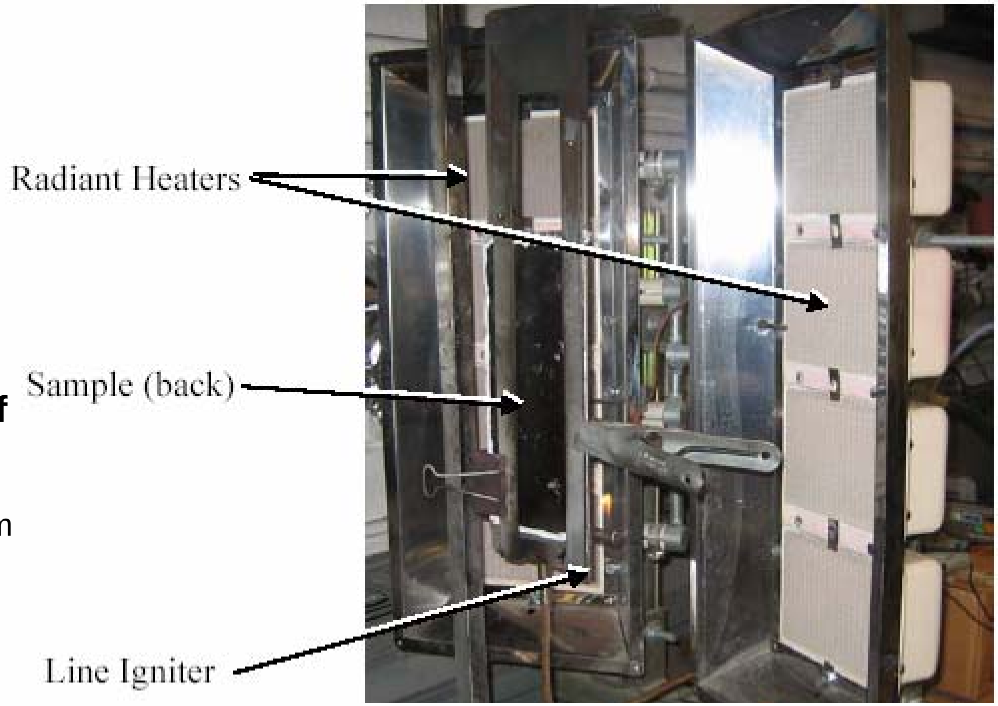
Properties

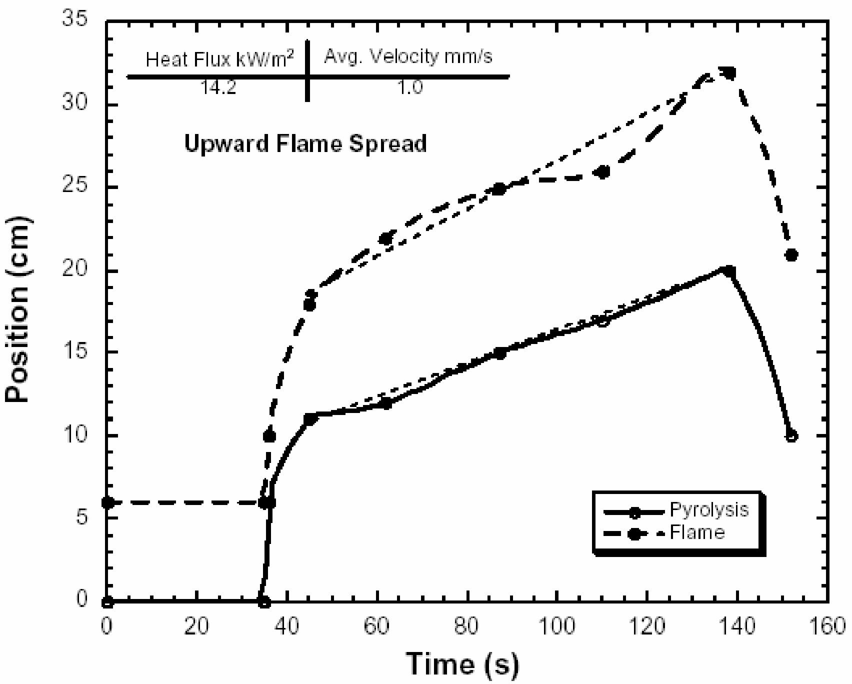
- **Resin is primary fuel for reactions**
  - Escapes the material through pores in the matrix
  - Heating causes material to swell as internal pressures rise
  - Flame jets can protrude from the material due to pressure release
  - Properties change as material changes in shape
    - Density decreases
    - Thermal conductivity of matrix decreases
  - Both flaming and non-flaming combustion can occur
    - Resin can produce flaming combustion
    - Char and carbon can smolder on the surface without flame
- **Thermal conductivity was measured with a home-built apparatus**
  - Measurements were made over a range of temperatures relevant to combustion
  - Heat loss errors were found with the apparatus, possibly up to 20% difference
  - More accurate methods are needed
  - Despite the errors, the dependency of thermal conductivity on temperature is clear



Flame Spread Experiments

- **Critical heat flux was found from cone calorimeter measurements**
  - Piloted ignition: 17.5 kW/m^2 (1.5 BTU/ft^{2}s)
  - Non-piloted ignition: 31.5 kW/m^2 (2.8 BTU/ft^{2}s)
- **Apparatus was developed in the work of Panagiotou and Quintiere**
  - Vertically mounted specimen
  - Surface exposed to radiant heat is 6 x 25 cm (2.4” x 9.8”)
  - Pre-heat time of 4 min was used to create thermal equilibrium on sample surface (found from critical heat flux for piloted ignition)
  - Flame spread is only a function of heat flux for this pre-heating condition, as flame speed is dependent upon surface temperature
- **Key findings**
  - Exposed heat flux of 1.25 BTU/ft^{2}s
  - Pilot flame in contact entire test
  - Flame spread of approx 7” over 2 ½ min
  - Pyrolysis spread of approx 12.6” over 2 ½ min

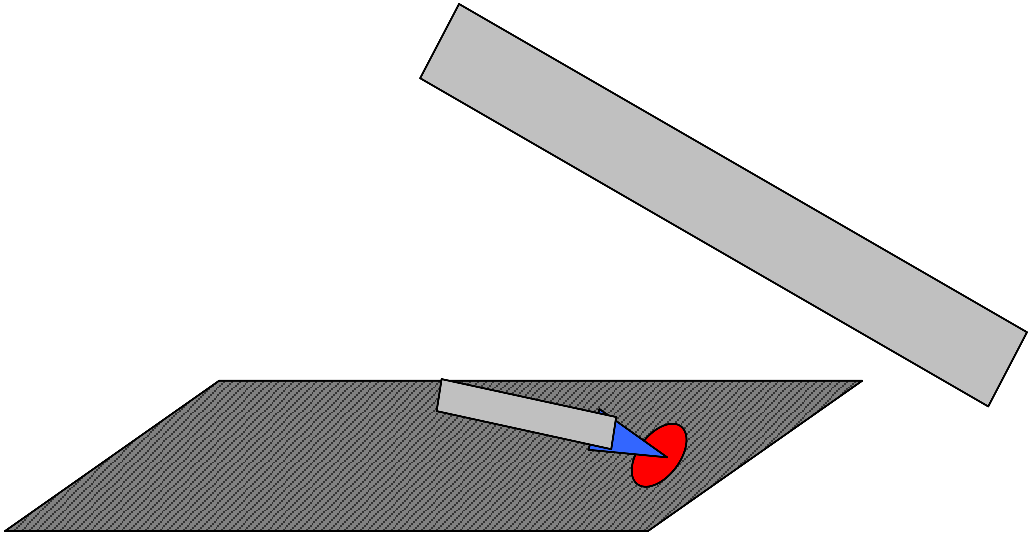




Preliminary FAATC Measurements

- **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

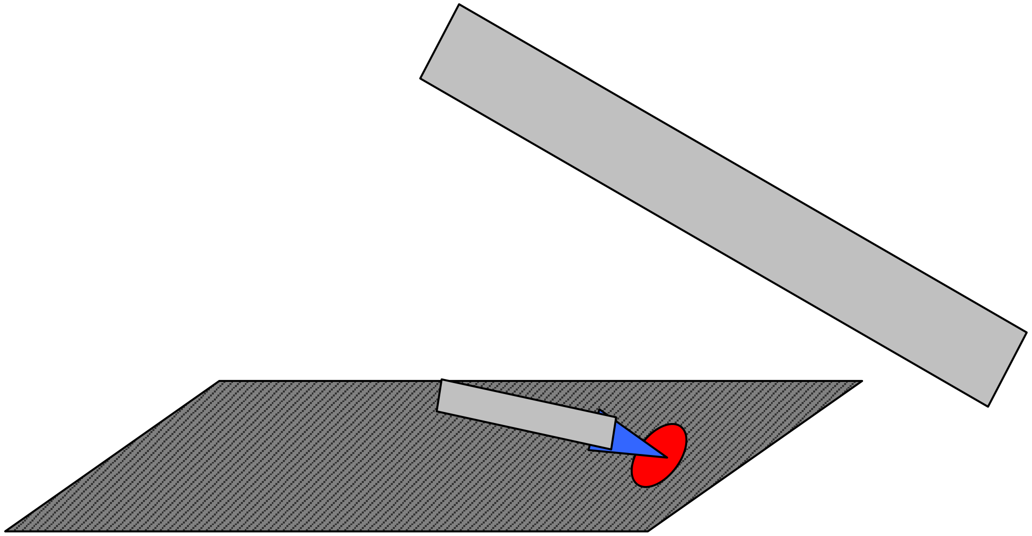
Configuration 1



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

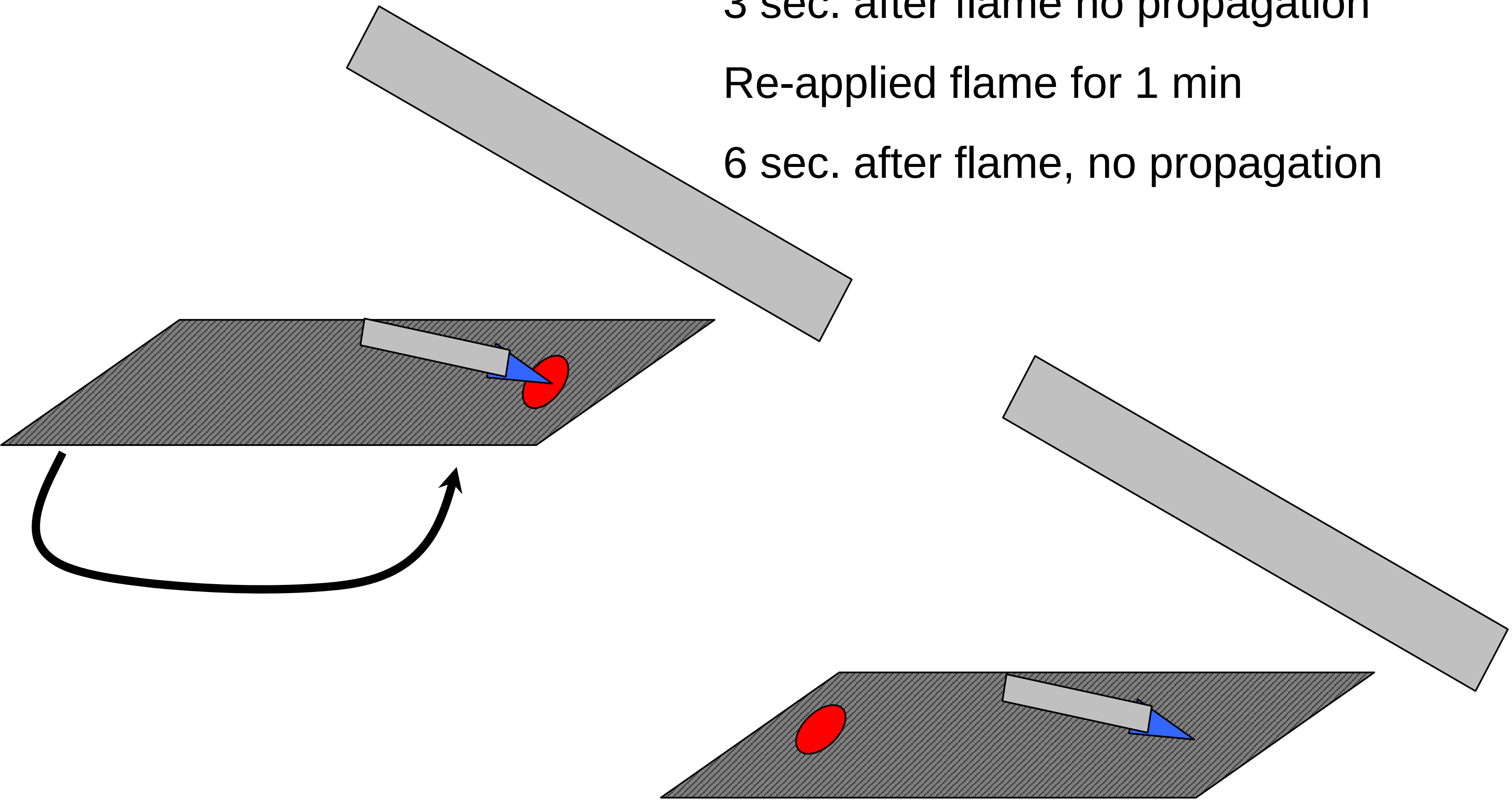
Rotated sample 180°, -> ~6 min pre-heat

30 sec. flame application

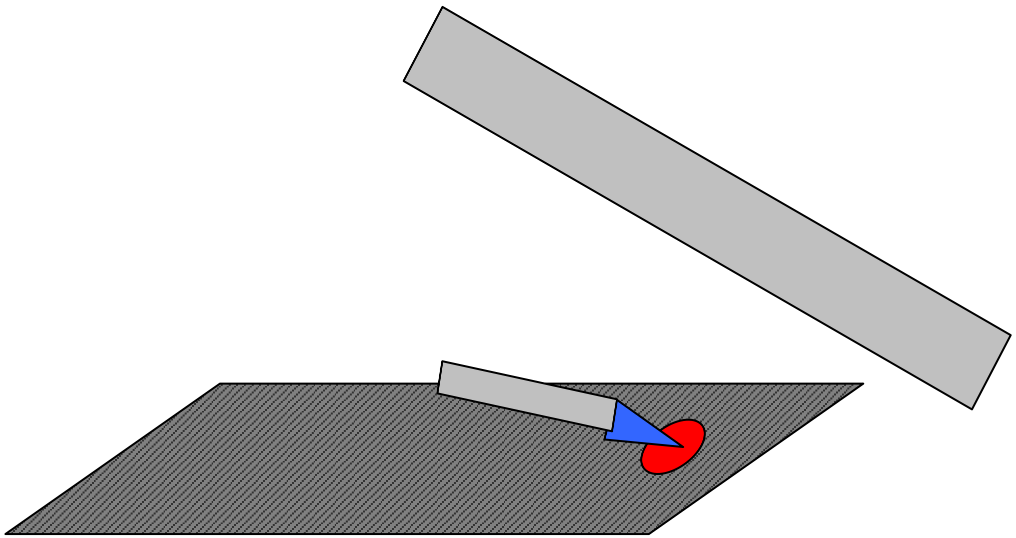
3 sec. after flame no propagation

Re-applied flame for 1 min

6 sec. after flame, no propagation



Configuration 5

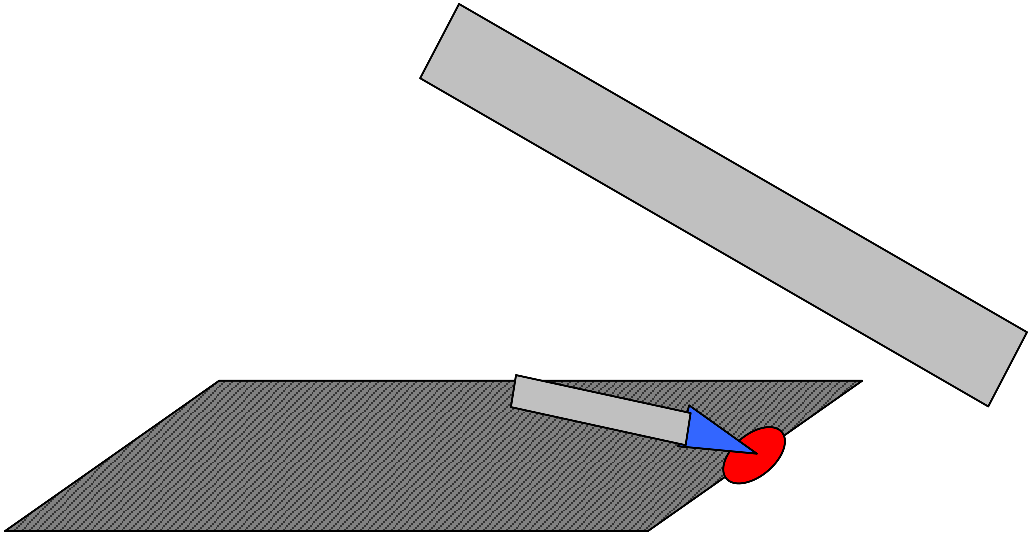


Damaged Panel

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

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
  - 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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