In-Flight Burn-Through Tests

Aluminum vs. composite materials

Federal Aviation Administration

Presented to: Aircraft Systems Fire Working Grp

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Objective

- To develop a test that replicates the burn-through characteristics of a typical aluminum skinned aircraft in in-flight conditions.
- Collect heat dissipation and burn-through data for aluminum material under in-flight conditions.
- Collect heat dissipation and burn-through data for composite material under in-flight conditions.

Facilities

- **The tests describe here will utilize the FAA Technical Center's Airflow Induction Facility.**
  - Subsonic wind tunnel
    - 5.5 foot by 16 foot test section
    - Airflow speed range of 200-650 mph
- **A test article was fabricated to simulate the top surface of an aircraft with a fire in the cabin/overhead area**

FAA Airflow Induction Facility

High Speed Test Section

Background

- Aluminum’s high capacity for heat rejection prevents burn though while in-flight due to the cooling effect of the airflow around the fuselage.
- Once on the ground, the cooling effect of the airflow no longer exists.
- Burn-through can occur within minutes of touchdown.

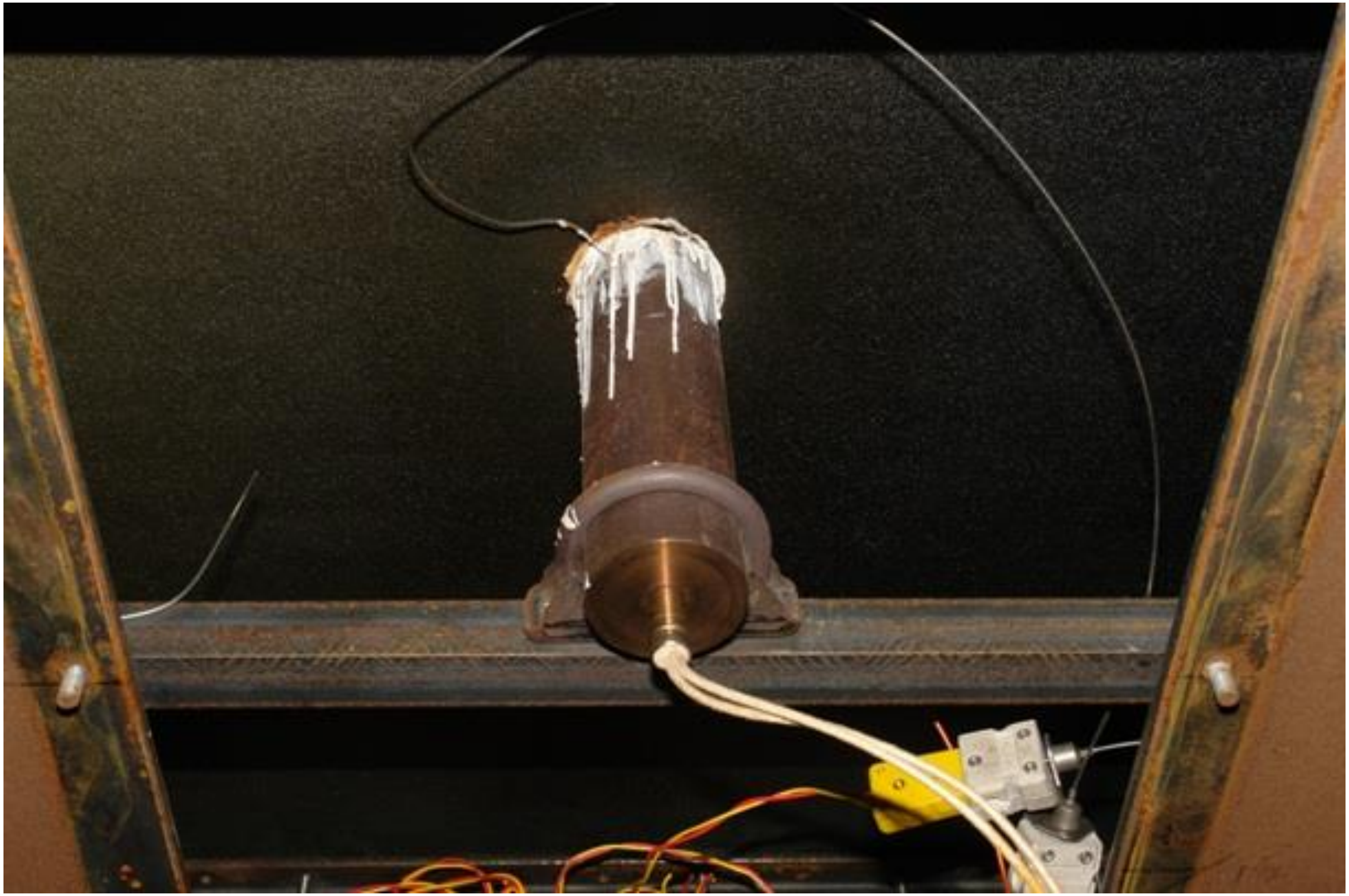
Test Design

- Construct long “ground plane” to smooth airflow over test section
- Replaceable test section located near rear of ground plane
- Construct aerodynamic faired “box” under test panel to hold heat / fire source
- Initial tests with electric hear source to determine heat transfer characteristics

Ground plane- use to smooth airflow over test panel, simulating top of aircraft fuselage

Faired Heat Source Test Chamber

Electric Heat Source Configuration



Test Design- Live Fire

- **Develop a fire source that can be operated with the wind tunnel in operation**
- **Size the fire intensity so that:**
  - Aluminum panel burns through under static (no airflow) conditions
  - Aluminum panel does NOT burn through under airflow conditions

Fire Source Selection

- **Several fire sources were evaluated for this test scenario**
  - Jet fuel pool fire
    - Naturally aspirated
    - Boosted with compressed air
  - Propane burner
  - Oxy/Acetylene torch
    - Standard nozzle tip
    - Rosebud tip (s)

Fire Source Selection

- Both the jet fuel pool fire and the propane torch suffered from oxygen starvation within the confines of the test fixture
- The addition of a compressed air source to the fixture improved the performance
- Ultimately, the fires from these sources were not repeatable within a reasonable tolerance

Jet Fuel Pool Fire Configuration

Fire Source Selection

- **To eliminate the oxygen starvation within the test fixture, an oxygen/acetylene torch was selected as the fire source**
  – The standard nozzle was too narrow, producing a very hot flame that penetrated the aluminum test panel in under two minutes
  – The nozzle was replaced with a series of “rosebud” nozzles in an attempt to spread the flame over a wider area. This was partially successful.
  – The solution was to place a steel plate in the fire path, forcing the flame to spread around it.

Oxygen-Acetylene Fire Source

Live Fire Calibration

- **With the goal of aluminum burn through static and no burn through under airflow conditions, the following settings were varied:**
  - Acetylene pressure
  - Oxygen pressure
  - Mixture settings and resultant flame appearance
  - Distance between torch tip and test panel
  - Size of steel diffuser plate
  - Holes in steel diffuser plate
  - Location of steel diffuser plate

Live Fire Calibration

- **After much trial and error a set of conditions were established such that:**
  - Static tests with aluminum panels yielded repeatable burn through times of 9-10 minutes
  - Tests in a 200 mph air stream produced no penetrations

Instrumentation

- **Interior panel temperature measured with two thermocouples, fixed to underside of test panel**
- **Panel topside temperature measured with FLIR infrared camera**
- **Flame temperature and heat flux**
- **Flame Visual characteristics monitored by video**

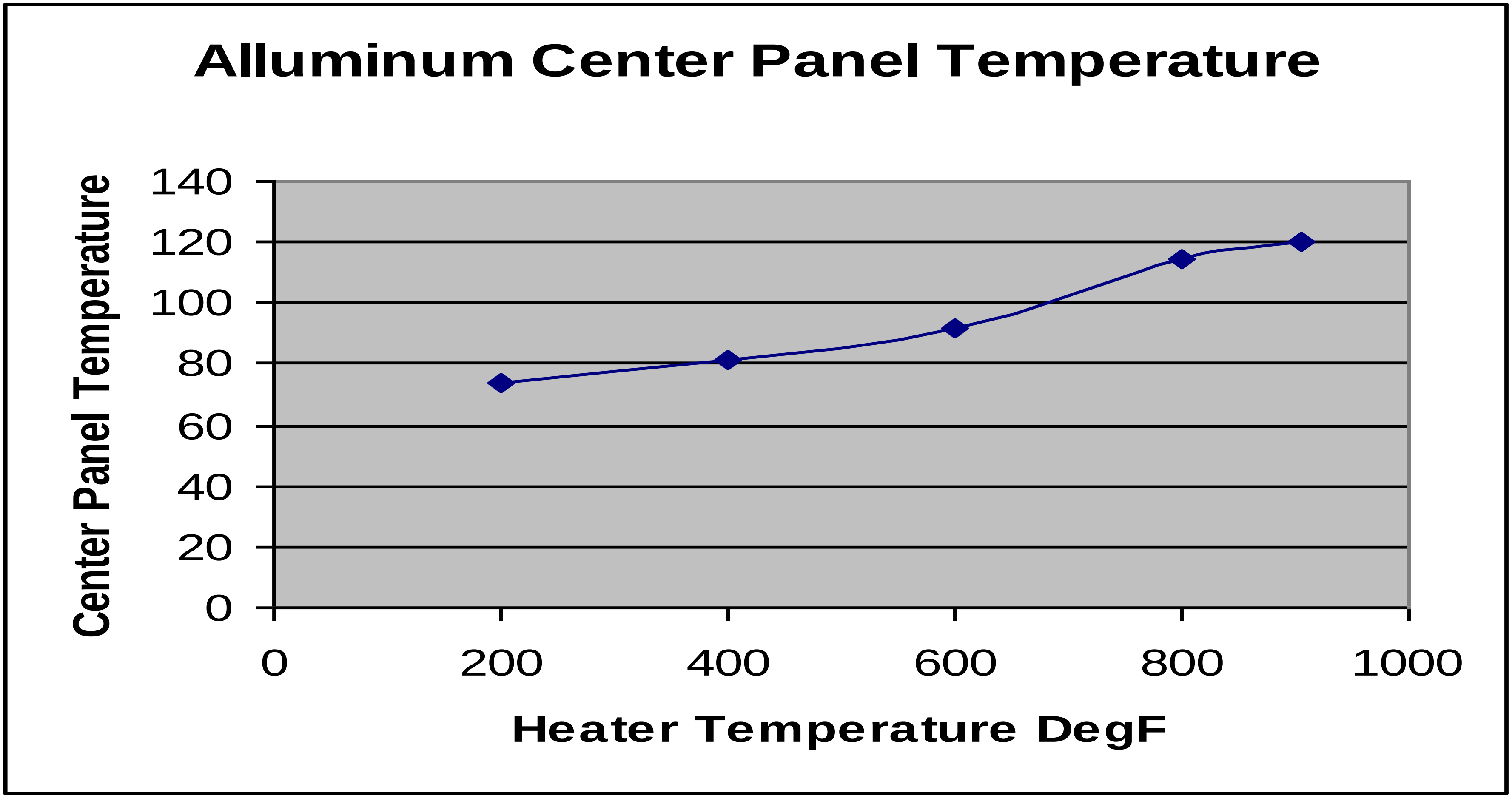
Heat Conduction Tests

- **Aluminum and composite panels exposed to an electric heat source**
- **Heater temperature was varied from 200 to 900 DegF**
- **Airflow conditions included**
  – Zero airflow (static)
  – 200 mph airflow
  – 300 mph airflow

Aluminum Test Results

- **Static 0.125” Aluminum Results**
  - Heater set at 900 DegF
  - Center temperature reached 120 DegF
  - 6” radius from center reached 76 DegF
  - 8” radius from center remained at ambient, 72 DegF

Static Aluminum Center Panel Temperatures



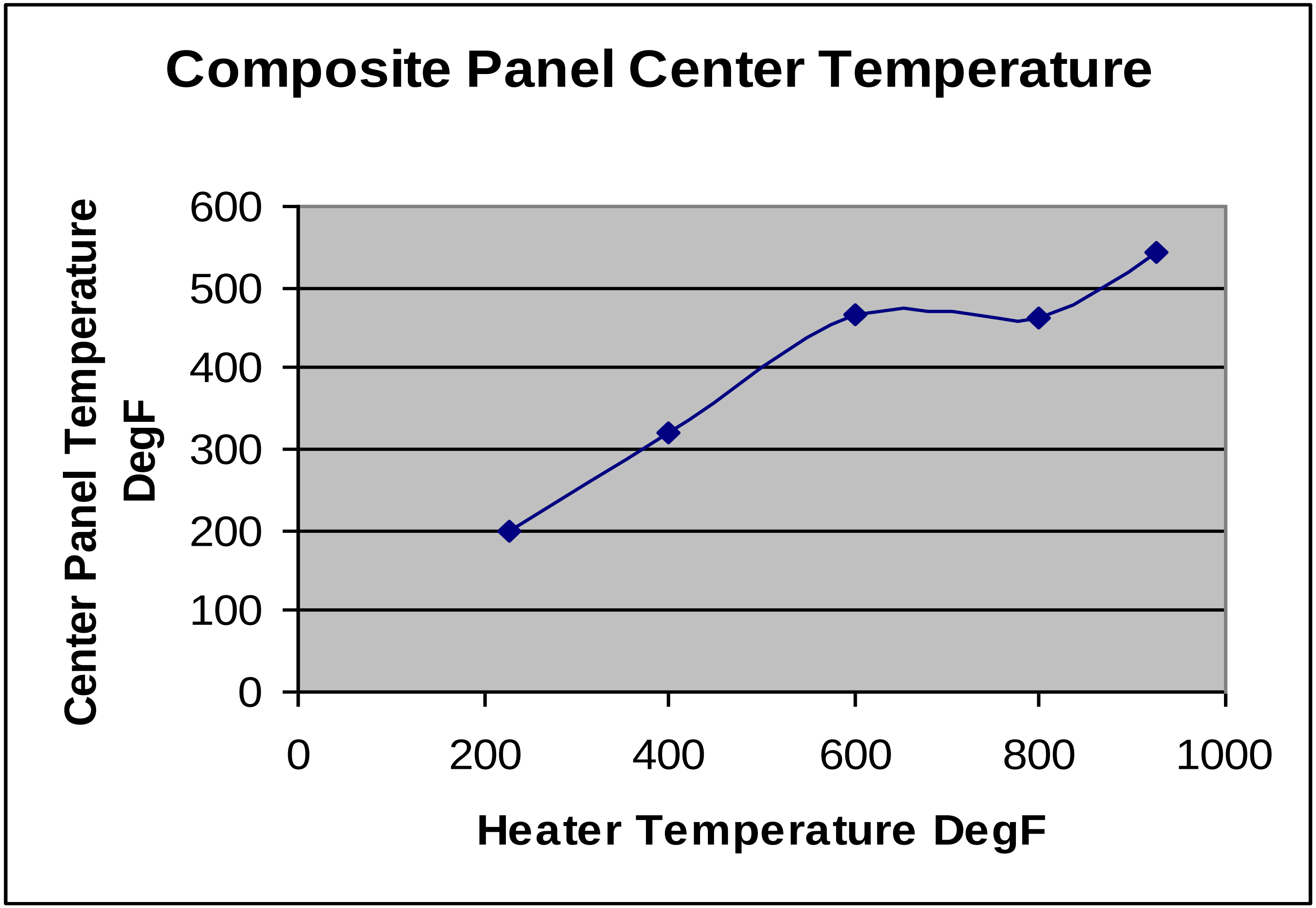
Aluminum Test Results

- **In-Flight 0.125” Aluminum results**
  – Heater temperature: 900 DegF
  – Ambient temperature 71.9 DegF
- **200 mph airflow:**
  – Panel center temperature: 91 DegF
  – 6” radius from center: 72 DegF
- **300 mph airflow:**
  – Panel center temperature: 79 DegF
  – 6” radius from center: 72 DegF

Composite Heat Conduction Test Results

- **Static 0.125” Composite Panel**
  - Panel Center temperatures much higher than aluminum
  - 6” radius temperatures remained at ambient
  - At heater temperatures above 600 DegF, the panel smoked where it contacted the heater
  - Center temperature reached 550 DegF at a heater setting of 900 DegF

Composite Static Heat Conduction Electric Heat Source Test Results



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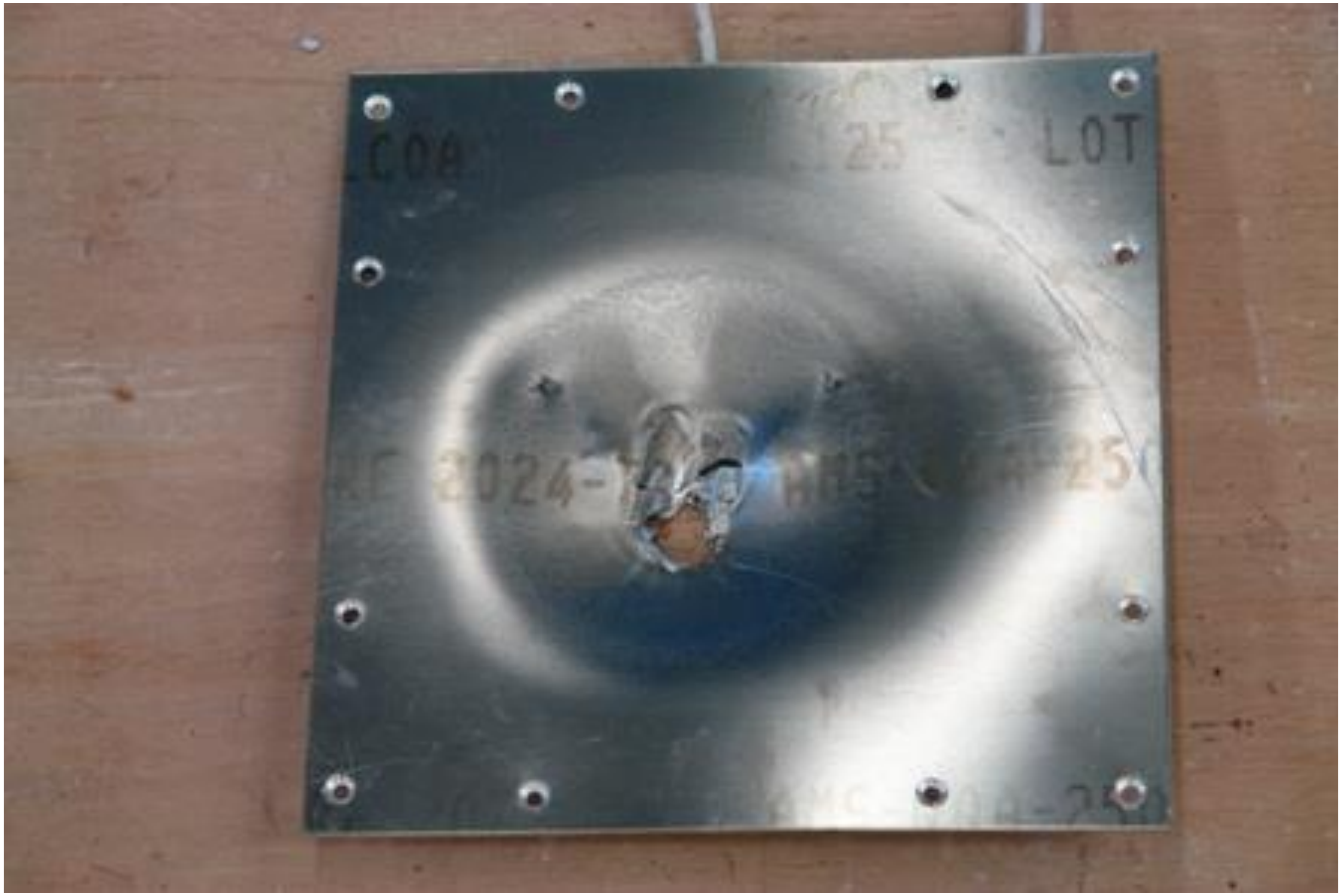
Live Fire Burn-Though Tests

- Test designed to compare the heat dissipation and burn-through characteristics of aluminum and composite panels
- Fire sized to burn-through aluminum under static conditions, but not in-flight
- Both static (no airflow) and in-flight conditions were tested

Live Fire Static Aluminum Results

- **0.125” aluminum panel**
  - Panel gradually heated up, approaching the melting point (1220 DegF)
  - Panel became plastic, sagging in the center
  - At melting point, the center failed, opening a hole in the panel
  - Time to failure, 14.8 minutes

Aluminum Post Test



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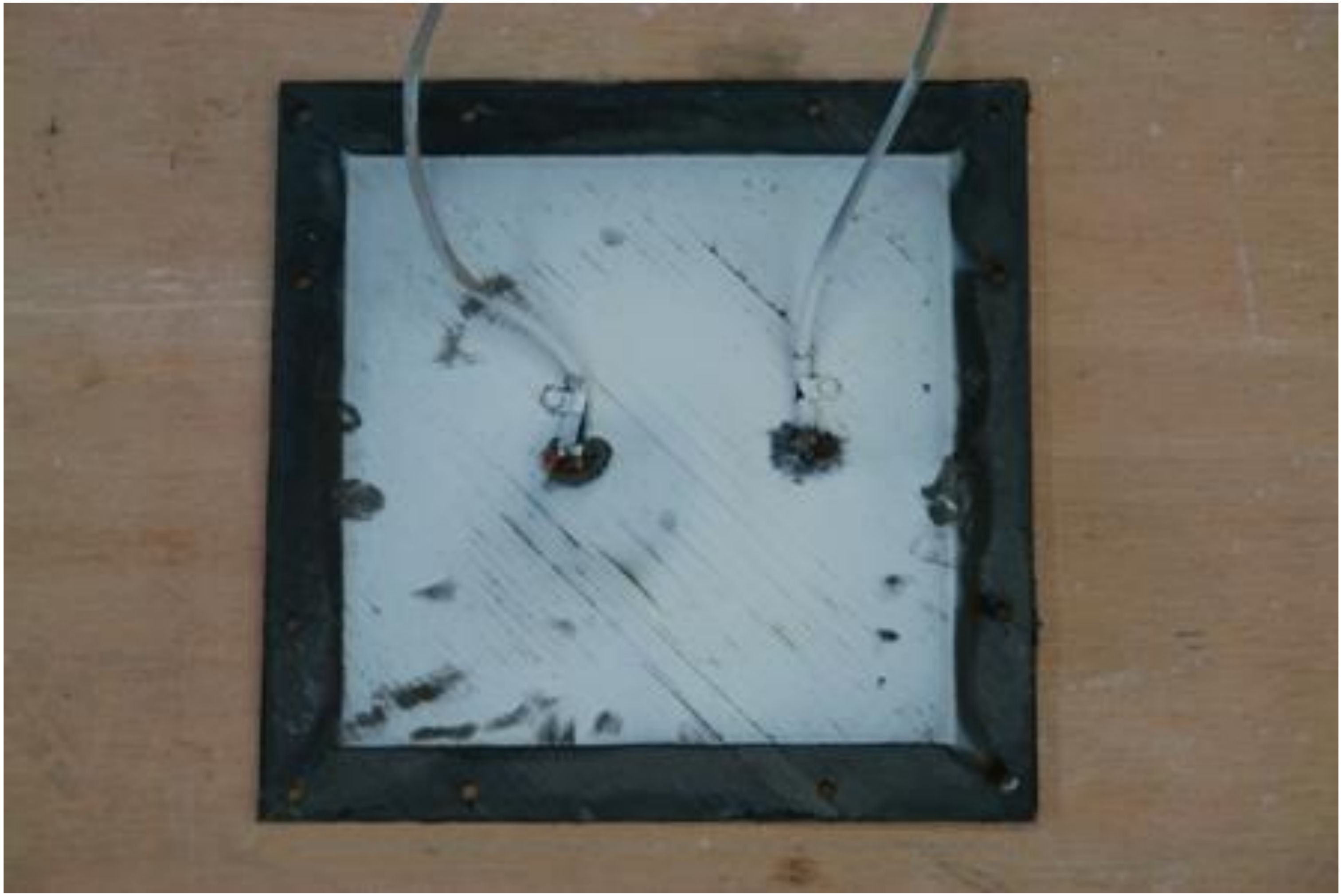
Live Fire In-Flight Aluminum Results

- Airflow at 200 mph
- Panel center temperature much slower to heat up
- Overall panel temperatures were 500 to 600 degrees lower than corresponding static test
- After 25 minutes, the airflow was stopped
- Burn-through then occurred 10.5 minutes later

Live Fire Static Composite Panel Results

- **Same test conditions as aluminum**
- **Much different results**
  - Topside temperatures peaked at 600 DegF
  - Considerable visible smoke from under the panel
  - 3:40 minutes into the test, a flash fire occurred under the panel
  - Test was terminated after 25 minutes
  - No burn through or damage to the topside of the panel
  - Underside of panel showed some resin consumed and first layer of cloth exposed.
  - Panel remained stiff and unyielding

Post Test Composite Panel



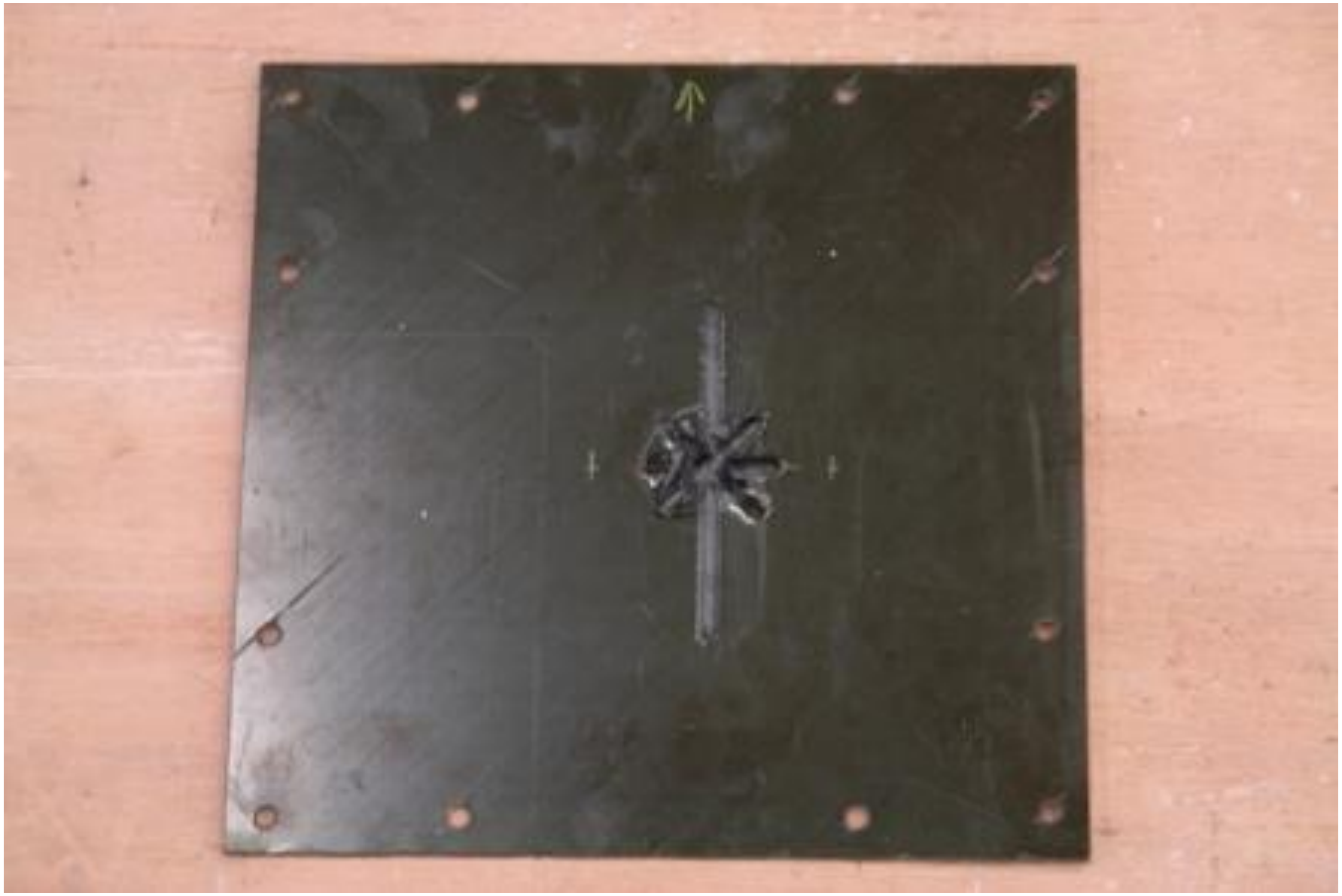
Live Fire In-Flight Composite Results

- **Airflow at 200 mph**
  - Topside panel temperatures 200 DegF lower that corresponding static test
- **Airflow increased to 300 mph**
  - Topside temperatures decreased, 350 DegF lower than corresponding static test
- **Airflow was shut off after 22 minutes**
  - Topside temperatures climbed to same level as static test
- **No burn-through**

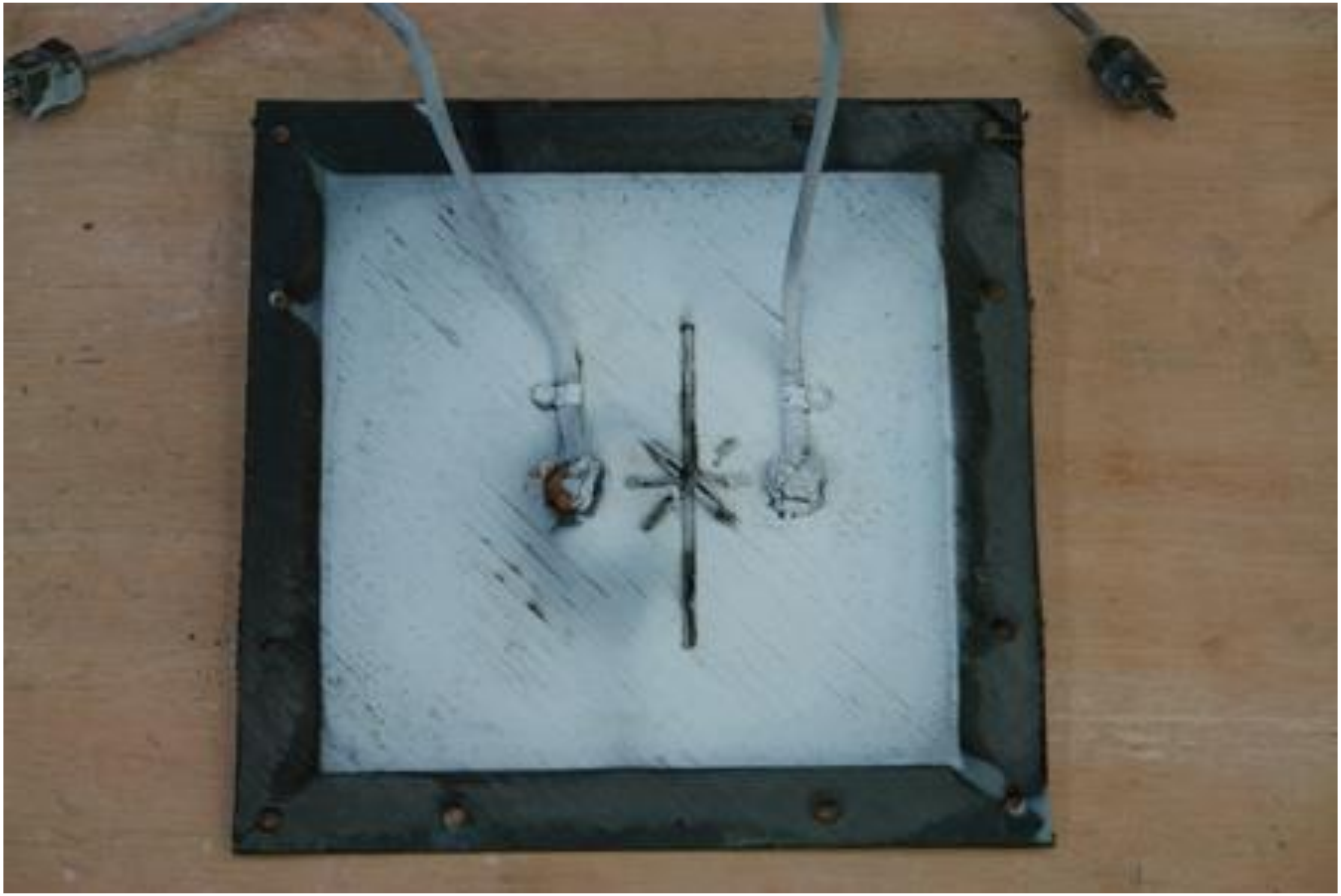
Damaged Composite Panel Results

- **The underside (fire) side of the panel was intentionally damaged**
  - Panel was scored one half the thickness of the panel (0.625”)
- **Static test was repeated**
- **The damaged panel performed as well as the undamaged panel**
  - No burn-through
  - Same resin consumption and exposed first layer of cloth

Damaged Composite Panel Before



Damage Composite Panel After



Discussion

- **Aluminum Panel Tests**
  - Aluminum transmits heat in a radial direction very effectively
  - Aluminum very effective in convective heat transfer to air, more so in a moving air-stream
  - In-flight airflow provides sufficient cooling to prevent burn-through
  - Once on the ground, burn-through can occur if the internal fire intensity is sufficient to raise the temperature of the aluminum to 1220 DegF

Discussion

- **Composite Panel Tests**
  - Composite panels do not effectively transfer heat in a radial direction
  - Composite panels do transmit heat normal to the panel
  - The resin is flammable and will be consumed on the panel surface facing the fire
  - The exposed fibers act as a fire blocking layer preventing further damage to the interior of the panel
  - Burn-through did not occur within the time frame of these tests, 25 minutes
  - Airflow over the top of the panel effectively cooled the surface

Conclusions

- **In-flight conditions cooled the aluminum panel top surface by 500-600 DegF**
- **In-flight conditions cooled the composite panel top surface by 200-350 DegF**
- **The resin in a composite panel is flammable, however the exposed fibers act as fire blocking layer, preventing further damage**
- **Composite panels conduct heat well normal to the panel face, and poorly within the plane of the panel**

Conclusions

- The resin in a composite panel gives off a flammable gas when exposed to a live fire
- The intentionally damage composite panel performed as well as the undamaged panels under these test conditions
- Composite panels are more burn-through resistant than aluminum panels under static (no air flow) conditions