Composite and Aluminum Wing Tank Flammability Comparison Testing

Federal Aviation Administration

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Overview - Background

- FAA has released a final rule requiring the reduction of flammability within high risk fuel tanks, with the benchmark being a traditional unheated aluminum wing tank

- Next generation aircraft scheduled to enter service in the coming years have composite skin that could change baseline fleet wing tank flammability
  - Logic assumes composite wings will be more flammable as they reject heat less effectively compared to aluminum
  - Could also absorb more heat and/or transfer heat more readily to the ullage

Overview - Wing Tank Flammability Parameters

Flammability Drivers on Ground

- Top skin and ullage are heated from sun
- Hot ullage heats top layer of fuel, causing evaporation of liquid fuel
- Bulk fuel temperature however, remains relatively low

Flammability Drivers In Flight

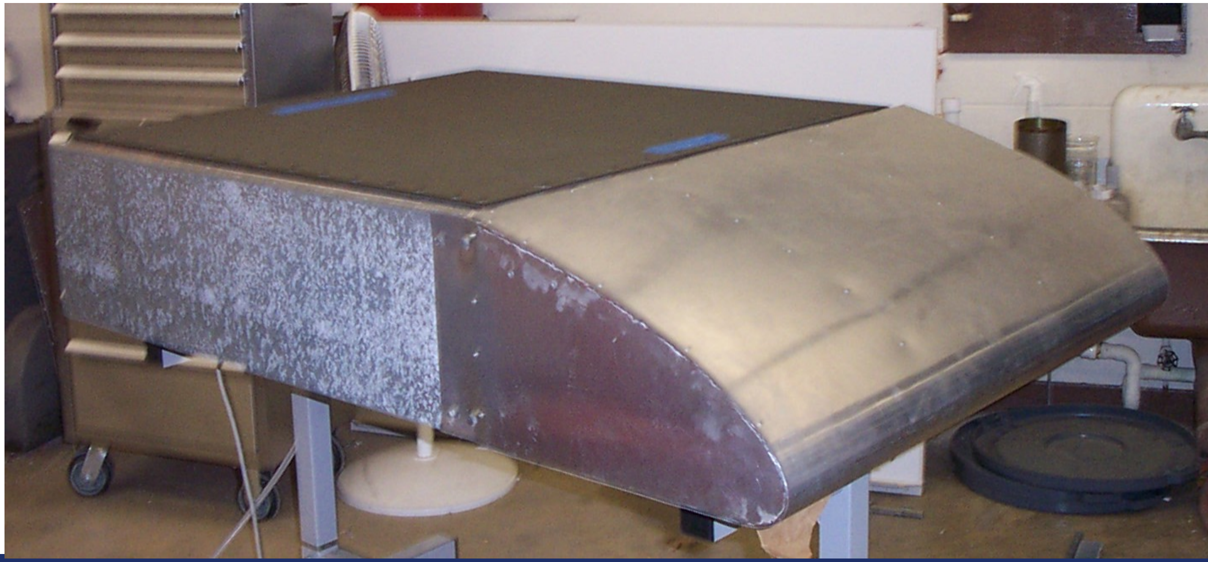
- Decreasing pressure causes further evaporation of fuel
- Cold air flowing over the tank causes rapid cooling and condensation of fuel vapor in ullage

➢ These concepts were observed during previous testing and reported on recently (see rpt #DOT/FAA/AR-08/8)

  - The objective is to now compare flammability progression in a wing fuel tank test article with both aluminum skin and composite skin with varying topcoats and thicknesses

Test Apparatus - Wing Tank Test Article

- Constructed wing tank test article from previous test article
  - Interchangeable aluminum and composite skin panels on top and bottom with an aerodynamic nose and tail piece
- Tank is vented and has a gas sample port for THC analysis, pressure transducer, and an extensive array of thermocouples
- Radiant panel heaters used to heat top surface to simulate ground conditions



Test Apparatus – Airflow Induction Test Facility

- Subsonic induction type, nonreturn design wind tunnel
- Induction drive powered by two Pratt & Whitney J-57 engines

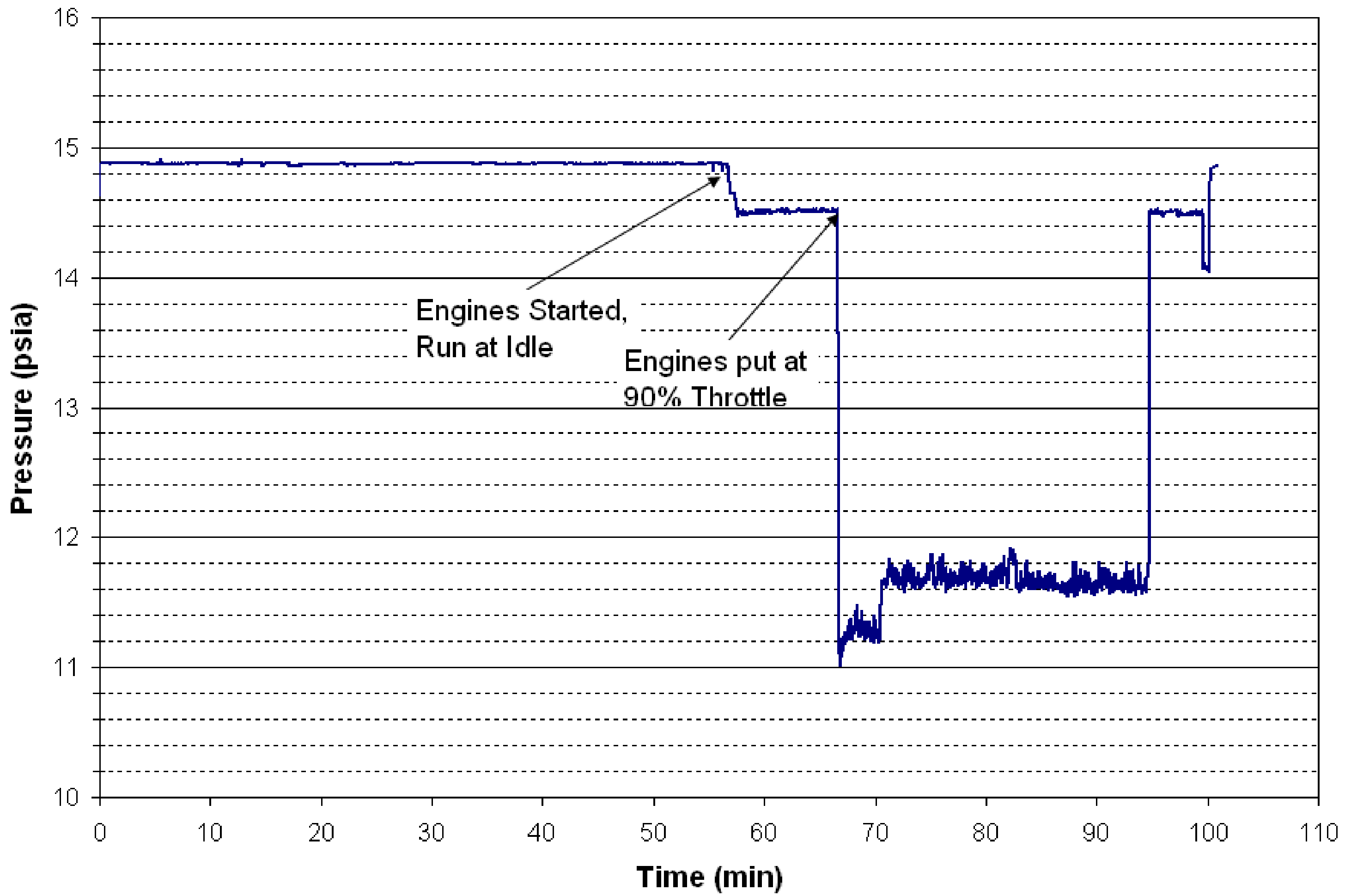
Test Apparatus – Airflow Induction Test Facility

- Test article was mounted in the high speed test section
  - 5-½ foot in diameter and 16 feet in length.

- Maximum airspeed of approximately 0.9 mach, though with the test article we measured airspeeds of approximately 0.5

Test Apparatus – Airflow Induction Test Facility

- Due to the design, a simulated altitude (i.e. reduction in pressure) is observed as the airspeed is increased.



Test Conditions – Airflow Induction Test Facility

- Fuel levels of 40, 60, 80% were examined
- Radiant heaters used to heat top surface of tank for 1 hour prior to fueling
  - Tests conducted with two different heat settings
- Fuel was preconditioned to 90F and transferred into the tank
- Heating of tank was continued for 1 hour at which point heaters were removed and wind tunnel was started.
- Engines initially run at idle for 5-10 minute warm up period and then taken to 90% throttle
- 90% throttle position maintained for a period of 30 minutes
- Discrete THC sample points were taken throughout testing

Previous Results

- Previous testing examined flammability/temperature profiles using bare materials (composite and aluminum) for top and bottom skin.

- These tests provided further evidence that ullage temperature is the primary driver of flammability for this configuration (i.e. wing tank being heated from above).

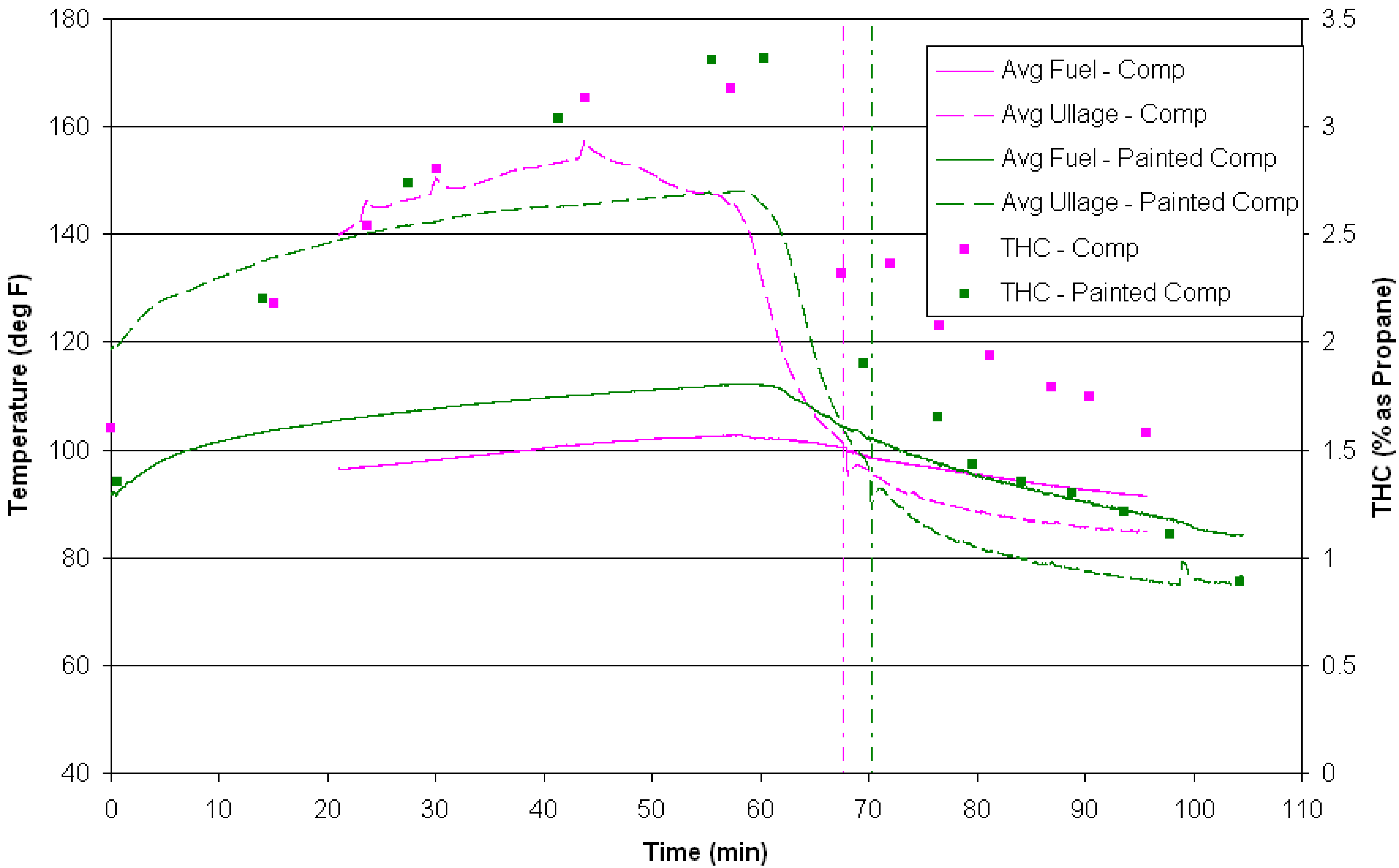
- The bare composite (black) resulted in much higher temperatures, and therefore also higher flammability readings than the bare aluminum, however
  1. Once airflow over the tank was initiated, temperature and flammability profiles behaved very similarly
  2. When aluminum tank was heated sufficiently, and the starting temperature and flammability values were equivalent, the two tanks behaved very similarly.

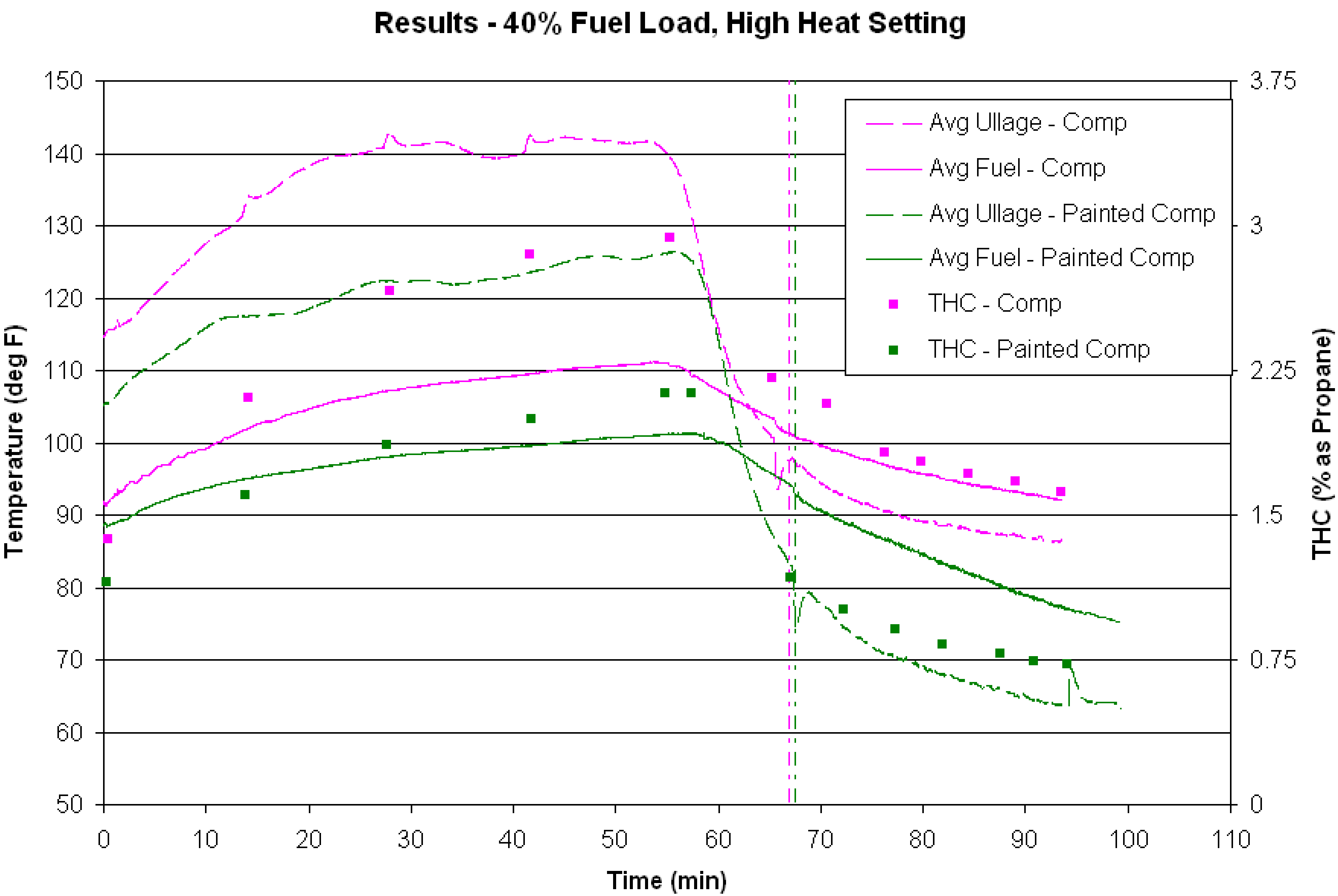
Current Tests

- For the current set of tests, aviation grade primer and a white topcoat were applied to the composite panels and the tests were repeated.

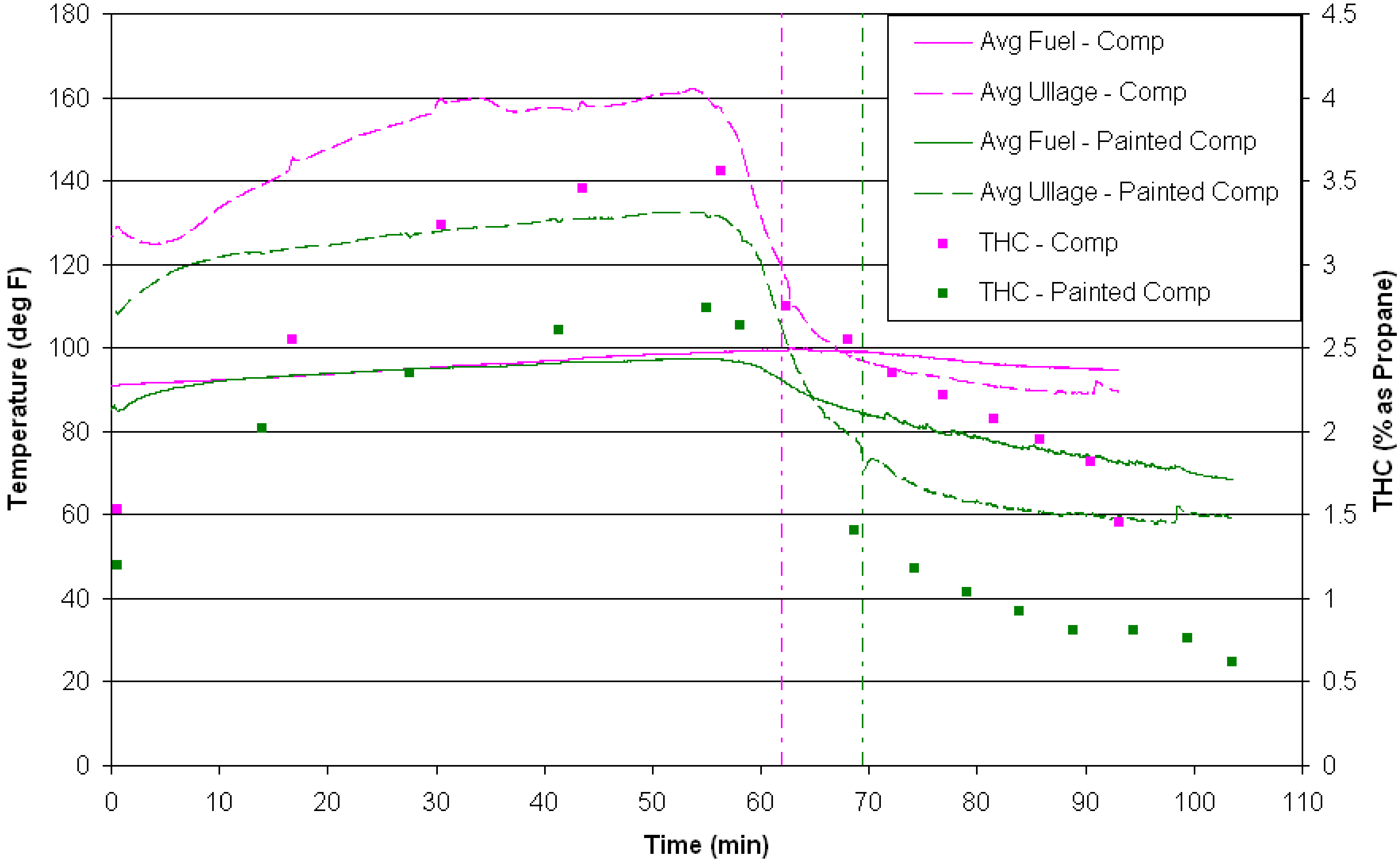
- Additionally, aviation grade primer and a black topcoat were applied to the aluminum panels.
  - Testing with these panels have not yet been completed.

Results - 60% Fuel Load, High Heat Setting




Results - 40% Fuel Load, High Heat Setting
Temperature (deg F)
150
140
130
120
110
100
90
80
70
60
50
THC (% as Propane)
3.75
3
2.25
1.5
0.75
0
0
10
20
30
40
50
60
70
80
90
100
110
Time (min)
Avg Ullage - Comp
Avg Fuel - Comp
Avg Ullage - Painted Comp
Avg Fuel - Painted Comp
THC - Comp
THC - Painted Comp

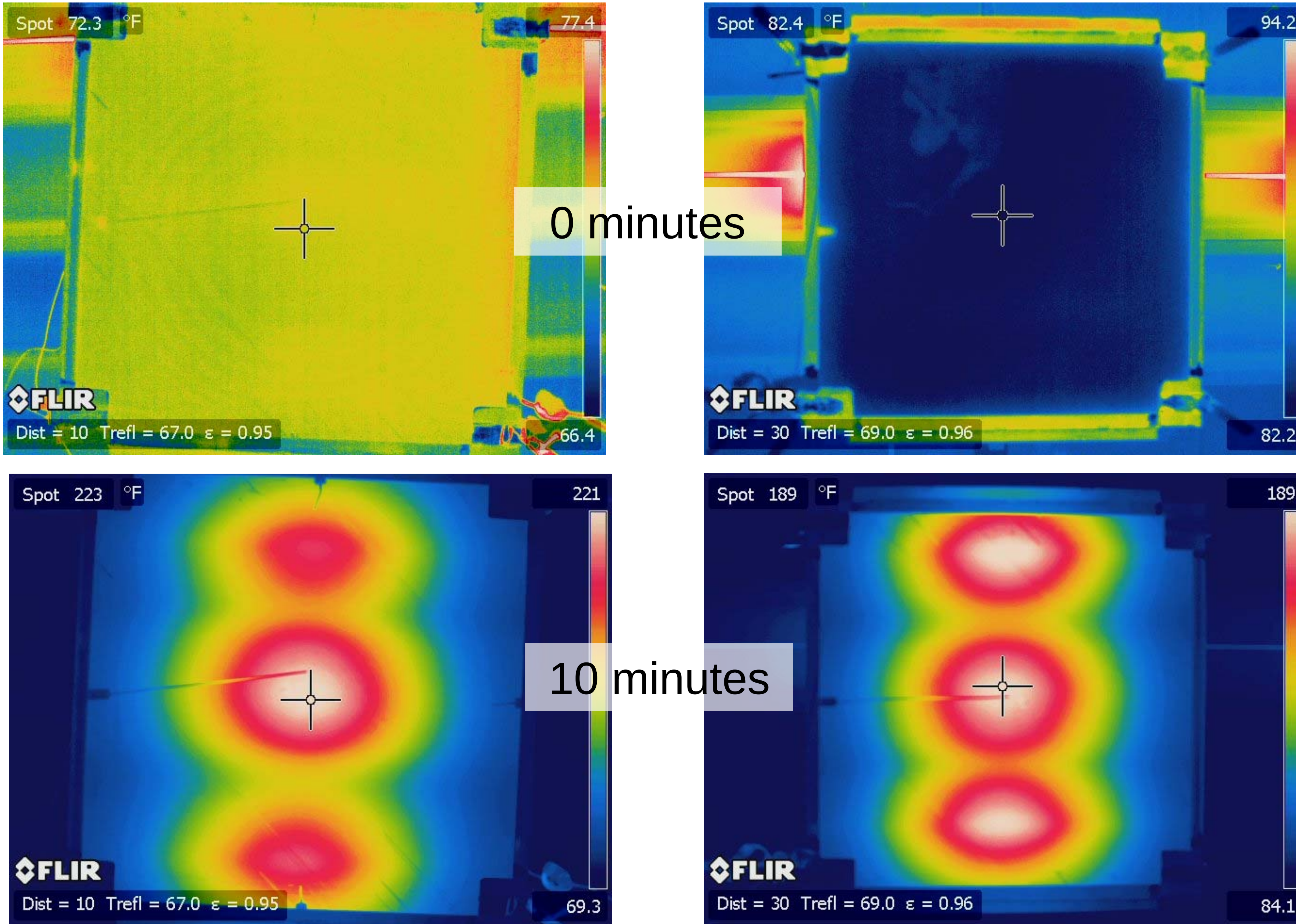
Results - 80% Fuel Load, High Heat Setting



Test Apparatus – Panel Heat Tests

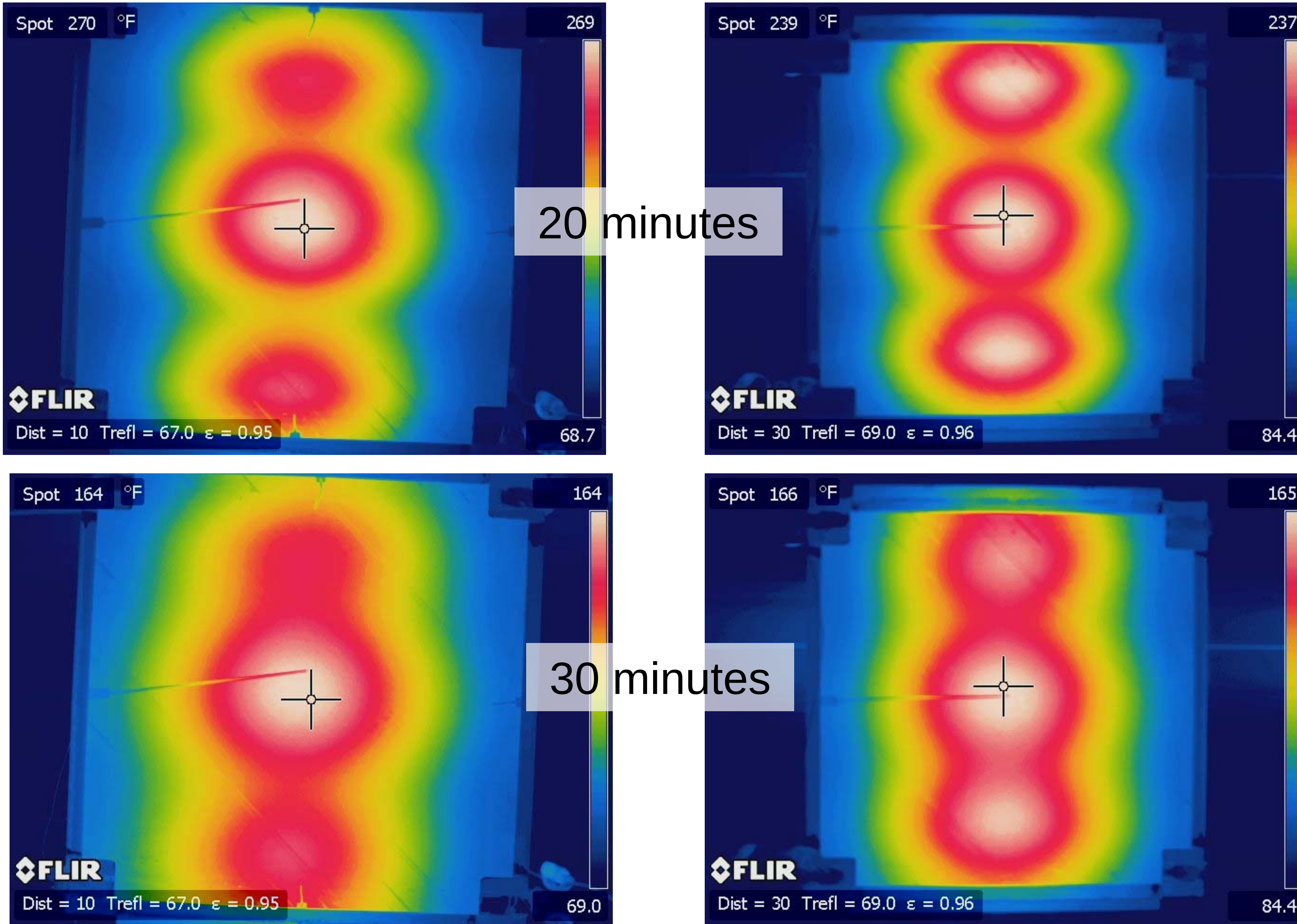
- Examined the static heating/cooling aspects of each material with support of the FAA Video Lab
- 3-ft x 3-ft panel of each material suspended and heated from above with 3 radiant panel heaters
- Panels were subjected to radiant heat for 20 minutes, followed by cooling of approximately 30 minutes
- Single thermocouple placed in center of panel, utilized as a reference point
- FLIR camera utilized to examine the panels' heat signature throughout test

Bare Composite **Painted Composite**



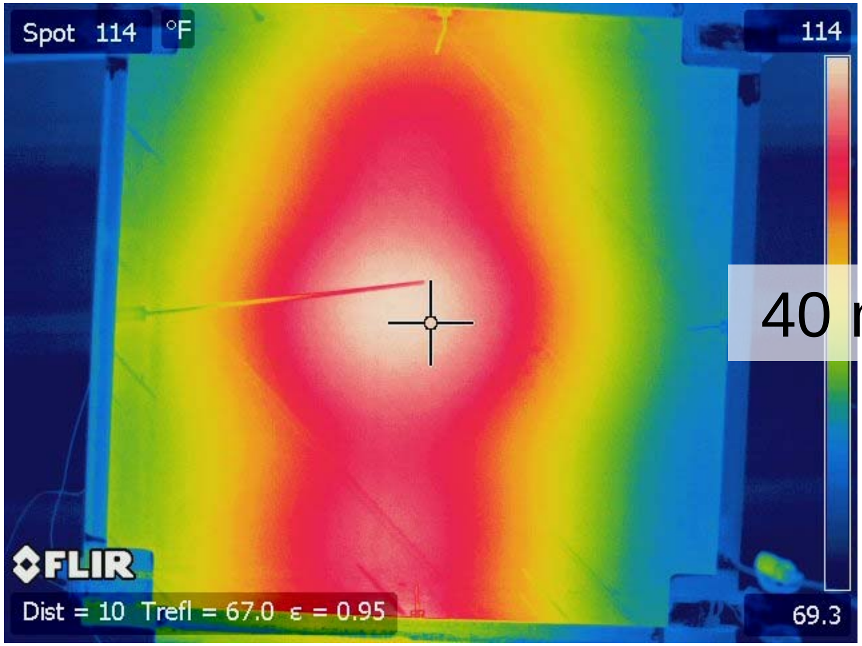
Bare Composite

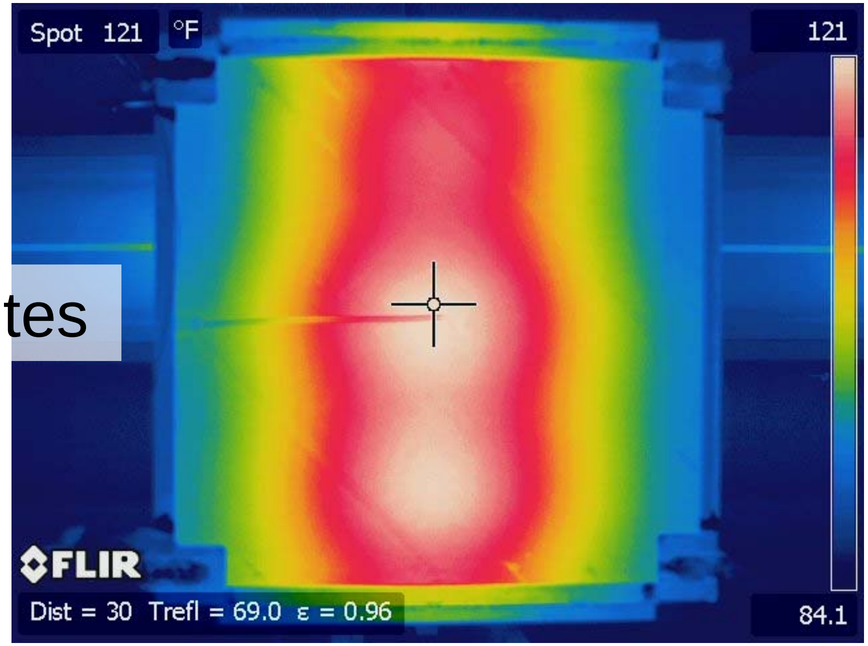
Painted Composite



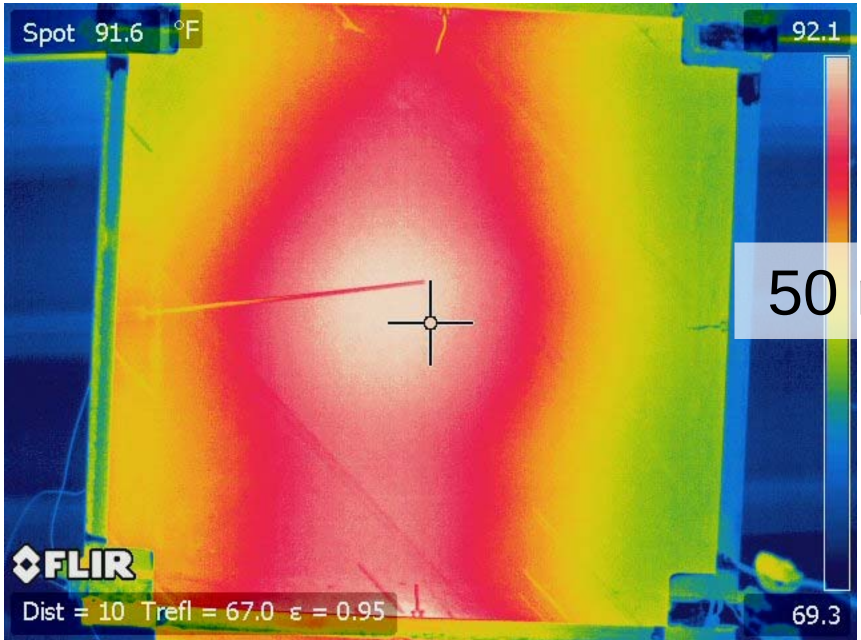
Bare Composite

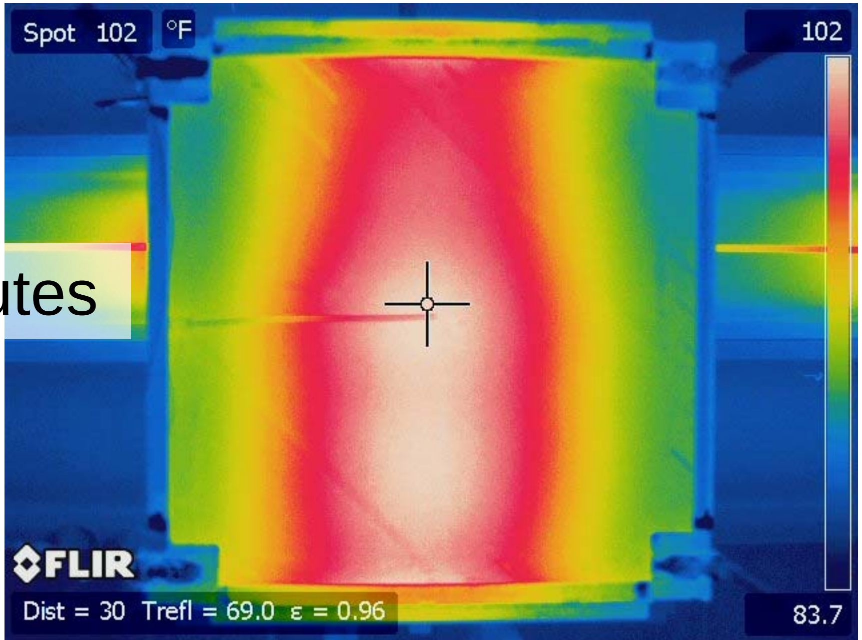
Painted Composite





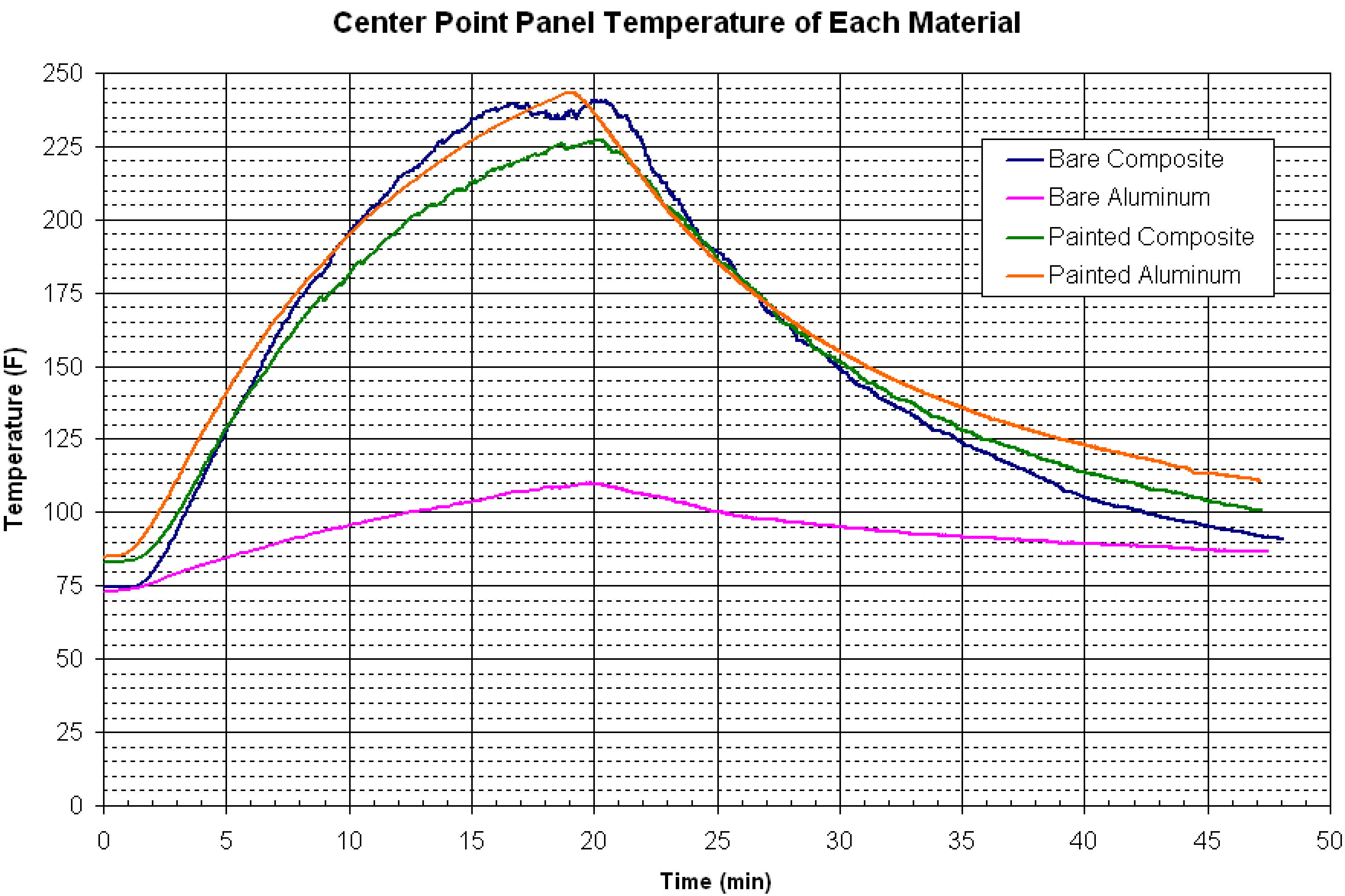
40 minutes





50 minutes

Panel Heat Tests – Results



Summary

- Based on 60% fuel load test in the wind tunnel, topcoat color appears to have very little to no effect on the resulting temperatures and flammability profiles.
- 40% and 80% fuel load tests with the painted composite panels need to be repeated due to suspicion of a non-functioning heater.
- Static heating/cooling tests with the FLIR camera also show little difference from the painted vs. bare composite materials.

Summary (cont.)

- Static heating/cooling tests with the FLIR camera show the black painted aluminum panel behaving very similarly to the composite panels.
- Further wind tunnel testing with the aluminum panels is needed to help confirm this behavior.

Planned Work

- Repeat 40% and 80% fuel load tests to correct for non-functioning heater
- Conduct further tests with black painted aluminum panels
- Examine the effects of varying thickness of composite panels
- 727 wing surge tank utilized in previous testing will be re-skinned with composite material for further testing