Composite and Aluminum Wing Tank Flammability Comparison Testing

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Outline

- Overview
- Enironmental Chamber Testing
- Airflow Induction Facility Testing
- Panel Heat Tests
- Planned Work

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)

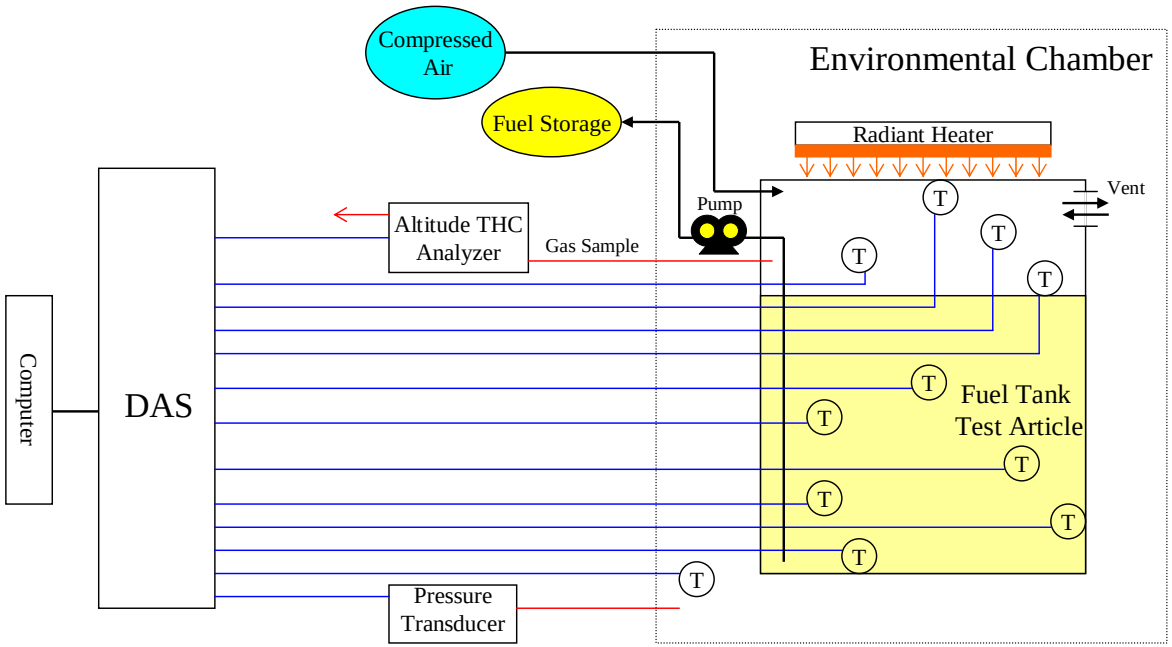
- The objective is to now compare flammability progression in a wing fuel tank test article with both aluminum skin and composite skin

Test Apparatus - Wing Tank Test Article

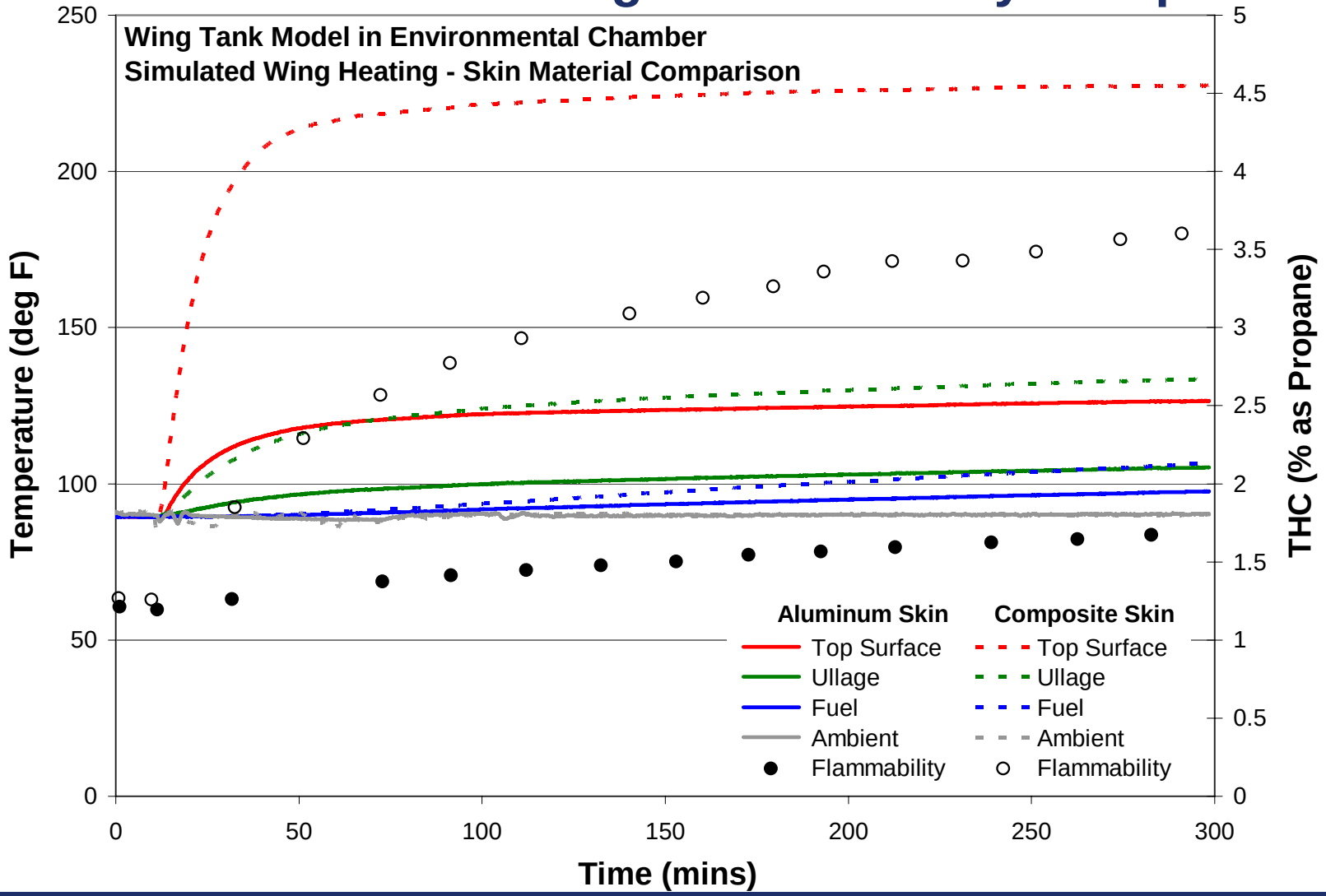
- Constructed wing tank test article from previous test article
  - Interchangeable aluminum and composite skin panels on top and bottom with an aerodynamic nose and tail piece
- Tank is vented and has a gas sample port for THC analysis, pressure transducer, and an extensive array of thermocouples
-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

Test Apparatus - Environmental Chamber Testing

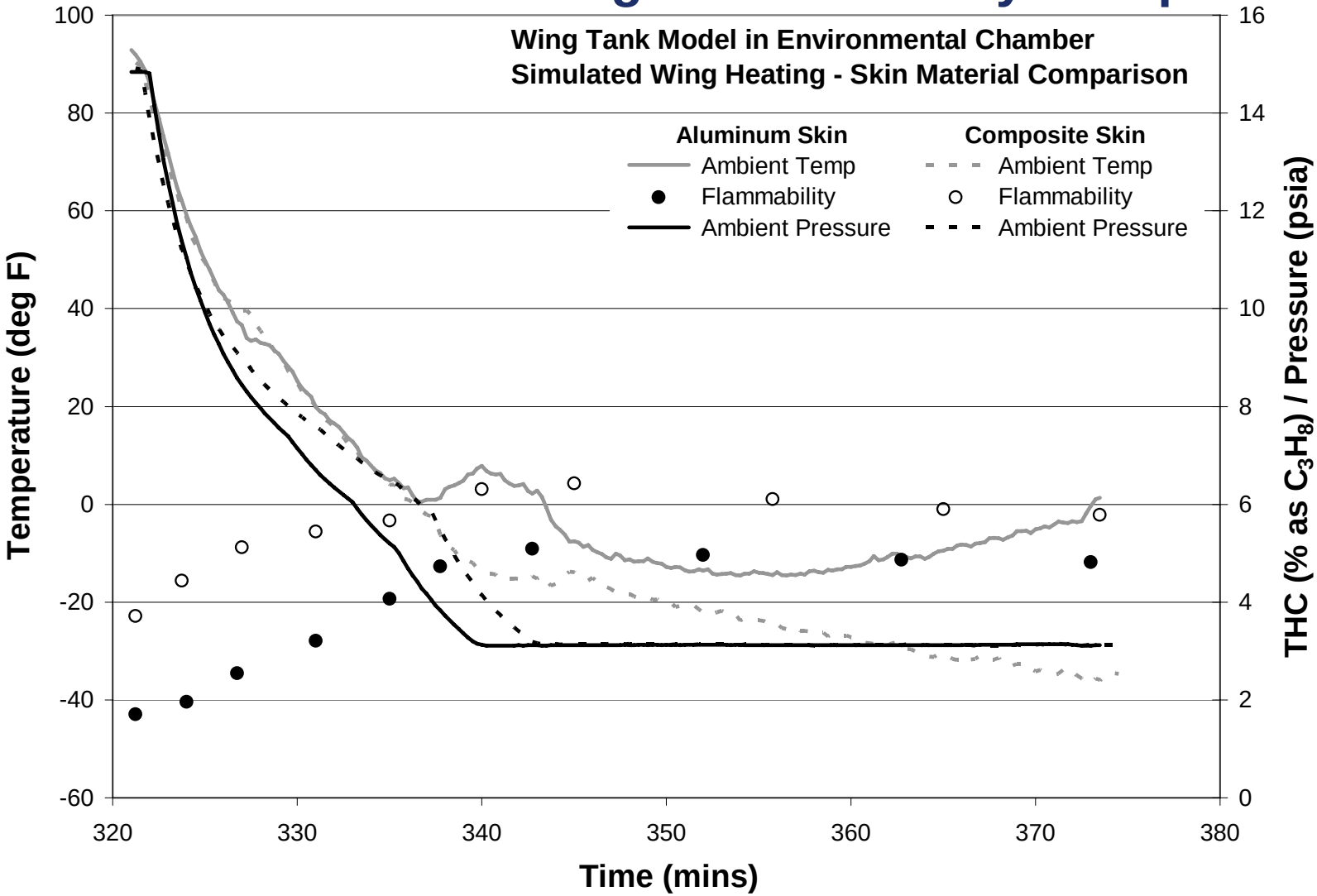
- Utilized recently made wing fuel tank test article in altitude chamber to compare Al and Composite Flammability
  - Performed two identical tests, one with each skin, with 90 deg F ambient temperature, moderate top heat, and average F.P. fuel
  - Measured skin, ullage and fuel temperature progressions over 5-hour period



Altitude Chamber Testing – Flammability Comparison



Altitude Chamber Testing – Flammability Comparison



Results - Scale Tank in Altitude Chamber

- Testing shows large increases in flammability with composite wing fuel tank skin not seen with aluminum skin when heated from top during ground conditions
  - Used same heat source, fuel flashpoint, and ambient temperature on tank with both skin surfaces
- When bringing the fuel tank to altitude and dropping the temperature, spike in flammability occurred for both
  - This is not representative of a wing fuel tank ullage because flight conditions not simulated
  - Altitude conditions not simulated with good fidelity (differing altitude profiles)

Test Apparatus – Airflow Induction Test Facility

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

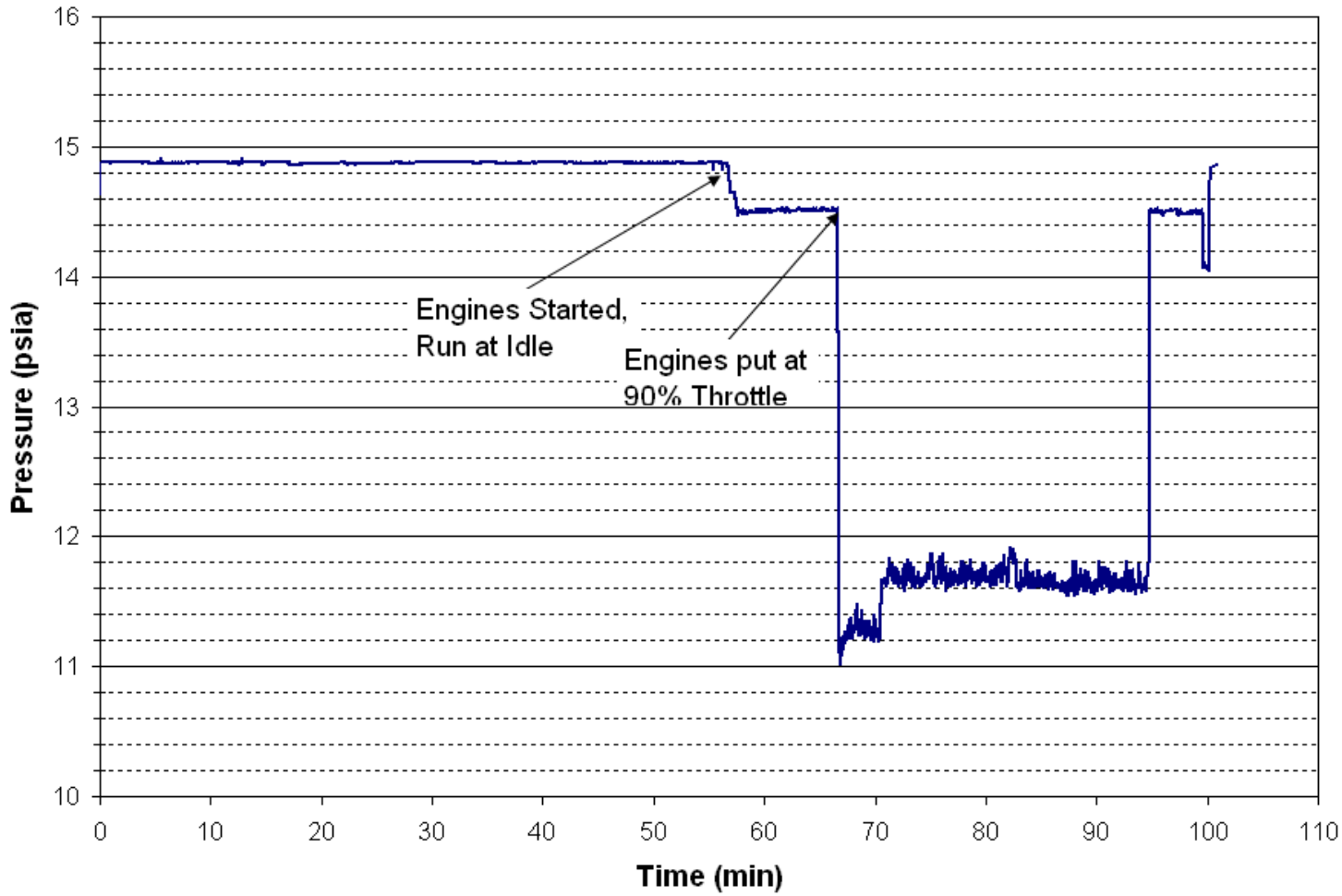
Test Apparatus – Airflow Induction Test Facility

- 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

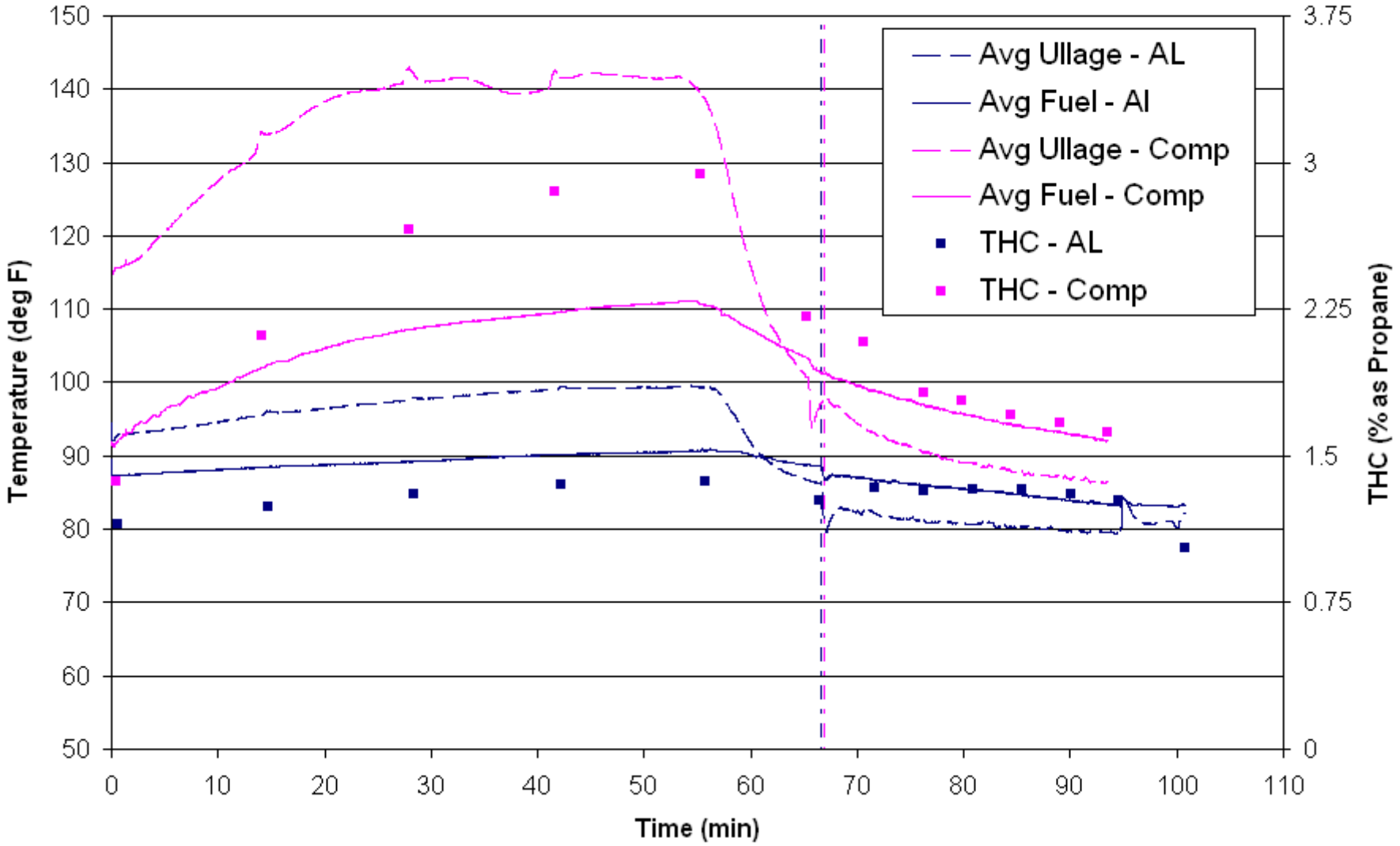
- Due to the design, a simulated altitude (i.e. reduction in pressure) is observed as the airspeed is increased.



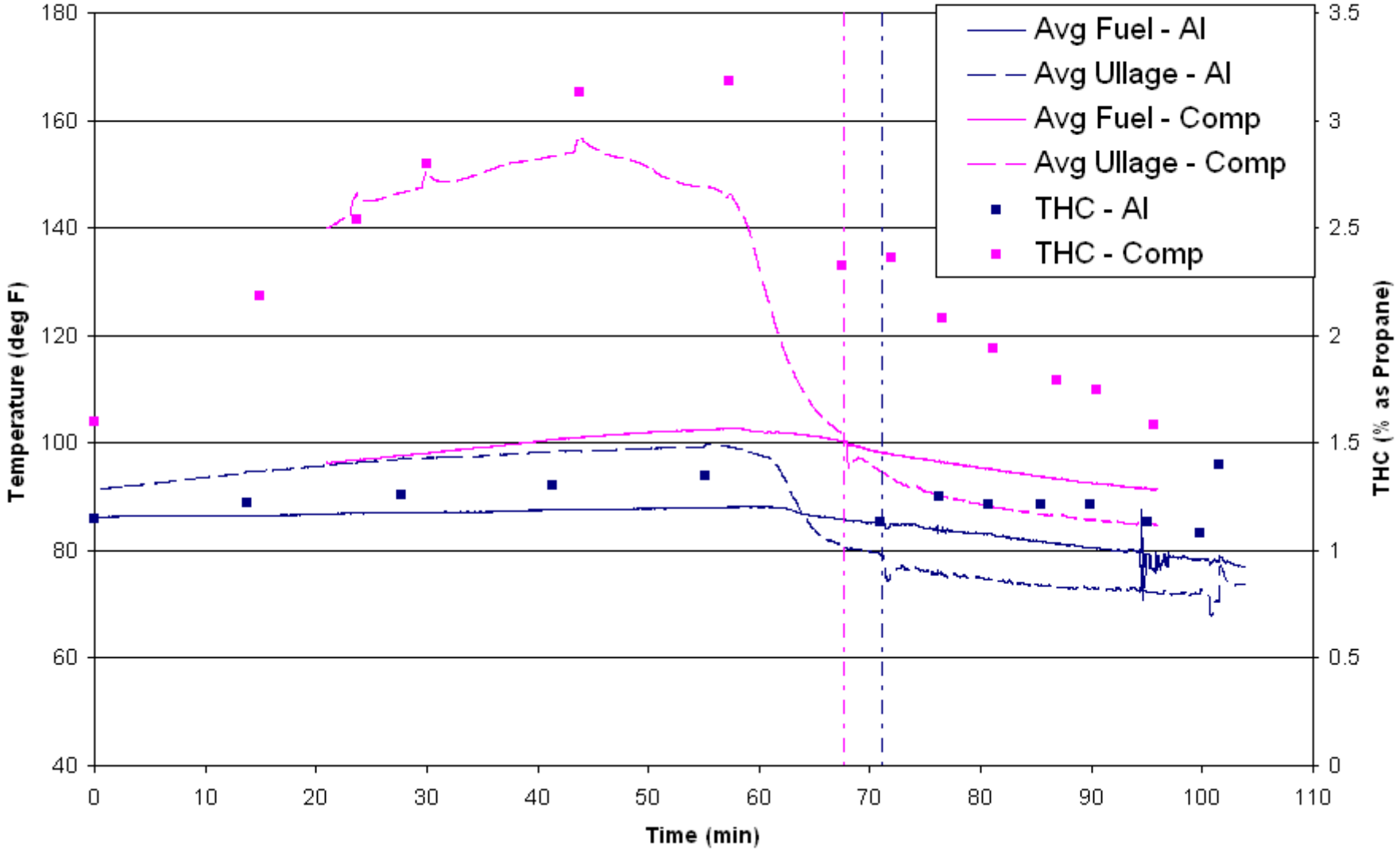
Test Conditions – Airflow Induction Test Facility

- 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

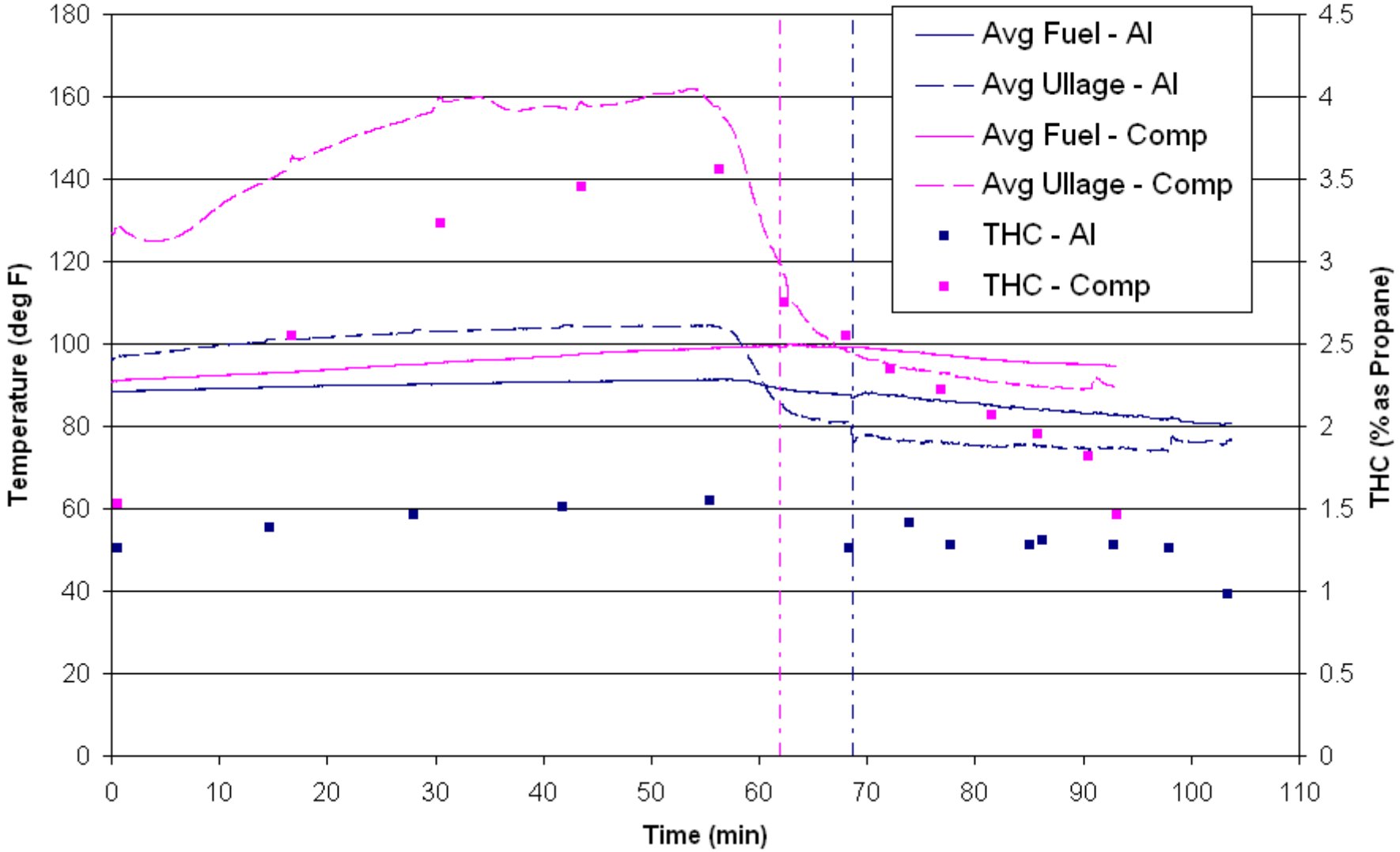
Results - 40% Fuel Load, High Heat Setting



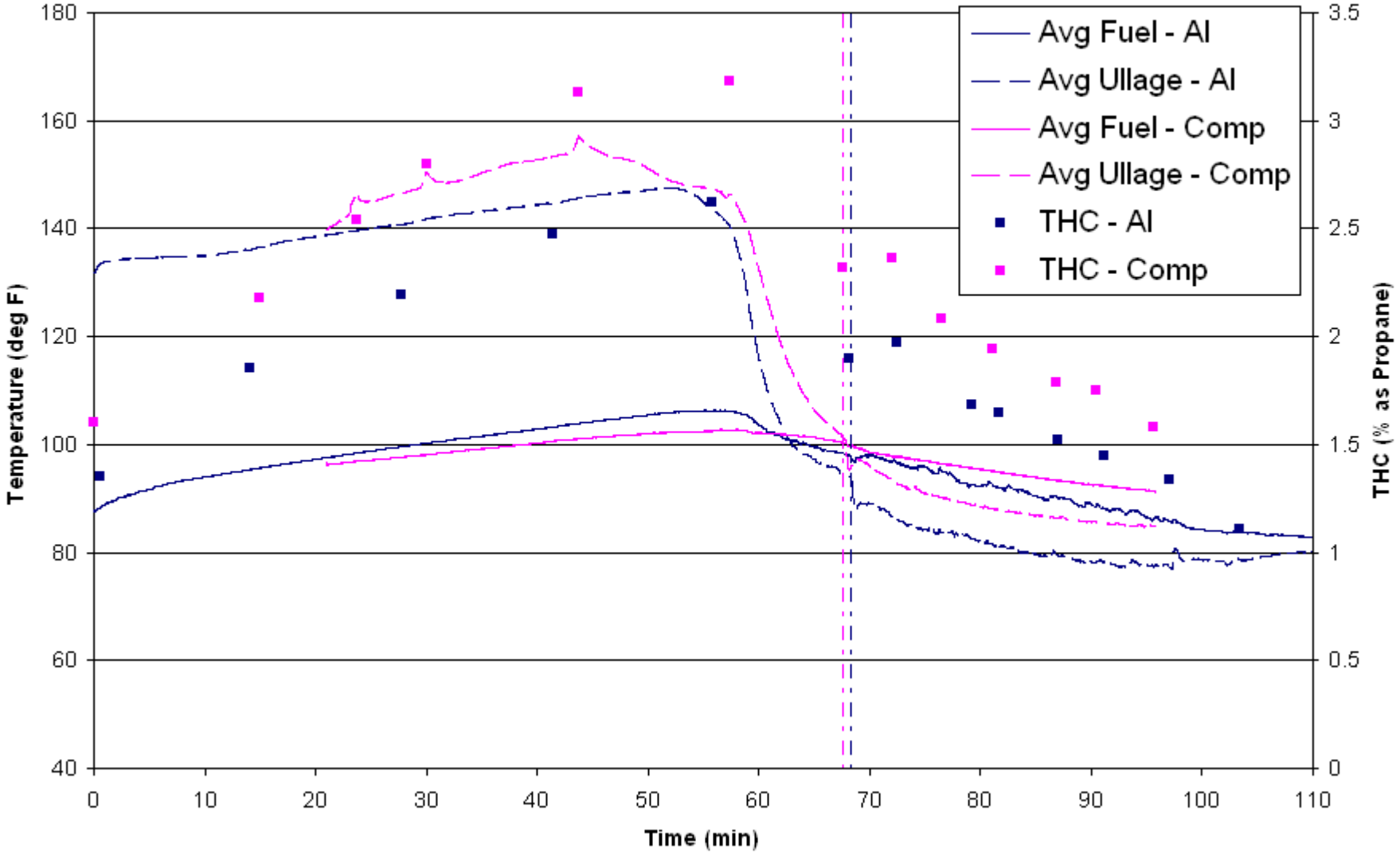
Results - 60% Fuel Load, High Heat Setting



Results - 80% Fuel Load, High Heat Setting



Results - 60% Fuel Load, Superheated Aluminum



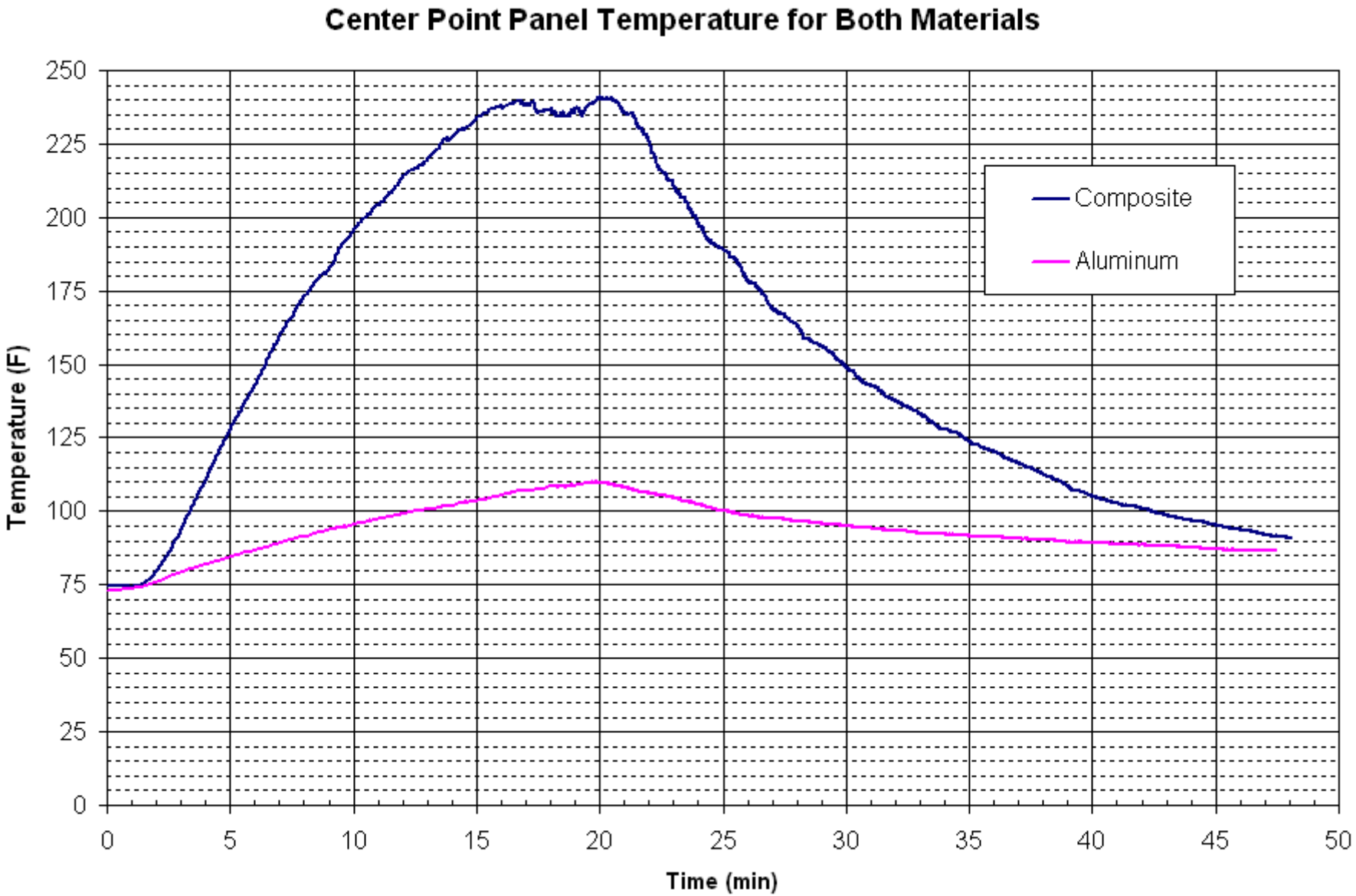
Results – Airflow Induction Facility Tests

- Similar to Environmental Chamber tests, significant increases in both ullage temperature and flammability are observed with composite as compared with aluminum skin
  - This correlation is evidence that ullage temperature is driver of flammability
- Fuel temperature increase is also observed, but not as severe
- When aluminum tank is heated sufficiently, and the starting temperature and flammability values are equivalent, the two tanks behave in a very similar manner.

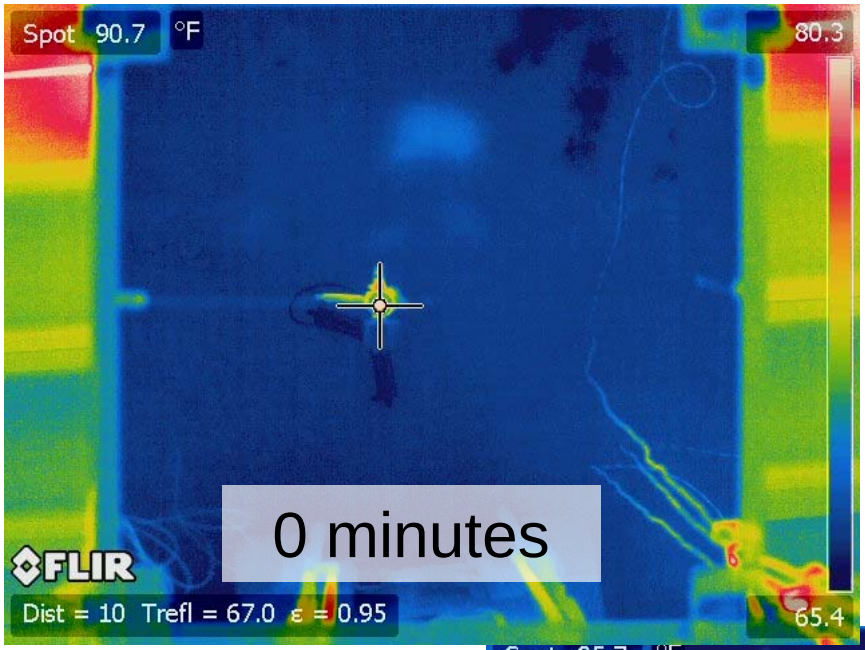
Test Apparatus – Panel Heat Tests

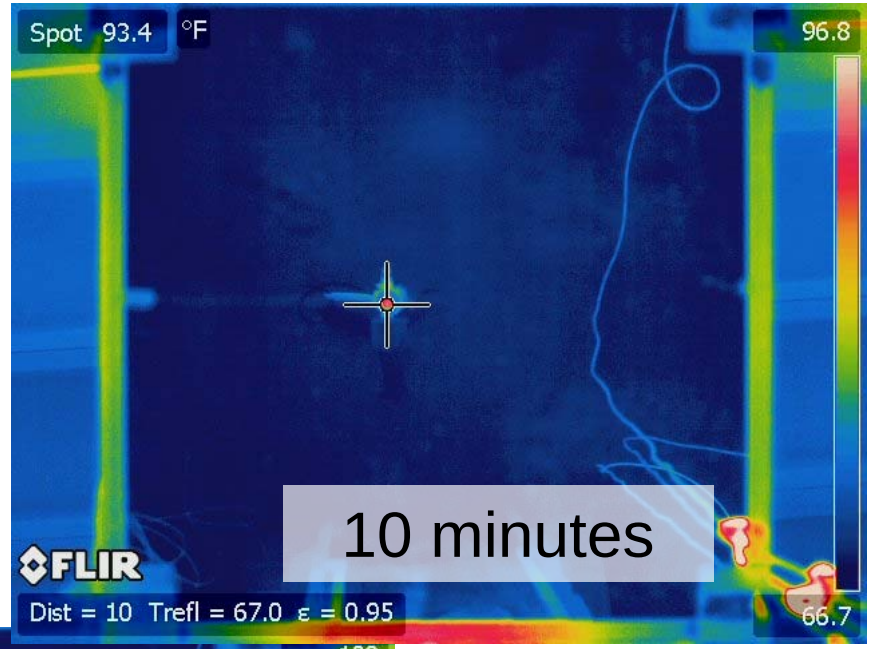
- Examined the static heating/cooling aspects of each material with support of the FAA Video Lab
- 3-ft x 3-ft panel of each material suspended and heated from above with 3 radiant panel heaters
- Panels were subjected to radiant heat for 20 minutes, followed by cooling of approximately 30 minutes
-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

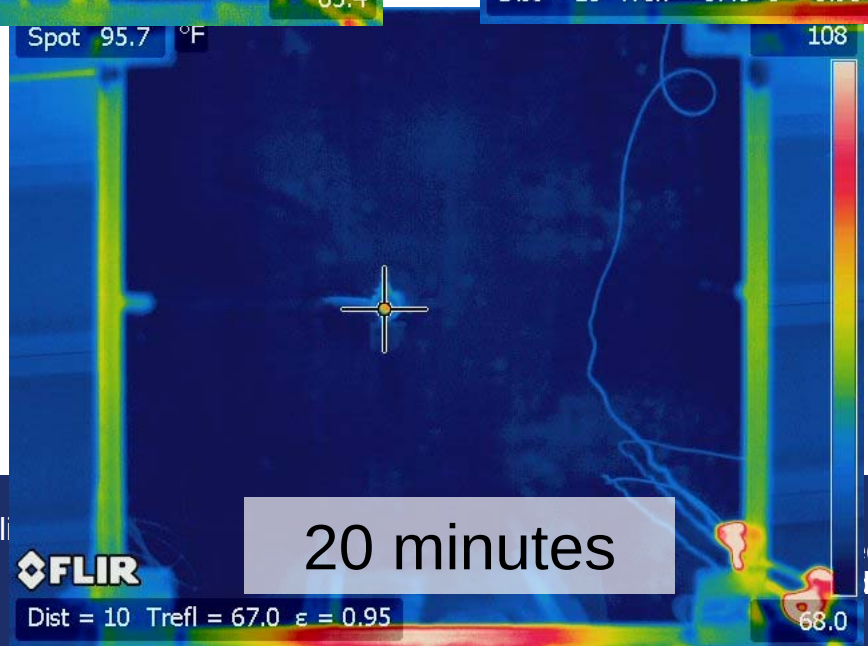
Panel Heat Tests – Results



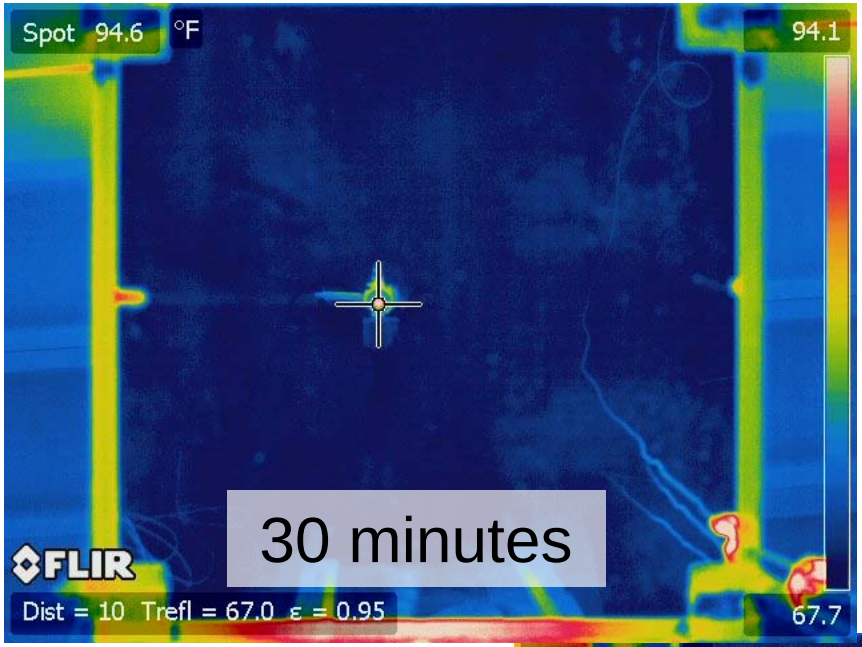
Aluminum Panel – FLIR Camera Results

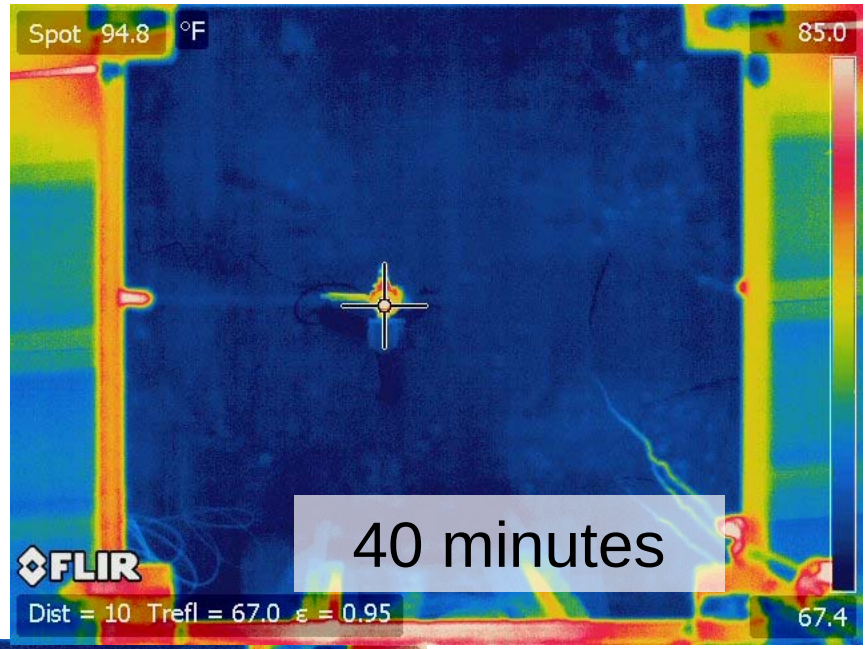


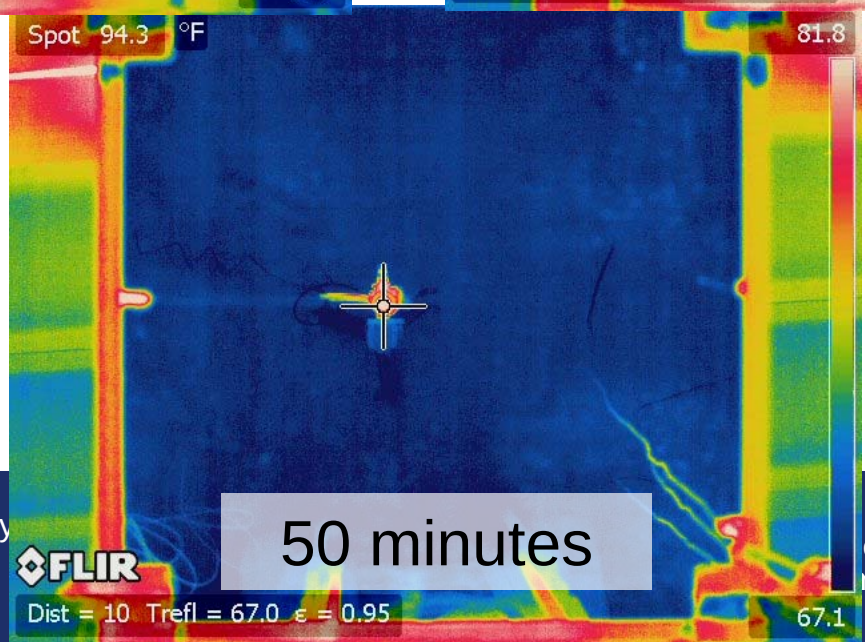




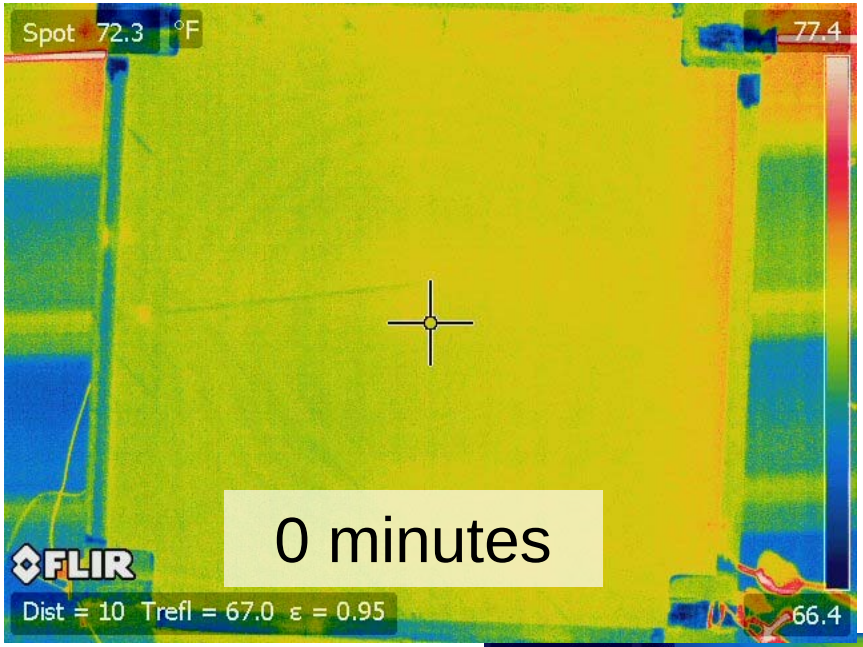
Aluminum Panel – FLIR Camera Results (cont.)

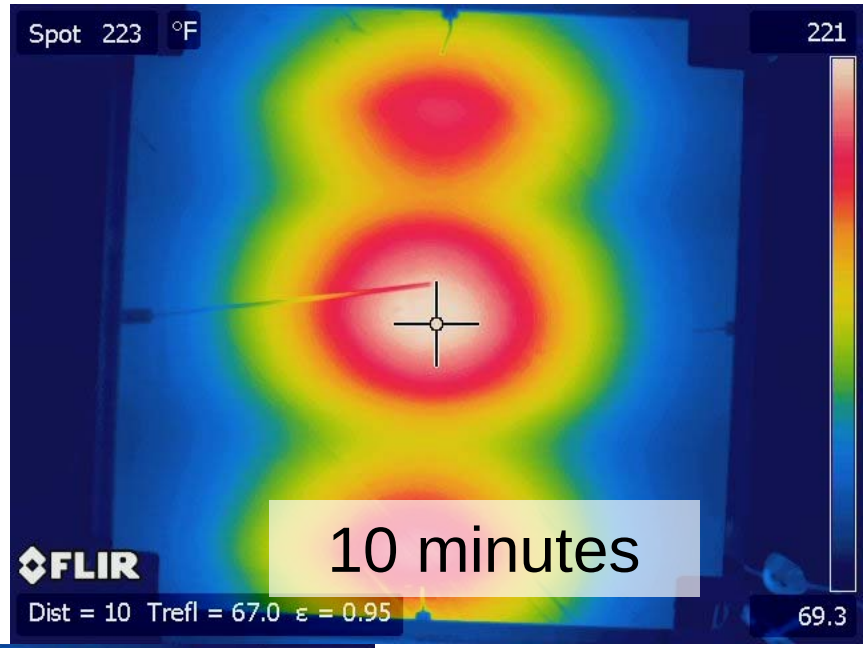


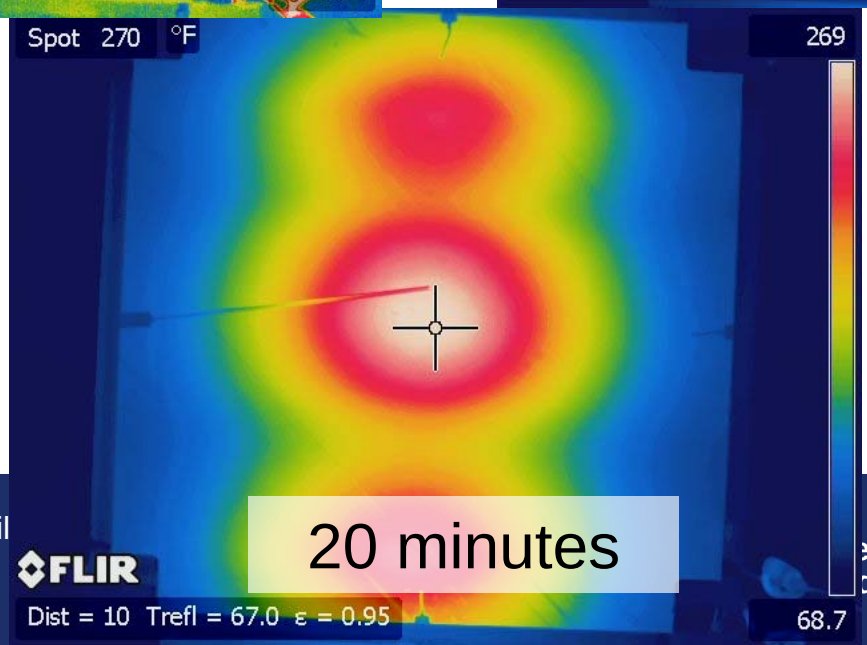




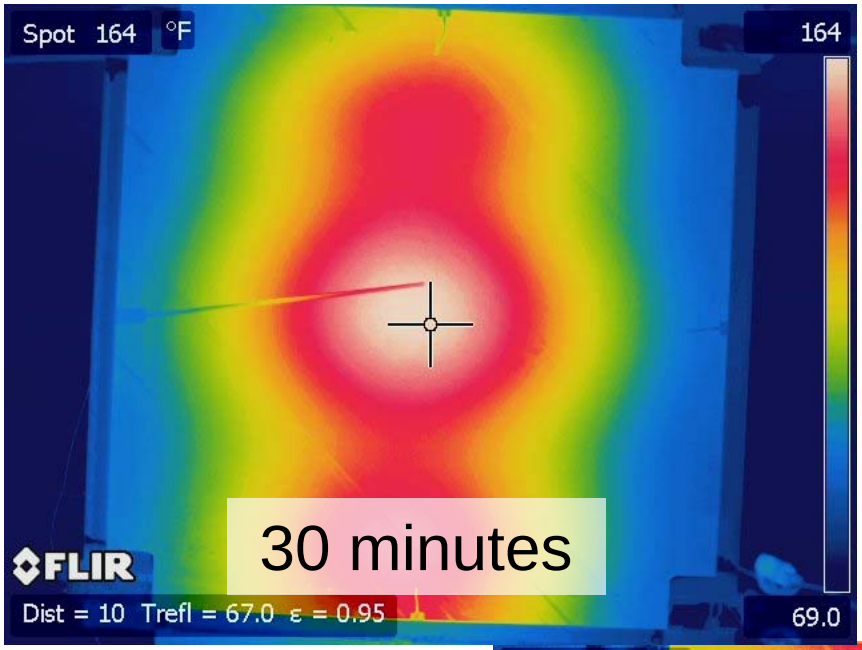
Composite Panel – FLIR Camera Results



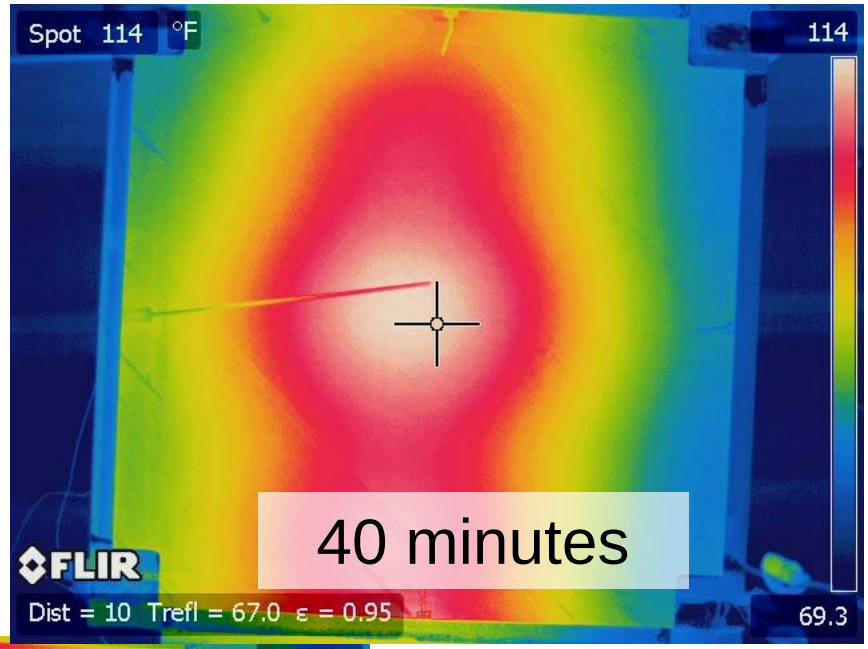




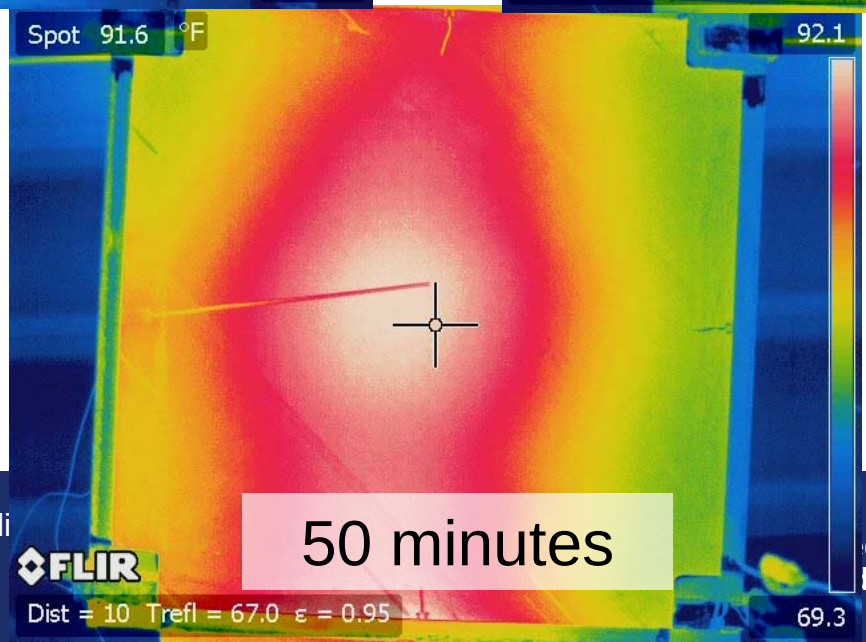
Composite Panel – FLIR Camera Results (cont.)



30 minutes



40 minutes



50 minutes

Planned Work

- Examine the effects of different colored topcoats on the heat rejection of composite and 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 this summer