Composite and Aluminum Wing Tank Flammability Comparison Testing

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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

Summary of Previous Results

The results of initial testing have been documented in FAA report DOT/FAA/AR-11/6 and is available on the Fire Safety Branch Website

- Initial testing consisted of:
  - Bare composite and aluminum panels
  - Aluminum panels with a black topcoat applied
  - Composite panels with a white topcoat applied

Summary of Previous Results

- Bare composite (black) resulted in significantly increased ullage temperatures, and therefore also higher flammability readings than the bare aluminum, however
  - Once airflow over the tank was initiated, temperature and flammability profiles behaved very similarly
  - When aluminum tank was heated sufficiently, and the starting temperature and flammability values were equivalent, the two tanks behaved very similarly.
- Black topcoat applied to aluminum panels had dramatic effect on fuel temperatures and flammability profile, making it behave more like the composite.
- White topcoat color applied to composite panel had little effect of tank temperatures and flammability levels.

Summary of Previous Results

- Based on these results, it was believed that the difference in how the topcoat affected results was not due to differences in property materials, but was rather due to the reflective behavior of the bare aluminum material

- Throughout testing, the overall correlation of high THC measurements with high ullage temperature increases was further indication that ullage temperature changes are the driving force behind in-flight flammability for wing tanks.

Current Tests

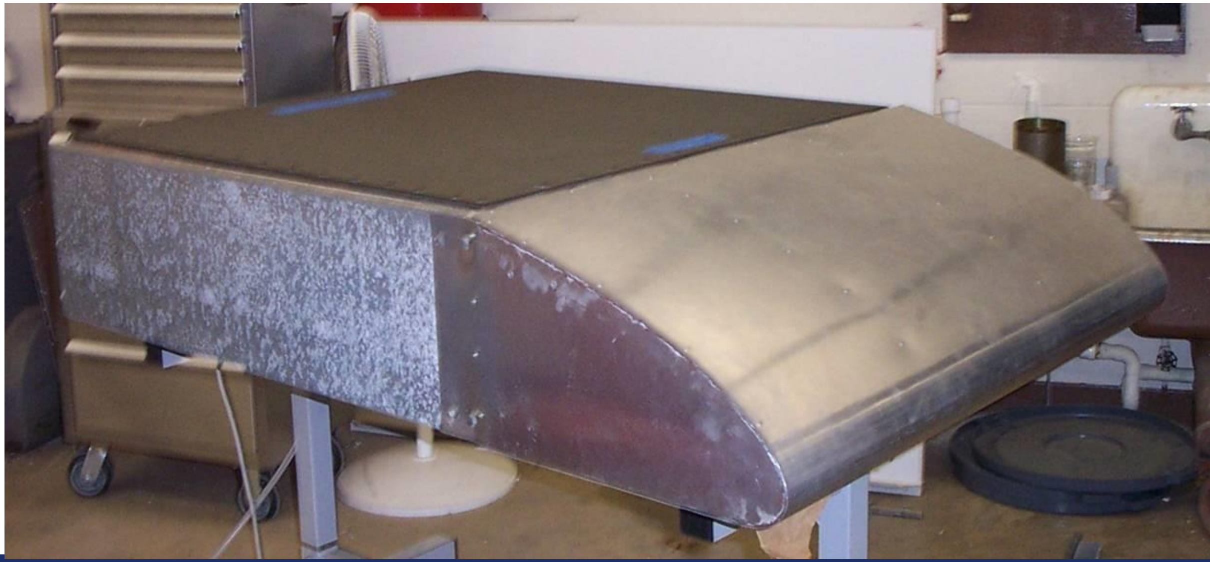
- Further testing was conducted with:
  - Aluminum panels with a white topcoat applied
  - Composite panels with a high reflectivity epoxy applied
  - Composite panels with varying thickness (¼″ to ¾″)
- In addition, a 727 wing surge tank was re-skinned with composite material and placed alongside aluminum 727 wing surge tank to provide a more realistic comparison.

Test Apparatus – Panel Heat Tests

- Test panels statically heated to examine the heat transfer through each panel.
- Test panel placed in rack with three radiative heaters placed 12” above.
- Heated for 20 minutes, followed by a 25-minute cool-down period.
- Center-point temperature on bottom surface recorded.

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

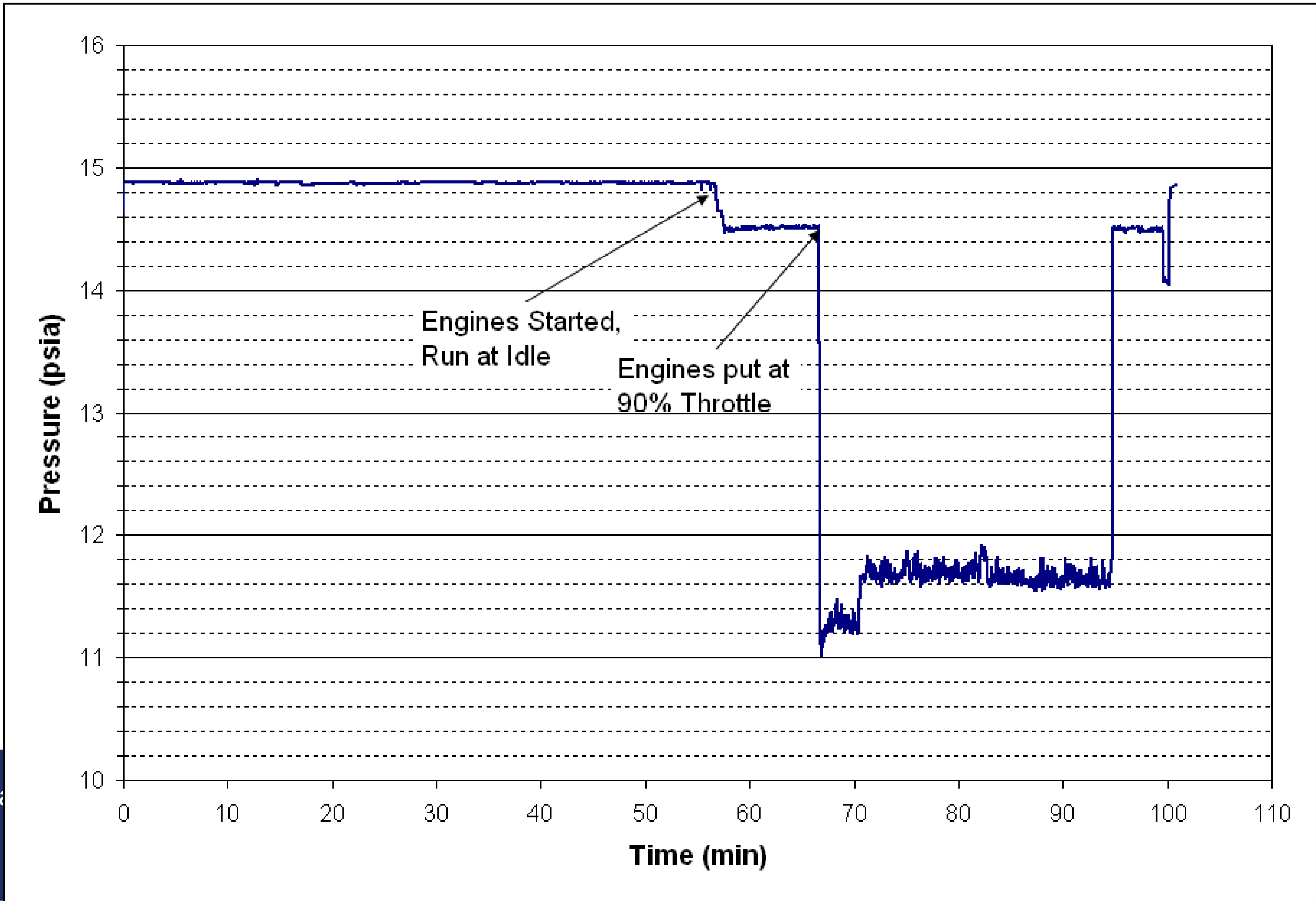
Test Apparatus – Airflow Induction Test Facility

- 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

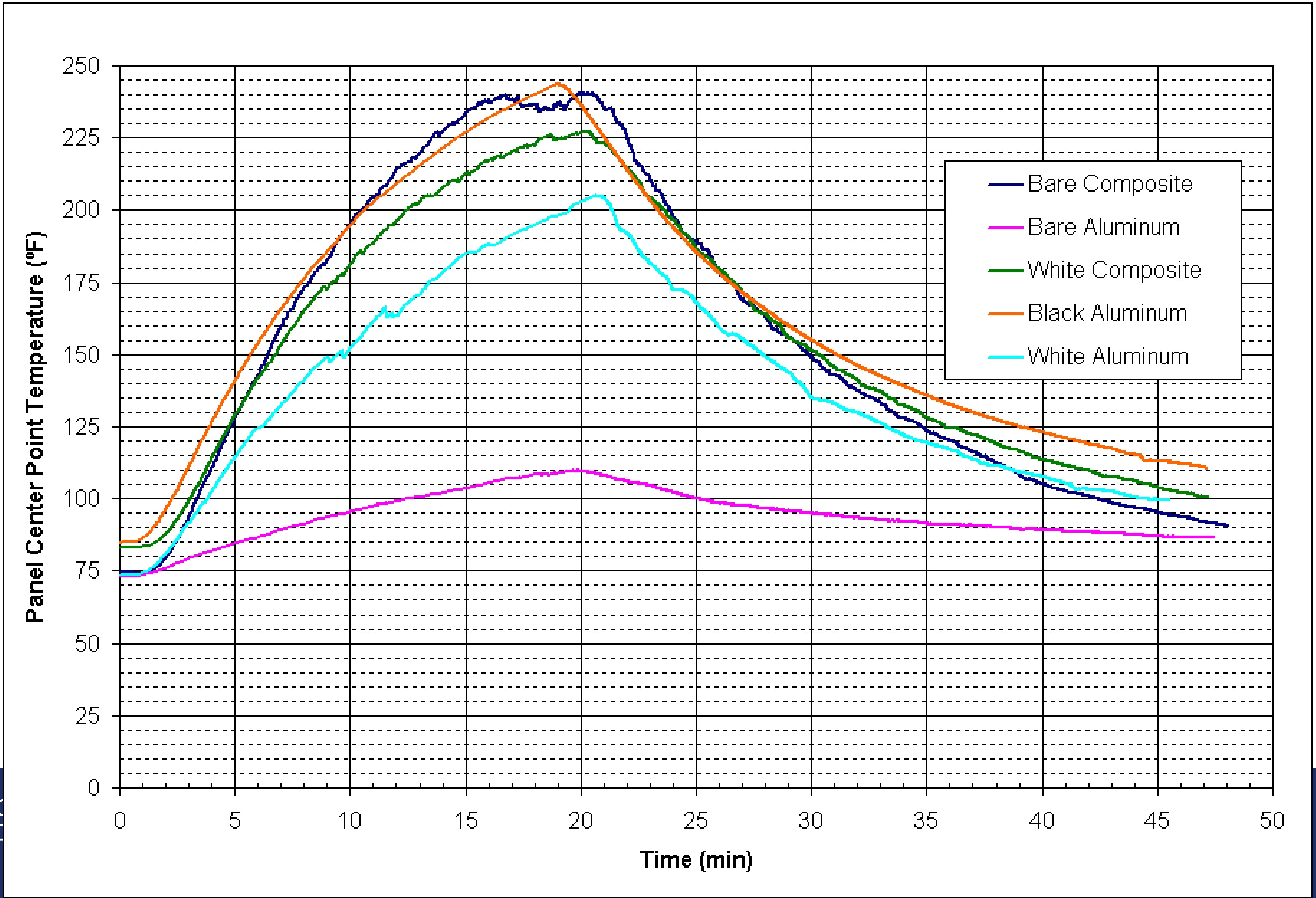
- Due to the design, a simulated altitude (i.e. reduction in pressure) is observed as the airspeed is increased.



Test Conditions – Airflow Induction Test Facility

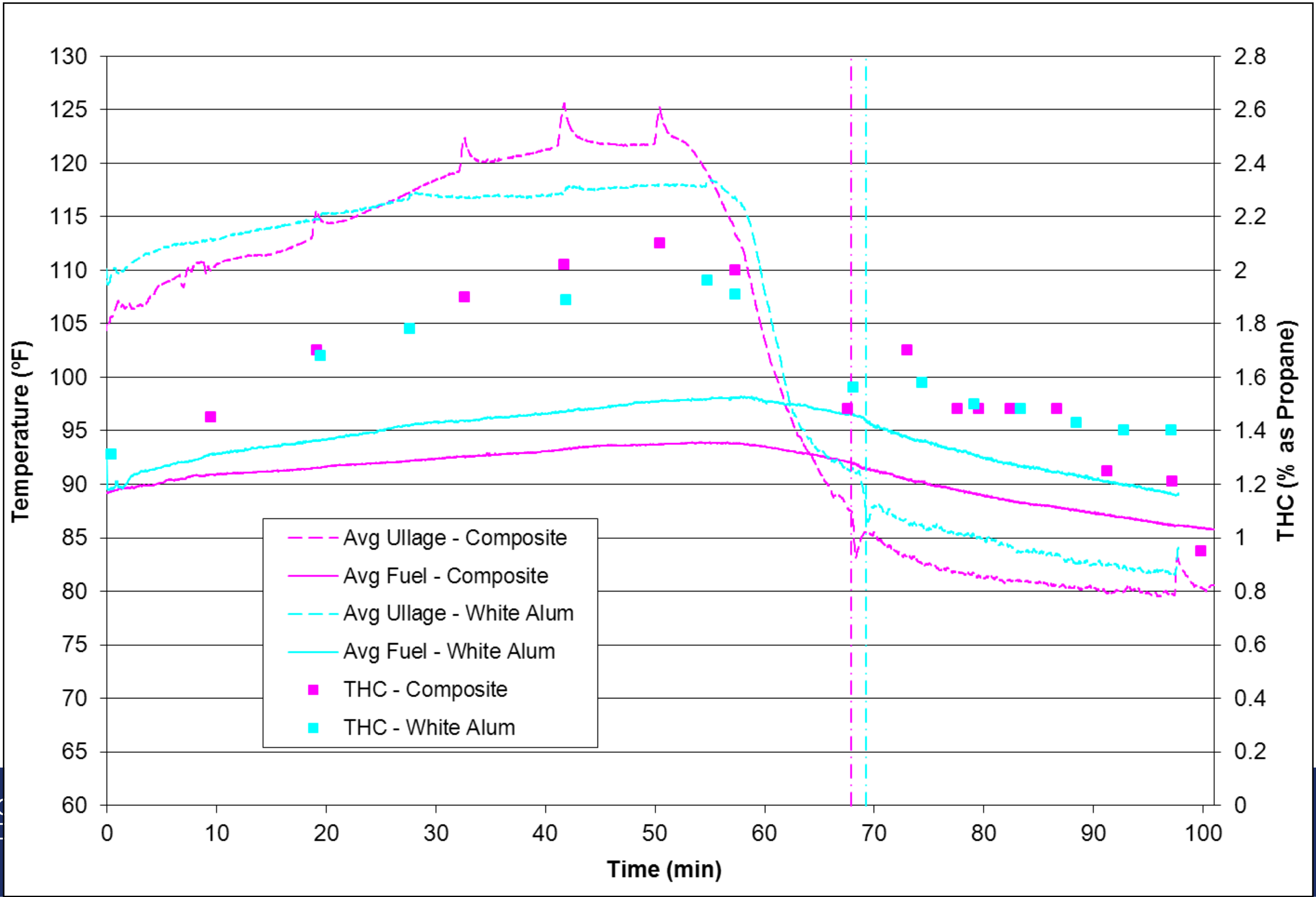
- Fuel levels of 40, 60, 80% were examined
- Three radiant heaters used to heat top surface of tank for 1 hour prior to fueling
  - Each heater had a low/high setting
  - For intermediate heat setting, two heaters on high setting were used
- Fuel was preconditioned to 90ºF and transferred into the tank
- 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

Panel Heat Test Results – Topcoat Effects

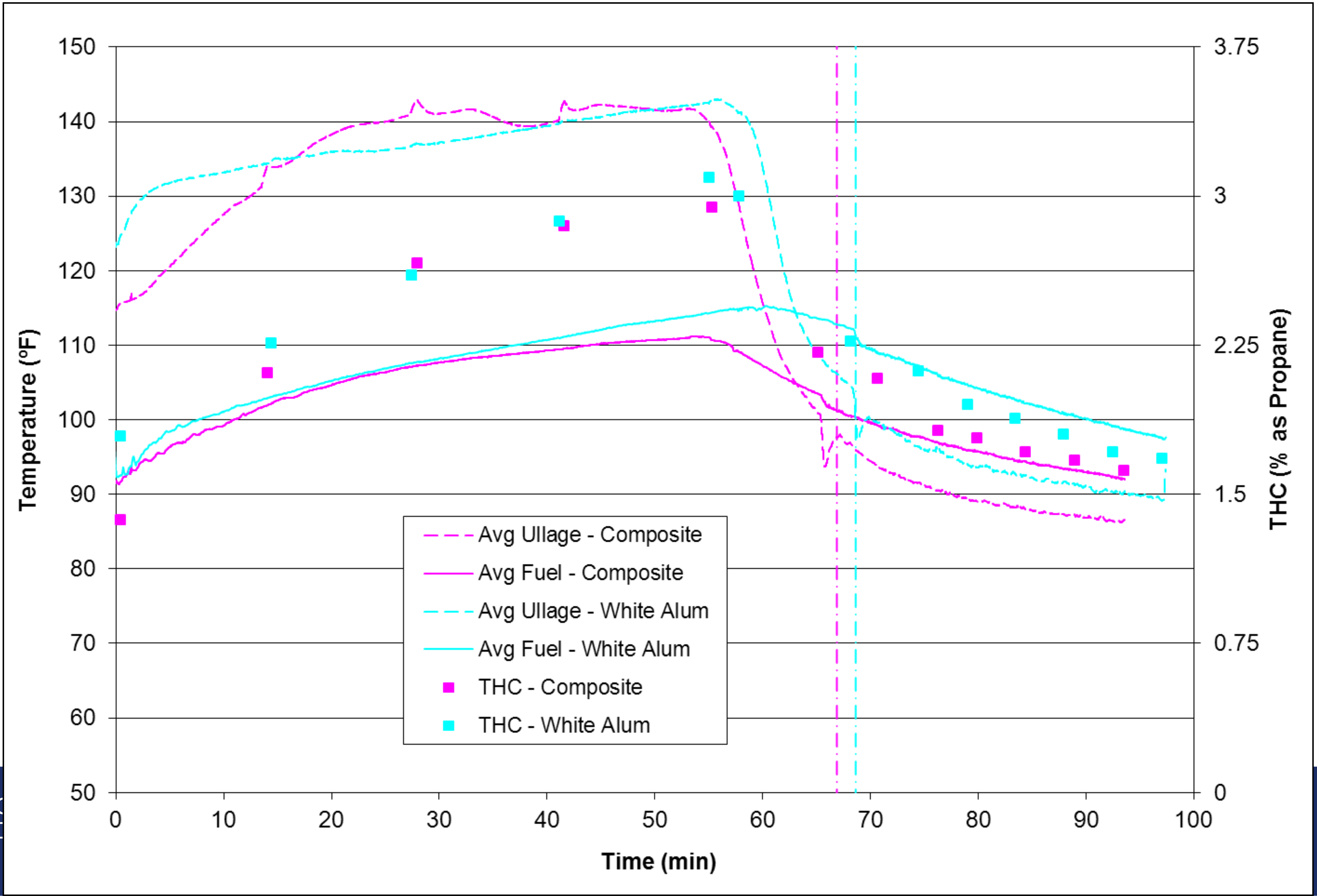


Airflow Induction Test Facility Results – Topcoat Effects

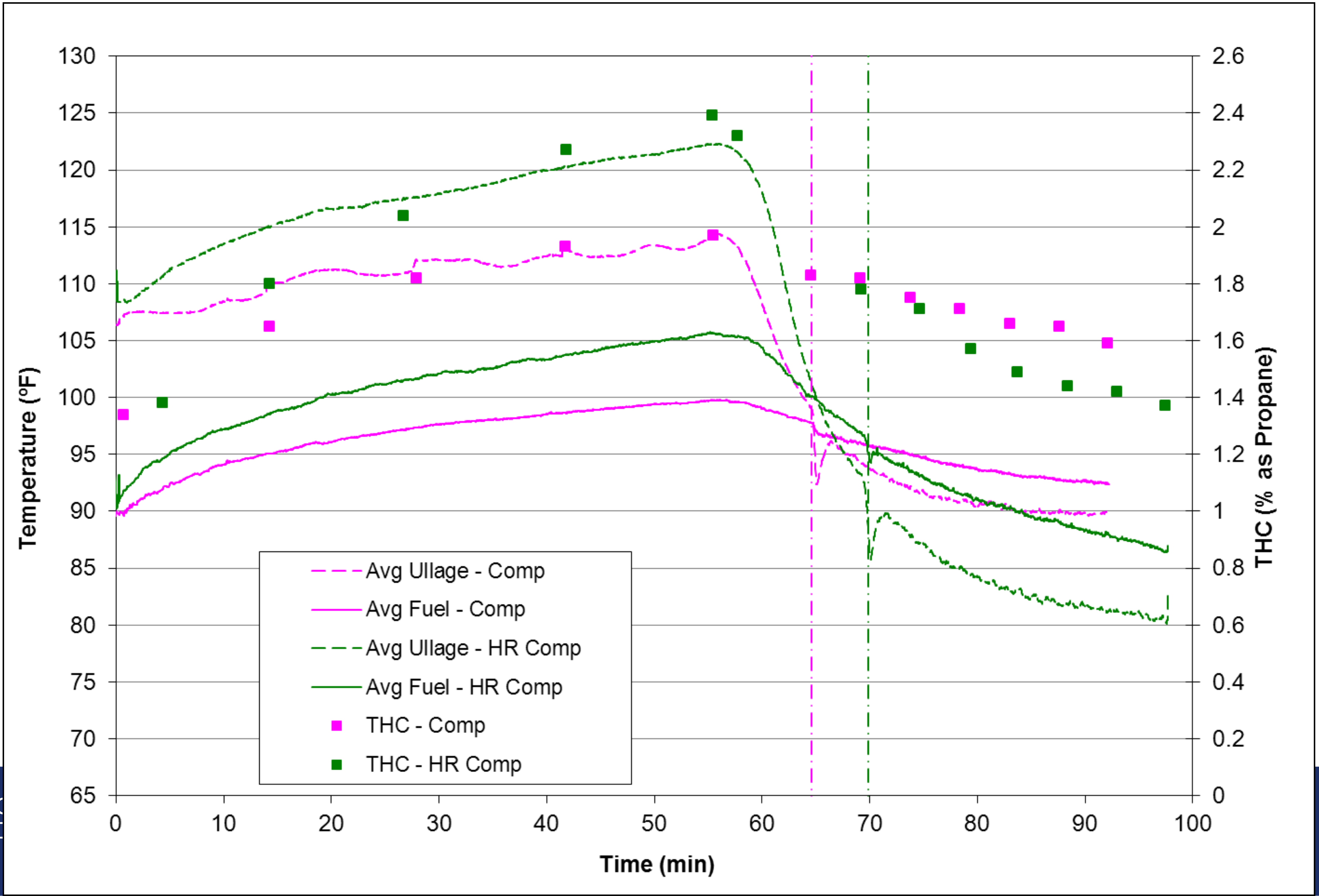
White-Painted Aluminum Results – 80% Fuel Load, Low Heat Setting



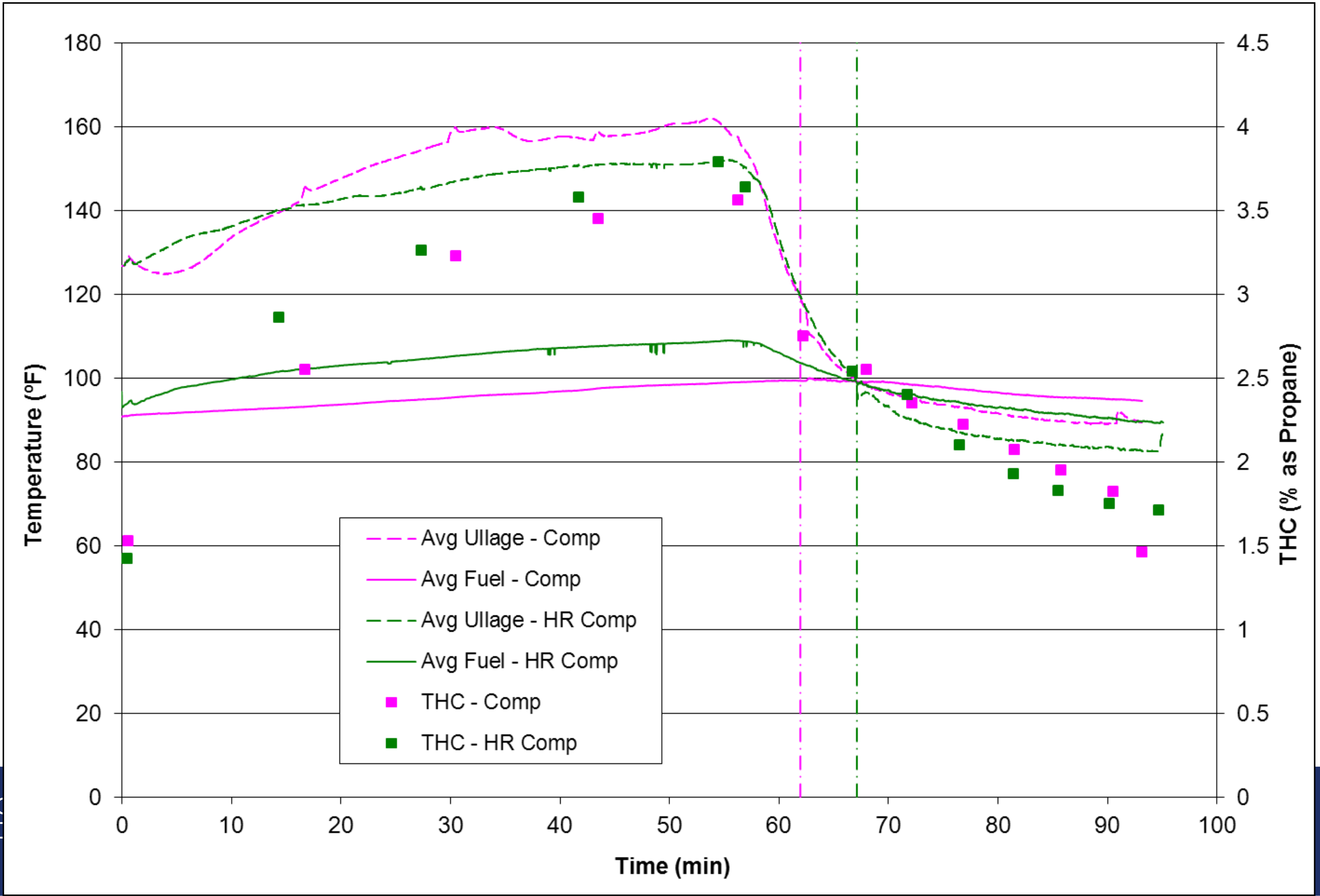
White-Painted Aluminum Results – 40% Fuel Load, High Heat Setting



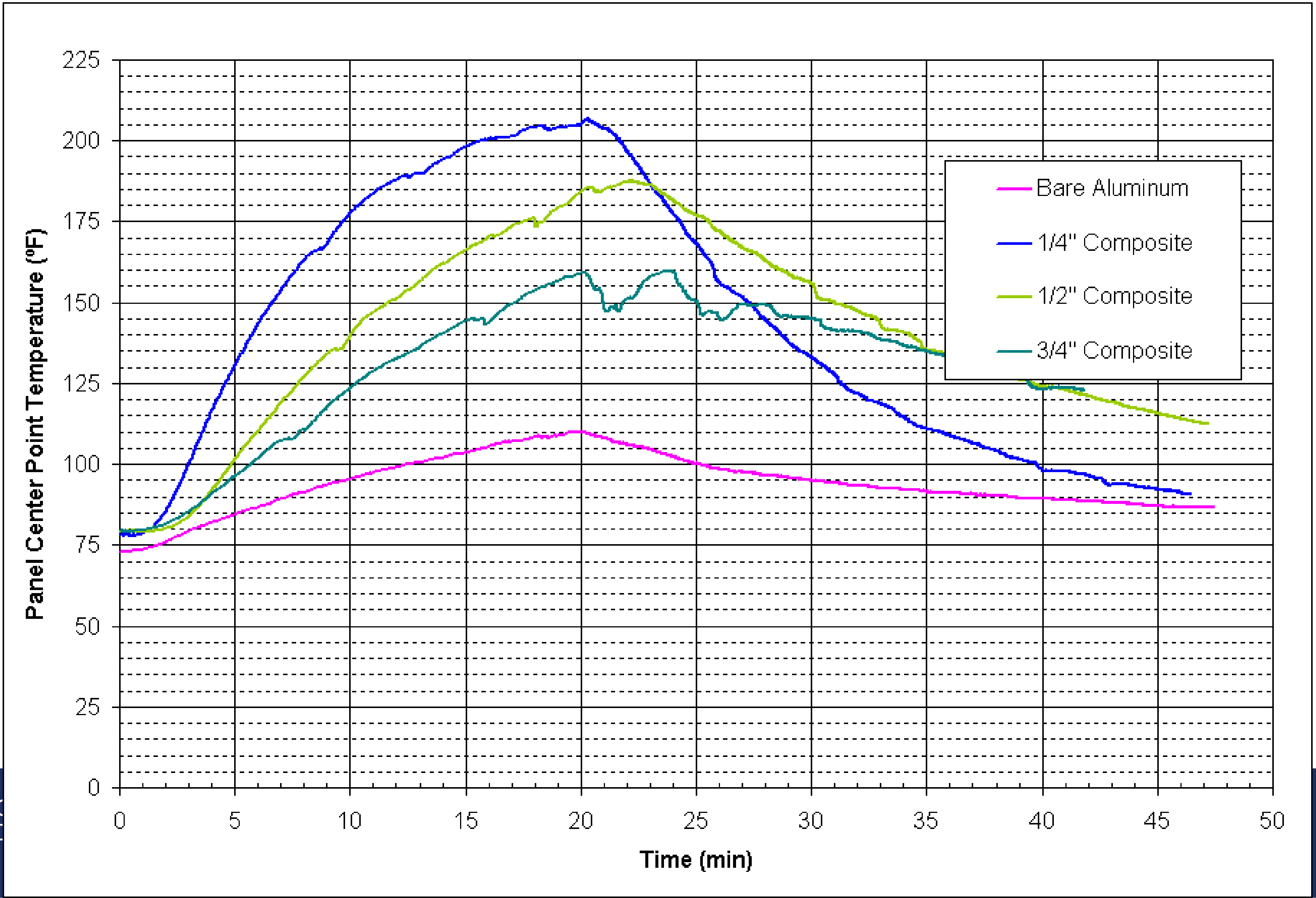
High Reflectivity Epoxy Composite Results – 40% Fuel Load, Low Heat Setting



High Reflectivity Epoxy Composite Results – 80% Fuel Load, High Heat Setting

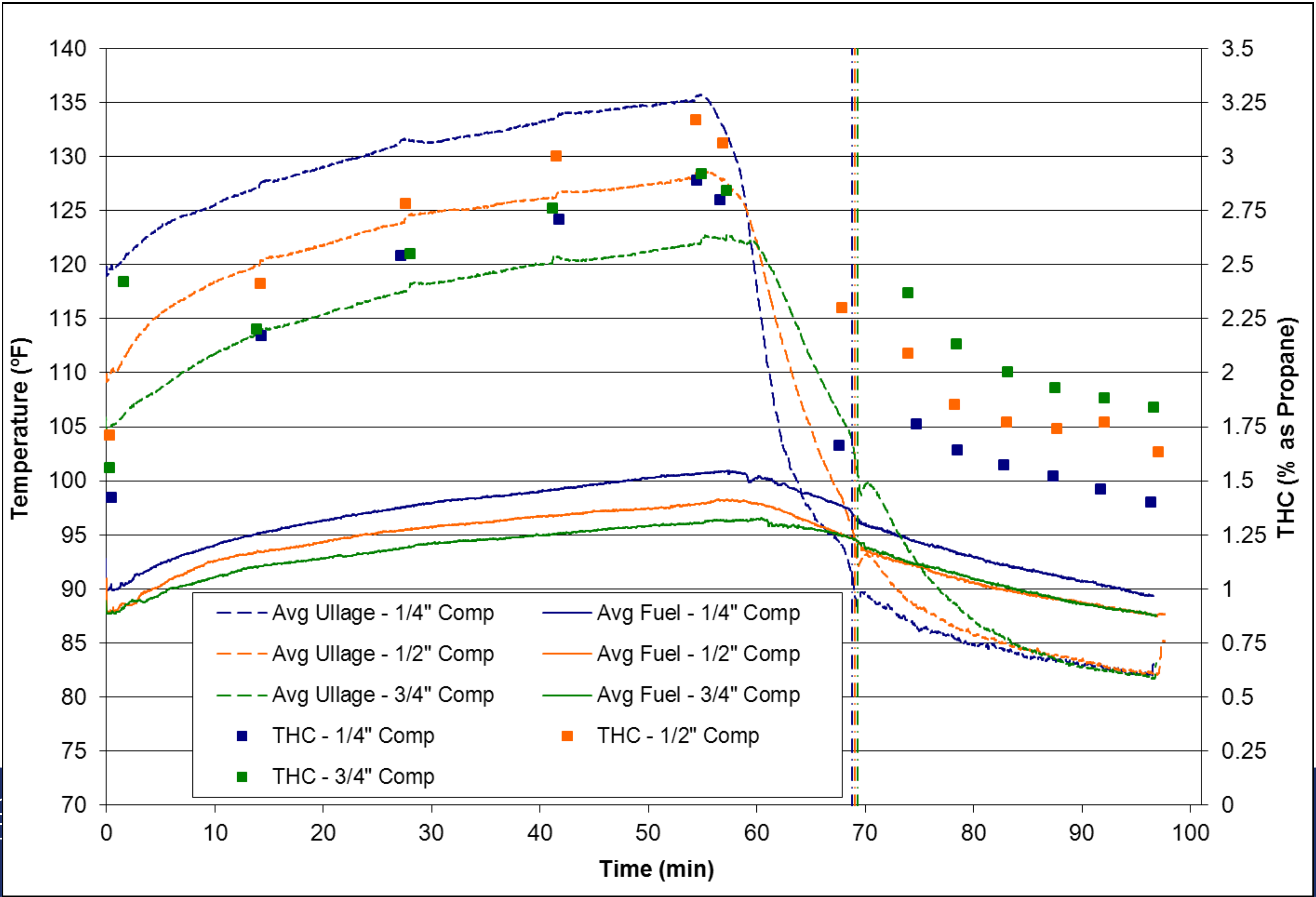


Panel Heat Test Results – Composite Thickness

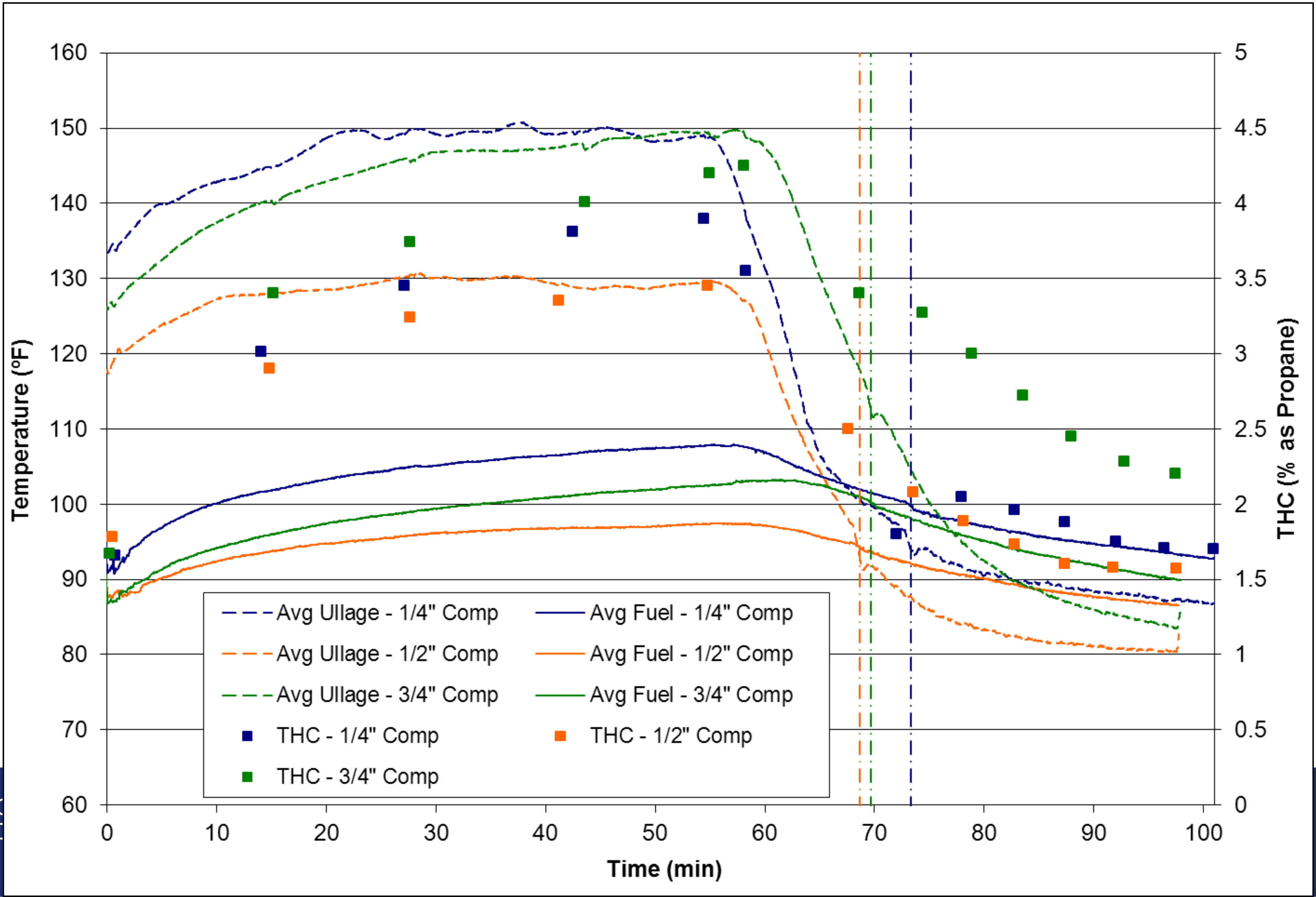


Airflow Induction Test Facility Results – Composite Thickness

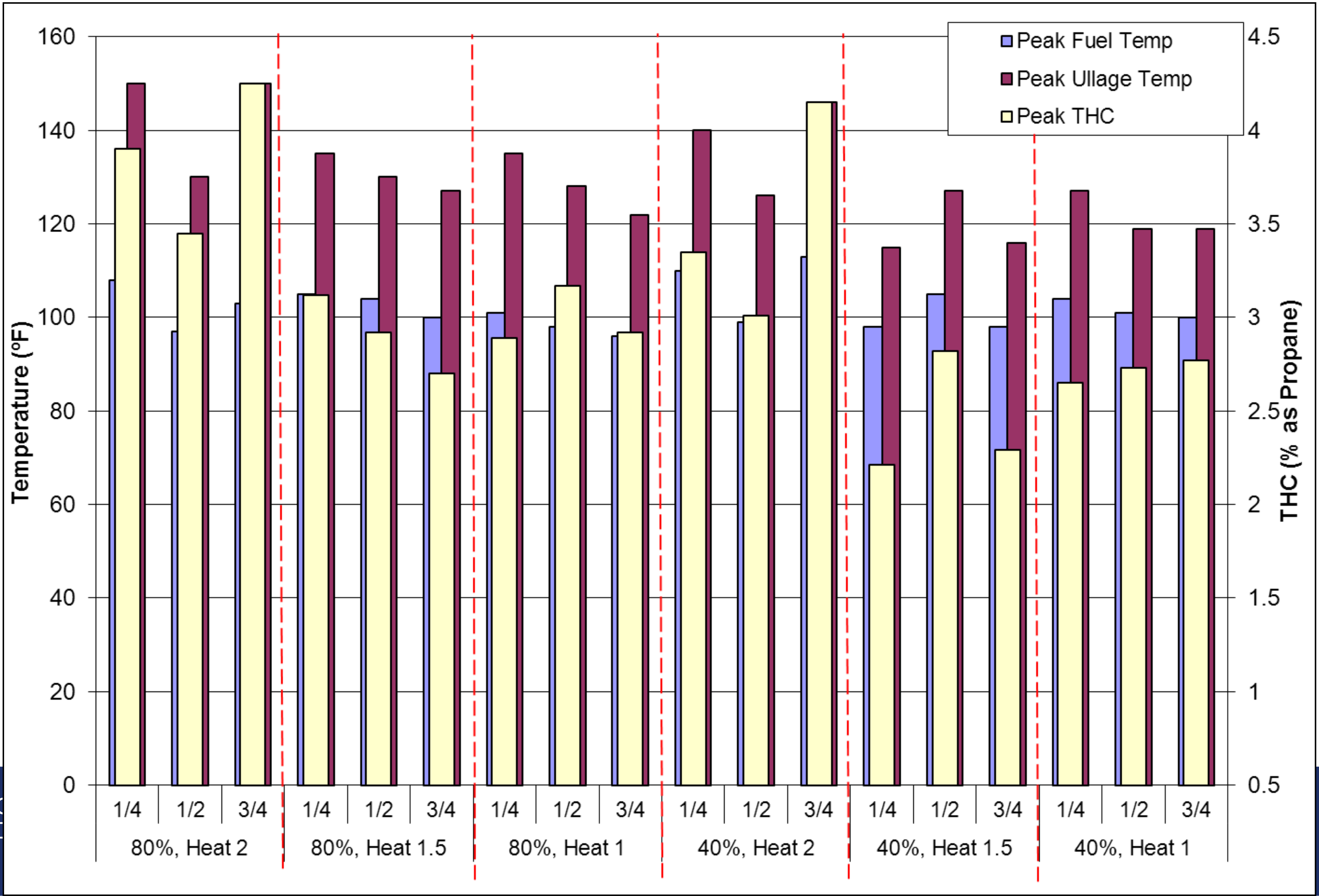
Composite Thickness Results – 80% Fuel Load, Low Heat Setting



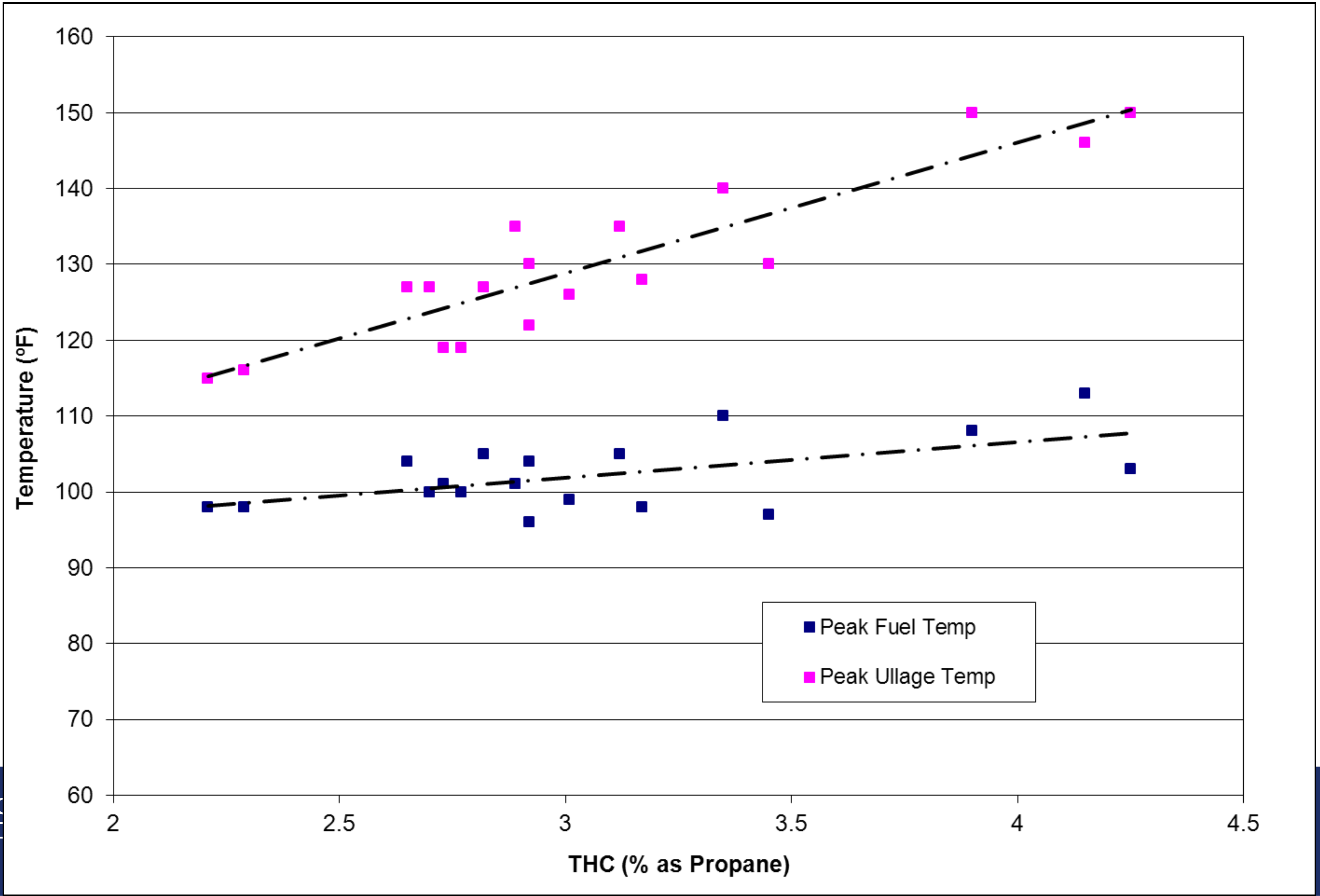
Composite Thickness Results – 80% Fuel Load, High Heat Setting



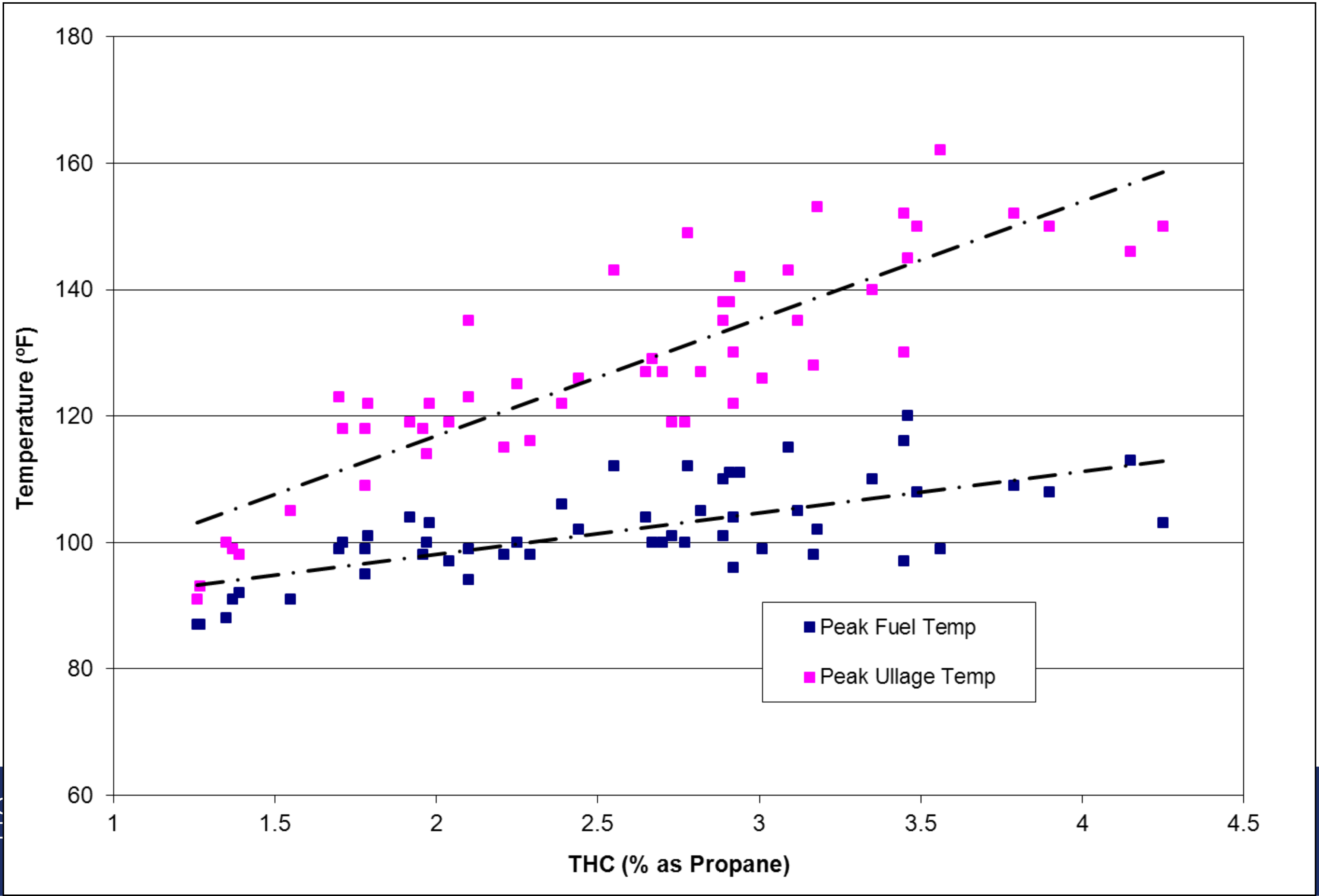
Summary of Panel Thickness Results



Panel Thickness Test Results



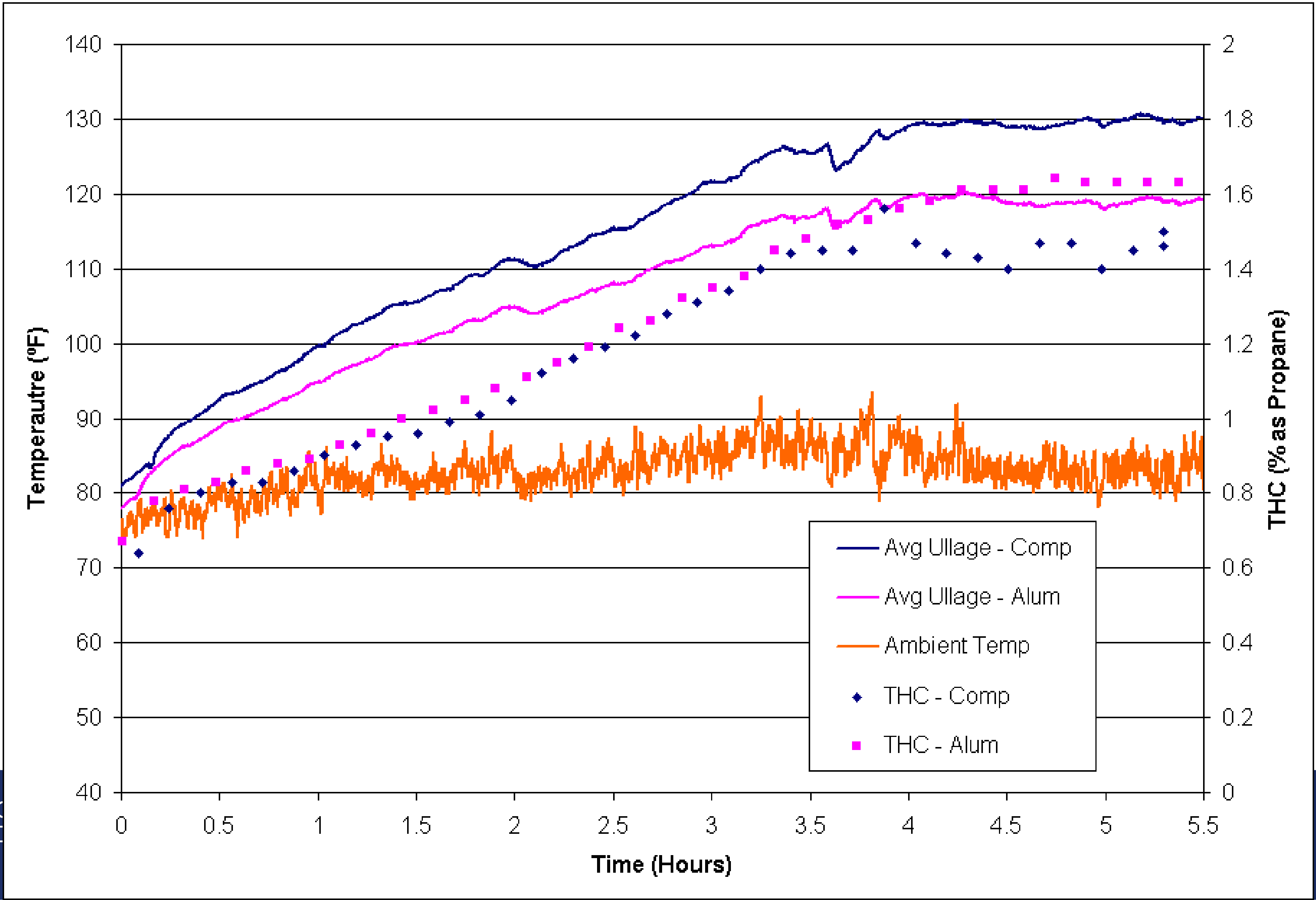
Summary Of All Airflow Induction Test Facility Results



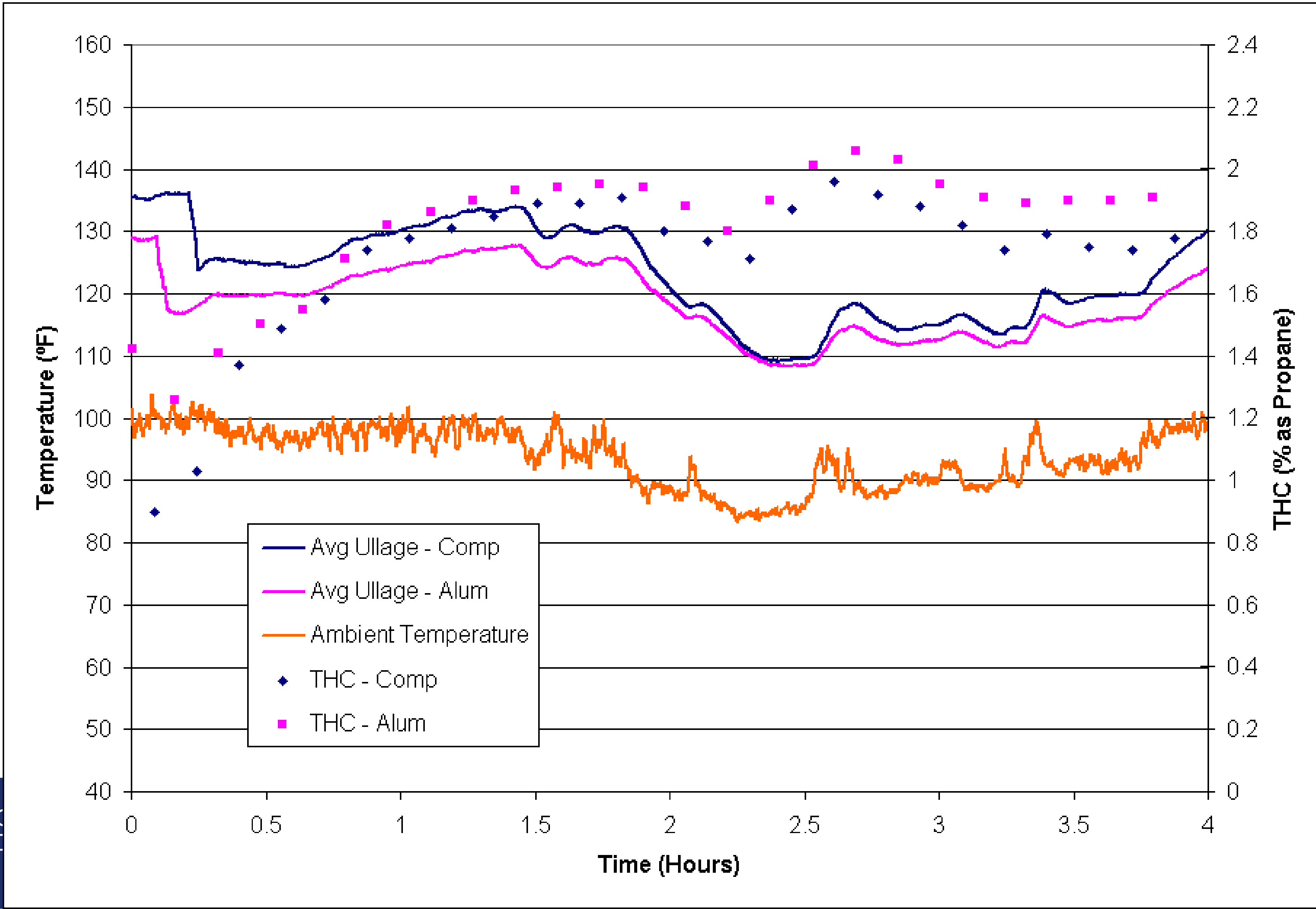
727 Wing Tank Test Articles

- Last 8 feet of each wing removed, upper panel covering entire surge tank of left wing removed, and re-skinned with an 1/8″ thick composite panel.
- Each surge tank instrumented with 12 thermocouples and THC sample line.
- Capacity of tank ~ 36.5 gallons
- Each tank was filled with 25 gallons of JP-8 fuel and allowed to heat/cool according to ambient conditions of the day.

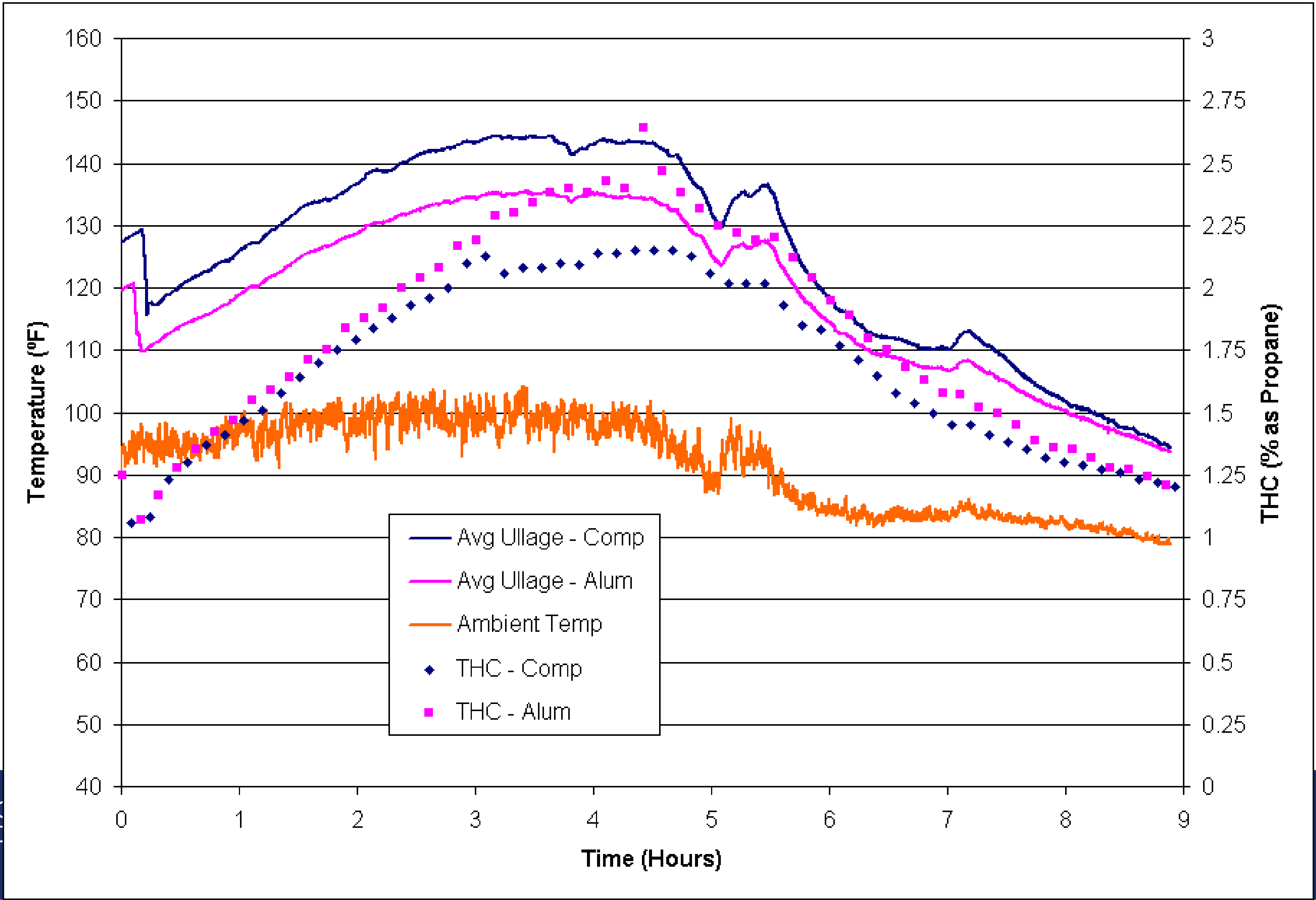
727 Wing Tank Test Results



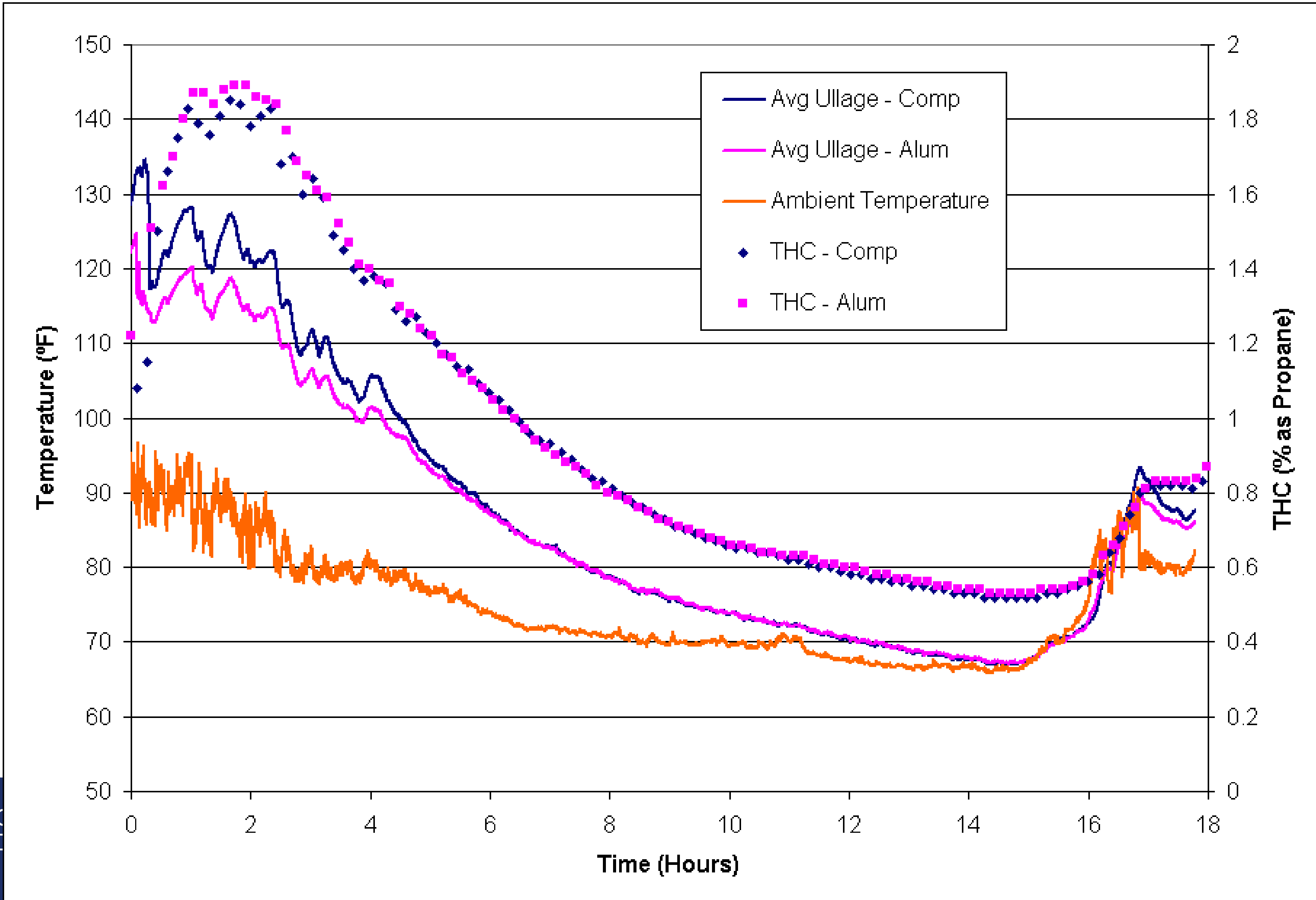
727 Wing Tank Test Results



727 Wing Tank Test Results



727 Wing Tank Test Results



Summary

TOPCOAT EFFECTS

- Bare aluminum resulted in relatively low flammability readings, whereas bare composite resulted in significantly increased ullage temperatures and flammability readings
  - Once airflow over the tank was initiated, temperature and flammability profiles behaved similarly

- Aluminum tank with either white or black topcoat applied behaved similarly to the composite tank

- Topcoat applied to the composite tank (white or high reflectivity) had little to no effect on the resulting temperatures and flammability profiles.

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Summary

COMPOSITE PANEL THICKNESS

- Panel heat tests with the composite panels of varying thickness showed that the thinner the material is, the more readily heat transmits through it.

- Once installed on the tank however, there was a large variation in results. Thus, a correlation between composite thickness and tank flammability was not able to be made.

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Summary

727 WING TANKS

- Tests in the two 727 wing tanks confirmed the results within the airflow induction test facility.
- The coated aluminum tank behaved very similarly to the composite tank in terms of both ullage/fuel temperatures and flammability readings.

OVERALL

- Throughout testing, a correlation of high THC measurements with ullage temperature increases was further indication that ullage temperature changes are the driving force behind in-flight flammability for wing tanks

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