# Composite and Aluminum Wing Tank Flammability Comparison Testing

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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)

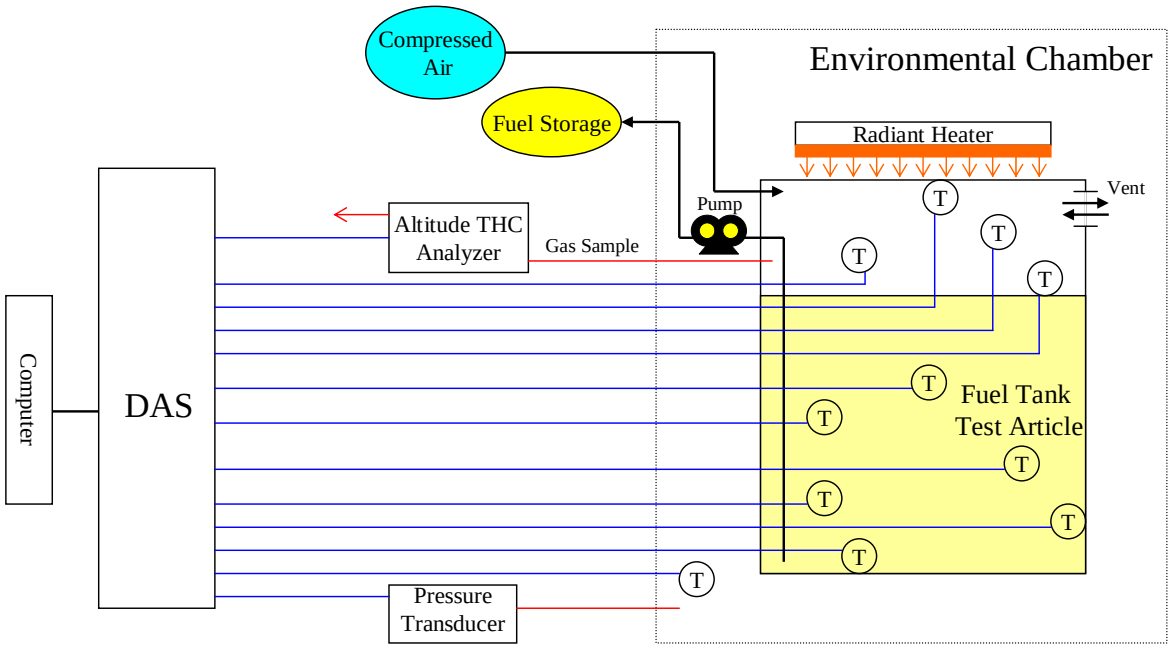
- The objective is to now compare flammability progression in a wing fuel tank test article with both aluminum skin and composite skin with varying topcoats and thicknesses

# Test Apparatus - Wing Tank Test Article

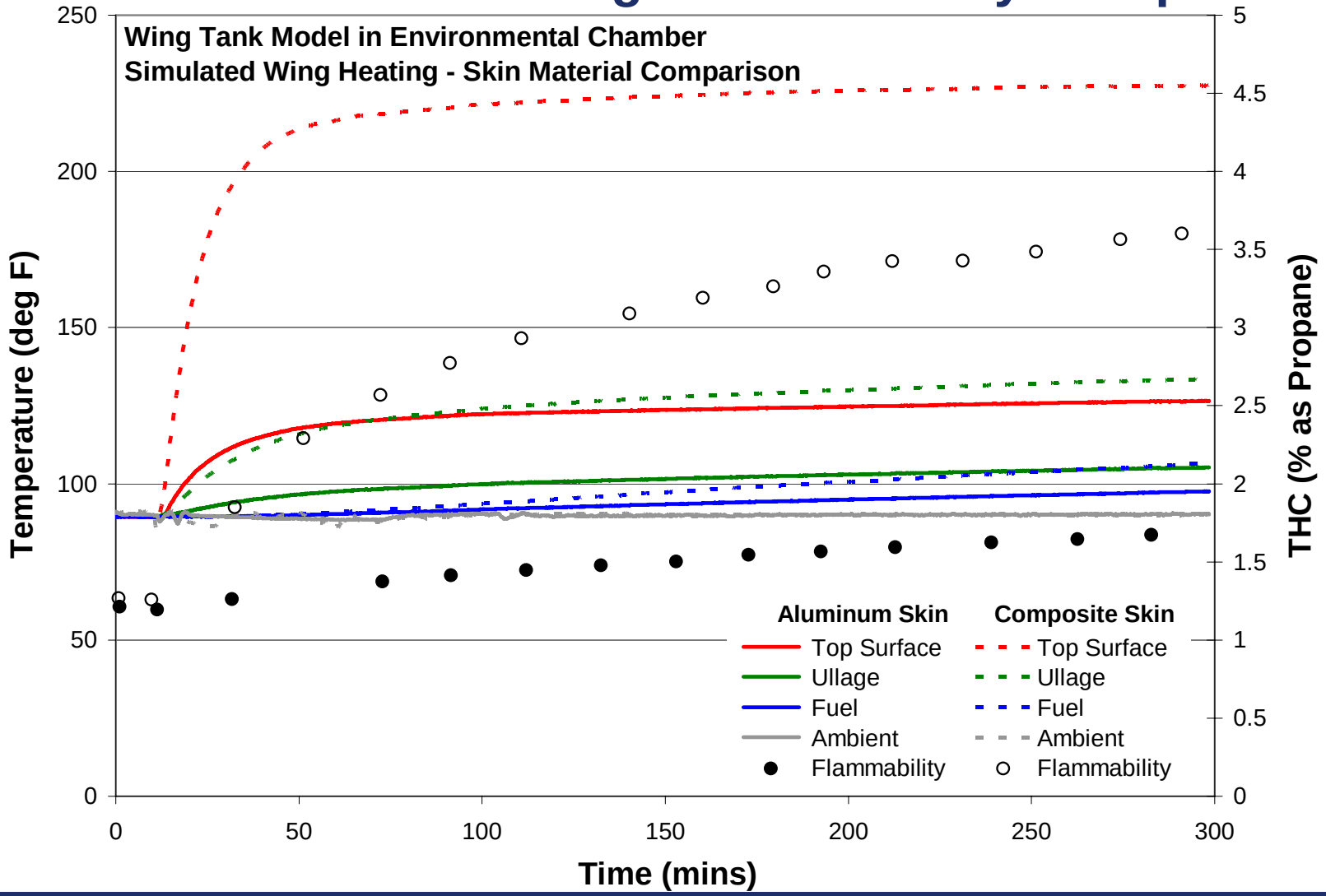
- Constructed wing tank test article from previous test article
  - Interchangeable aluminum and composite skin panels on top and bottom with an aerodynamic nose and tail piece
- Tank is vented and has a gas sample port for THC analysis, pressure transducer, and an extensive array of thermocouples
-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

# Test Apparatus - Environmental Chamber Testing

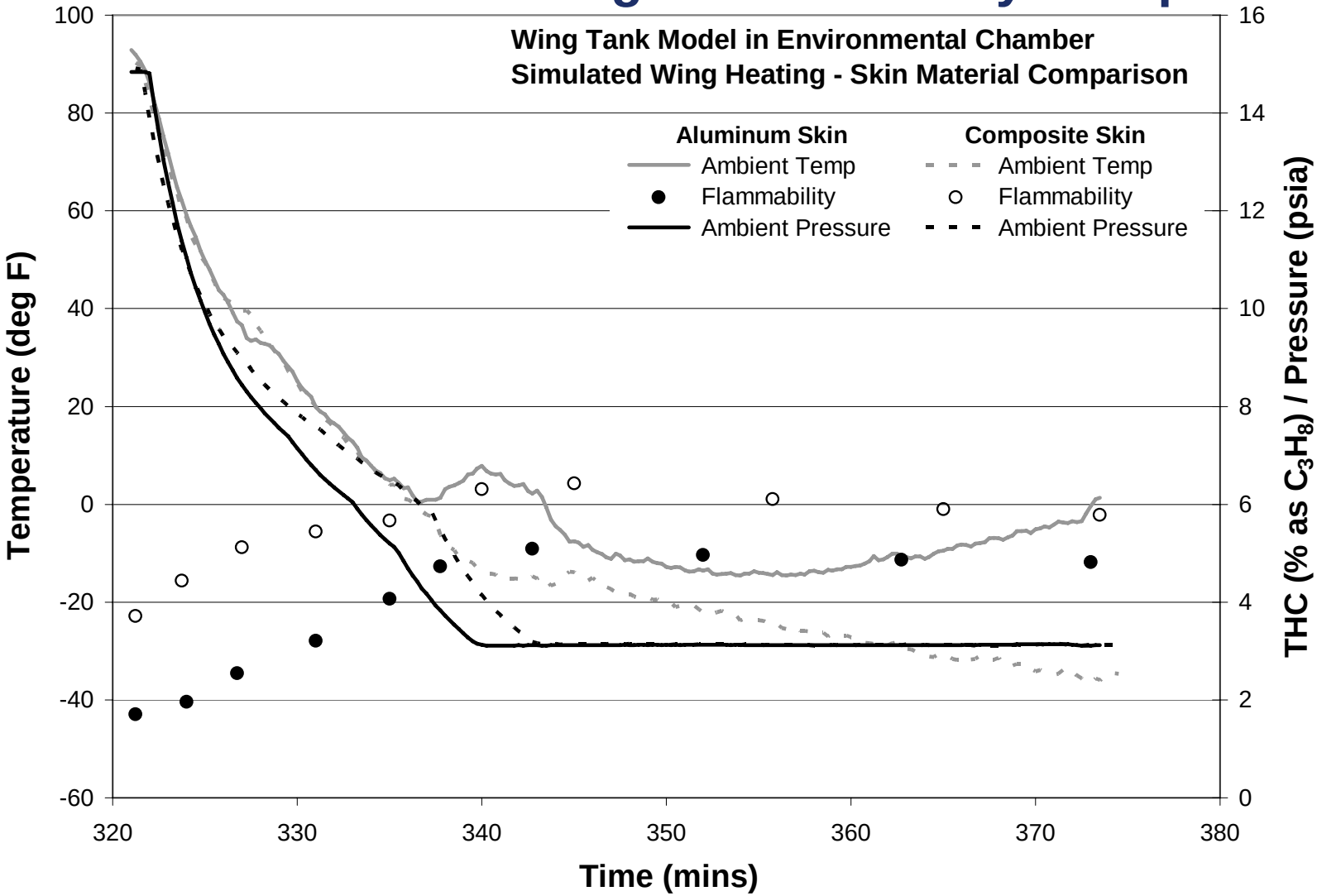
- Utilized recently made wing fuel tank test article in altitude chamber to compare Al and Composite Flammability
  - Performed two identical tests, one with each skin, with 90 deg F ambient temperature, moderate top heat, and average F.P. fuel
  - Measured skin, ullage and fuel temperature progressions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

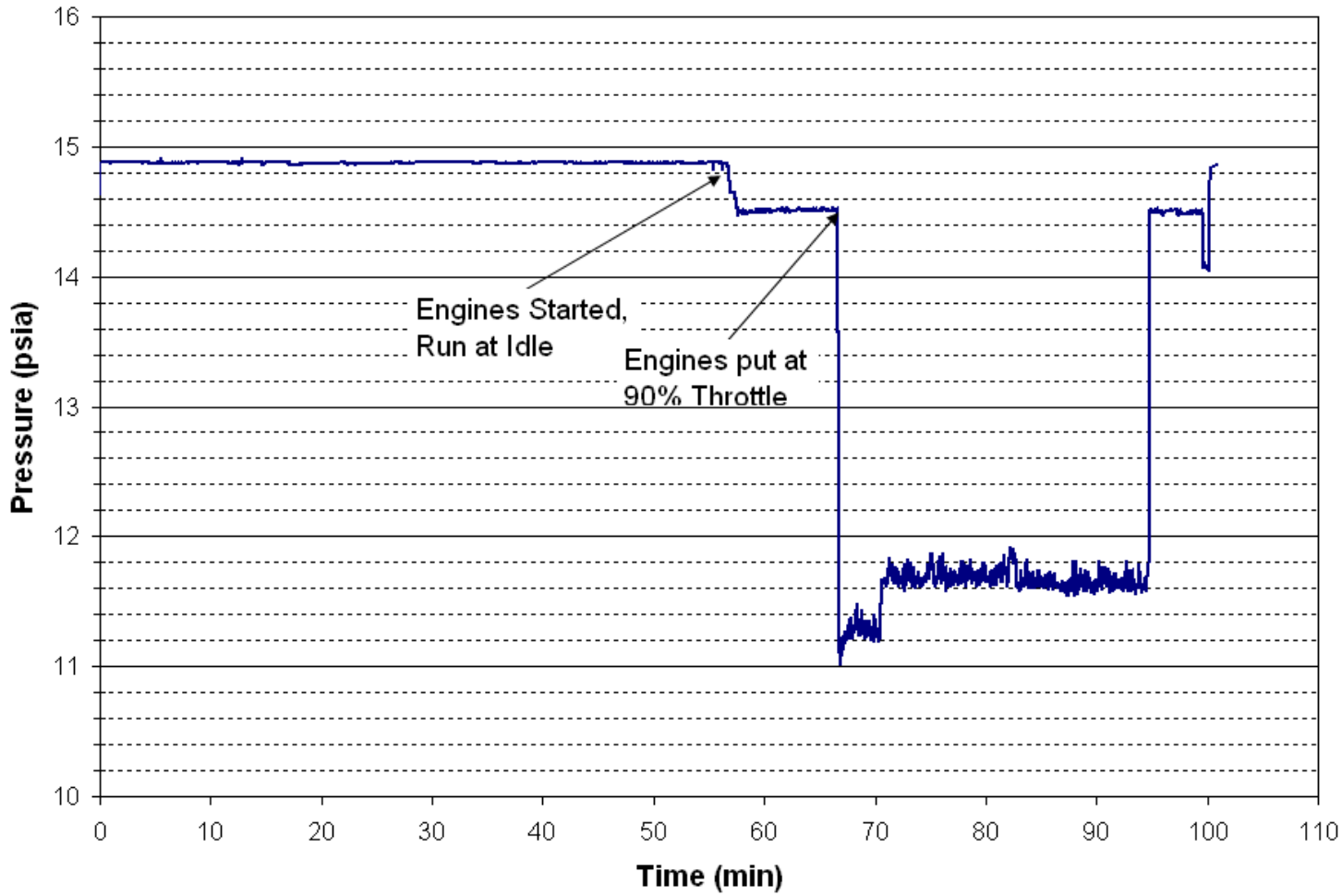
# Test Apparatus – Airflow Induction Test Facility

- 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.

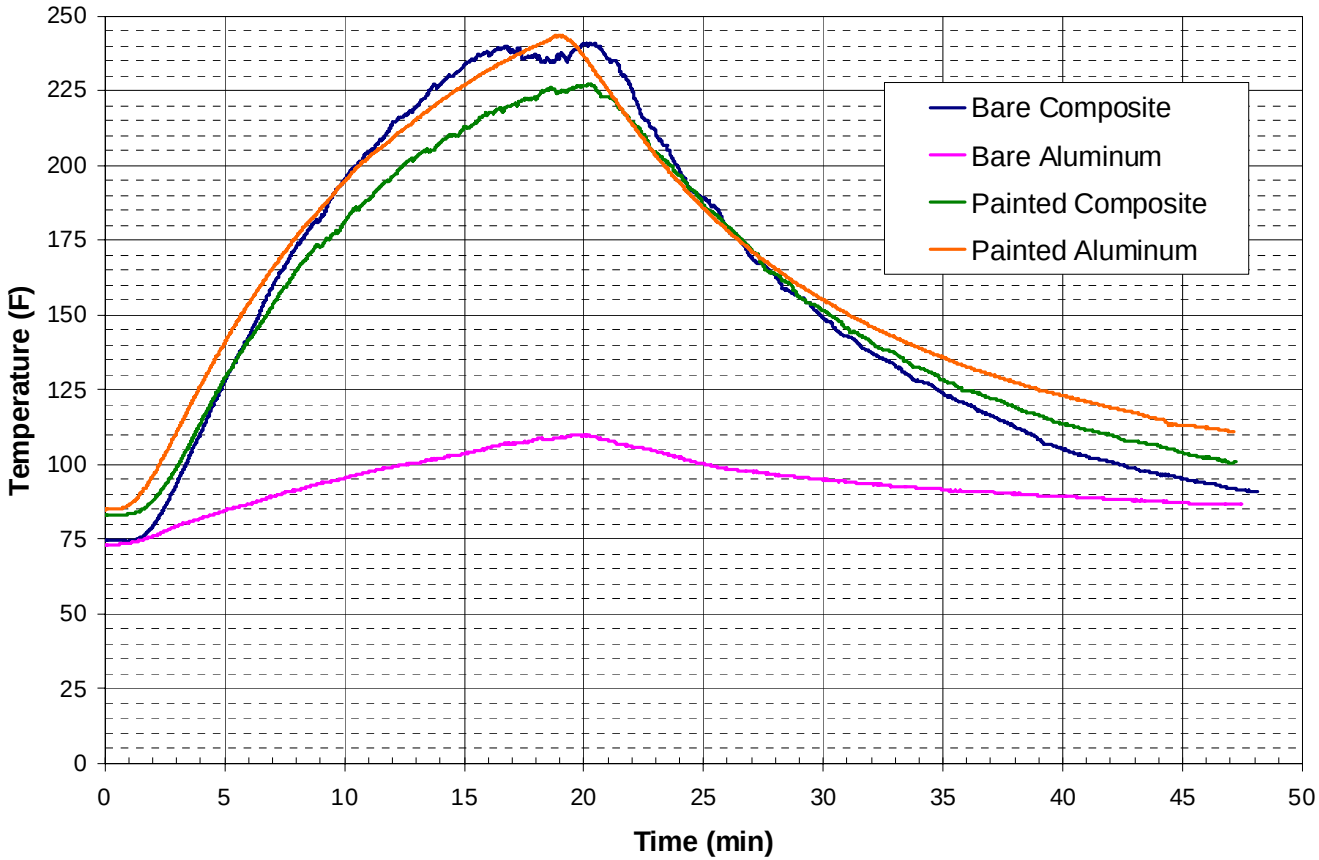


# Test Conditions – Airflow Induction Test Facility

- Fuel levels of 40, 60, 80% were examined
- Radiant heaters used to heat top surface of tank for 1 hour prior to fueling
- 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
- In addition to the bare materials, white-painted composite and black-painted aluminum panels were tested

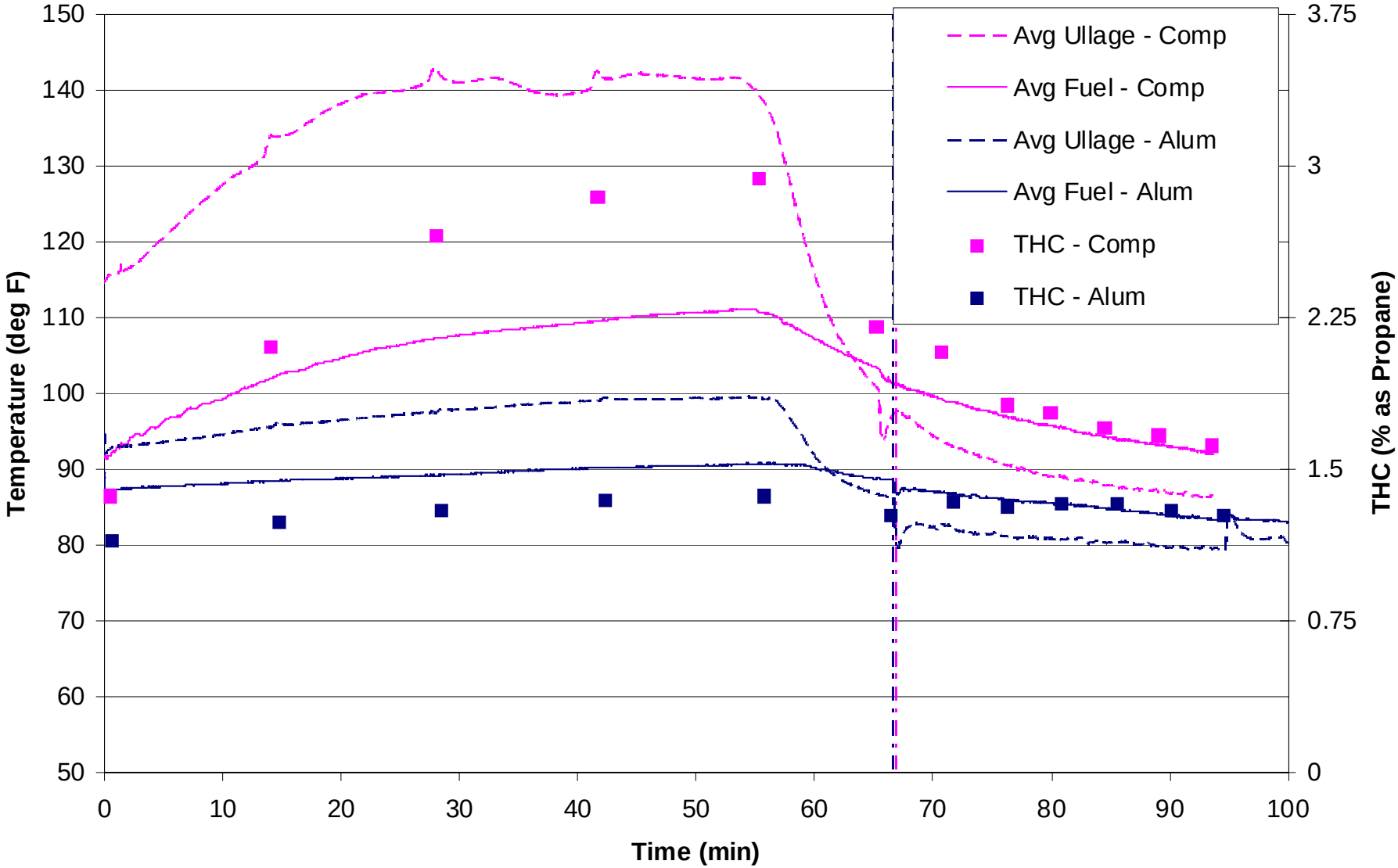
# Initial Panel Heat Tests

- Each panel was heated from above with a single thermocouple placed at the center-point on the bottom surface.

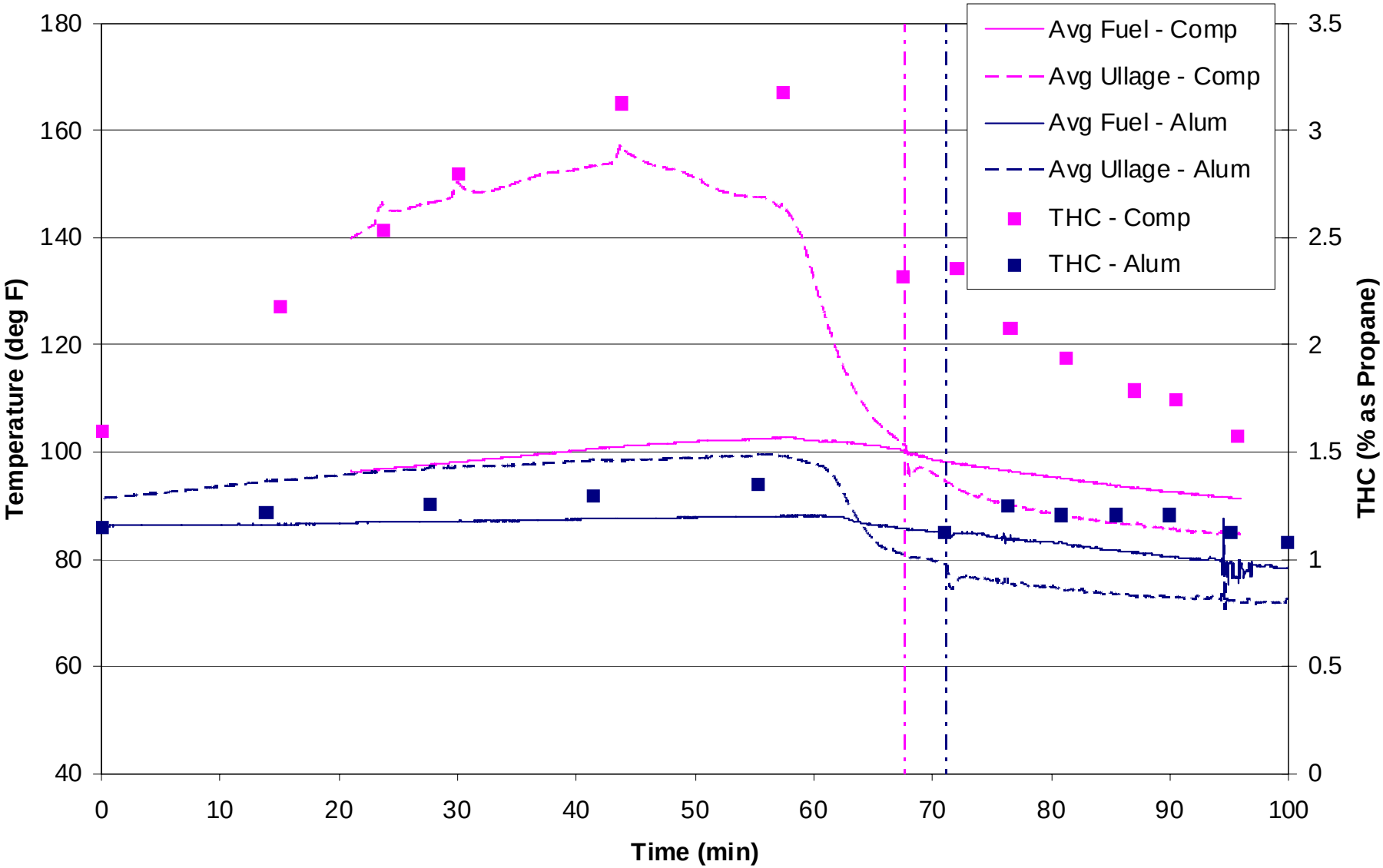


# Bare Material Results

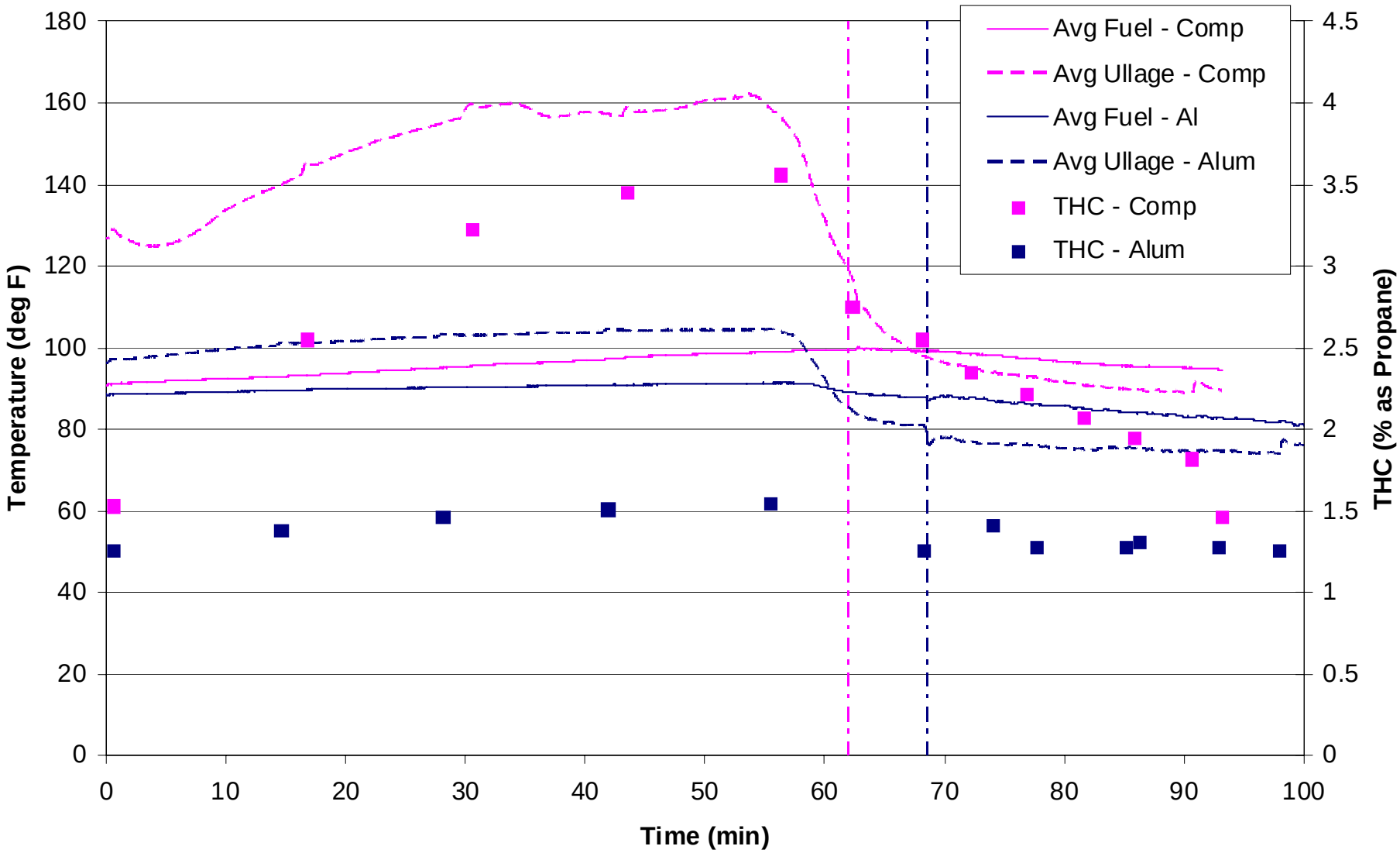
## Results - 40% Fuel Load, High Heat Setting



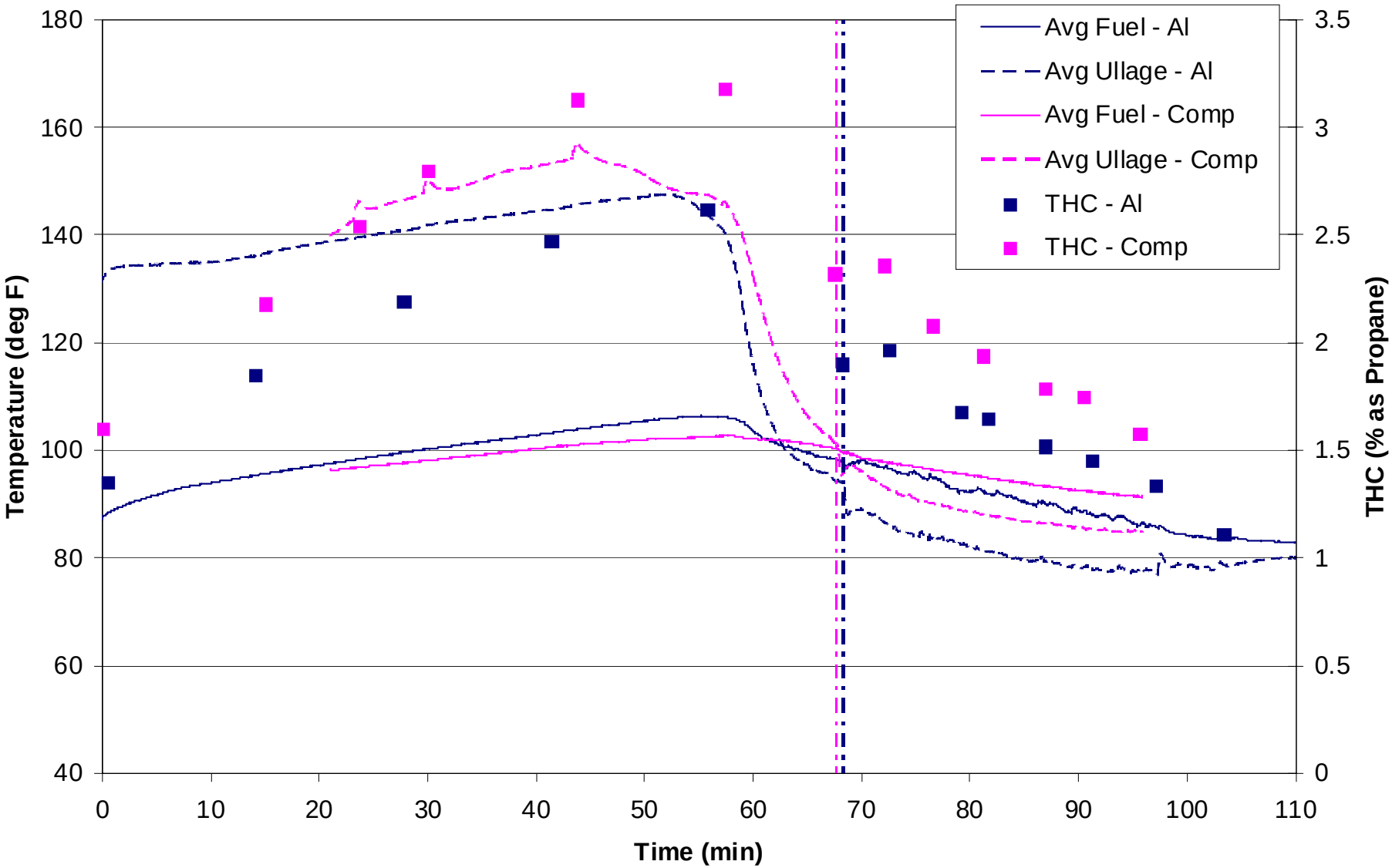
## Results - 60% Fuel Load, High Heat Setting



## Results - 80% Fuel Load, High Heat Setting

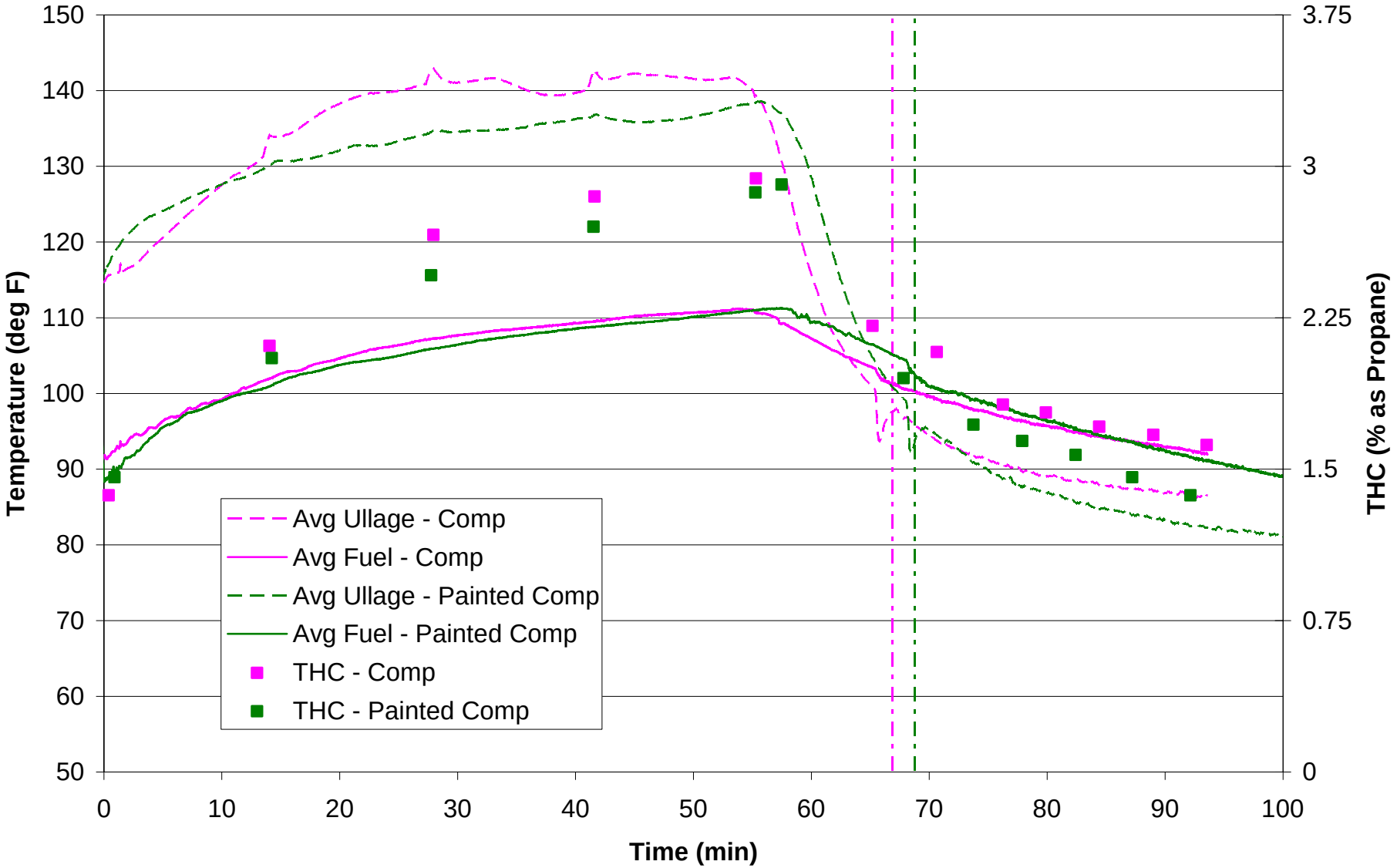


## Results - 60% Fuel Load, Superheated Aluminum

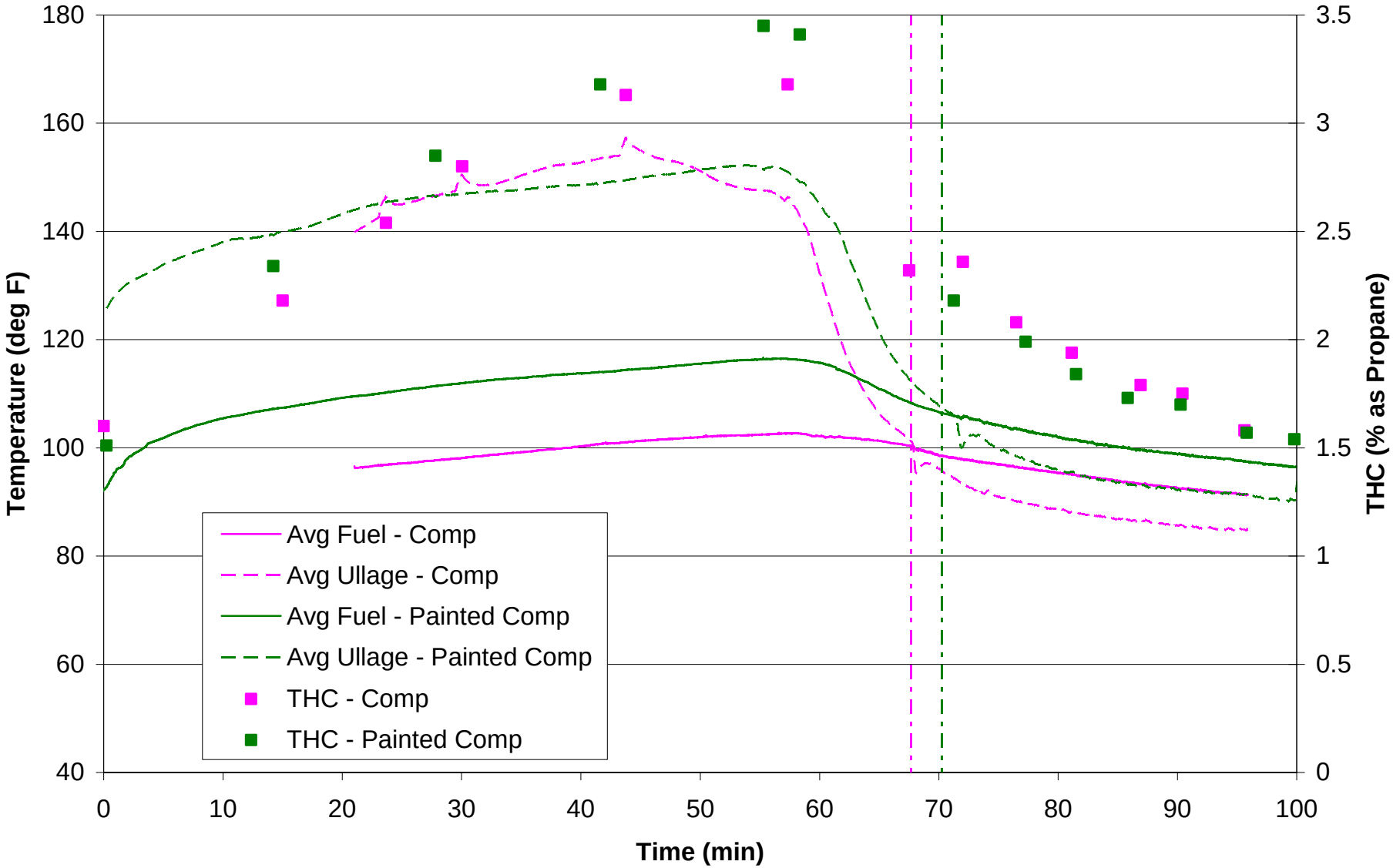


# Painted Composite Results

# Results - 40% Fuel Load, Painted Composite, High Heat

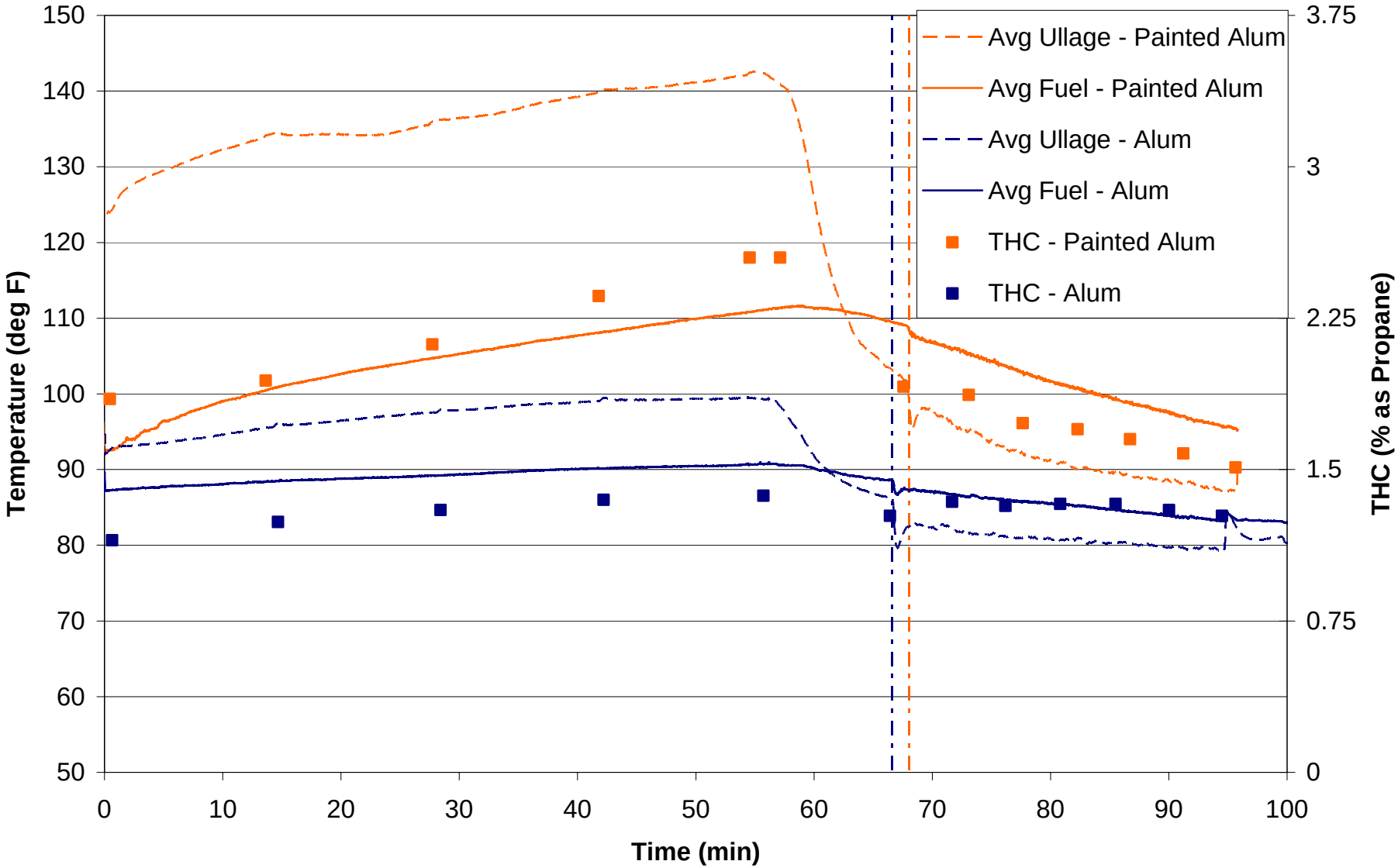


## Results - 60% Fuel Load, Painted Composite, High Heat

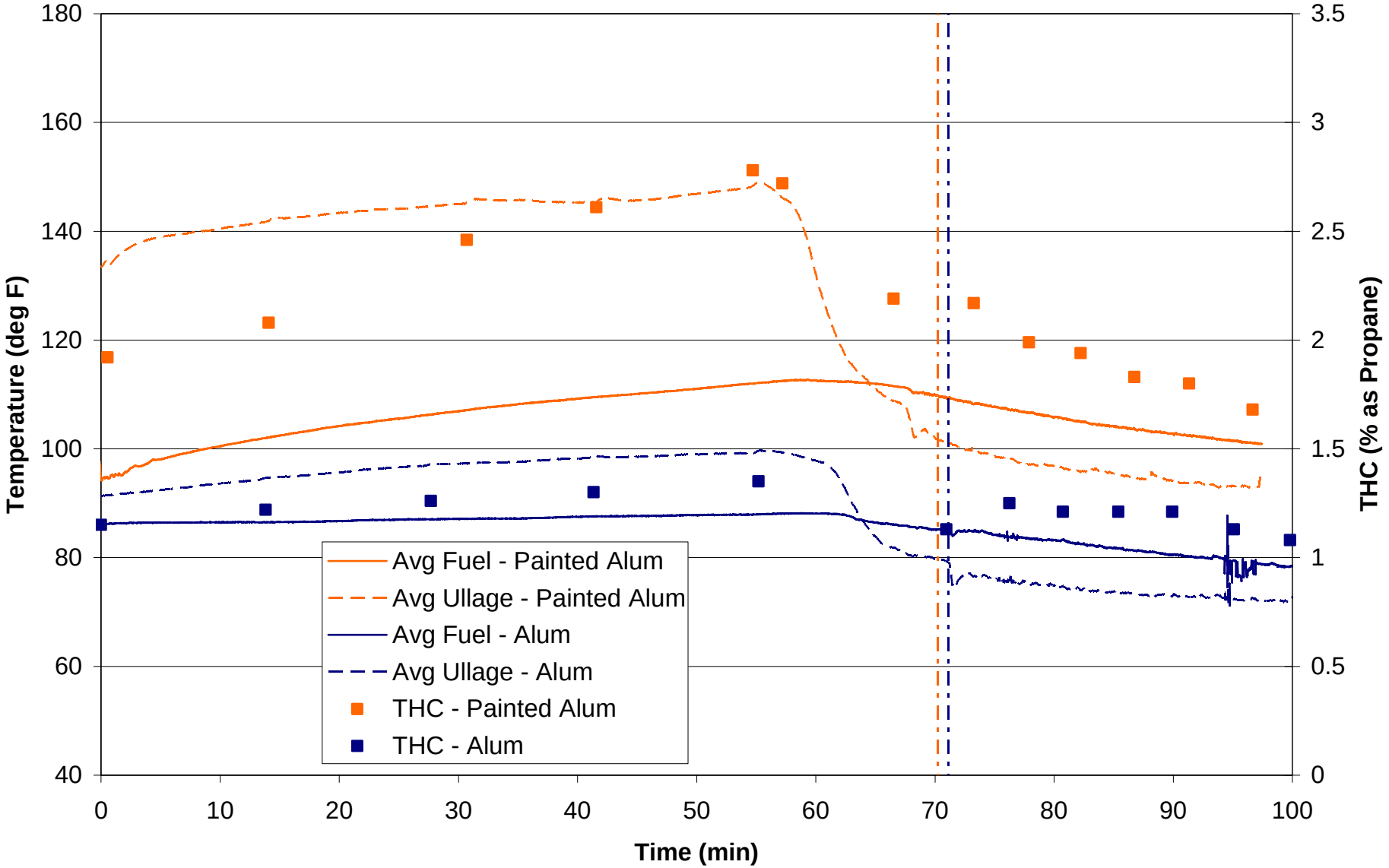


# Painted Aluminum Results

# Results - 40% Fuel Load, Painted Aluminum, High Heat



## Results - 60% Fuel Load, Painted Aluminum, High Heat



# Summary of Results

- Similar to Environmental Chamber Tests, the 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.

- Fuel temperature increase is also observed, but not as severe.

# Summary of Results

- Topcoat color for composite panel had little to no effect on the resulting temperatures and flammability profiles.
- Topcoat color for aluminum panel has dramatic effect on fuel temperatures and flammability profile, making it behave more like the composite
- The overall correlation of high THC measurements with high ullage temperature increases is further indication that ullage temperature changes are the driving force behind in-flight flammability for wing tanks.
  - This is contradictory to how the Fuel Tank Flammability Assessment Method calculates flammability exposure

# Planned Work

- Conduct tests with aluminum panel painted white.
- Conduct tests with various thickness composite panels.
- 727 wing surge tank utilized in previous testing has been re-skinned with composite material for further testing to be conducted next spring/summer.