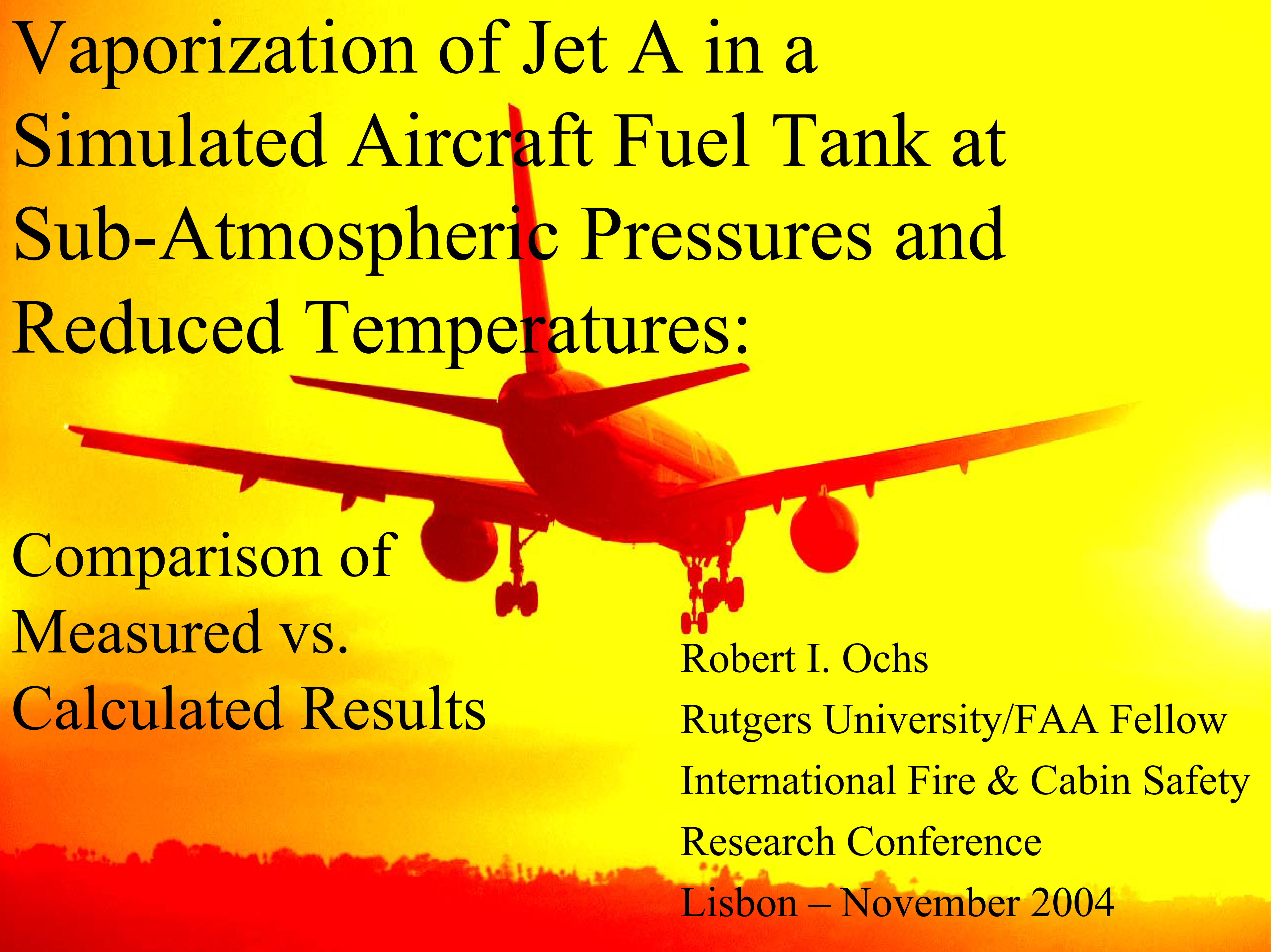
Vaporization of Jet A in a Simulated Aircraft Fuel Tank at Sub-Atmospheric Pressures and Reduced Temperatures:

Comparison of Measured vs. Calculated Results



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Outline

- Motivation for research
- Development of experimental setup and procedures
- Test plan in matrix form
- Discussion of results
- Conclusions

Motivation

- Flammable conditions can exist in airplane fuel tanks under certain conditions
  - Tank floor heating due to ductwork routed under fuel tanks
  - Hot liquid fuel vaporizes until equilibrium is reached between the liquid and gas phase
- Modeling heat and mass flux occurring within the tank can give a good approximation of the relative level of flammability in the ullage, given certain parameters

Modeling

- Numerical modeling can be used as a substitute for full-scale experimentation.
- Results from fuel vaporization experiments under varying ambient conditions can be used to validate calculations

Requirements for Experimental Setup

- Ability to vary fuel tank floor temperature with *uniform* floor heating
- Setup with capability of changing ambient temperature and pressure with controlled profiles
- Measurement of temporal changes in liquid, surface, ullage, and ambient temperatures
- Ability to asses the amount of fuel escaping into the ullage space/condensing on the tank surfaces

Measuring Input Parameters for the Model

Heat Transfer

- Thermocouples on tank surface, ullage, and liquid fuel.

Mass Transfer

- FID Hydrocarbon analyzer used to measure the concentration of evolved gasses in the ullage
- Pressure measurement for vaporization calculations

Fuel Properties

- Fuel tested in lab for flashpoint
- Used fuel composition from published data of fuels with similar flashpoints

Experimental Setup

- Fuel tank – 36”x36”x24”, ¼” aluminum
- Sample ports
- Heated hydrocarbon sample line
- Pressurization of the sample for sub-atmospheric pressure experiments by means of a heated head sample pump
- Intermittent (at 10 minute intervals) 30 sec long sampling
- FID hydrocarbon analyzer, cal. w/2% propane
- 12 K-type thermocouples
- Blanket heater for uniform floor heating
- Unheated tank walls and ceiling
- JP-8 jet fuel

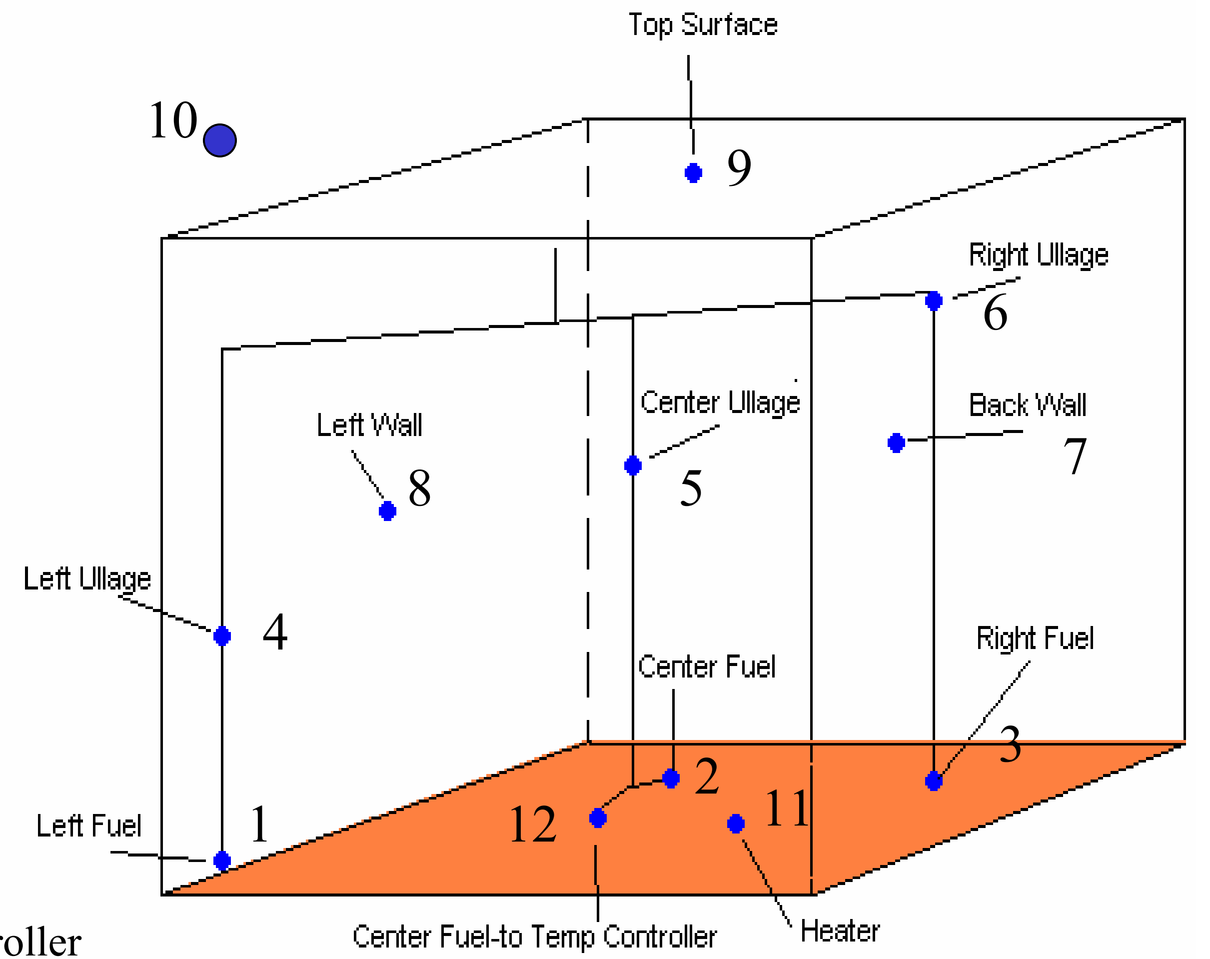
Experimental Setup

- Fuel tank inside environmental chamber
  - Programmable variation of chamber pressure and temperature
    - Vacuum pump system
    - Air heating and refrigeration

Thermocouple Locations

Thermocouple Channel:

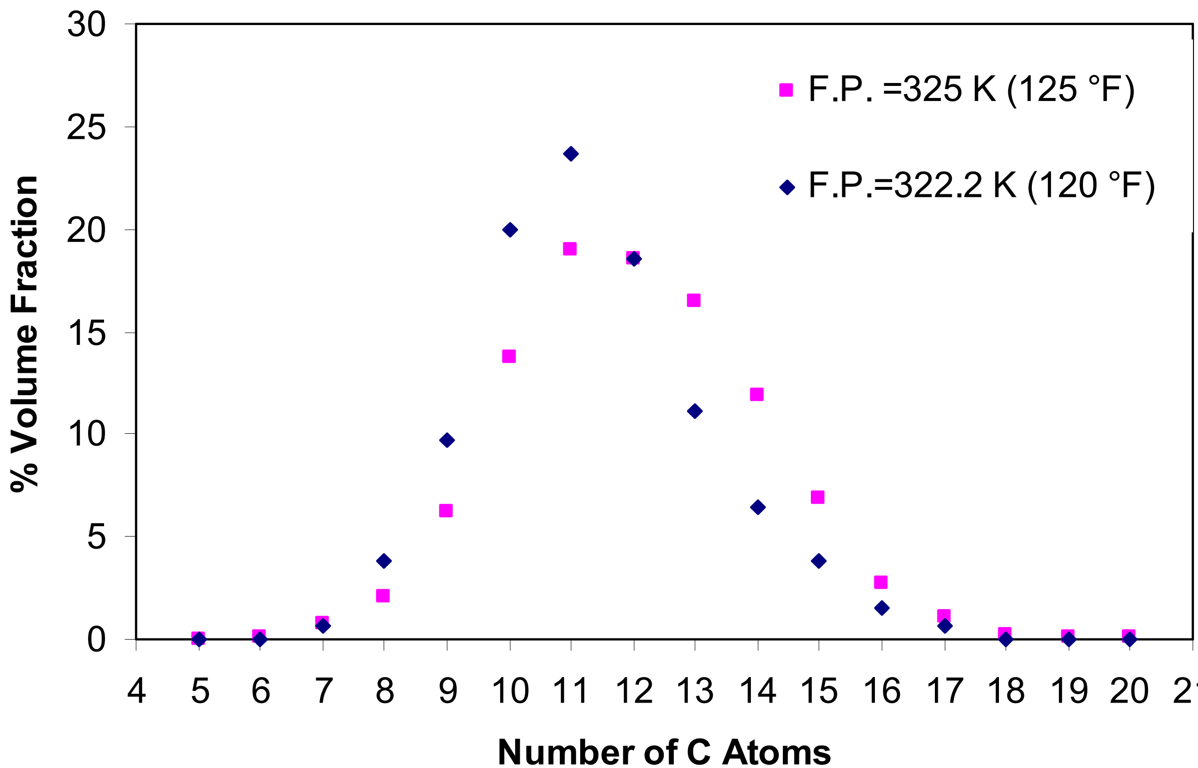
1. Left Fuel
2. Center Fuel
3. Right Fuel
4. Left Ullage
5. Center Ullage
6. Right Ullage
7. Rear Surface
8. Left Surface
9. Top Surface
10. Ambient
11. Heater
12. Heater Temperature Controller



Measuring Ullage Vapor Concentration

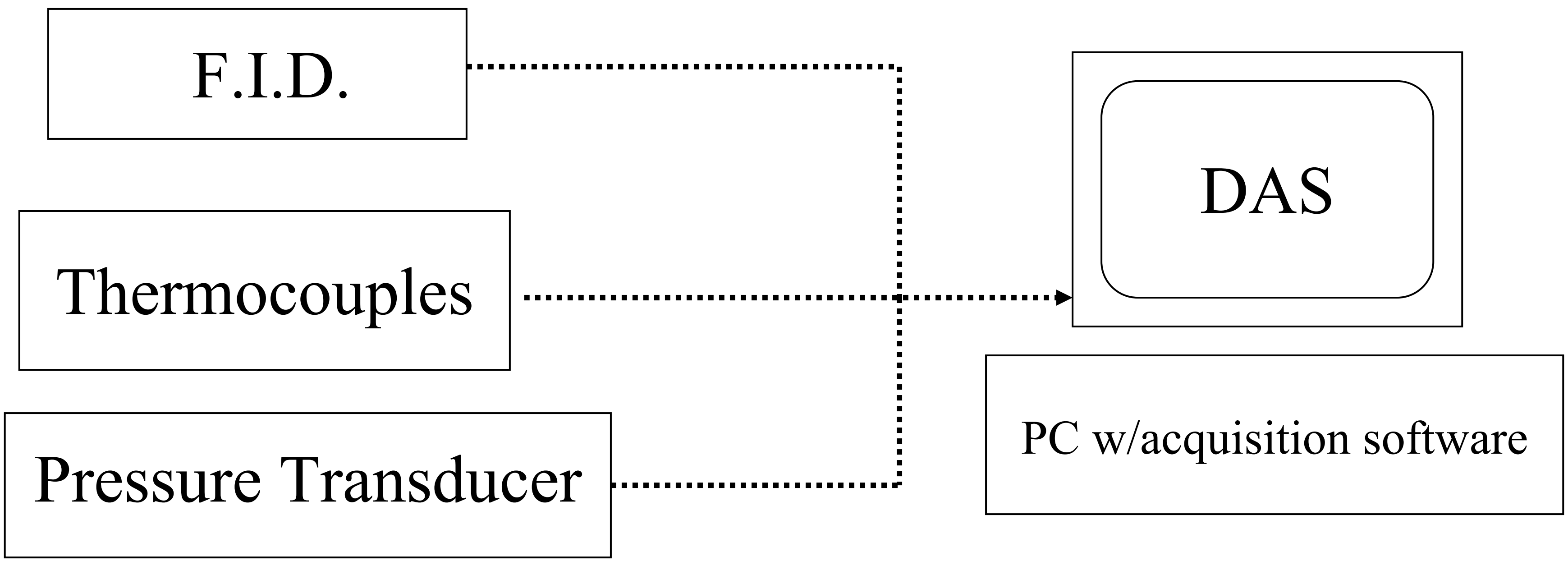
- Flame ionization detector
  - J.U.M. Model VE7 heated total hydrocarbon analyzer
  - Detects concentration of hydrocarbons by burning vapor in a hydrogen flame
  - Upon combustion, a complicated ionization process is initiated which releases many free ions
  - Positive ions collect at one electrode, negative ions at the other
  - The current generated between the electrodes is directly proportional to the amount of hydrocarbons in the sample

Fuel Compositions



Laboratory Setup

Data Acquisition



Experimental Procedure

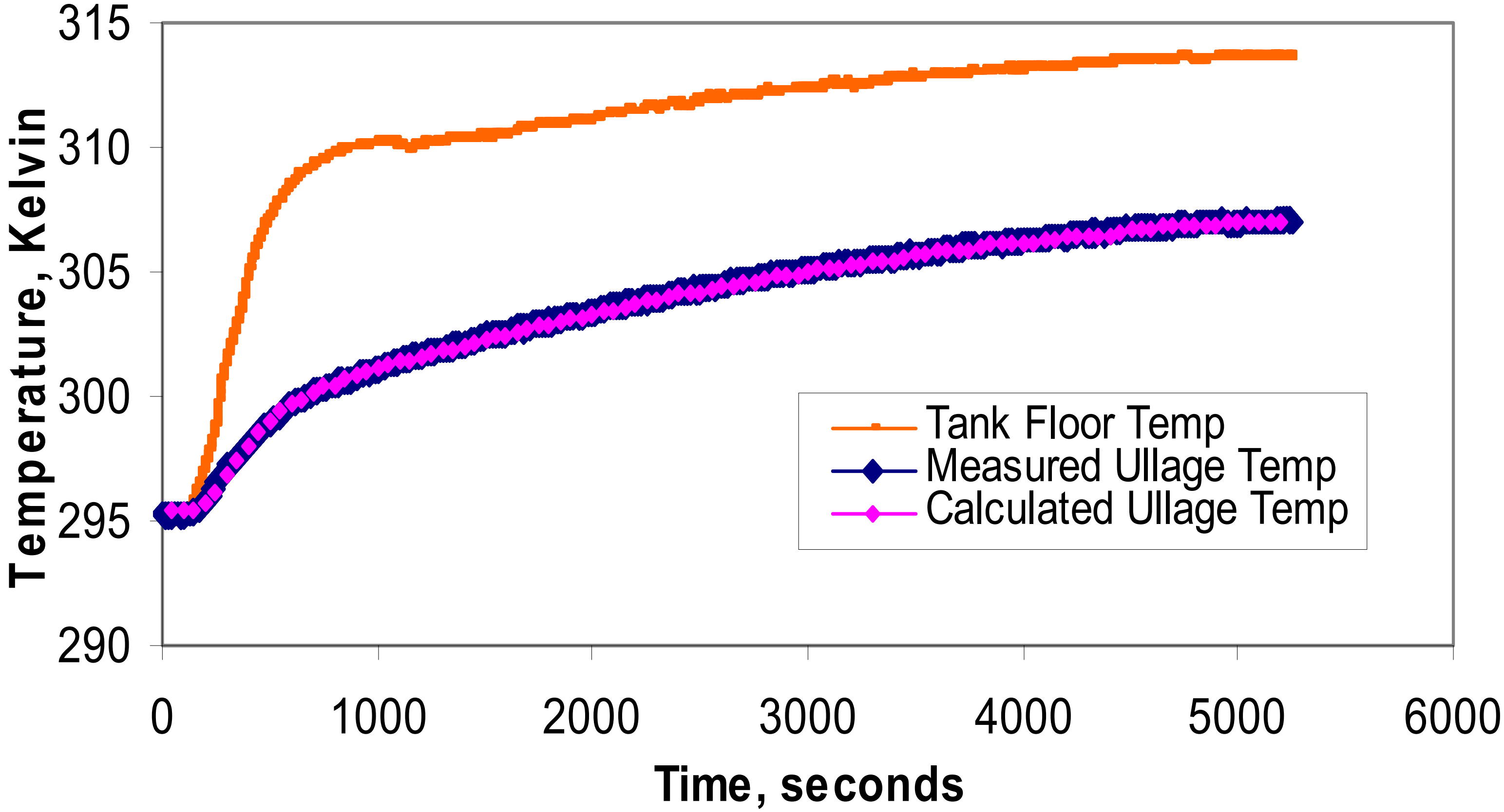
- Fill tank with specified quantity of fuel
- Adjust chamber pressure and temperature to desired values, let equilibrate for 1-2 hours
- Begin to record data with DAS
- Take initial hydrocarbon reading to get initial quasi-equilibrium fuel vapor concentration
- Set tank pressure and temperature as well as the temperature variation
- Experiment concludes when hydrocarbon concentration levels off and quasi-equilibrium is attained

Test Matrix

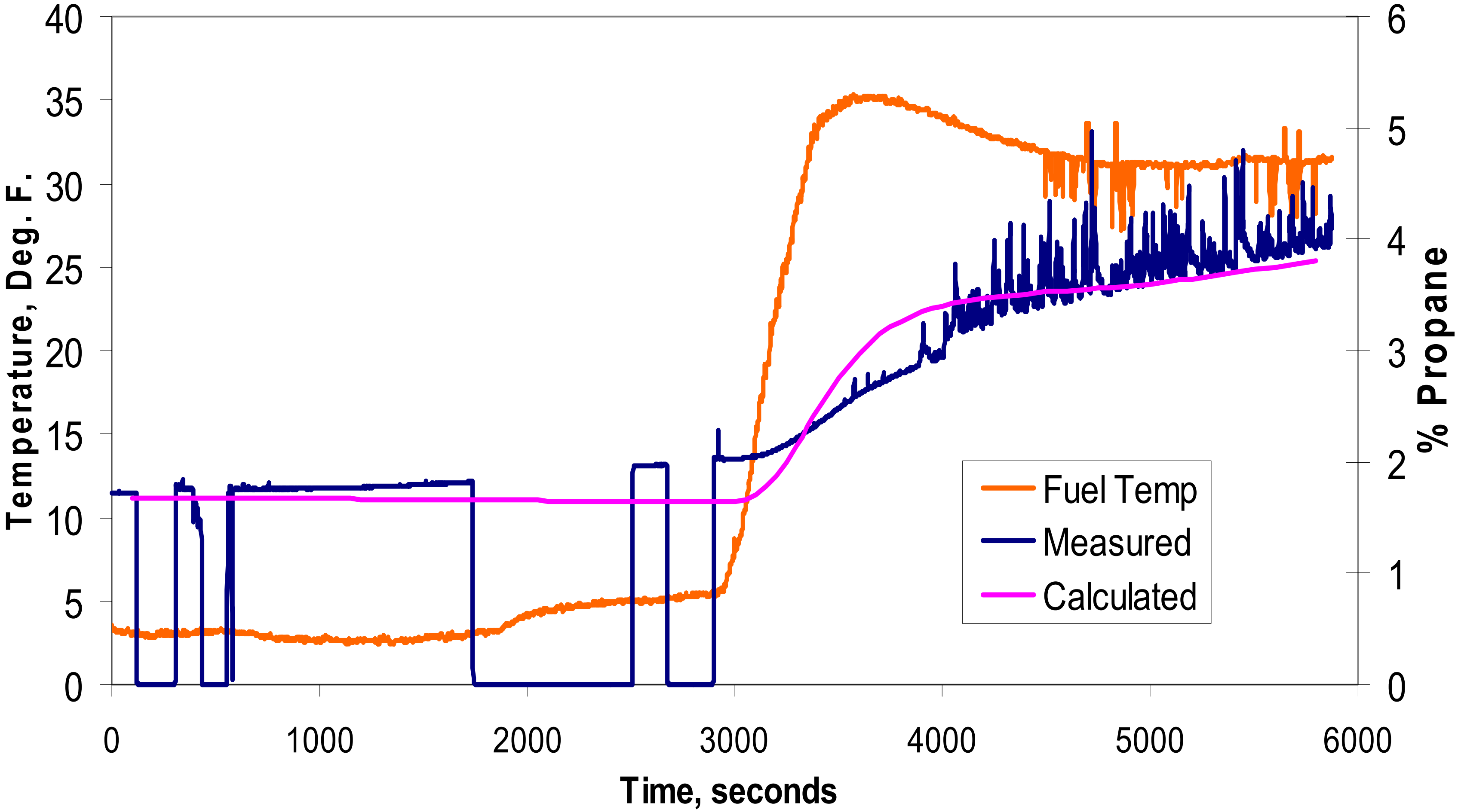
	Altitude			
Test Type:	***0***	***10,000***	***20,000***	***30,000***
Const. P	X	X	X	X
Vary T & P	*N/A*	X	X	X
Isooctane	X	*N/A*	*N/A*	*N/A*
Dry Tank	X	*N/A*	*N/A*	X

- 5 gallon fuel load for every test
- Temperature, pressure profiles created to simulate in-flight conditions

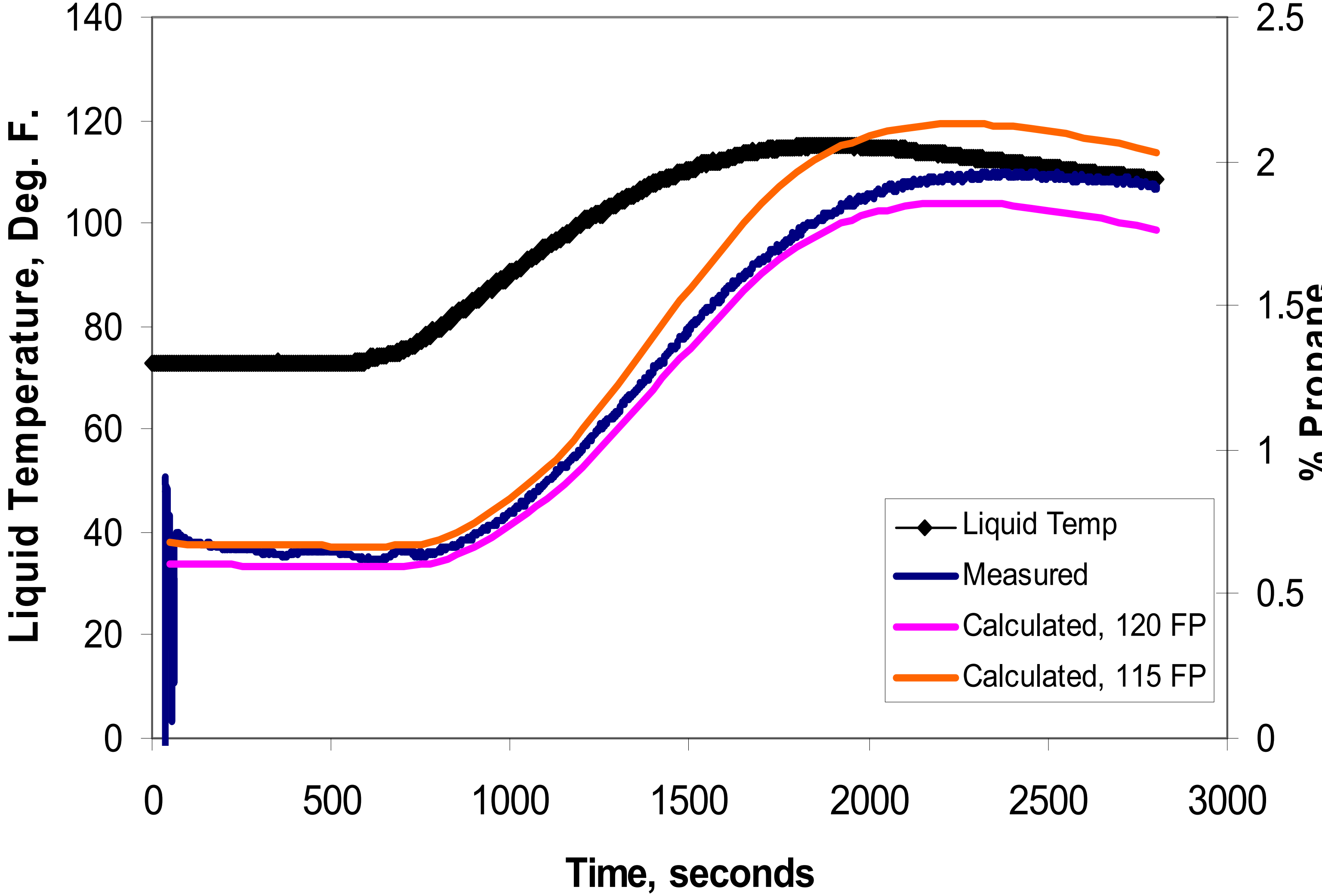
Initial Validation: Dry Tank



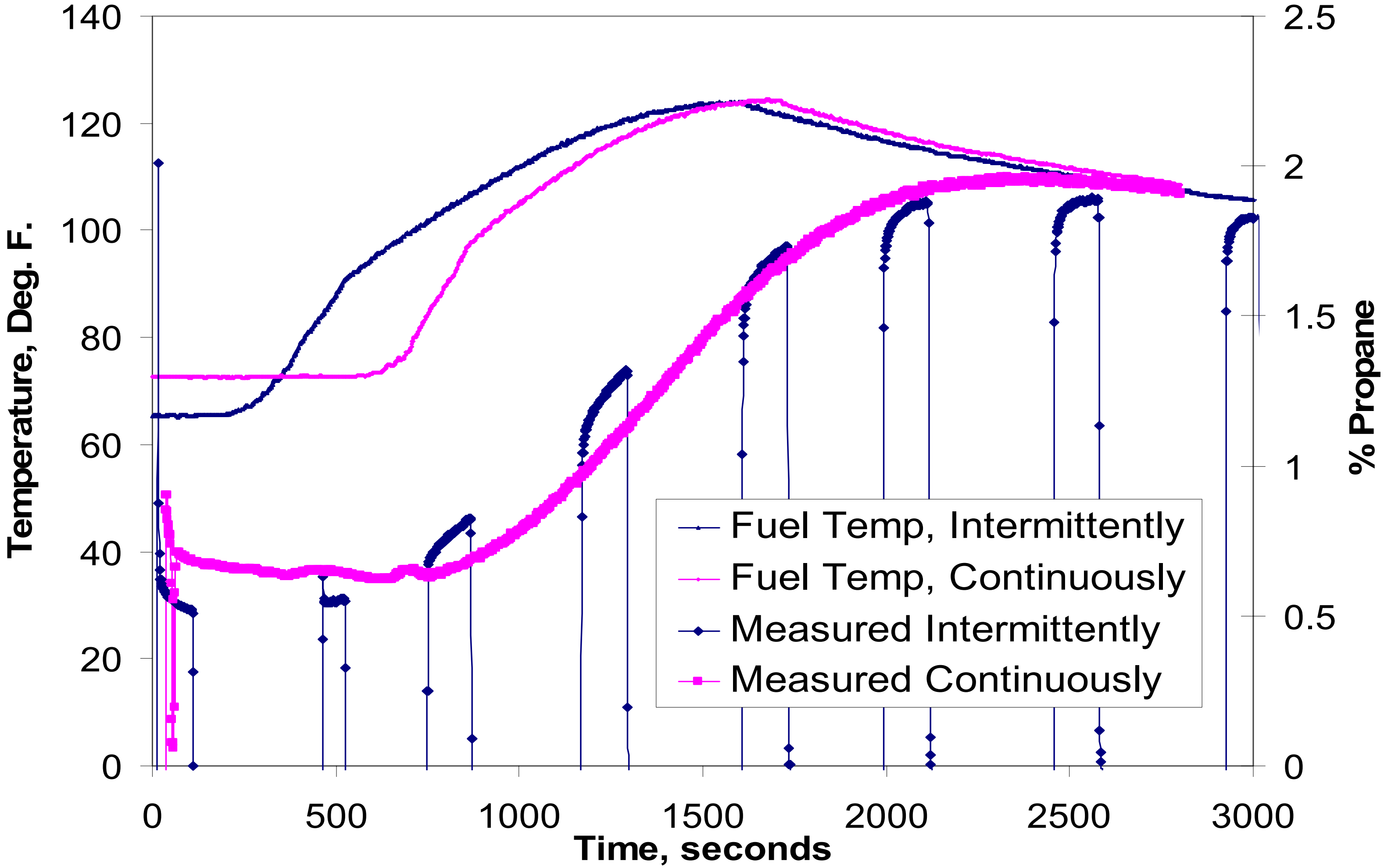
Initial Validation: Isooctane



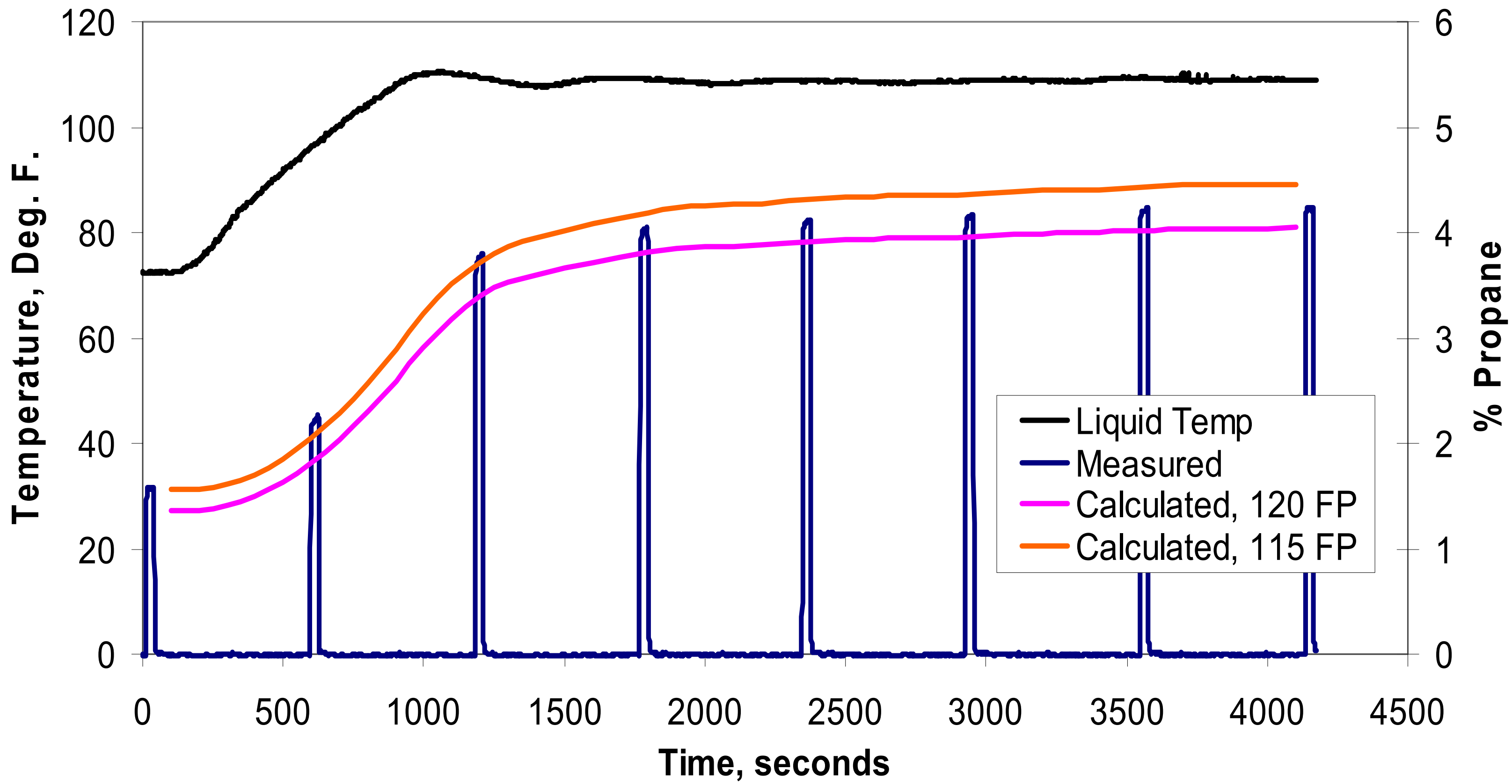
Tank Heating at Sea Level



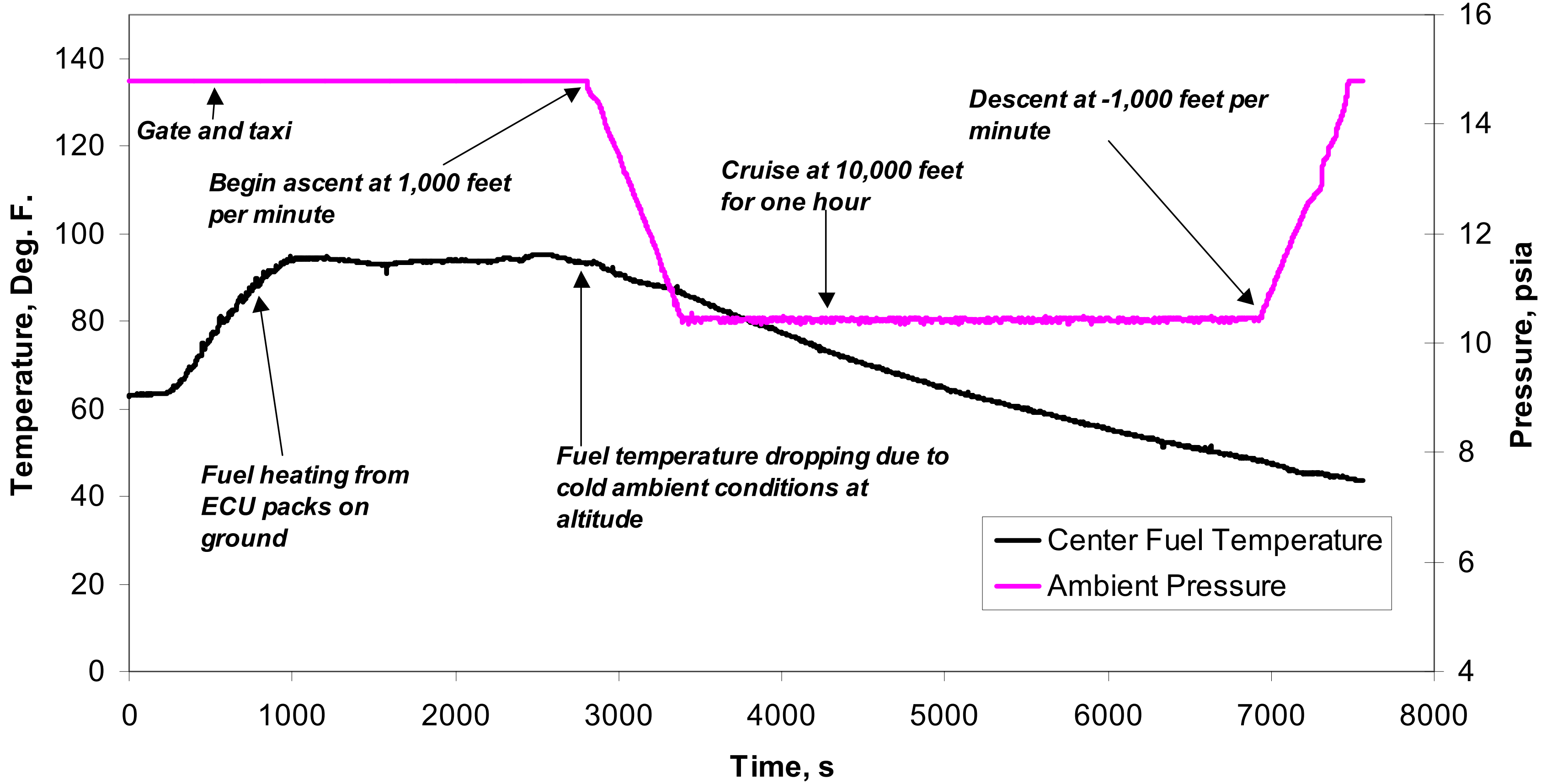
Continuous vs. Intermittent Sampling



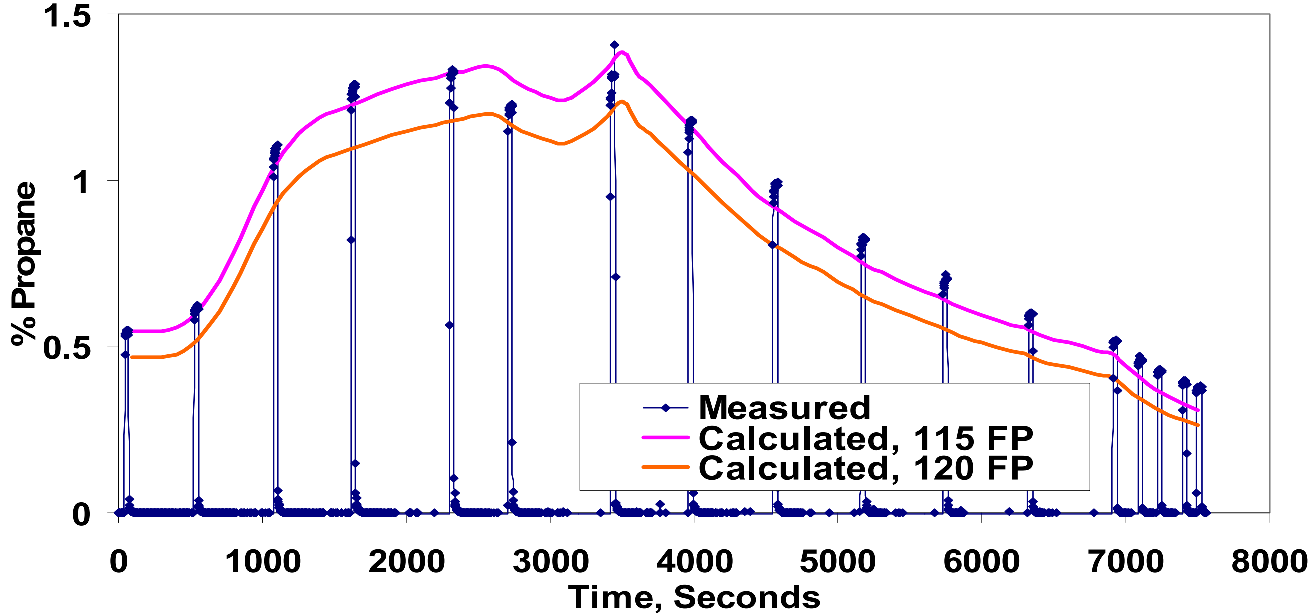
Tank Heating at 10,000’

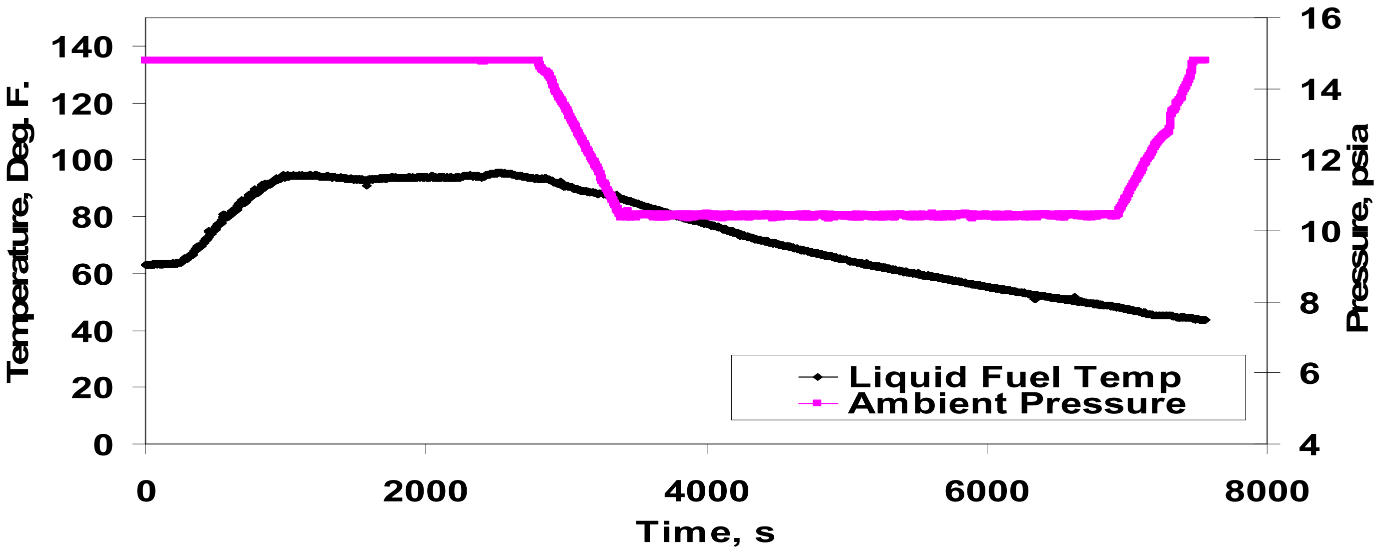


Simulated Flight Profile

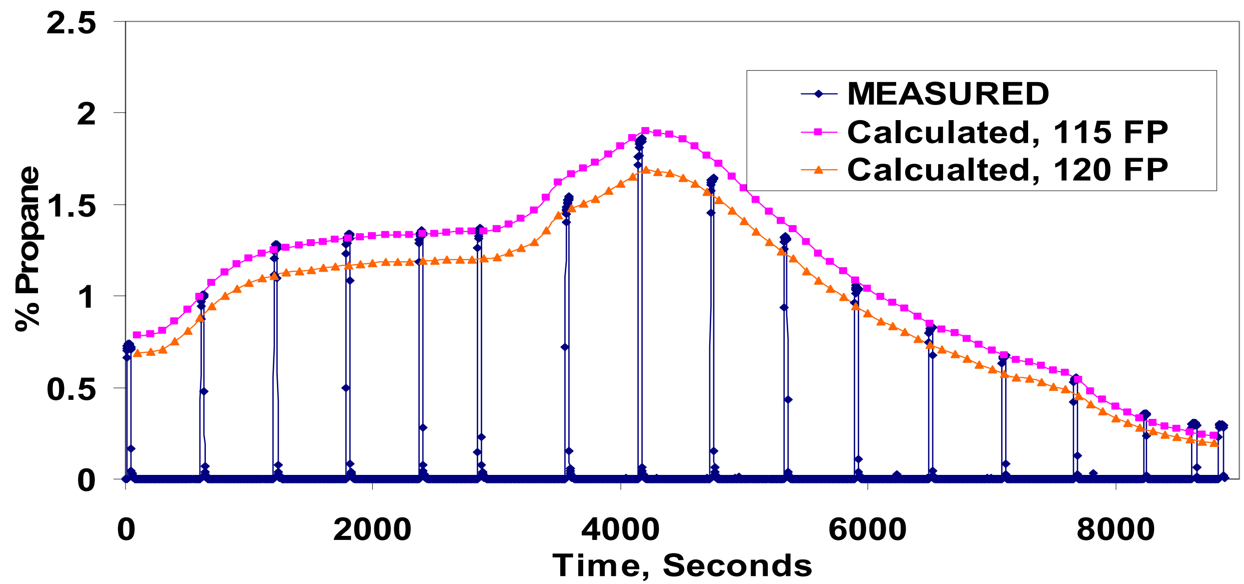


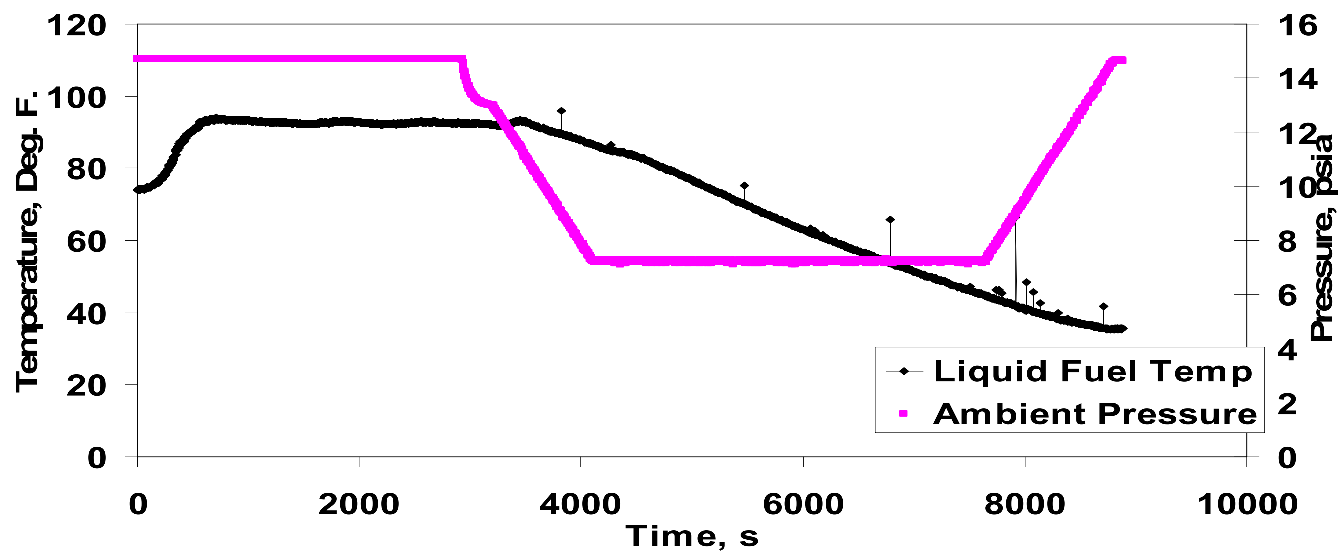
Flight Profile: up to 10,000' Altitude



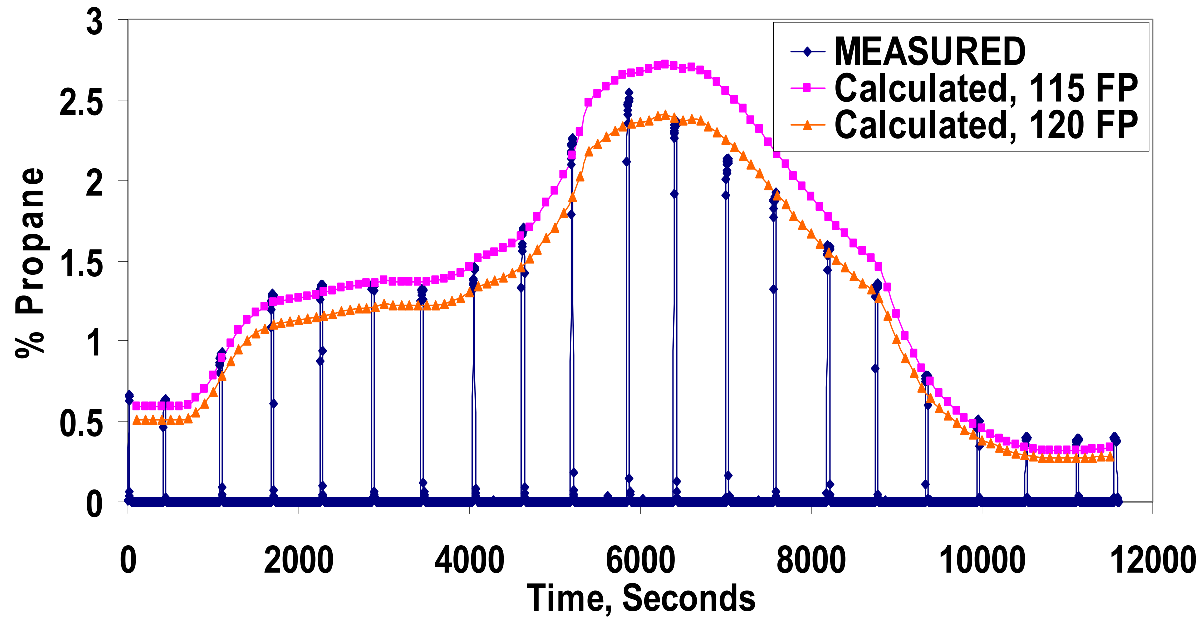


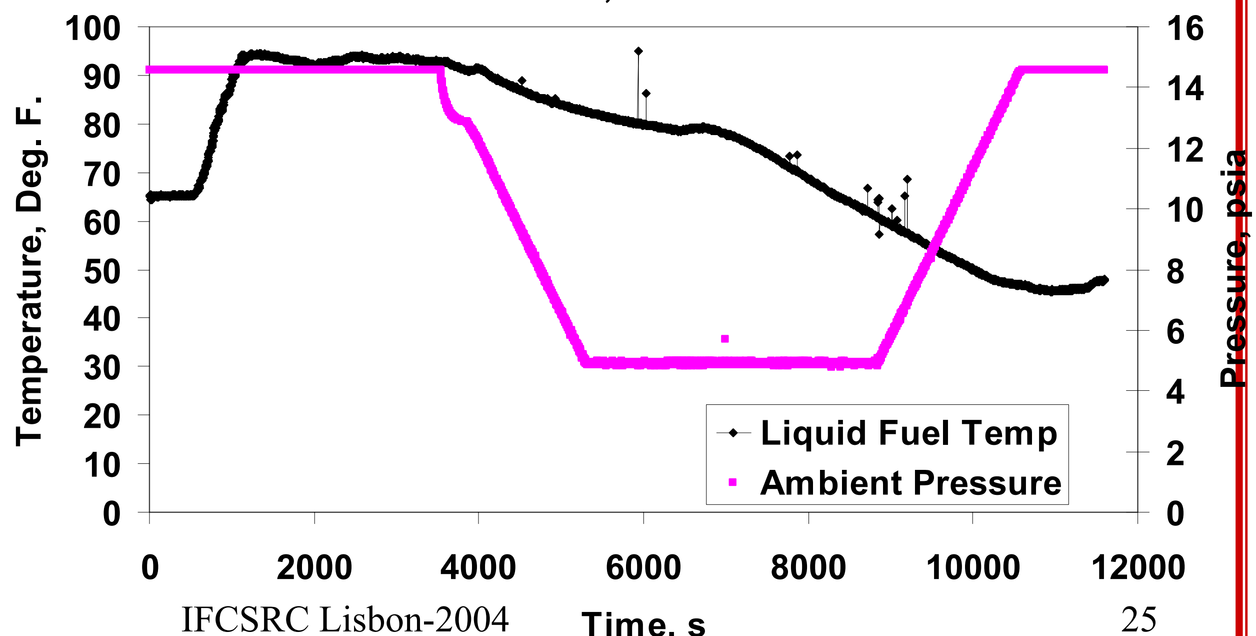
Flight Profile: up to 20,000 ft. Altitude





Flight Profile: up to 30,000 ft. Altitude





Conclusions

- Experiment was well suited for validation of the model
- Initial validation showed accuracy of heat and mass transfer correlations for simplified conditions
- Model shows very good agreement for varying ambient conditions in a controlled experiment
- Uncertainty in fuel composition can change results significantly
- Can be used for full scale fuel tanks for general predictions; complex geometry and flow field in actual tanks complicate the calculations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