State of the Art of Fuel Tank Ullage Oxygen Concentration Measurement

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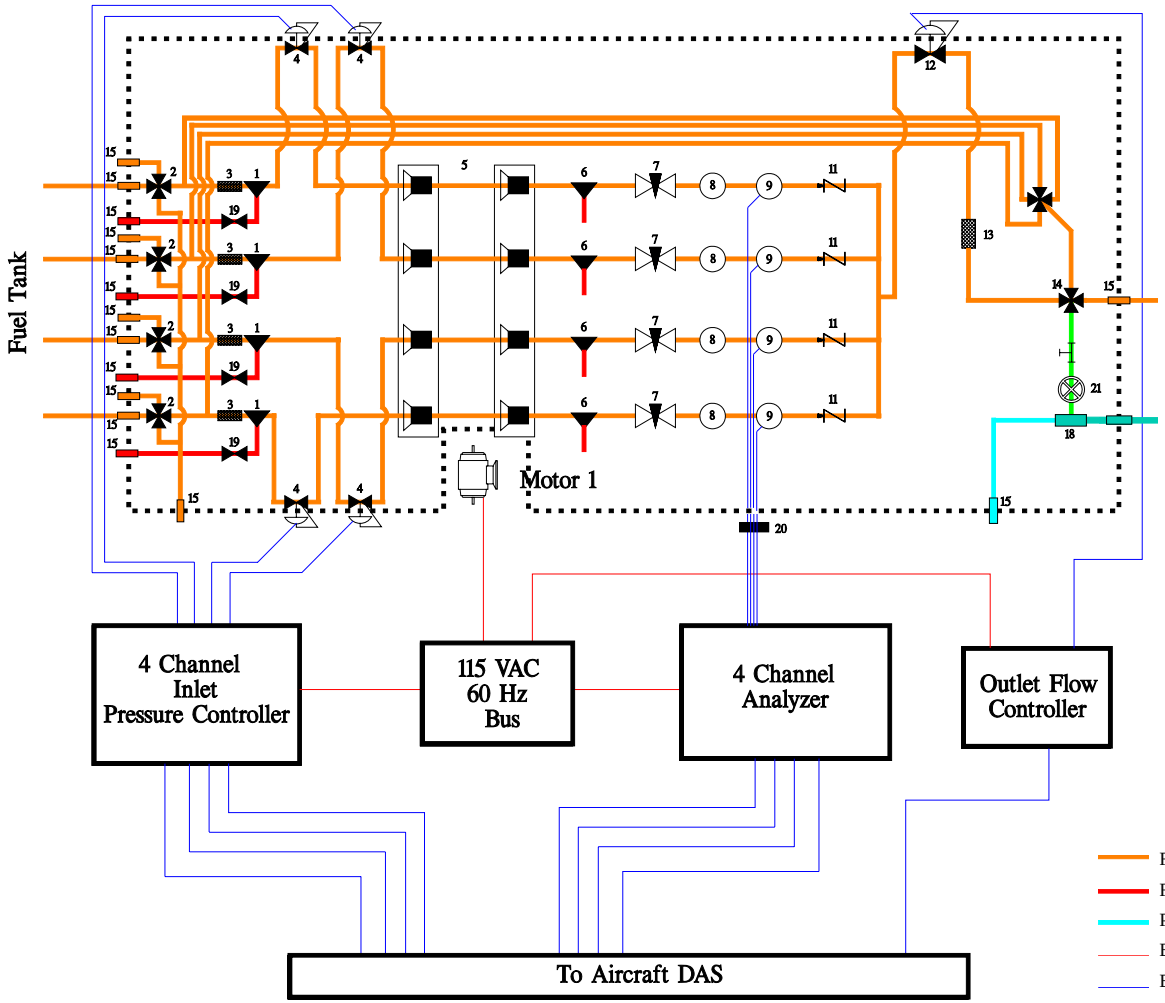
Background

- The measurement of ullage oxygen concentration is important to the fuel tank inerting community when researching methods, validating models, and certifying systems
  - FAA method for measuring ullage oxygen concentration at reduced ullage pressures has been successful but can be cumbersome
- Emerging products have the potential to simplify and improve upon R&D / Certification work on fuel tank inerting
  - Air Force has spent some money in this area giving SBIR money to 4 companies and “developing” two methods
  - Galvanic cell technology cheaper and more effective than ever
  - In situ measurements would be great if practical

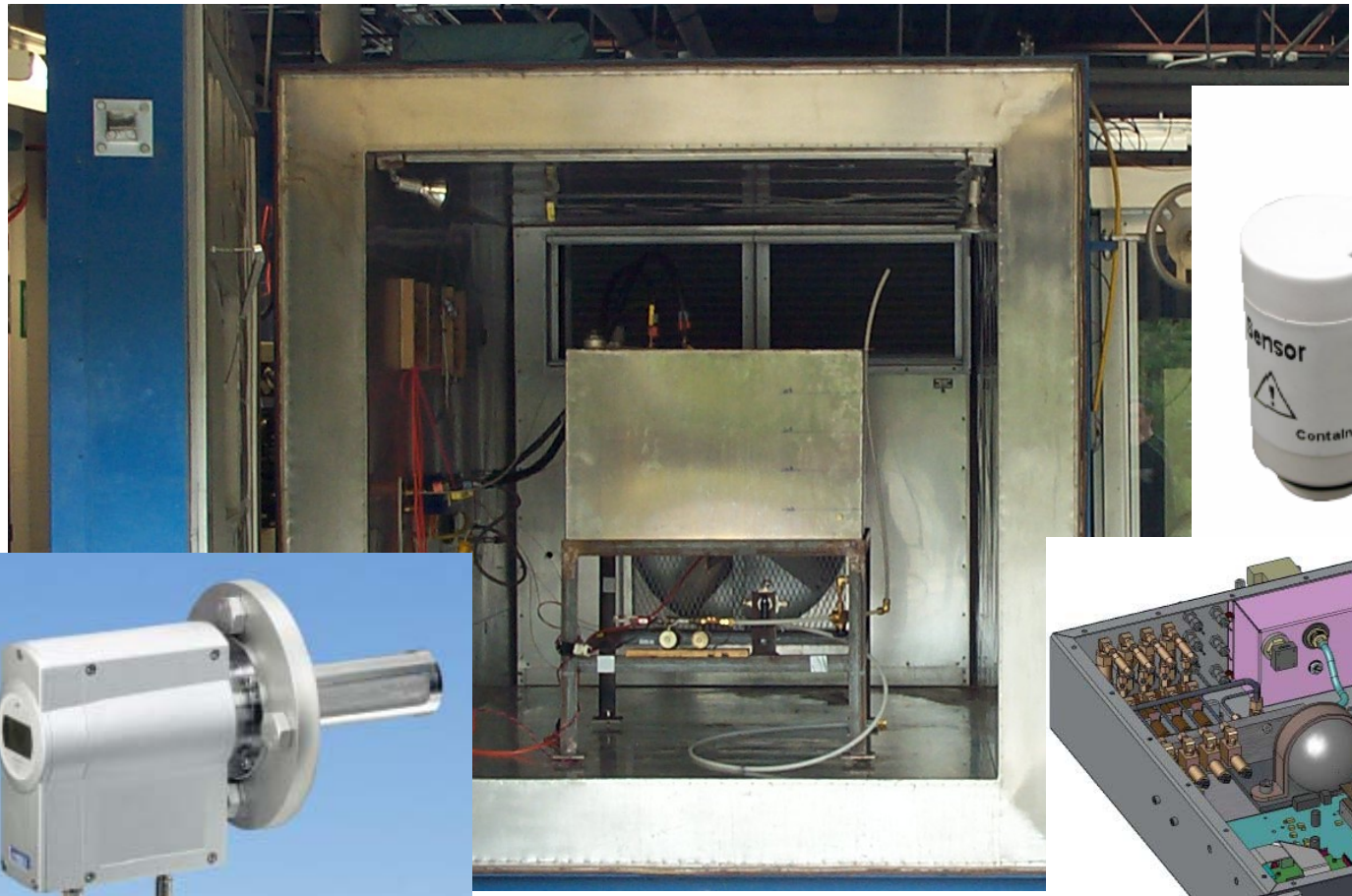
Technologies Examined

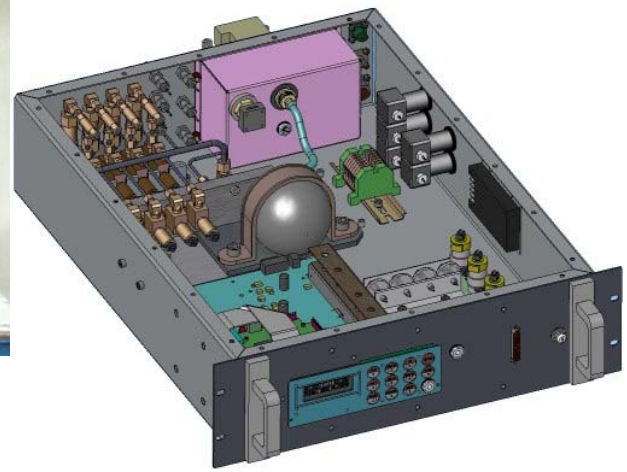
- FAA gas sampling method with traditional galvanic cell
  - Same as OBOAS regulated sample train without safety features
- In situ galvanic cell
  - Ultra low power, intrinsically safe, galvanic cell can be used in situ and calibrated for low pressure exposure
- Gas sampling using light absorption with TLD
  - Unregulated sample train using a sample “cylinder” that measures infrared light absorption from a tunable diode type laser
- In situ light absorption using TLD
  - Similar sensor technology as sampling method packaged in a 5” probe
- In situ next generation fluorescence quenching
  - Small fiber optic probe with temperature compensation built in

FAA Oxygen Concentration Measurement Method



FAA Environmental Chamber with Test Equipment



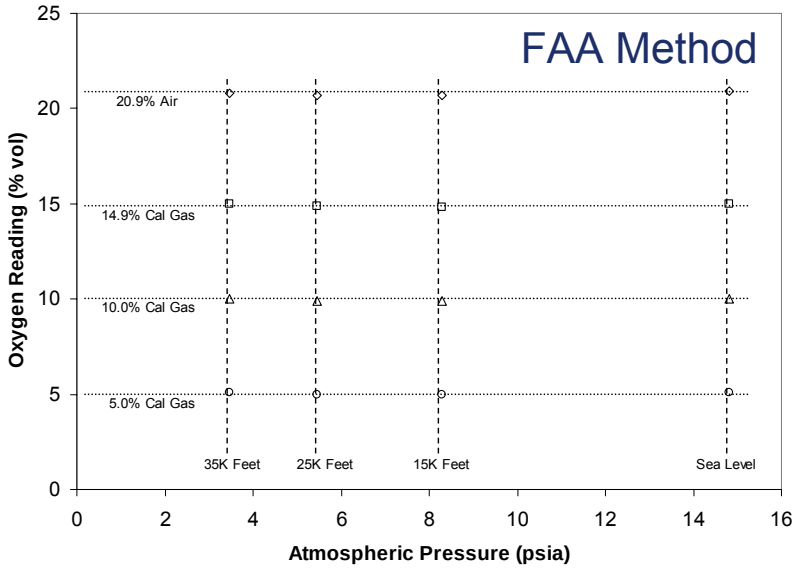


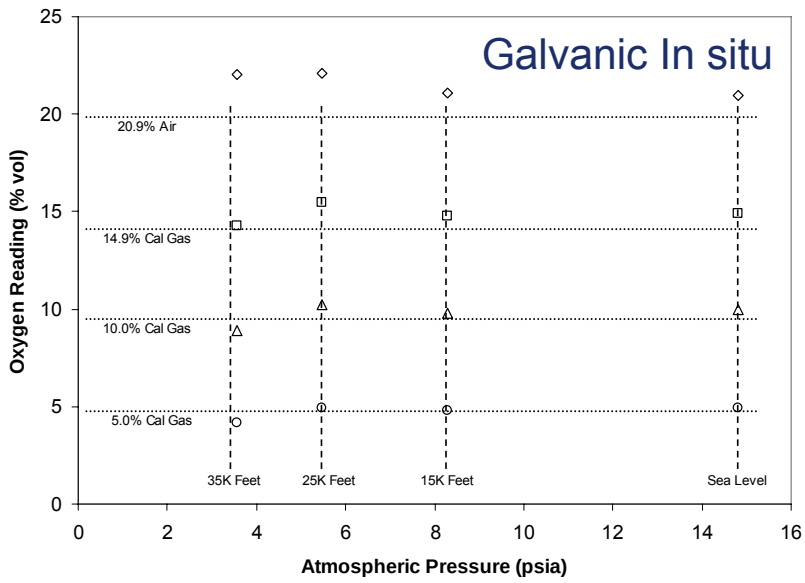
Testing Performed

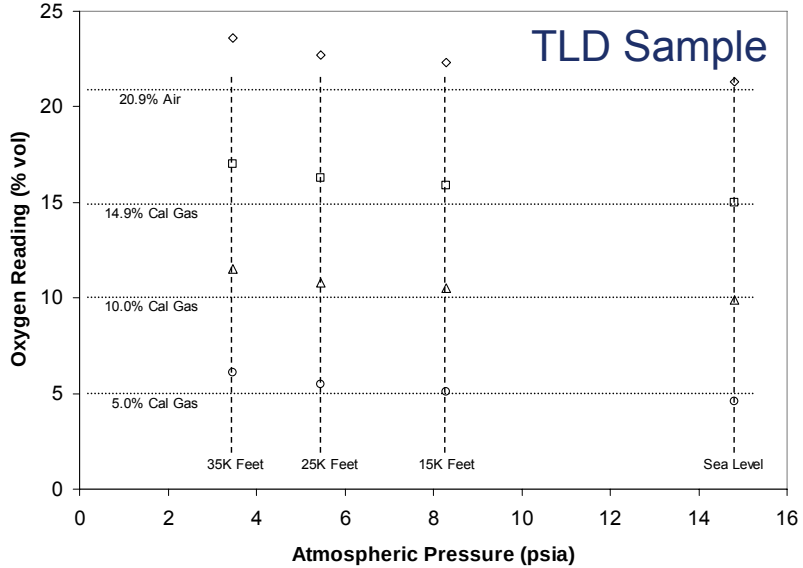
- First - put all available sensors in a PVC tube and exposed them to calibration gases at various altitudes
- Second - installed the available sensors in test tank and exposed them to simulated CWT ullage environment and flight cycle
  - Used existing 17^3 foot aluminum fuel tank in altitude chamber
  - Put fuel in tank as well as inerted the ullage with nitrogen
  - Performed simulated mission complete with ground heat up, ascent, cruise, and descent with simulated inerting system performance
- Fluorescence quenching not available at the time of testing
  - Equipment installed on Alenia aircraft for validation testing

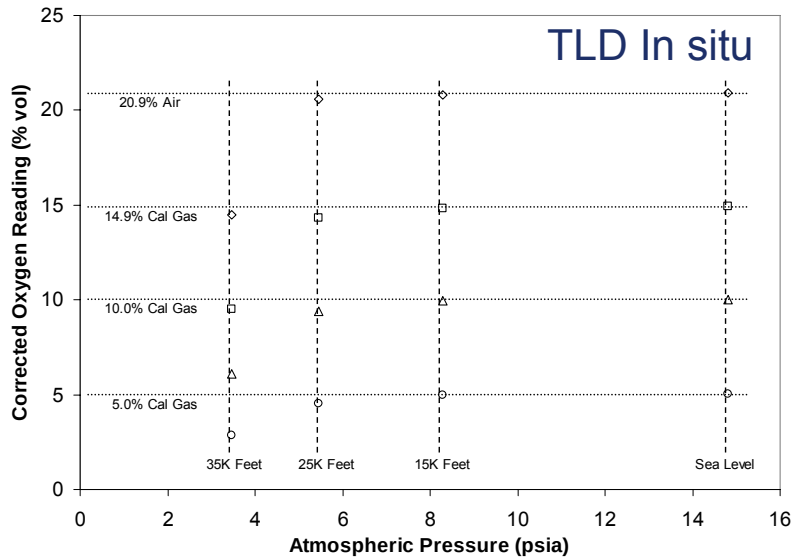
Results – Evaluation of Methods Data

- The different methods gave varying results at what gases and altitudes duplicated calibration gases best
  - FAA method only one that duplicated calibration gases consistently
- All tested technologies followed the general trend of the FAA method data for the simulated CWT ullage test
  - Both TLD methods could not give results at low partial pressures of oxygen
  - In situ galvanic cell gave sporadic results after being exposed to low static pressures
- Preliminary tests on the Alenia aircraft of the Next Gen Fluorescence quenching gave reasonable results on ground
  - Flight test data trends do not jive with reality

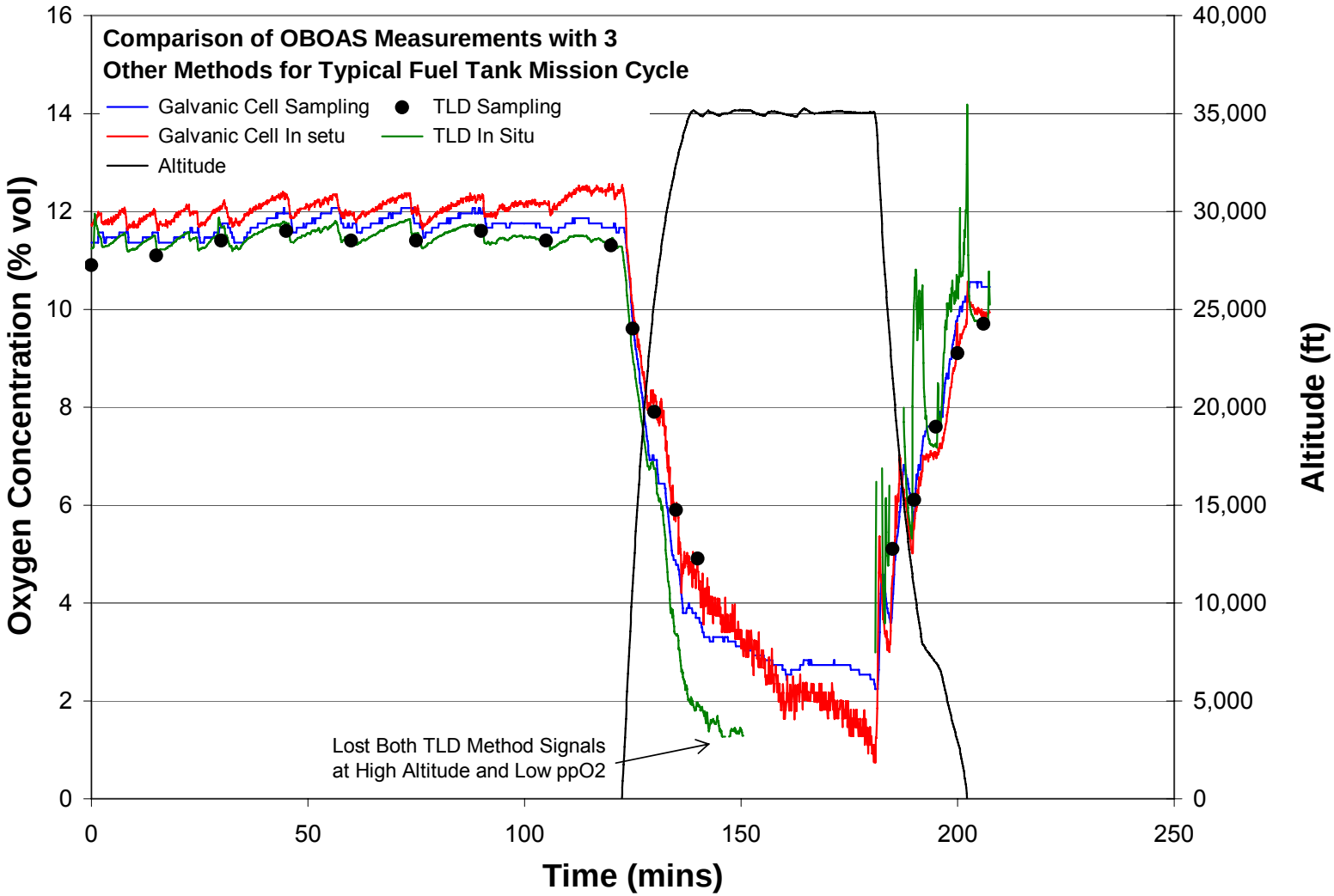

FAA Method
Oxygen Reading (% vol)
Atmospheric Pressure (psia)
20.9% Air
14.9% Cal Gas
10.0% Cal Gas
5.0% Cal Gas
35K Feet
25K Feet
15K Feet
Sea Level


Galvanic In situ
Oxygen Reading (% vol)
Atmospheric Pressure (psia)
20.9% Air
14.9% Cal Gas
10.0% Cal Gas
5.0% Cal Gas
35K Feet
25K Feet
15K Feet
Sea Level

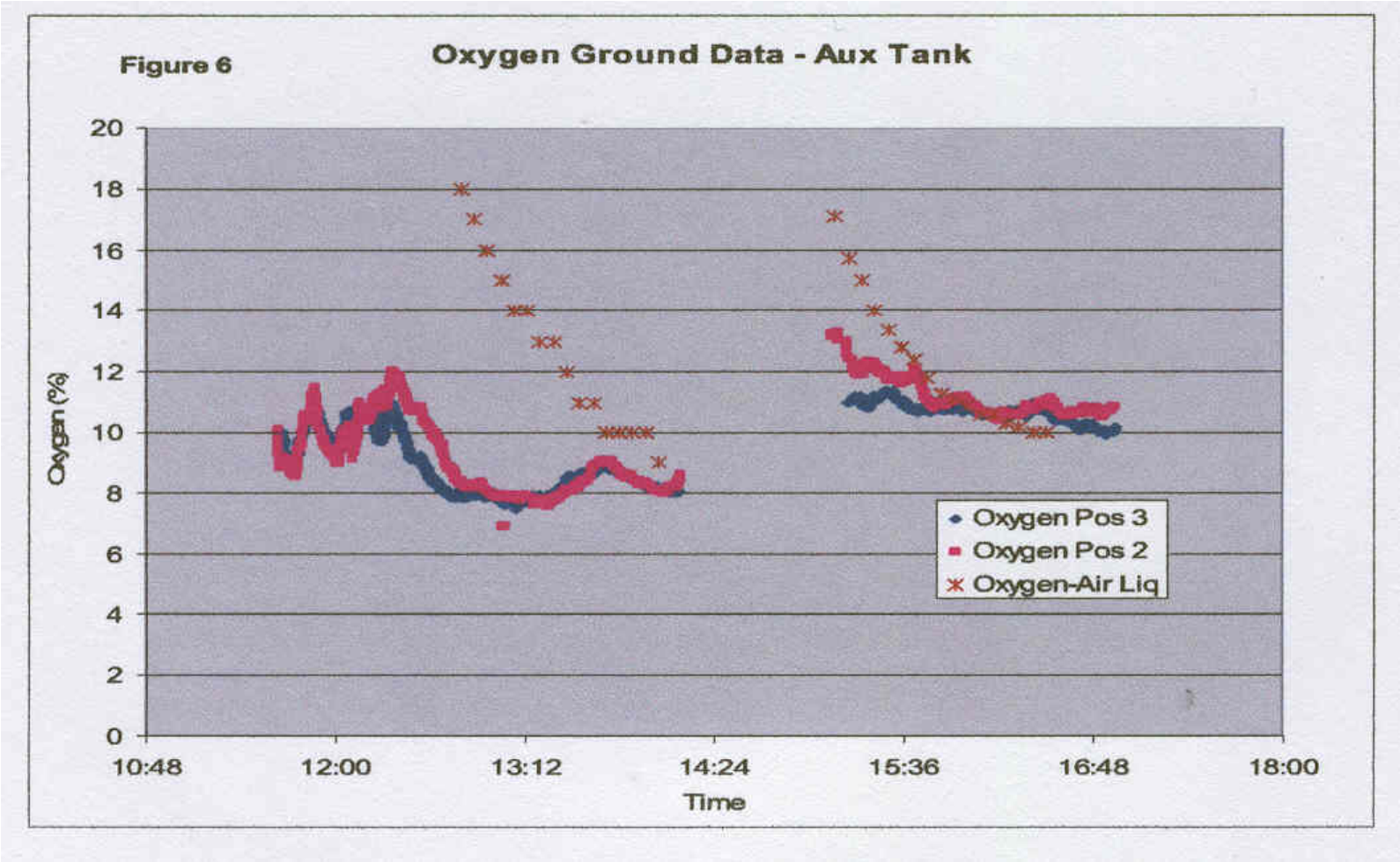

TLD Sample
Oxygen Reading (% vol)
Atmospheric Pressure (psia)
20.9% Air
14.9% Cal Gas
10.0% Cal Gas
5.0% Cal Gas
35K Feet
25K Feet
15K Feet
Sea Level


TLD In situ
Corrected Oxygen Reading (% vol)
Atmospheric Pressure (psia)
20.9% Air
14.9% Cal Gas
10.0% Cal Gas
5.0% Cal Gas
35K Feet
25K Feet
15K Feet
Sea Level

Results of CWT Environment Simulation Test



Alenia Aircraft Ground Testing Results



Summary

- State of the art of ullage oxygen concentration measurement has improved considerable in the last 3-5 years
  - Several TLD absorption products available
  - Fluorescence quenching probes in flight test aircraft fuel tanks
- Additional work needed for all of these products to be able to duplicate a wide range of calibrations gases at a wide range of altitudes