Measuring Oxygen Concentration in a Fuel Tank Ullage

Federal Aviation Administration

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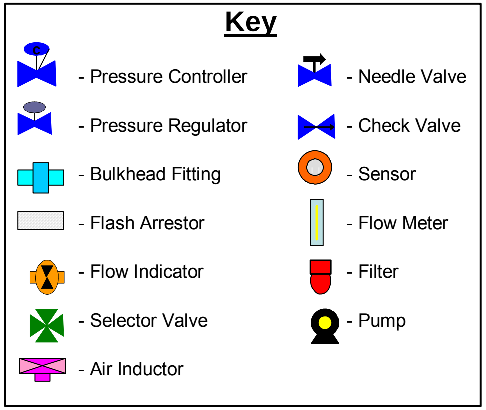
Background

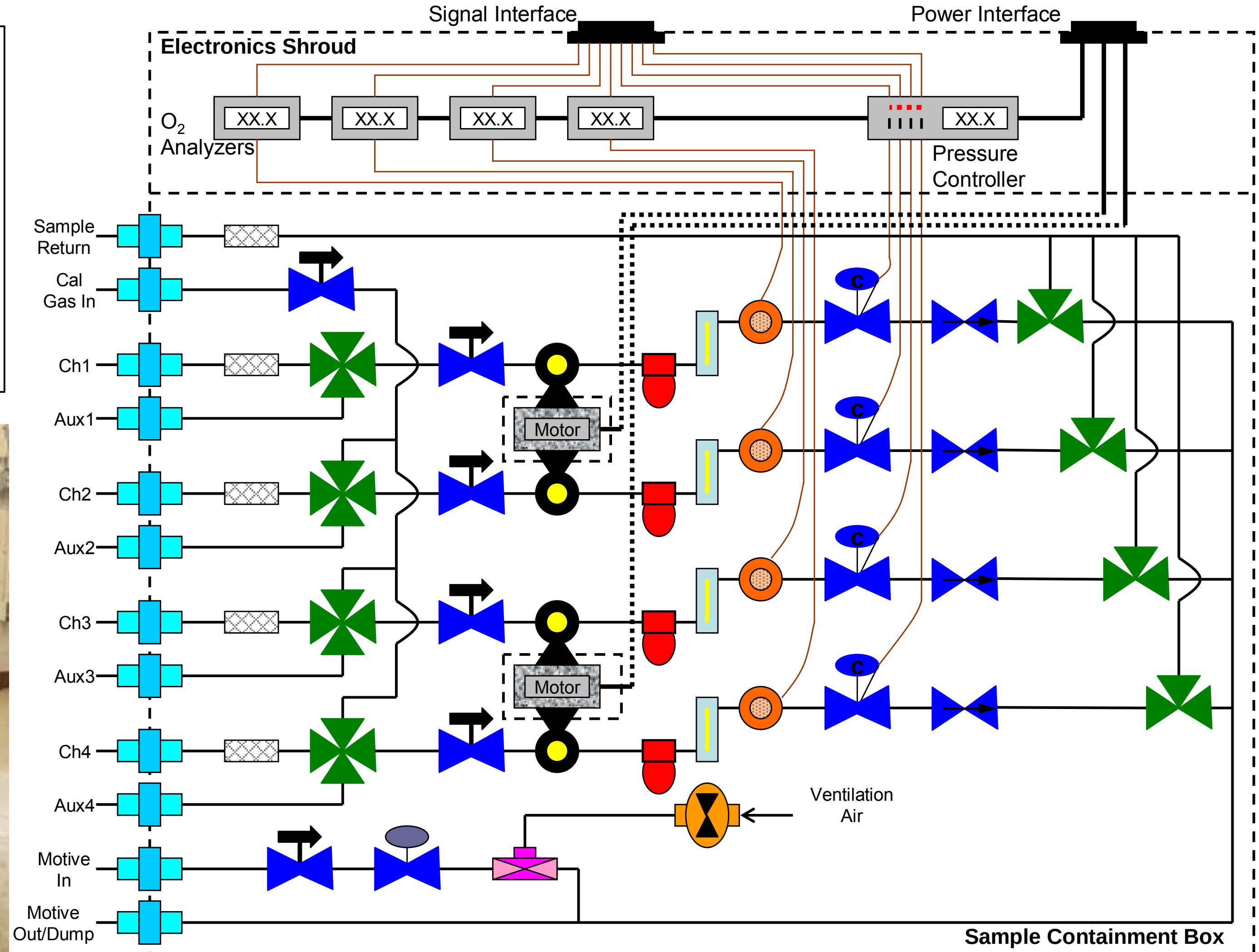
- FAA has been seeking to improve fuel tank safety in the wake of TWA Flight 800 in July of 1996
  - Rule published requiring extensive flammability reduction on both future built and existing aircraft on present types
- The measurement of ullage oxygen concentration is important to the fuel tank inerting 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 for fuel tank inerting

Technologies/Methods Examined

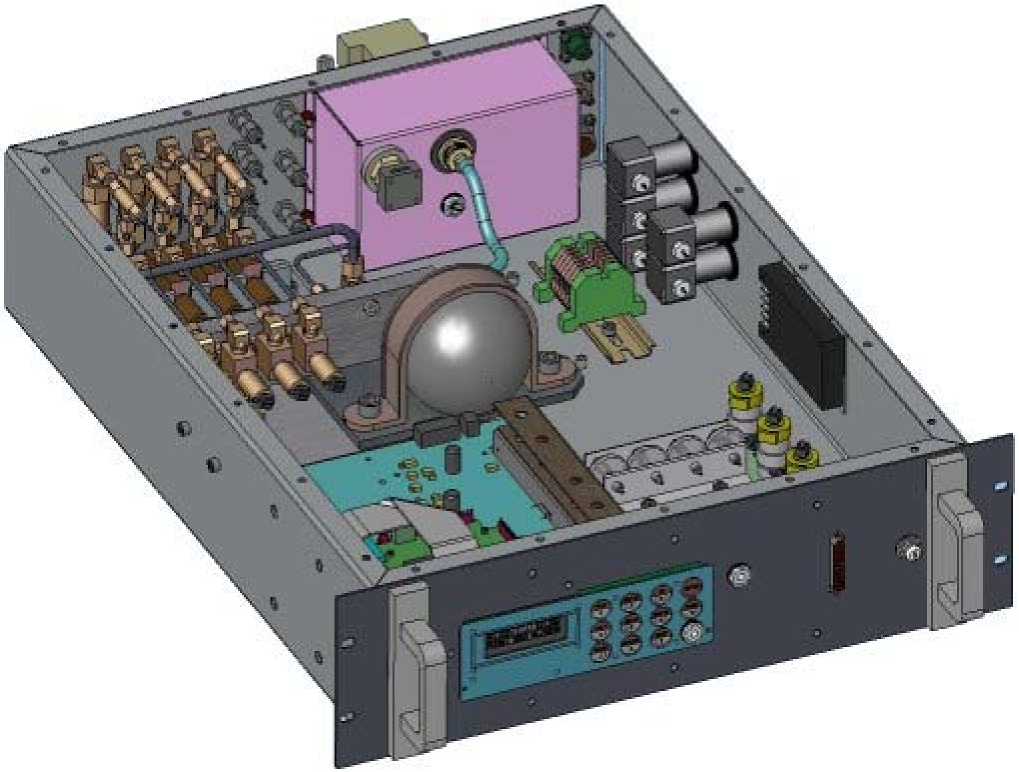
- Improved FAA gas sampling method
  - Made design changes to OBOAS regulated sample train and packaging based on lessons learned during FAA flight testing
  - New system is lighter, smaller, quieter, but not proven to have equivalent level of safety
- Light Absorption with unregulated gas sample train (Oxigraf)
  - Unregulated sample train uses a sensor that measures infrared light absorption using a tunable laser diode (TLD technology)
  - Proprietary software used to interpret spectral data
- Optical fluorescence using in situ probe (ASF)
  - Small fiber optic probe uses spectrometer to interpret coherent light signal which is highly dependent on temperature/pressure
  - Used in situ (in place) which has many advantages (low power, small size/weight, rapid response) but also has limitations

FAA Oxygen Concentration Measurement Method





Light Absorption Method using TLD



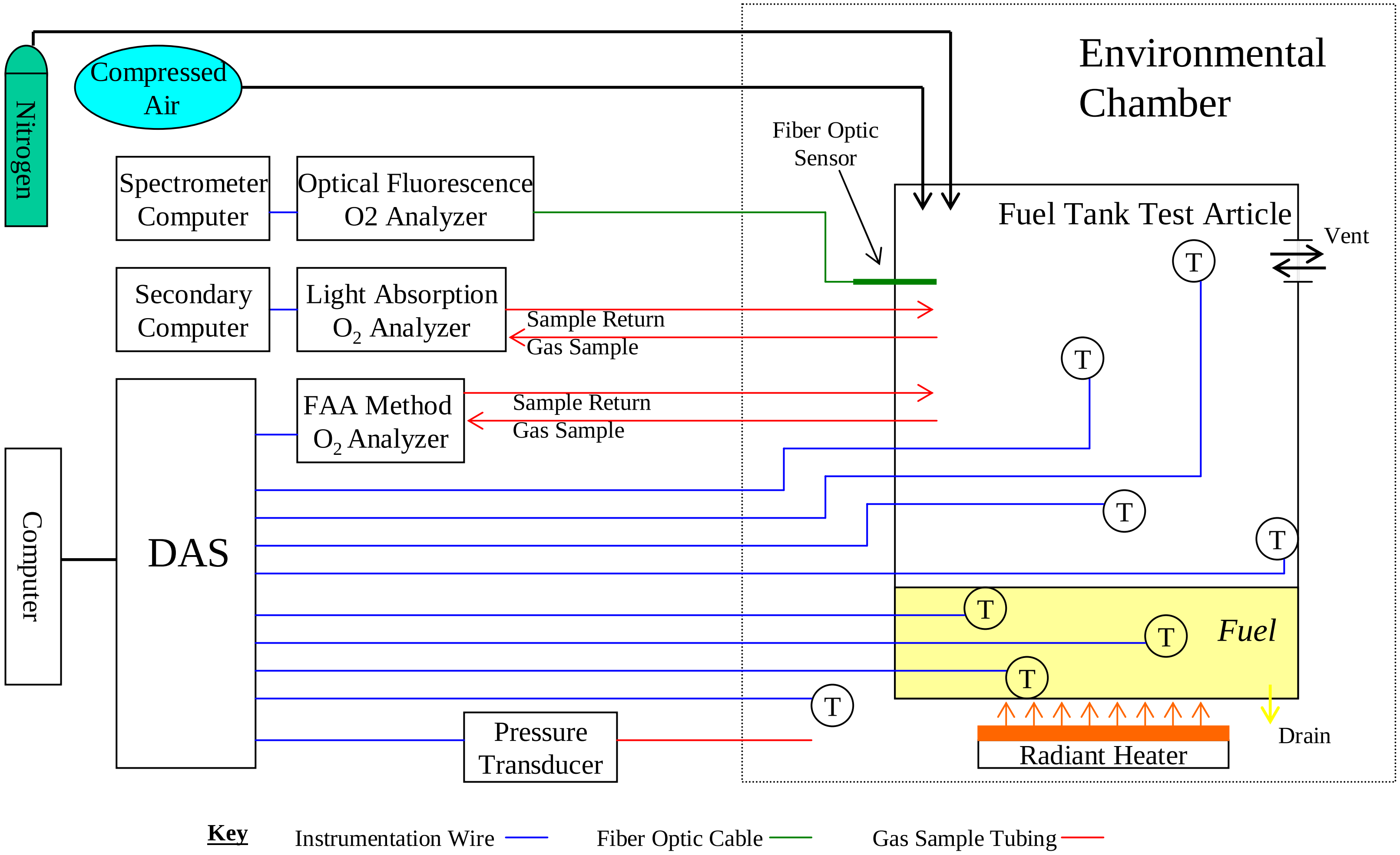
Oxigraf O2N2 Flight Test Oxygen Analyzer

Optical Fluorescence (ASF) Used In Situ

Testing Performed

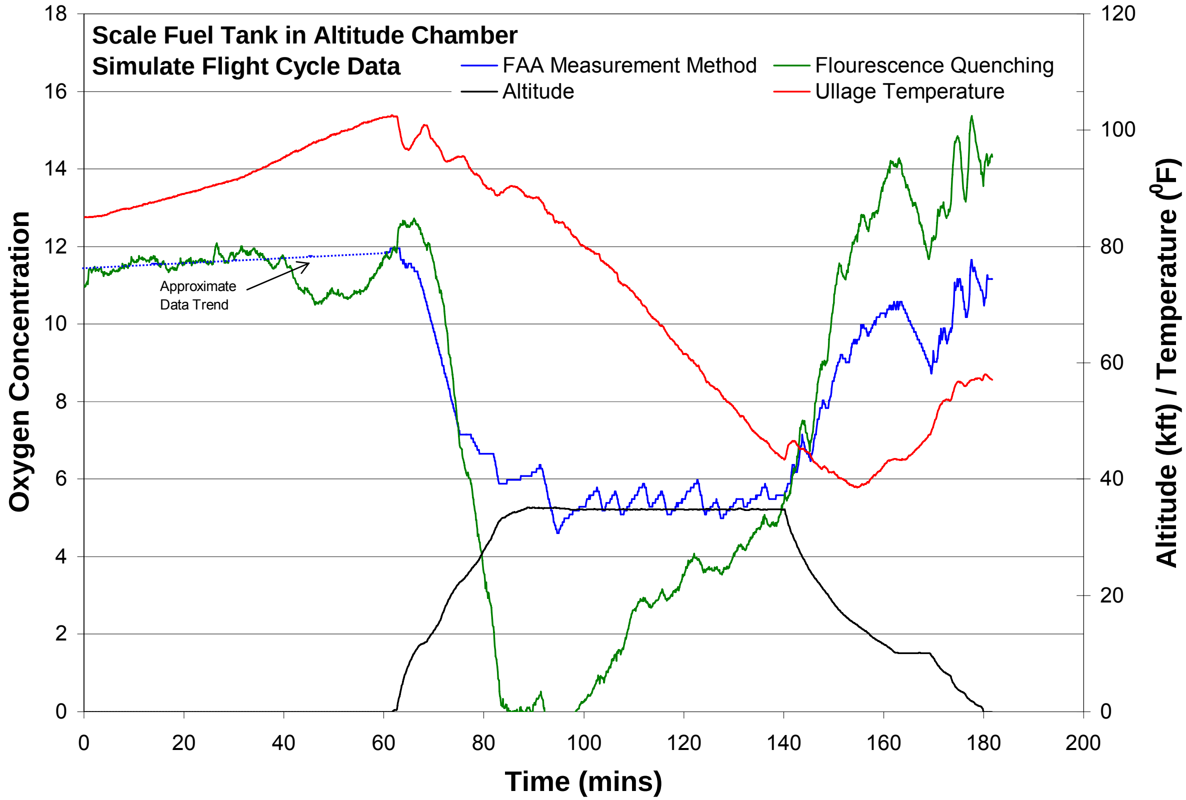
- First – had all methods used in a PVC tube which was flooded with various calibration gases at various temperatures and altitudes
  - Also examined response time of method by seeing how long it took for instrument to go from 5% to 15% (within 0.1% of stability)
- Second - installed the available methods in test tank and exposed them to simulated CWT ullage environment and flight cycle
  - Used existing 17 cubic foot aluminum fuel tank in altitude chamber
  - Put fuel in tank as well as inerted the ullage with nitrogen
  - Performed simulated mission with ground heat up, ascent, cruise, and descent with simulated inerting system performance
  - Temperature between 110 & -10 ºF, altitudes 0-36K feet

Block Diagram of Fuel Tank Ullage Simulation



Results – Previously Acquired Data

- Previously performed tests illustrated how the optical fluorescence method in situ could follow trends of FAA method with large magnitude errors
  - Had trouble giving valid numbers at low partial pressures
  - Also the temperature cycling of the mission seemed to effect the data adversely

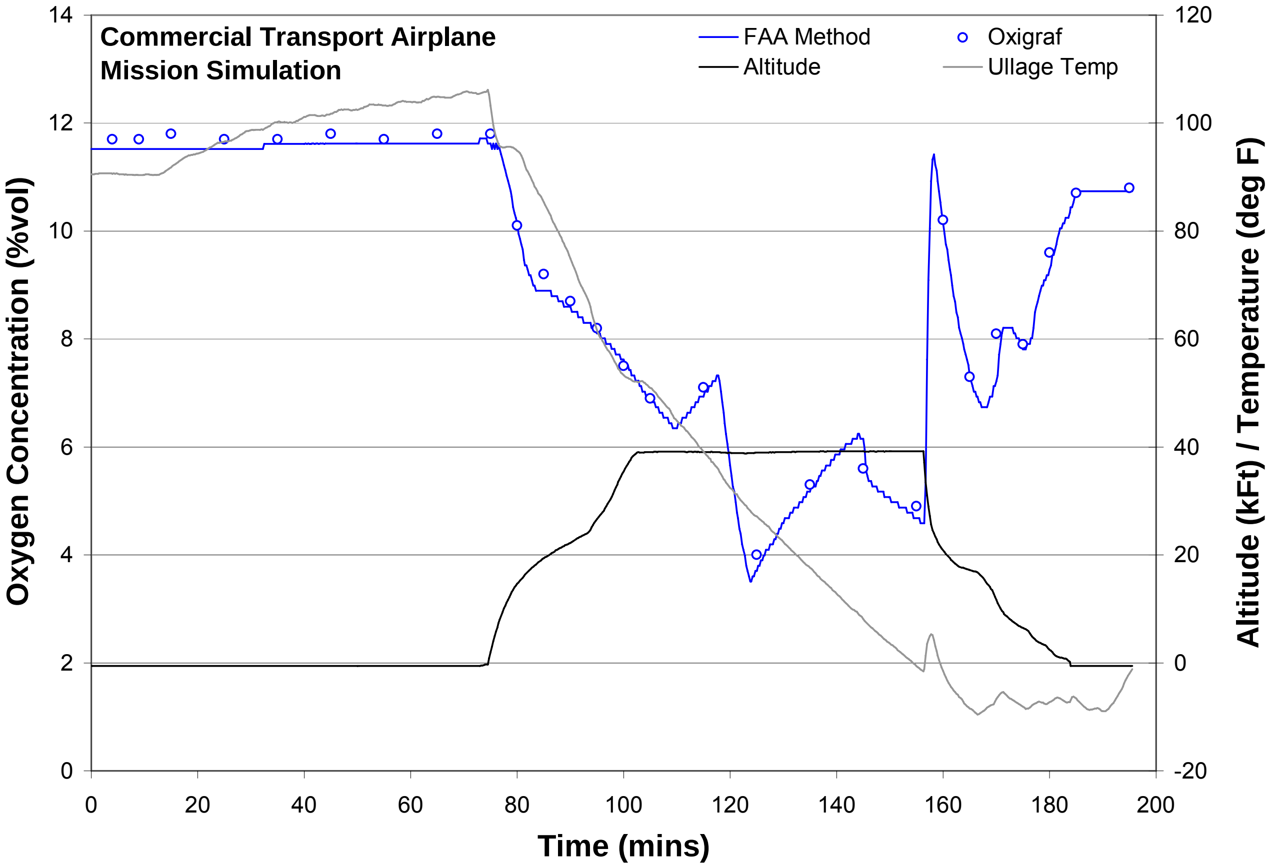


Results – Calibration Gas Exposure

- Exposed all methods to the stated calibration gases at several altitudes and temperatures typical of a commercial transport airplane fuel tank ullage
  - Preliminary data with optical fluorescence system did not do well so manufacturer went off to work out the problems
  - the FAA method and light absorption method duplicated calibration gases well (+/- 0.2% O_2 from 5-15% O_2)
- The light absorption method was the fastest responding method with the FAA method and the optical fluorescence method in a distant second (more than twice as slow)
  - The optical fluorescence has the potential to be the fastest when developmental software is made more streamlined
  - FAA method will never be significantly faster

Results – Airplane Fuel Tank Simulation

- Measured fuel tank test article ullage [O_2] with both the FAA method and the light absorption method
  - Results of Oxigraf and FAA method very close
  - The inerting of test tank erratic due to problems, but this illustrates the small advantage of rapid response



Summary

- Both the FAA method and the light absorption method duplicate calibration gases well at a variety of conditions and both agree on oxygen concentration measurements made during a simulation of an inert commercial transport airplane fuel tank flight cycle
  - Light absorption system has faster response time but appears to be of little advantage
  - Light absorption system already performed some flight testing and is slated for more with several OEMs / Operators
- Optical fluorescence method still working out problems but slated for more chamber examinations in May