In Situ Multi-Species (O_2, N_2, Fuel, other) Fiber Optic Sensor for Fuel Tank Ullage

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A fiber optic sensor for the real-time and in situ measurement of nitrogen (N_2), oxygen (O_2), hydrocarbon (HC) fuel vapors, and other gases has been developed for aircraft fuel tank inerting applications over the past several years at Glenn Research Center. The intrinsically-safe, solid-state fiber optic sensor system is reliable and provides a 1% (by volume) precision measurement of multiple gases in a 5-sec time window. The sensor has no consumable parts to wear out and requires less than 25 W of electrical power to operate. The sensor head is rugged and compact which allows it to be used in harsh environments such as inside an aircraft fuel tank, or as a feedback sensor in the vent-box of an on-board inert gas generation system (OBIGGS). The present sensor technology is unique in its ability to measure N_2 concentration directly, and in its ability to differentiate different types of HC fuels. Although maximum O_2 partial pressures are currently used as a means to characterize aircraft fuel tank fire-safety, the physics governing the ignition of a fuel-oxidizer mixture in a fuel tank is dependent on many factors, including: the thermicity of the mixture (inerting level dependent), the kinetics of the mixture (equivalence ratio and fuel stock dependent), and the ignition source type and duration (spark or other). The present sensor system provides value-added information by simultaneously and directly measuring the **nitrogen-oxygen-fuel** triplet, which provides the following advantages: (1) information regarding the extent of inerting by N_2, (2) information regarding the chemical equivalence ratio, (3) information regarding the composition of the aircraft fuel, and (4) by providing a self-consistent calibration by utilizing a singular sensor for all species. Using the extra information made available by this sensor permits the ignitability of a fuel-oxidizer mixture to be more accurately characterized, which may permit a reduction in the amount of inerting required on a real-time basis, and yet still maintain a fire-safe fuel tank. This translates to an increase in fuel tank fire-safety through a better understanding of the physics, and at the same time, a reduction in compressed bleed air usage and concomitant aircraft operational costs over the long-run.

Figure 1 shows a schematic of the fiber optic sensor system (left). The system utilizes a small (mW level) excitation laser and an optical detection system, both of which can be remotely located away from the fuel tank using rugged multimode optical fibers. Multiple sensor heads can be utilized with a single main optical detection system for a cost-effective multi-point sensor system. The signal from the sensor can be used for both a safety-warning system and also as a feedback sensor to precisely control an OBIGGS set-point. Figure 1 also shows the typical real-time multi-species data for a tank undergoing nitrogen and air purging (right). Note the small error bars and rapid time response of the signal. The present fiber optic sensor also has applications in the following areas: hidden space and cargo space false-alarm-free fire detection (by detecting CO_2 and CO, and lack of O_2); assurance of fire-mitigation procedure execution by detecting fire suppressants; and the validation and testing of other aircraft fuel tank safety sensor systems.

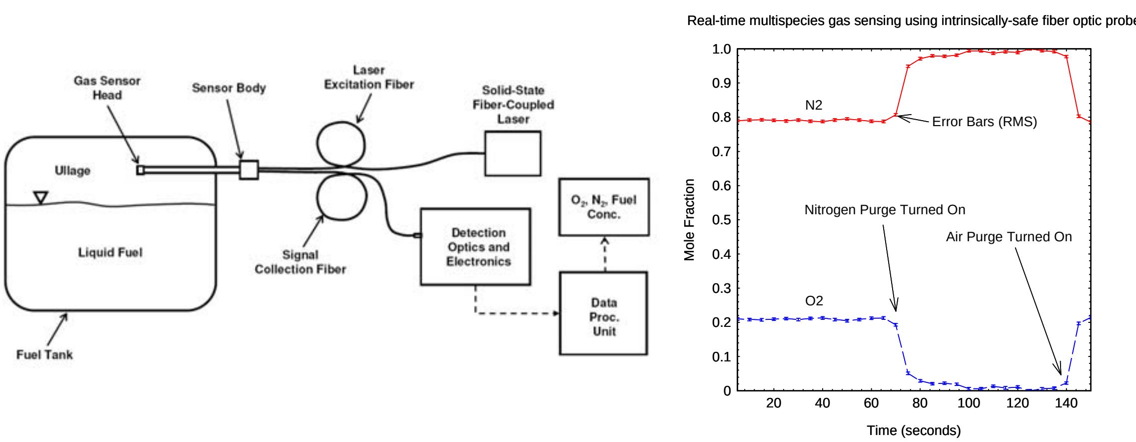

Figure 1: (Left) Schematic of fiber optic in situ multi-gas sensor system (left). Real-time data showing quantitative nitrogen (N_2) and oxygen (O_2) concentrations changing as a function of time in a tank undergoing purging.