Modeling Flammability Exposure in a Commercial Transport Fuel Tank

William Cavage, Robert Ochs, and Steven Summer
FAA Fire Safety Research Branch

Significant emphasis has been placed on fuel tank safety since the TWA Flight 800 accident in July 1996. This prompted the Federal Aviation Administration (FAA) to study methods that could limit the flammability exposure of fuel tanks in the commercial transport fleet. The effort was focused on high-flammability exposure fuel tanks, which are center wing and body-style fuel tanks. Extensive development and analysis by the FAA Fire Safety Branch has illustrated that fuel tank inerting during aircraft operation could be cost-effective if air separation modules (ASM) could be integrated into an inert gas generation system in an effective manner. Also, the study of center wing fuel tank ullage flammability through the use of scale experiments and analytical models has been pursued by the FAA extensively. This research allows for a more complete understanding of both the inerting requirements and the factors that affect the flammability exposure for a commercial transport airplane fuel tank.

To demonstrate the use of hollow-fiber membrane ASMs for inerting commercial transport airplane fuel tanks, the FAA, with the assistance of several aerospace companies, developed a prototype onboard inert gas generation system, with ASMs, that uses aircraft bleed air to generate nitrogen-enriched air (NEA) at varying flows and purities (NEA oxygen concentration) during a commercial airplane flight cycle. Additionally the FAA developed models and experimental methods to study the progression of flammability of an aircraft fuel tank throughout a typical flight cycle.

A series of ground and flight tests were performed, in conjunction with National Aeronautics and Space Administration (NASA) aircraft operations personnel, designed to evaluate the simplified inerting system and examine the flammability of both the center wing and one inboard wing fuel tank. The FAA inerting system was mounted in the pack bay of a NASA 747 SCA, which is used for transporting the Space Shuttle Orbiter. During testing the inerting system was operated while fuel tank oxygen concentration and flammability was measured using special instrumentation developed by the FAA. This gave a complete picture of the ability of the inerting system to reduce the flammability exposure of a commercial airplane CWT.

The results of the testing indicated that the FAA inerting system operated as expected. Inerting system warm-up times had no measurable effect on the ability of the system to keep the ullage inert during typical commercial transport flight conditions. Using a variable flow methodology allowed for a greater amount of NEA to be generated on descent at a higher oxygen concentration (lower purity) as intended and allowed for improved inert gas distribution by decreasing the worst bay oxygen concentration. All assumptions concerning ground operations and aircraft turn-around with and inert ullage were validated. Flammability measurements from both the CWT and the wing tank showed trends were consistent with experimental and computational analysis previously performed and allowed for the potential improvement of ullage flammability models.