

would be operated with flammable fuel vapors in their fuel tank ullage. Commercial transports operated in the United States, and in most overseas locales, use Jet A or Jet A-1 fuel, which typically limits exposure to operation in the flammability range to warmer days.

#### *Fire Triangle*

Three conditions must be present in a fuel tank to support combustion. These include the presence of a suitable amount of fuel vapor, the presence of sufficient oxygen, and the presence of an ignition source. This has been named the fire triangle. Each point of the triangle represents one of these conditions. Because of technological limitations in the past, the FAA philosophy regarding the prevention of fuel tank explosions to ensure airplane safety was to only preclude ignition sources within fuel tanks. This philosophy included application of fail-safe design requirements to fuel tank components (lightning design requirements, fuel tank wiring, fuel tank temperature limits, etc.) that are intended to preclude ignition sources from being present in fuel tanks even when component failures occur.

#### *Need To Address Flammability*

Three accidents have occurred in the last 13 years as the result of unknown ignition sources within the fuel tank in spite of past efforts, highlighting the difficulty in continuously preventing ignition from occurring within fuel tanks. In 1996 the National Transportation Safety Board (NTSB) issued recommendations to improve fuel tank safety that included prevention of ignition sources and addressing fuel tank flammability, *i.e.*, the other two points of the fire triangle.

The FAA initiated safety reviews of all larger transport airplane type certificates to review the fail-safe features of previously approved designs and also initiated research into the feasibility of amending the regulations to address fuel tank flammability. Results from the safety reviews indicated a significant number of single and combinations of failures that can result in ignition sources within the fuel tanks. The FAA has adopted rulemaking to require design and/or maintenance actions to address these issues; however, past experience indicates unforeseen design and maintenance errors can result in development of ignition sources. These findings show minimizing or preventing the formation of flammable vapors by addressing the flammability points of the fire triangle will enhance fuel tank safety. On April 3, 1997, the FAA published a notice in

the **Federal Register** (62 FR 16014) that requested comments concerning the 1996 NTSB recommendations regarding reduced flammability. That notice provided significant discussion of the service history, background, and issues related to reducing flammability in transport airplane fuel tanks. Comments submitted to that notice indicated additional information was needed before the FAA could initiate rulemaking action to address all of the recommendations.

Past safety initiatives by the FAA and industry to reduce the likelihood of fuel tank explosions resulting from post crash ground fires have evaluated means to address other factors of the fire triangle. Previous attempts were made to develop commercially viable systems or features that would reduce or eliminate other aspects of the fire triangle (fuel or oxygen) such as fuel tank inerting or ullage space vapor "scrubbing" (ventilating the tank ullage with air to remove fuel vapor to prevent the accumulation of flammable concentrations of fuel vapor). Those initial attempts proved to be impractical for commercial transport airplanes due to the weight, complexity, and poor reliability of the systems, or undesirable secondary effects such as unacceptable atmospheric pollution.

#### *Fuel Tank Harmonization Working Group*

On January 23, 1998, the FAA published a notice in the **Federal Register** that established an Aviation Rulemaking Advisory Committee (ARAC) working group, the Fuel Tank Harmonization Working Group (FTHWG). The FAA tasked the FTHWG with providing a report to the FAA recommending regulatory text to address limiting fuel tank flammability in both new type certificates and the fleet of in service airplanes. The ARAC consists of interested parties, including the public, and provides a public process to advise the FAA concerning development of new regulations. [Note: The FAA formally established ARAC in 1991 (56 FR 2190, January 22, 1991), to provide advice and recommendations concerning the full range of the FAA's safety-related rulemaking activity.]

The FTHWG evaluated numerous possible means of reducing or eliminating hazards associated with explosive vapors in fuel tanks. On July 23, 1998, the ARAC submitted its report to the FAA. The full report is in the docket created for this ARAC working group (Docket No. FAA-1998-4183). This docket can be reviewed on the U.S. Department of Transportation electronic

Document Management System on the Internet at <http://dms.dot.gov>.

The report provided a recommendation for the FAA to initiate rulemaking action to amend § 25.981, applicable to new type design airplanes, to include a requirement to limit the time transport airplane fuel tanks could operate with flammable vapors in the vapor space of the tank. The recommended regulatory text proposed, "Limiting the development of flammable conditions in the fuel tanks, based on the intended fuel types, to less than 7 percent of the expected fleet operational time, or providing means to mitigate the effects of an ignition of fuel vapors within the fuel tanks such that any damage caused by an ignition will not prevent continued safe flight and landing." The report included a discussion of various options for showing compliance with this proposal, including managing heat input to the fuel tanks, installation of inerting systems or polyurethane fire suppressing foam, and suppressing an explosion if one occurred.

The level of flammability defined in the proposal was established based on a comparison of the safety record of center wing fuel tanks that, in certain airplanes, are heated by equipment located under the tank, and unheated fuel tanks located in the wing. The ARAC concluded that the safety record of fuel tanks located in the wings with a flammability exposure of 2 to 4 percent of the operational time was adequate and that if the same level could be achieved in center wing fuel tanks, the overall safety objective would be achieved. The thermal analyses documented in the report revealed that center wing fuel tanks that are heated by air conditioning equipment located beneath them contain flammable vapors, on a fleet average basis, in the range of 15 to 30 percent of the fleet operating time.

During the ARAC review, it was also determined that certain airplane types do not locate heat sources adjacent to the fuel tanks and have significant surface areas that allow cooling of the fuel tank by outside air. These airplanes provide significantly reduced flammability exposure, near the 2 to 4 percent value of the wing tanks. The group therefore determined that it would be feasible to design new airplanes such that fuel tank operation in the flammable range would be limited to nearly that of the wing fuel tanks. Findings from the ARAC report indicated that the primary method of compliance available at that time with the requirement proposed by the ARAC would likely be to control heat transfer