

recognizes that fuel tank flammability reduction systems could be developed that would meet the flammability requirements of § 25.981(c), Amendment 25-102, but may not preclude fuel tanks from routinely being flammable under the specific operating conditions present when recent accidents occurred.

#### *Definition of "Inert"*

The definition of "inert" within these proposed special conditions provides that all portions of the tank under evaluation, including the bulk average of individual compartments, are equal to or less than the 12 percent oxygen limit at sea level. This is necessary because fuel tanks that are compartmentalized may encounter localized oxygen concentrations in one or more compartments that exceed the 12 percent value. Currently there is not adequate data available to establish whether exceeding the 12 percent limit in one compartment of a fuel tank could create a hazard. For example, ignition of vapors in one compartment could result in a flame front within the compartment that travels to adjacent compartments and results in an ignition source that exceeds the ignition energy values used to establish the 12 percent limit. Therefore, ignition in other compartments of the tank may be possible. Technical discussions with the applicant indicate the pressure rise in a fuel tank that was at or near the 12 percent oxygen concentration level would likely be well below the value that would rupture a typical transport airplane fuel tank. While this may be possible to show, it is not within the scope of these proposed special conditions. Therefore, the effect of the definition of "inert" within these proposed special conditions is that the bulk average of each individual compartment or bay of the tank be evaluated and shown to meet the oxygen concentration limits specified in the definitions section of these proposed special conditions (12 percent or less at sea level) to be considered inert.

#### *Determining Flammability*

The methodology for determining fuel tank flammability defined for use in these proposed special conditions is based on that used by ARAC to compare the flammability of unheated aluminum wing fuel tanks to that of tanks that are heated by adjacent equipment. The ARAC evaluated the relative flammability of airplane fuel tanks using a statistical analysis commonly referred to as a "Monte Carlo" analysis that considered a number of factors affecting formation of flammable vapors in the

fuel tanks. The Monte Carlo analysis calculates values for the parameter of interest by randomly selecting values for each of the uncertain variables from distribution tables. This calculation is conducted over and over to simulate a process where the variables are random within defined distributions. The results of a large number of flights can then be used to approximate the results of the real world exposure of a large fleet of airplanes.

Factors that are considered in the Monte Carlo analysis included in these special conditions include those affecting all airplane models in the transport airplane fleet such as: a statistical distribution of ground, overnight, and cruise air temperatures likely to be experienced worldwide, a statistical distribution of likely fuel types, and properties of those fuels, a definition of the conditions when the tank in question will be considered flammable, and those affecting specific airplane models such as climb and descent profiles, fuel management, heat transfer characteristics of the fuel tanks, statistical distribution of flight lengths (mission durations) expected for the airplane model worldwide, etc. To quantify the fleet exposure, the Monte Carlo analysis approach is applied to a statistically significant number (1,000,000) of flights where each of the factors described above is randomly selected. The flights are then selected to be representative of the fleet using the defined distributions of the three variables. For example, flight one may be a short mission on a cold day with an average flash point fuel, and flight two may be a long mission on an average day with a low flash point fuel, and on and on until 1,000,000 flights have been defined in this manner. For every one of the 1,000,000 flights, the time that the fuel temperature is above the flash point of the fuel is calculated and used as the parameter that established whether the fuel tank is flammable. Averaging the results for all 1,000,000 flights provides an average percentage of the flight time that any particular flight is considered to be flammable. While these special conditions do not require that the analysis be conducted for 1,000,000 flights, the accuracy of the Monte Carlo analysis improves as the number of flights increases. Therefore, to account for this improved accuracy Appendix 2 of the special conditions defines lower flammability limits if the applicant chooses to use fewer than 1,000,000 flights.

The determination of whether the fuel tank is flammable is based on the temperature of the fuel in the tank

determined from the tank thermal model, the atmospheric pressure in the fuel tank, and properties of the fuel loaded for a given flight, which is randomly selected from a database consisting of worldwide data. The criteria in the model is based on the assumption that as these variables change, the concentration of vapors in the tank instantaneously stabilizes and that the fuel tank is at a uniform temperature. This model does not include consideration of the time lag for the vapor concentration to reach equilibrium, the condensation of fuel vapors from differences in temperature that occur in the fuel tanks, or the effect of mass loading (times when the fuel tank is at the unusable fuel level and there is insufficient fuel at a given temperature to form flammable vapors).

#### *Definition of Transport Effects*

The effects of mass loading and the effects of fuel vaporization and condensation with time and temperature changes, referred to as "transport effects" in these proposed special conditions, are excluded from consideration in the Monte Carlo model used for demonstrating compliance with these proposed special conditions. These effects have been excluded because they were not considered in the original ARAC analysis, which was based on a relative measure of flammability. For example, the 3 percent flammability value established by the ARAC as the benchmark for fuel tank safety for wing fuel tanks did not include the effects of cooling of the wing tank surfaces and the associated condensation of vapors from the tank ullage. If this effect had been included in the wing tank flammability calculation, it would have resulted in a significantly lower wing tank flammability benchmark value. The ARAC analysis also did not consider the effects of mass loading which would significantly lower the calculated flammability value for fuel tanks that are routinely emptied, e.g., center wing tanks. The FAA and JAA have determined that using the ARAC methodology provides a suitable basis for determining the adequacy of an FRS system.

#### *Flammability Limit*

The FAA, in conjunction with the Joint Airworthiness Authorities (JAA) and Transport Canada, has developed criteria within these proposed special conditions that require overall fuel tank flammability to be limited to 3 percent of the fleet average operating time. This overall average flammability limit consists of times when the system