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Special Conditions: Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F Airplanes; Flammability Reduction Means (Fuel Tank Inerting); Final Special Conditions; Rule

DEPARTMENT OF TRANSPORTATION

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[Docket No. NM270; Special Conditions No. 25–285–SC]

Special Conditions: Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F Airplanes; Flammability Reduction Means (Fuel Tank Inerting)

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final special conditions.

SUMMARY: These special conditions are issued for the Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes. These airplanes, as modified by Boeing Commercial Airplanes, include a new flammability reduction means that uses a nitrogen generation system to reduce the oxygen content in the center wing fuel tank so that exposure to a combustible mixture of fuel and air is substantially minimized. This system is intended to reduce the average flammability exposure of the fleet of airplanes with the system installed to a level equivalent to 3 percent of the airplane operating time. The applicable airworthiness regulations do not contain adequate or appropriate safety standards for the design and installation of this system. These special conditions contain the additional safety standards the Administrator considers necessary to ensure an acceptable level of safety for the installation of the system and to define performance objectives the system must achieve to be considered an acceptable means for minimizing development of flammable vapors in the fuel tank installation.

DATES: The effective date of these special conditions is March 17, 2005.

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SUPPLEMENTARY INFORMATION:

Background

Boeing Commercial Airplanes intends to modify Model 747 series airplanes to incorporate a new flammability reduction means (FRM) that will inert the center fuel tanks with nitrogen-enriched air (NEA). Though the provisions of § 25.981, as amended by amendment 25–102, will apply to this design change, these special conditions address novel design features.

Regulations used as the standard for certification of transport category airplanes prior to amendment 25–102, effective June 6, 2001, were intended to prevent fuel tank explosions by eliminating possible ignition sources from inside the fuel tanks. Service experience of airplanes certificated to the earlier standards shows that ignition source prevention alone has not been totally effective at preventing accidents. Commercial transport airplane fuel tank safety requirements have remained relatively unchanged throughout the evolution of piston-powered airplanes and later into the jet age. The fundamental premise for precluding fuel tank explosions has involved establishing that the design does not result in a condition that would cause an ignition source within the fuel tank ullage (the space in the tank occupied by fuel vapor and air). A basic assumption in this approach has been that the fuel tank could contain flammable vapors under a wide range of airplane operating conditions, even though there were periods of time in which the vapor space would not support combustion.

Fuel Properties

Jet fuel vapors are flammable in certain temperature and pressure ranges. The flammability temperature range of jet engine fuel vapors varies with the type and properties of the fuel, the ambient pressure in the tank, and the amount of dissolved oxygen released from the fuel into the tank. The amount of dissolved oxygen in a tank will also vary depending on the amount of vibration and sloshing of the fuel that occurs within the tank.

Jet A fuel is the most commonly used commercial jet fuel in the United States. Jet A–1 fuel is commonly used in other parts of the world. At sea level and with no sloshing or vibration present, these fuels have flammability characteristics such that insufficient hydrocarbon molecules will be present in the fuel vapor-air mixture, to ignite when the temperature in the fuel tank is below approximately 100 °F. Too many hydrocarbon molecules will be present in the vapor to allow it to ignite when the fuel temperature is above approximately 175 °F. The temperature range where a flammable fuel vapor will form can vary with different batches of fuel, even for a specific fuel type. In between these temperatures the fuel vapor is flammable. This flammability temperature range decreases as the airplane gains altitude because of the corresponding decrease of internal tank air pressure. For example, at an altitude of 30,000 feet, the flammability temperature range is about 60 °F to 120 °F.

Most transport category airplanes used in air carrier service are approved for operation at altitudes from sea level to 45,000 feet. Those airplanes operated in the United States and in most overseas locations use Jet A or Jet A–1 fuel, which typically limits exposure to operation in the flammability range to warmer days.

We have always assumed that airplanes would sometimes be operated with flammable fuel vapors in their fuel tank ullage (the space in the tank occupied by fuel vapor and air).

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. Between 1996 and 2000 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), Fuel Tank Ignition Prevention Measures, 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 (defined in this rule as flammability exposure evaluation time (FEET)), 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 FEET 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 airplane operation with fuel tanks that were flammable 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 into and out of fuel tanks. Design features such as locating the air conditioning equipment away from the fuel tanks, providing ventilation of the air conditioning bay to limit heating and to cool fuel tanks, and/or insulating the tanks from heat sources, would be practical means of complying with the regulation proposed by the ARAC.

In addition to its recommendation to revise § 25.981, the ARAC also recommended that the FAA continue to evaluate means for minimizing the development of flammable vapors within the fuel tanks to determine whether other alternatives, such as ground-based inerting of fuel tanks, could be shown to be cost effective.

To address the ARAC recommendations, the FAA continued with research and development activity to determine the feasibility of requiring inerting for both new and existing designs.

FAA Rulemaking Activity

Based in part on the ARAC recommendations to limit fuel tank flammability exposure on new type designs, the FAA developed and published amendment 25–102 in the **Federal Register** on May 7, 2001 (66 FR 23085). The amendment included changes to § 25.981 that require minimization of fuel tank flammability to address both reduction in the time fuel tanks contain flammable vapors, (§ 25.981(c)), and additional changes regarding prevention of ignition sources in fuel tanks. Section 25.981(c) was based on the FTHWG recommendation to achieve a safety level equivalent to that achieved by the fleet of transports with unheated aluminum wing tanks, between 2 to 4 percent flammability. The FAA stated in the preamble to Amendment 25–102 that the intent of the rule was to—

> * * * require that practical means, such as transferring heat from the fuel tank (e.g., use of ventilation or cooling air), be incorporated into the airplane design if heat sources were

placed in or near the fuel tanks that significantly increased the formation of flammable fuel vapors in the tank, or if the tank is located in an area of the airplane where little or no cooling occurs. The intent of the rule is to require that fuel tanks are not heated, and cool at a rate equivalent to that of a wing tank in the transport airplane being evaluated. This may require incorporating design features to reduce flammability, for example cooling and ventilation means or inerting for fuel tanks located in the center wing box, horizontal stabilizer, or auxiliary fuel tanks located in the cargo compartment.

Advisory circulars associated with Amendment 25–102 include AC 25.981–1B, ''Fuel Tank Ignition Source Prevention Guidelines,'' and AC 25.981–2, ''Fuel Tank Flammability Minimization.'' Like all advisory material, these advisory circulars describe an acceptable means, but not the only means, for demonstrating compliance with the regulations.

FAA Research

In addition to the notice published in the **Federal Register** on April 3, 1997, the FAA initiated research to provide a better understanding of the ignition process of commercial aviation fuel vapors and to explore new concepts for reducing or eliminating the presence of flammable fuel air mixtures within fuel tanks.

Fuel Tank Inerting

In the public comments received in response to the 1997 notice, reference was made to hollow fiber membrane technology that had been developed and was in use in other applications, such as the medical community, to separate oxygen from nitrogen in air. Air is made up of about 78 percent nitrogen and 21 percent oxygen, and the hollow fiber membrane material uses the absorption difference between the nitrogen and oxygen molecules to separate the NEA from the oxygen. In airplane applications NEA is produced when pressurized air from an airplane source such as the engines is forced through the hollow fibers. The NEA is then directed, at appropriate nitrogen concentrations, into the ullage space of fuel tanks and displaces the normal fuel vapor/air mixture in the tank.

Use of the hollow fiber technology allowed nitrogen to be separated from air, which eliminated the need to carry and store the nitrogen in the airplane. Researchers were aware of the earlier system's shortcomings in the areas of weight, reliability, cost, and performance. Recent advances in the technology have resolved those concerns and eliminated the need for storing nitrogen on board the airplane.

Criteria for Inerting

Earlier fuel tank inerting designs produced for military applications were based on defining ''inert'' as a maximum oxygen concentration of 9 percent. This value was established by the military for protection of fuel tanks from battle damage. One major finding from the FAA's research and development efforts was the determination that the 9 percent maximum oxygen concentration level benchmark, established to protect military airplanes from high-energy ignition sources encountered in battle, was significantly lower than that needed to inert civilian transport airplane fuel tanks from ignition sources resulting from airplane system failures and malfunctions that have much lower energy. This FAA research established a maximum value of 12 percent as being adequate at sea level. The test results are currently available on FAA Web site: *http://www.fire.tc.faa.gov/pdf/tn02-79.pdf* as FAA Technical Note ''Limiting Oxygen Concentrations Required to Inert Jet Fuel Vapors Existing at Reduced Fuel Tank Pressures,'' report number DOT/FAA/AR–TN02/79. As a result of this research, the quantity of NEA that is needed to inert commercial airplane fuel tanks was lessened so that an effective FRM can now be smaller and less complex than was originally assumed. The 12 percent value is based on the limited energy sources associated with an electrical arc that could be generated by airplane system failures on typical transport airplanes and does not include events such as explosives or hostile fire.

As previously discussed, existing fuel tank system requirements (contained in earlier Civil Air Regulation (CAR) 4b and now in 14 Code of Federal Regulations (CFR) part 25) have focused solely on prevention of ignition sources. The FRM is intended to add an additional layer of safety by reducing the exposure to flammable vapors in the heated center wing tank, not necessarily eliminating them under all operating conditions. Consequently, ignition prevention measures will still be the principal layer of defense in fuel system safety, now augmented by substantially reducing the time that flammable vapors are present in higher flammability tanks. We expect that by combining these two approaches, particularly for tanks with high flammability exposure, such as the heated center wing tank or tanks with limited cooling, risks for future fuel tank explosions can be substantially reduced.

Boeing Application for Certification of a Fuel Tank Inerting System

On November 15, 2002, Boeing Commercial Airplanes applied for a change to Type Certificate A20WE to modify Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes to incorporate a new FRM that inerts the center fuel tanks with NEA. These airplanes, approved under Type Certificate No. A20WE, are four-engine transport airplanes with a passenger capacity up to 624, depending on the submodel. These airplanes have an approximate maximum gross weight of 910,000 lbs with an operating range up to 7,700 miles.

Type Certification Basis

Under the provisions of § 21.101, Boeing Commercial Airplanes must show that the Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes, as changed, continue to meet the applicable provisions of the regulations incorporated by reference in Type Certificate No. A20WE, or the applicable regulations in effect on the date of application for the change. The regulations incorporated by reference in the type certificate are commonly referred to as the ''original type certification basis.'' The regulations incorporated by reference in Type Certificate A20WE include 14 CFR part 25, dated February 1, 1965, as amended by Amendments 25–1 through 25–70, except for special conditions and exceptions noted in Type Certificate Data Sheet A20WE.

In addition, if the regulations incorporated by reference do not provide adequate standards with respect to the change, the applicant must comply with certain regulations in effect on the date of application for the change. The FAA has determined that the FRM installation on the Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes must also be shown to comply with § 25.981 at amendment 25–102.

If the Administrator finds that the applicable airworthiness regulations (14 CFR part 25) do not contain adequate or appropriate safety standards for the Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes because of a novel or unusual design feature, special conditions are prescribed under the provisions of § 21.16.

In addition to the applicable airworthiness regulations and special conditions, the Model 747–100/200B/

200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes must comply with the fuel vent and exhaust emission requirements of 14 CFR part 34 and the acoustical change requirements of § 21.93(b).

Special conditions, as defined in § 11.19, are issued in accordance with § 11.38 and become part of the type certification basis in accordance with § 21.101.

Special conditions are initially applicable to the model for which they are issued. Should the type certificate for that model be amended later to include any other model that incorporates the same or similar novel or unusual design feature, or should any other model already included on the same type certificate be modified to incorporate the same or similar novel or unusual design feature, the special conditions would also apply to the other model under the provisions of § 21.101.

Novel or Unusual Design Features

Boeing has applied for approval of an FRM to minimize the development of flammable vapors in the center fuel tanks of Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes. Boeing also plans to seek approval of this system on Boeing Model 737, 757, 767, and 777 airplanes.

Boeing has proposed to voluntarily comply with § 25.981(c), amendment 25–102, which is normally only applicable to new type designs or type design changes affecting fuel tank flammability. The provisions of § 21.101 require Boeing to also comply with §§ 25.981(a) and (b), amendment 25–102, for the changed aspects of the airplane by showing that the FRM does not introduce any additional potential sources of ignition into the fuel tanks.

The FRM uses a nitrogen generation system (NGS) that comprises a bleed-air shutoff valve, ozone converter, heat exchanger, air conditioning pack air cooling flow shutoff valve, filter, air separation module, temperature regulating valve controller and sensor, high-flow descent control valve, float valve, and system ducting. The system is located in the air conditioning pack bay below the center wing fuel tank. Engine bleed air from the existing engine pneumatic bleed source flows through a control valve into an ozone converter and then through a heat exchanger, where it is cooled using outside cooling air. The cooled air flows through a filter into an air separation module (ASM) that generates NEA, which is supplied to the center fuel tank, and also discharges oxygen-enriched air (OEA). The OEA from the ASM is mixed with cooling air from the heat exchanger to dilute the oxygen concentration and then exhausted overboard. The FRM also includes modifications to the fuel vent system to minimize dilution of the nitrogen-enriched ullage in the center tank due to cross-venting characteristics of the existing center wing fuel tank vent design.

Boeing originally proposed that the system be operated only during flight and that the center tank would continue to be inert on landing and remain inert during normal ground procedures. Boeing has more recently stated that the FRM design may include the capability to be operated on the ground.

Boeing has proposed that limited dispatch relief for operation with an inoperative NGS be allowed. Boeing has initially proposed a 10-day master minimum equipment list (MMEL) relief for the system. Boeing originally proposed that there be no cockpit or maintenance indication onboard for the NGS, and that periodic maintenance, using ground service equipment, be performed to verify system operation. More recently Boeing has stated that to meet operator needs and system reliability and availability objectives, built-in test functions would be included and system status indication of some kind would be provided. In addition, indications would be provided in the cockpit on certain airplane models that have engine indicating and crew alerting systems. The reliability of the system is expected to be designed to achieve a mean time between failure (MTBF) of 5000 hours or better.

Discussion

The FAA policy for establishing the type design approval basis of the FRM design will result in application of §§ 25.981(a) and (b), amendment 25–102, for the changes to the airplane that might increase the risk of ignition of fuel vapors. Boeing will therefore be required to substantiate that changes introduced by the FRM will meet the ignition prevention requirements of §§ 25.981(a) and (b), amendment 25–102 and other applicable regulations.

With respect to compliance with § 25.981(c), AC 25.981–2 provides guidance in addressing minimization of fuel tank flammability within a heated fuel tank, but there are no specific regulations that address the design and installation of an FRM that inerts the fuel tank. Since amendment 25–102 was adopted, significant advancements in inerting technology have reduced the size and complexity of inerting systems. Developments in inerting technology have made it practical to significantly reduce fuel tank flammability below the levels required within the rule. However, due to factors such as the limited availability of bleed air and electrical power, it is not considered practical at this time to develop systems for retrofit into existing airplane designs that can maintain a non-flammable tank ullage in all fuel tanks or during all operating conditions. These special conditions include additional requirements above that of amendment 25–102 to § 25.981(c) to minimize fuel tank flammability, such that the level of minimization in these special conditions would prevent a fuel tank with an FRM from being flammable during specific warm day operating conditions, such as those present when recent accidents occurred.

Definition of ''Inert''

For the purpose of these special conditions, the tank is considered inert when the bulk average oxygen concentration within each compartment of the tank is 12 percent or less at sea level up to 10,000 feet, then linearly increasing from 12 percent at 10,000 feet to 14.5 percent at 40,000 feet and extrapolated linearly above that altitude. The reference to each section of the tank 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 (the minimum amount of energy required to ignite fuel vapors) 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 special conditions. Therefore, the effect of the definition of ''inert'' within these special conditions is that the bulk average of each individual compartment or bay of the tank must be evaluated and shown to meet the oxygen concentration limits specified in the definitions section of these 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 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 randomly selected from defined distributions for each of the variables. The results of changing these variables for 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 required by 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, and a definition of the conditions when the tank in question will be considered flammable. The analysis also includes factors 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 factors described previously. 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, and the tank is not inert, is calculated and used to establish if 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 these 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 quantity loaded for a given flight, which is randomly selected from a database consisting of worldwide data. The criteria in the model are 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). However, fresh air drawn into an otherwise inert tank during descent does not immediately saturate with fuel vapors so localized concentrations above the inert level during descent do not represent a hazardous condition. These special conditions allow the time during descent, where a localized amount of fresh air may enter a fuel tank, to be excluded from the determination of fuel tank flammability exposure.

Definition of Transport Effects

The effects of low fuel conditions (mass loading) and the effects of fuel vaporization and condensation with time and temperature changes, referred to as ''transport effects'' in these special conditions, are excluded from consideration in the Monte Carlo model used for demonstrating compliance with these 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 FRM system.

The effect of condensation and vaporization in reducing the flammability exposure of wing tanks is comparable to the effect of the low fuel condition in reducing the flammability exposure of center tanks. We therefore consider these effects to be offsetting, so that by eliminating their consideration, the analysis will produce results for both types of tanks that are comparable. Using this approach, it is possible to follow the ARAC recommendation of using the unheated aluminum wing tank as the standard for evaluating the flammability exposure of all other tanks. For this reason, both factors have been excluded when establishing the flammability exposure limits. During development of these harmonized special conditions, the FAA and the European Joint Aviation Authorities (JAA) agreed that using the ARAC methodology provides a suitable basis for determining the flammability of a fuel tank and consideration of transport effects should not be permitted.

Flammability Limit

The FAA, in conjunction with the Joint Airworthiness Authorities (JAA) and Transport Canada, has developed criteria within these 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 performance cannot maintain an inert tank ullage, primarily during descent when the change in ambient pressures draws air into the fuel tanks and those times when the FRM is inoperative due to failures of the system and the airplane is dispatched with the system inoperative.

Specific Risk Flammability Limit

These special conditions also include a requirement to limit fuel tank flammability to 3 percent during ground operations, takeoff, and climb phases of flight to address the specific risk associated with operation during warmer day conditions when accidents have occurred. The specific risk requirement is intended to establish minimum system performance levels and therefore the 3 percent flammability limit excludes reliability related contributions, which are addressed in the average flammability assessment. The specific risk requirement may be met by conducting a separate Monte Carlo analysis for each of the specific phases of flight during warmer day conditions defined in the special conditions, without including the times when the FRM is not available because of failures of the system or dispatch with the FRM inoperative.

Inerting System Indications

Fleet average flammability exposure involves several elements, including—

• The time the FRM is working properly and inerts the tank or when the tank is not flammable;

• The time when the FRM is working properly but fails to inert the tank or part of the tank, because of mission variation or other effects;

• The time the FRM is not functioning properly and the operator is unaware of the failure; and

• The time the FRM is not functioning properly and the operator is aware of the failure and is operating the airplane for a limited time under MEL relief.

The applicant may propose that MMEL relief is provided for aircraft operation with the FRM unavailable; however, it is considered a safety system that should be operational to the maximum extent practical. Therefore, these special conditions include reliability and reporting requirements to enhance system reliability so that dispatch of airplanes with the FRM inoperative would be very infrequent. Cockpit indication of the system function that is accessible to the flightcrew is not an explicit requirement, but may be required if the results of the Monte Carlo analysis show the system cannot otherwise meet the flammability and reliability requirements defined in these special conditions. Flight test demonstration and analysis will be required to demonstrate that the performance of the inerting system is effective in inerting the tank during those portions of ground and the flight operations where inerting is needed to meet the flammability requirements of these special conditions.

Various means may be used to ensure system reliability and performance. These may include: System integrity monitoring and indication, redundancy of components, and maintenance actions. A combination of maintenance indication and/or maintenance check procedures will be required to limit exposure to latent failures within the system, or high inherent reliability is needed to assure the system will meet the fuel tank flammability requirements. The applicant's inerting system does not incorporate redundant features and includes a number of components essential for proper system operation. Past experience has shown inherent reliability of this type of system would be difficult to achieve. Therefore, if system maintenance indication is not provided for features of the system essential for proper system operation, system functional checks at appropriate intervals determined by the reliability analysis will be required for these features. At a minimum, proper function of essential features of the system should be validated once per day by maintenance review of indications or functional checks, possibly prior to the first flight of the day. The determination of a proper interval and procedure will follow completion of the certification testing and demonstration of the system's reliability and performance prior to certification.

Any features or maintenance actions needed to achieve the minimum reliability of the FRM will result in fuel system airworthiness limitations similar to those defined in § 25.981(b). Boeing will be required to include in the instructions for continued airworthiness (ICA) the replacement times, inspection intervals, inspection procedures, and the fuel system limitations required by § 25.981(b). Overall system performance and reliability must achieve a fleet average flammability that meets the requirements of these special conditions. If the system reliability falls to a point where the fleet average flammability exposure exceeds these requirements, Boeing will be required to define appropriate corrective actions, to be approved by the FAA, that will bring the exposure back down to the acceptable level.

Boeing proposed that the FRM be eligible for a 10-day MMEL dispatch interval. The Flight Operations Evaluation Board (FOEB) will establish the approved interval based on data the applicant submits to the FAA. The MMEL dispatch interval is one of the factors affecting system reliability analyses that must be considered early in the design of the FRM, prior to FAA approval of the MMEL. Boeing requested that the authorities agree to use of an MMEL inoperative dispatch interval for design of the system. Boeing data indicates that certain systems on the airplane are routinely repaired prior to the maximum allowable interval. These special conditions require that Boeing use an MMEL inoperative dispatch interval of 60 hours in the analysis as representative of the mean time for which an inoperative condition may occur for the 10-day MMEL maximum interval requested. Boeing must also include actual dispatch inoperative interval data in the quarterly reports required by Special Condition III(c)(2). Boeing may request to use an alternative interval in the reliability analysis. Use of a value less than 60 hours would be a factor considered by the FOEB in establishing the maximum MMEL dispatch limit. The reporting requirement will provide data necessary to validate that the reliability of the FRM achieved in service meets the levels used in the analysis.

Appropriate maintenance and operational limitations with the FRM inoperative may also be required and noted in the MMEL. The MMEL limitations and any operational procedures should be established based on results of the Monte Carlo assessment, including the results associated with operations in warmer climates where the fuel tanks are flammable a significant portion of the FEET when not inert. While the system reliability analysis may show that it is possible to achieve an overall average fleet exposure equal to or less than that of a typical unheated aluminum wing tank, even with an MMEL allowing very long inoperative intervals, the intent of the rule is to minimize flammability. Therefore, the shortest practical MMEL relief interval should be proposed. To ensure limited airplane operation with the system inoperative and to meet the reliability requirements of these special conditions, appropriate level messages that are needed to comply with any dispatch limitations of the MMEL must be provided.

Confined Space Hazard Markings

Introduction of the FRM will result in NEA within the center wing fuel tank and the possibility of NEA in compartments adjacent to the fuel tank if leakage from the tank or NEA supply lines were to occur. Lack of oxygen in these areas could be hazardous to maintenance personnel, the passengers, or flightcrew. Existing certification requirements do not address all aspects of these hazards. Paragraph II(f) of the special conditions requires the applicant to provide markings to emphasize the potential hazards associated with confined spaces and areas where a hazardous atmosphere could be present due to the addition of an FRM.

For the purposes of these special conditions, a confined space is an enclosed or partially enclosed area that is big enough for a worker to enter and perform assigned work and has limited or restricted means for entry or exit. It is not designed for someone to work in regularly, but workers may need to enter the confined space for tasks such as inspection, cleaning, maintenance, and repair. (Reference U.S. Department of Labor Occupational Safety & Health Administration (OSHA), 29 CFR 1910.146(b).) The requirement in the special conditions does not significantly change the procedures maintenance personnel use to enter fuel tanks and are not intended to conflict with existing government agency requirements (*e.g.*, OSHA). Fuel tanks are classified as confined spaces and contain high concentrations of fuel vapors that must be exhausted from the fuel tank before entry. Other precautions such as measurement of the oxygen concentrations before entering a fuel tank are already required. Addition of the FRM that utilizes inerting may result in reduced oxygen concentrations due to leakage of the system in locations in the airplane where service personnel would not expect it. A worker is considered to have entered a confined space just by putting his or her head across the plane of the opening. If the confined space contains high concentrations of inert gases, workers who are simply working near the opening may be at risk. Any hazards associated with working in adjacent spaces near the opening should be identified in the marking of the opening to the confined space. A large percentage of the work involved in properly inspecting and modifying airplane fuel tanks and their associated systems must be done in the interior of the tanks. Performing the necessary tasks requires inspection and maintenance personnel to physically enter the tank, where many environmental hazards exist. These potential hazards that exist in any fuel tank, regardless of whether nitrogen inerting has been installed, include fire and explosion, toxic and irritating chemicals, oxygen deficiency, and the confined nature of the fuel tank itself. In order to prevent related injuries, operator and repair station maintenance organizations have developed specific procedures for identifying, controlling, or eliminating the hazards associated with fuel-tank entry. In addition government agencies have adopted safety requirements for use when entering fuel tanks and other confined spaces. These same procedures would be applied to the reduced oxygen environment likely to be present in an inerted fuel tank.

The designs currently under consideration locate the FRM in the fairing below the center wing fuel tank. Access to these areas is obtained by opening doors or removing panels which could allow some ventilation of the spaces adjacent to the FRM. But this may not be enough to avoid creating a hazard. Therefore, we intend that marking be provided to warn service personnel of possible hazards associated with the reduced oxygen concentrations in the areas adjacent to the FRM.

Appropriate markings would be required for all inerted fuel tanks, tanks adjacent to inerted fuel tanks and all fuel tanks communicating with the inerted tanks via plumbing. The plumbing includes, but is not limited to, plumbing for the vent system, fuel feed system, refuel system, transfer system and cross-feed system. NEA could enter adjacent fuel tanks via structural leaks. It could also enter other fuel tanks through plumbing if valves are operated or fail in the open position. The markings should also be stenciled on the external upper and lower surfaces of the inerted tank adjacent to any openings to ensure maintenance personnel understand the possible contents of the fuel tank. Advisory Circular 25.981–2 will provide additional guidance regarding markings and placards.

Affect of FRM on Auxiliary Fuel Tank System Supplemental Type Certificates

Boeing plans to offer a service bulletin that will install the FRM on existing in-service airplanes. Some in-service airplanes have auxiliary fuel tank systems installed that interface with the center wing tank. The Boeing FRM design is intended to provide inerting of the fuel tank volume of the 747 and does not include consideration of the auxiliary tank installations. Installation of the FRM on existing airplanes with auxiliary fuel tank systems may therefore require additional modifications to the auxiliary fuel tank system to prevent development of a condition that may cause the tank to exceed the 12 percent oxygen limit. The FAA will address these issues during development and approval of the service bulletin for the FRM.

Disposal of Oxygen-Enriched Air (OEA)

The FRM produces both NEA and OEA. The OEA generated by the FRM could result in an increased fire hazard if not disposed of properly. The OEA produced in the proposed design is diluted with air from a heat exchanger, which is intended to reduce the OEA concentration to non-hazardous levels. Special requirements are included in these special conditions to address potential leakage of OEA due to failures and safe disposal of the OEA during normal operation.

To ensure that an acceptable level of safety is achieved for the modified airplanes using a system that inerts heated fuel tanks with NEA, special conditions (per § 21.16) are needed to address the unusual design features of an FRM. These special conditions contain the additional safety standards that the Administrator considers necessary to establish a level of safety equivalent to that established by the existing airworthiness standards.

Discussion of Comments

Notice of Proposed Special Conditions No. 25–03–08–SC for the Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes was published in the **Federal Register** on December 9, 2003 (68 FR 68563). Thirteen commenters responded to the notice.

General Comments

Comment: One commenter supports the special conditions but states that ignition source prevention must still be provided. The commenter believes that the combination of flammability reduction and ignition source prevention is the most effective means to prevent fuel tank explosions.

FAA Reply: The safety assessment required by Special Federal Aviation Regulation (SFAR) No. 88, Fuel Tank System Fault Tolerance Evaluation, identifies design and maintenance changes that are needed to prevent ignition sources in transport category airplanes. The FAA is developing a number of airworthiness directives (ADs) to address ignition sources resulting from single failures in all fuel tanks and combinations of failures in tanks that have been classified as high flammability. We will not issue ADs to address combinations of failures in high flammability tanks if the FRM is installed because of the significant improvement in fuel tank safety offered by the FRM required by this special condition. We are not considering a change to the current ignition prevention analysis requirements that include assuming a flammable ullage. No changes were made as a result of this comment.

Comment: Two commenters believe the special conditions for the FRM are not appropriate because the special conditions are written to fit the applicant's proposed design of an inerting system to reduce flammability of fuel tanks and are therefore considered ''prejudiced.'' One of these commenters adds that regulatory guidance should be unprejudiced and available before development of any design.

FAA Reply: We do not concur. As stated earlier in this document, these special conditions are specific to certification of an FRM based on inerting technology. As discussed in AC 25.981–2, inerting, as well as other technologies such as cooling, is an acceptable means of compliance with § 25.981(c). No changes were made as a result of this comment.

Comment: Two commenters believe the limited FRM, as described in the special conditions, would not comply with the requirements of §§ 25.981(c) and 25.1309 for new airplane designs (post amendment 25–102) with high flammability fuel tanks.

FAA Reply: As stated earlier, these special conditions apply specifically to certification of an FRM for applicable Boeing Model 747 series airplanes and do not apply to new airplane designs. However, we have determined that an FRM that complies with these special conditions would meet the intent of § 25.981(c). No changes were made as a result of this comment.

Comment: One commenter would support rulemaking to investigate amending § 25.981 (and revising AC 25.981–2) to:

- Clarify that ''minimization of flammable vapors'' in accordance with § 25.981(c) is to be accomplished through design features ensuring the tank will have inherent low flammability (*e.g.* venting, cooling, control of heat transfer, etc.); and
- Eliminate the possibility of compliance for future airplane designs through the installation of a limited FRM.

FAA Reply: On February 17, 2004, the FAA Administrator announced plans to issue a notice of proposed rulemaking that will require approximately 3,800 Airbus and Boeing planes be fitted with systems that reduce the presence of flammable vapors in fuel tanks. This proposal could require airlines to install new systems to reduce fuel tank flammability on existing and newly produced larger passenger jets. We are also considering amending § 25.981(c) and revising AC 25.981–2 to further limit fuel tank flammability. No changes were made as a result of these comments.

Comment: The commenter requests that before proceeding with any further regulatory activities, the FAA should provide additional detailed information on whether SFAR 88 changes are sufficient to cover the requirements of § 25.981. The commenter believes that ''SFAR 88 meets the requirement of § 25.981(c)(2) and does not understand the need to also address § 25.981(c)(1).'' This commenter also states that harmonization with the European Aviation Safety Agency (EASA) on these special conditions is essential for industry.

FAA Reply: We do not concur with the commenter's first statement. A direct relationship between SFAR 88 and § 25.981(c)(1), or § 25.981(c)(2), does not exist. SFAR 88 addresses ignition source prevention, while § 25.981(c)(1) acknowledges an ignition source may be present under some remote circumstances. Section 25.981(c)(2) assumes that an ignition can occur—in essence that SFAR 88 was not successful and also flammable vapors are present—and requires that the resulting ignition of flammable vapor will not prevent continued safe flight and landing. The FAA has fully coordinated these special conditions with the JAA/EASA. No changes were made as a result of these comments.

Comment: One commenter notes that although the special condition requirements for system reliability and performance are very specific, they do not address the qualification standards that the system will have to meet. Additional guidance on this subject would be appropriate. Another commenter expresses concern about use of the terms ''intended'' and ''expected'' in the special conditions when relating to an FRM. It is the commenter's opinion that the use of these terms indicates that the applicant is not confident that their design ''will'' or ''shall'' contribute to the overall safety of the airplanes.

FAA Reply: We do not concur. In the preamble to the special conditions, we state that the applicant is required to show compliance with the applicable airworthiness regulations and special conditions. In part, the applicable regulations, § 25.1301 and § 25.1309, require the applicant to show that the equipment ''functions properly when installed'' and ''is designed to ensure that they perform their intended functions under any foreseeable operating condition.'' Irrespective of any wording in the preamble to the special conditions, the special conditions include requirements to address foreseeable specific safety issues that are not addressed by the current regulations. Any airplane that meets the requirements of the special conditions will maintain the level of safety intended by the applicable requirements of the Code of Federal Regulations (CFR). No changes were made as a result of these comments.

Comment: One commenter states that there are various statements made throughout the special conditions that refer to reliability and maintenance of the system. It is the commenter's opinion that these statements are specific to implementation, and the actual approach should be derived using standard methodology used for certification of the airplane.

FAA Reply: To achieve the desired safety level of the FRM, we believe the special condition requirements for determining reliability and maintainability of the FRM are necessary. This is to ensure that the FRM is an acceptable means by which the development of flammable vapors in the center wing tank is minimized as required by § 25.981. No changes were made as a result of this comment.

Comment: One commenter notes that ''inert'' is not defined consistently throughout the special conditions. The commenter suggests the use of only one definition and proposes the definition used in special condition paragraph I. Definitions. The same commenter also requests clarification if linear extrapolation of oxygen concentration can be used for aircraft ceilings above 40,000 feet, and clarification of the difference between the terms ''bulk'' and ''bulk average.''

FAA Reply: We concur that the definition of inert needs to be consistent throughout the special conditions and have therefore modified the definition of inert in the preamble to incorporate the definition of inert provided in paragraph I. Definitions of the special conditions. With respect to aircraft altitudes above 40,000 feet, we have added that linear extrapolation can continue for oxygen concentration from 14.5 percent at 40,000 feet to the required operating altitude. Concerning the use of bulk and bulk average in the special conditions, we have modified the preamble and special conditions to consistently use the term ''bulk average'' when referring to the fuel temperature or oxygen concentration within the fuel tank.

Comment: The commenter requests that the FAA clarify if the FRM is a safety enhancement system or a safety system. The commenter notes that in the preamble discussion of the ''Inerting System Indication,'' the FAA states that the applicant may propose master minimum equipment list (MMEL) relief be provided for airplane operation with the FRM unavailable. The system, however, is considered a safety system that should be operational to the maximum extent practical. If this system is considered a safety system, then a form of redundancy will have to be built in. At this time, the applicant's design does not show any redundancy.

FAA Reply: The FRM is a safety system designed to provide an additional layer of protection to the ignition prevention means already in place. The system by itself is not intended to be fully redundant since it provides a second layer of protection. The FRM is intended to be a safety enhancement system that provides an additional layer of protection by reducing the exposure to flammable vapors in the heated center wing fuel tank. This protection, when added to ignition prevention measures, will substantially reduce the likelihood of future fuel tank explosions in the fleet. The applicant has proposed a 10-day MMEL relief period, but the Flight Operations Evaluation Board (FOEB) will determine and approve the appropriate MMEL intervals based on data the applicant submits to the FAA. The applicant must show that the fleet average flammability exposure of a tank with an FRM installed is equal to or less than 3 percent, including any time when the system is inoperative. No changes were made as a result of these comments.

Comment: One commenter says the cost of the FRM is substantial and justification for it is debatable. The commenter believes the FRM will put a heavy economic burden on the slowly recovering airline industry and only supports the adoption of an FRM on new type designs and newly built airplanes as an improvement in fuel system safety. This commenter also says that considering the potential affects of this subject on the European airline industry, joint European position activity is critical to ensure that decisions are based on safety grounds and not on political motivations.

FAA Reply: We do not concur with the commenter regarding the impact of cost associated with the issuance of the special conditions. These special conditions are unique to the applicant's certification of an FRM for the applicable Boeing Model 747 series airplanes and do not mandate that an FRM must be added to an operator's 747 fleet. They have been fully harmonized with EASA. The FAA announcement of issuance of a notice of proposed rulemaking that would propose retrofit and production incorporation of FRM into U.S-registered airplanes is a separate rulemaking effort that will require a cost benefit analysis and will be published for public comment. No changes were made as a result of this comment.

Comment: One commenter notes that the applicant has planned a 3-month, in-service evaluation (ISE) of the FRM. It is the opinion of two other commenters that a 4,000-hour (12 month) ISE should be specified before certification of the FRM because—

• It adds complexity,

• It has not yet been retrofitted in an in-service airplane,

• It has no proven track record for reliability, and

• Ground and flight tests are not sufficient to demonstrate overall reliability of the system.

The commenters say that maintenance and performance features of the system were designed to support a 10-day relief under the MMEL program. If the demonstrated performance and reliability of the system meet design objectives, then the FAA should support the planned relief. Another commenter recommends a one-year in-service evaluation (ISE) program following the first installation of an FRM and prior to FRM installation on a production airplane. This commenter says that past experience has shown reliability and system degradation by oil contamination scenarios, with the engine and APU being the source, and carbon particle buildup on components similar to those required by the proposed FRM, due to airport and airplane turbine exhausts. This commenter believes that one year would be an adequate time for the manufacturer to develop and provide corrective actions for discrepancies or reliability issues with the FRM that are identified during the ISE program.

FAA Reply: We do not concur with the commenters. The industry commonly conducts ISE through cooperative efforts between the type certificate holder and the airlines prior to fleetwide introduction of changes. While the FAA agrees an ISE might be appropriate, we traditionally do not mandate it. An ISE can be part of a manufacturer's incorporation strategy for optional equipment. FAA certification of a system is required before an ISE can be conducted on a U.S.-registered transport category airplane; therefore, an ISE is not related to certification requirements. The reliability reporting requirements in the special conditions will provide data to determine if actions are needed to correct discrepancies and improve system reliability after certification of the system. No changes were made as a result of these comments.

Comment: Three commenters request that the FAA consider 9 percent as the maximum oxygen concentration at sea level. One commenter disagrees with the premise that the wing fuel tanks offer an acceptable minimum level of flammability exposure and is concerned about using this minimum level for development of inerting systems. The commenters believe that the maximum oxygen concentration of 12 percent at sea level should be considered as a level of reduced flammability rather than inert, and that 9 percent should be used as the long-term goal for defining a tank as inert. Another commenter states that 12 percent oxygen concentration will not protect the center or wing fuel tanks from external hazards and that 9 percent should be used to protect the tanks. The commenter requests clarification of why 12 percent oxygen concentration at sea level is specified in the special conditions instead of the maximum 9 percent.

Three commenters want the minimum oxygen concentration percentage at sea level to be 10 percent. They refer to paragraph 7(a)(1) of AC 25.981–2, which reads: ''An oxygen concentration of 10 percent or less by volume is acceptable for transport airplane fuel tanks inerted with nitrogen, without additional substantiation.'' One commenter believes this acceptable oxygen concentration establishes a minimum acceptable performance standard in terms of the threat (ignition source energy), and 10 percent or less should be the average design concentration for each fuel cell with no area at a concentration greater than 11.5 percent. Another commenter says that 10 percent contradicts the definition of ''inert,'' as proposed, and would like the FAA to provide the acceptable oxygen concentration level (percentage by volume) and the fundamental justification for this level. Minimum performance inherent in the AC method must be guaranteed. The final commenter would like to know if AC 25.981–2 will be revised if the FAA believes that 12 percent is adequate.

Two commenters referenced applying an adequate safety factor to the maximum 12 percent oxygen concentration limit. One commenter referenced various reports they believe support the use of a 20 percent safety margin that should be applied to the FRM. The commenter states that the FAA uses safety factors in design of aircraft structure, components, and systems and to deviate from good design practice is not in the interest of public safety. This commenter suggests that the FAA follow industry practice.

FAA Reply: We do not concur with the commenters. The special condition requirement of 12 percent maximum oxygen concentration at sea level is based on FAA oxygen content testing and review of other test data, such as Navy gunfire tests. These data show that 12 percent oxygen concentration will prevent a fuel tank explosion for airplane system failure and malfunction-generated ignition sources. Additionally, data from the Navy testing provided in document NWC TP 7129, ''The Effectiveness of Ullage Nitrogen-Inerting Systems Against 30 mm High-Explosive Incendiary Projectiles,'' dated May 1991, shows that 12 percent oxygen concentrations are also very effective at mitigating the effects of a high-energy incendiary projectile puncturing the fuel tank ullage.

We plan to revise AC 25.981–2 to include the definition of inert that is used in these special conditions.

Summary

Comment: The commenter refers to the statement in the summary paragraph that the regulations do not contain adequate or appropriate safety standards. The commenter considers this statement invalid and fails to comprehend what is missing in the regulations to adequately address certification of an FRM and why special conditions would be required. The commenter agrees with the FAA that the FRM installation must comply with § 25.981 at amendment 25–102, the fuel vent and exhaust emission requirements of part 34, and the acoustical requirements of § 21.93(b). The commenter also believes that §§ 25.831(b), 25.1301, 25.1307, 25.1309, 25.1316, 25.1321, 25.1322, 25.1357, 25.1431, 25.1438, and 25.1461 might also apply.

FAA Reply: Many of the regulations quoted by the commenter are applicable, and compliance with these requirements must be shown for certification of the FRM for the applicable Boeing Model 747 series airplanes. However, part 25 regulations do not contain adequate or appropriate safety standards for the performance of the FRM. The basis to issue special conditions is addressed in § 21.16. No changes were made as a result of this comment.

Background

Comment: This commenter believes ignition source prevention has failed. The commenter points to the 1997 notice, in which the FAA requested industry comments on the mitigation of hazards posed by flammable fuel tank vapors. In that notice, the FAA cites 13 fuel tank explosion/ignition events and three non-operational events, for a total of 16 during the 1959–1996 timeframe, before the Thailand B737 center wing tank explosion. The commenter says that since the ignition sources for the last three accidents are unknown, an FRM must safeguard against unknown ignition sources of unknown ignition energy. A significant number of single failures and combinations of failures can result in ignition sources within fuel tanks; therefore an acceptable system must safeguard against all (except extremely improbable) ignition sources within the fuel tank. The commenter also notes that approximately 550 people lost their lives in these explosions.

FAA Reply: The ignition prevention safety reviews conducted following the 1996 accident revealed many previously unknown single component failures that could result in ignition sources within the fuel tanks. We will issue additional ADs, where necessary, to require design or maintenance actions to address these newly discovered deficiencies. The safety reviews also identified combinations of failures that could result in an ignition source. Because service experience and analysis indicated that these combinations were less likely to occur, we determined that it was not practical to address them in existing airplanes. The safety reviews also confirmed that unforeseen design and maintenance errors exist and result in development of ignition sources. As discussed earlier in this document, the NTSB recommendations included not just preventing ignition sources, but also reducing fuel tank flammability. The NTSB concluded that ''a fuel tank design and certification philosophy that relies solely on the elimination of all ignition sources, while accepting the existence of fuel tank flammability, is fundamentally flawed because experience has demonstrated that all possible ignition sources cannot be determined and reliably eliminated.'' Therefore, the purpose of these special conditions is not to address additional rulemaking for prevention of ignition sources but to certificate a specific fuel tank FRM for Boeing Model 747 series airplanes. No changes were made as a result of this comment.

Comment: The commenter states that service experience of airplanes certificated to the earlier standards shows that ignition source prevention alone has not been totally effective at preventing accidents. The commenter notes that after the TWA 800 accident, fuel tank system rulemaking activity started in such an excessive way that the FAA has mandated over 50 ADs and proposed changes to part 25. After other fuel tank explosion accidents prior to the flight TWA 800 accident, the FAA did not change the design standards of fuel tank systems. SFAR 88 was the first real rulemaking activity where the FAA mandated ignition source reduction throughout the fleet. Those changes are not incorporated at this time. The commenter therefore believes the FAA cannot say that the past service experience for ignition source prevention alone has not been totally effective in preventing accidents. Currently, the results of ignition source prevention measures are unknown.

This same commenter also believes that the addition of SFAR 88 and an FRM will not reduce the chance of maintenance induced errors and may have an opposite effect in that it could introduce the risk of further human factors errors.

FAA Reply: We do not concur. Past experience shows that detailed design reviews, similar to those required by SFAR 88, have not been effective at eliminating ignition sources. Following an accident in 1976, we conducted an exhaustive investigation and design review of the lightning protection features of the fuel tank system, including full scale testing of the wing. From this, we mandated design changes to improve lightning protection of the system. Subsequent review of the airplane design required by SFAR 88 revealed the need for additional bonding modifications that will be mandated. Failure of other components within the fuel tank system and components adjacent to the fuel tank could also cause ignition sources. These examples show that it is very difficult to identify all ignition sources during design. Additionally, past experience also indicates unforeseen design and maintenance errors can result in development of ignition sources.

We have issued multiple ADs to address ignition source prevention and believe that implementation of design changes intended to prevent ignition sources identified by SFAR 88 will prevent about 50 percent of future fuel tank explosions. The more significant changes to fuel tank systems resulting from the SFAR 88 activity include:

- Features to prevent dry running of fuel pumps within the fuel tanks;
- Ground fault protection of fuel pump power supplies for pumps or wires exposed to the fuel tank ullage;
- Additional electrical bonds on some components;
- Electrical energy limiters on wiring entering fuel tanks that are normally

emptied and located within the fuselage contour;

- Electrical bond integrity checks; and
- Improved maintenance programs.

While we believe these modifications and maintenance program changes will significantly improve safety, the results of the safety reviews conducted as part of SFAR 88 show there is uncertainty in the effectiveness of ignition source prevention alone. The addition of an FRM will significantly improve fuel tank safety by reducing or preventing flammable vapors in the fuel tank and will incorporate fail-safe features into the fuel tank system that account for design and maintenance errors. No changes were made as a result of these comments.

Fuel Properties

Comment: The commenter says that the new generation airplanes (B737NG, B757, B767, and B777) are not certified to use Jet B or JP–4 wide-cut fuels. The commenter also points out that AD 85–11–52R1 prohibits the use of Jet B and JP–4 on Boeing Model 737–300 series airplanes.

FAA Reply: We do not concur. While wide-cut fuels are not commonly used in the world fleets, some of the airplanes mentioned do allow at least limited use. Other models are certified for unrestricted use. Significant use of lower flash-point fuels could affect the percentage of time the fuel tanks are flammable. Therefore, to achieve consistent flammability exposure, the flash point of the approved fuels must be considered in the analysis used for demonstrating compliance. No changes were made as a result of these comments.

Fire Triangle

Comment: The commenter points to the FAA statement, ‘‘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.’’ It is the commenter's opinion that there never was a technological limitation. The commenter refers to a test the FAA conducted in the 1970s of a nitrogen fuel tank inerting system on a DC–9 airplane, and that system maintained oxygen concentration less than 8 percent under all normal and emergency flight conditions. The commenter also listed other airplanes that use NEA, liquid nitrogen, and explosion suppressant systems to minimize fuel tank flammability. The commenter further points out that in March 2002, the Aviation Rulemaking Advisory Committee (ARAC) concluded that fuel tank inerting may provide safety benefits and warrants continued industry and government research. Then, in December 2002, an on-board nitrogen generator intended to pump the inert gas into an emptying fuel tank was unveiled. The commenter states that all of this demonstrates the capabilities of industry.

FAA Reply: While we agree with the commenter that the earlier systems were available, we do not agree that they were practical for commercial transport airplanes because of the cost, complexity, weight, and poor reliability of the systems. The FRM that will be certified for installation on Boeing Model 747 series airplanes reduces fuel tank flammability by inerting the tanks with nitrogen using hollow fiber membrane technology that does not require installation of an air compressor to produce NEA, thereby reducing cost, complexity, and weight. As previously discussed, more recent research has found that a simpler inerting system that reduces the oxygen concentration of the fuel tank to 12 percent or less at sea level is sufficient in achieving the desired safety level. No changes were made as a result of these comments.

Fuel Tank Harmonization Working Group

Comment: The commenter points to several references throughout the preamble discussion to a flammability exposure of 2 to 4 percent and requests that this be changed to 5 percent. The commenter says that the ARAC, in their 1998 report, estimated wing fuel tank exposure as 5 percent. The commenter also points to the reference to 3 percent flammability value for the wing fuel tanks in the preamble discussion of ‘‘Definition of Transport Effects’’ and requests that this also be changed to 5 percent.

FAA Reply: We concur in part. Although the ARAC report did identify a flammability exposure of 2 to 6 percent in the Task Group 8 section, in other locations of the report a generalized value of 5 percent was used. In the original discussion in the proposed special conditions, we incorrectly referenced a range of 2 to 4 percent instead of the actual value of 2 to 6 percent. We consider the estimated range that was based on a flammability analysis of a number of different airplane models to be more representative of the wing fuel tank flammability range across various airplane models. No changes were made as a result of these comments.

Comment: The commenter says that the data presented in the discussion of the Fuel Tank Harmonization Working Group should be for historical reasons, and the criteria used for determining the need for an FRM should be AC 25.981–2.

FAA Reply: We do not concur. The purpose of AC 25.981–2 is to provide guidance for demonstrating compliance with § 25.981(c) to:

- Minimize fuel tank flammability; and
- Mitigate the hazards if ignition of the fuel vapors occurs.

The AC does not provide criteria to determine if a system is required to reduce flammability in fuel tanks.

We infer from the commenter's remarks that they believe these special conditions will mandate the installation of an FRM, which is not the case. These special conditions do not represent rulemaking to mandate the reduction of a fuel tank flammability system. Instead, they are required to support certification of novel features of the FRM not addressed by existing regulations, and include additional requirements to address warm day operations during ground, takeoff, and climb portions of the flight where previous accidents have occurred. No changes were made as a result of these comments.

Comment: One commenter considers the flammability range of l5 to 30 percent of fleet operating time for fuel tanks containing flammable vapors, as documented in the ARAC report, a large range. This range indicates that the actual percent depends on assumptions. This commenter believes that a Monte Carlo analysis should not be a part of the certification process as it is an analysis that is based on flawed assumptions. The commenter considers use of statistical methods more consistent with the FAA philosophy for fail-safe designs. The commenter believes that aviation safety would be undesirably low if a Monte Carlo analysis was used for the design and certification of navigation and guidance systems, ground proximity warning systems, weather radar, wind shear avoidance, engine fire protection, etc. Another commenter also contends that the assumptions used in the Monte Carlo analysis are not supported by historical data.

FAA Reply: We do not concur with the first comment. The 15–30 percent addresses the range of average flammability exposures across the airplane models in the fleet. Specific airplane models will have a fixed average flammability exposure. We do agree that variations in assumptions for the analysis could result in large differences in the results of the flammability analysis. For this reason, the special conditions incorporate specific parameters that must be used when determining fuel tank flammability. The Monte Carlo methodology has been used in a wide range of industries to address safety concerns. Previous ARAC activities recommended use of the Monte Carlo method for calculating average fuel tank flammability exposure. This methodology has recently been used by industry to evaluate the flammability exposure of fuel tanks as part of the SFAR 88 activities. We therefore expect the applicant as well as industry already have a good understanding of how to use the model. No changes were made as a result of these comments.

FAA Rulemaking Activity

Comment: The commenter notes that the ARAC recommendations referenced in this discussion did not use the word ''reduction.'' The commenter believes that the word ''reduction'' in § 25.981(c) needs further study. The commenter also says that the 2 to 4 percent flammability of unheated aluminum wing fuel tanks should not be used as a criterion in the special conditions, and notes that AC 25.981–2 does not specifically address the center wing fuel tank like the special conditions but includes all tanks (including wing tanks).

FAA Reply: We do not concur with the comment concerning the use of unheated aluminum wing fuel tanks as the criterion for an acceptable level of fuel tank flammability. AC 25.981–2 does provide clarification under section 5, paragraph (d)(3), that the intent of § 25.981 is ''to require that the exposure to formation or presence of flammable vapors is equivalent to that of an unheated wing tank in the transport airplane being evaluated.'' The special conditions incorporate the intent of § 25.981(c) and also include additional requirements for warm day conditions where previous accidents have occurred. The special conditions also include requirements to address novel design features that are not covered under the applicable airworthiness standards of part 25. No changes were made as a result of these comments.

Fuel Tank Inerting

Comment: Two commenters say the applicant's proposed design does not include an essential verification system (NEA sensors and indication) to ensure that the appropriate nitrogen concentrations will be directed into the fuel tank to displace the fuel vapors in the ullage space. One commenter compares this to the statement in the discussion of ''Criteria for Inerting'' that the combination of ignition prevention and reduction of flammable vapors in the tank will substantially reduce the number of future fuel tank explosions.

FAA Reply: We do not concur. To comply with the special conditions, the applicant must demonstrate that the FRM meets the specific performance and reliability requirements. An indication system would be required if it is shown that the FRM cannot meet these requirements unless one is installed. No changes were made as a result of these comments.

Comment: The commenter requests that the reference to ''using the size difference'' in the first paragraph be changed to ''using the absorption difference,'' as this would more accurately reflect how hollow fiber membranes function.

FAA Reply: We concur with the commenter and revised the sentence to read: ''* * * the hollow fiber membrane material uses the absorption difference between the nitrogen and oxygen molecules to separate the NEA from the oxygen.''

Comment: The commenter says that it does not have to be pressurized air from the airplane engines that is used to produce NEA; compressed air from any source can be used.

FAA Reply: We agree, however these special conditions address a specific system design for the applicable Boeing Model 747 series airplanes using bleed air from the airplane engines to generate NEA. We recognize there may be other means to achieve the same goal. No changes were made as a result of this comment.

Comment: The commenter contends that technology has not kept up with the need to eliminate the need for stored nitrogen because hollow fiber technology does not produce enough NEA to inert the center tank during all phases of flight, including descent. Hollow fiber technology, as described in the special conditions, will not inert the wing tanks.

FAA Reply: We do not concur. The applicant has selected hollow fiber technology as a means to produce NEA to inert the center wing tank on Model 747 series airplanes. The applicant must show that the FRM will inert the center tank. Hollow fiber technology could be used to inert wing fuel tanks; however, there is no requirement in the special conditions to do so. No changes were made as a result of this comment.

Criteria for Inerting

Comment: The commenter requests that this discussion be revised as shown below. The commenter says the FAA proposed wording implies that the 9 percent military and 12 percent commercial oxygen concentration values are intended to be equivalent. The 9 percent is a military limit for zero exposure. The 12 percent is a benchmark for evaluating minimization of flammability exposure, equivalent to wing tanks.

Criteria for Inerting

Earlier fuel tank inerting designs produced for military applications were based on defining ''inert'' as a maximum oxygen concentration of 9 percent. One major finding from the research and development efforts conducted by the FAA was the determination that the 9 percent maximum oxygen concentration limit established to protect military airplanes was significantly lower than necessary to prevent significant pressure rise for the majority of ullage conditions. This FAA research supports a value of 12 percent as a benchmark at sea level for determining when the likelihood of significant pressure rise is low. The test results are currently available on FAA Web site: www.fire.tc.faa.gov, and will be published in FAA Technical Note 'Limiting Oxygen Concentrations Required to Inert Jet Fuel Vapors Existing at Reduced Fuel Tank Pressures,' report number DOT/FAA/AR–TN02/79.

It should be noted that the 12% benchmark is not intended to claim that ignition is impossible below 12%. 14 CFR 25.981 (c) requires minimization of flammability, not elimination. ARAC evaluations concluded complete elimination of flammability was impractical and unnecessary. 14 CFR 25.981(c) was based on reducing flammability exposure to equal or less than wing tanks, which have an acceptable safety history. The 12% benchmark is used to divide exposure time when significant pressure rise is unlikely, from exposure time when significant pressure rise is more likely. Testing indicates there is also significant ability to inhibit ignition for many fuel vapor conditions when oxygen content is above 12%, but no credit is taken for these conditions.

As a result of this research and the 12 percent benchmark, the quantity of nitrogen-enriched air that is needed to inert commercial airplane fuel tanks was reduced. This reduction in nitrogen-enriched air, coupled with advancements in design technology, facilitates the development of an effective flammability reduction system that approaches simple and practical.''

FAA Reply: We do not concur. The 12 percent requirement in the special conditions is based on testing of flammability using electrical ignition sources caused by airplane system failures. It is not intended to address combat threats. However, data from the Navy tests concludes that inerting to 9 percent oxygen has little benefit over 12 percent for protection of fuel tanks from overpressure caused by ignition from 30 millimeter Hi energy incendiary rounds.

No changes were made as a result of this comment.

Type Certification Basis

Comment: The commenter points to two statements concerning compliance with § 25.981, which appear to be confusing regarding applicability to the FRM. First, the commenter asks for clarification as to the extent to which § 25.981 is applied to the system. The commenter assumes it is only those areas exposed to fuel vapor under normal operation. The commenter also points to paragraph two of the ''Novel or Unusual Design Features,'' which states that compliance is required for the changed aspects of the airplane by showing that the FRM does not introduce any additional potential ignition risk into the fuel tanks.

FAA Reply: There are two aspects of the FRM concept. First, it is the means chosen to achieve the requirements of § 25.981(c) to minimize fuel tank flammability for the applicable 747 series airplanes. In this case, the applicant chose to introduce NEA into the center wing tank and assure that it is dispersed throughout. Having made that choice, the applicant is required to ensure that the changes introduced by the system (*i.e.*, FRM) do not introduce any potential ignition sources into the tank. No changes were made as a result of this comment.

Comment: The commenter says that compliance with § 25.981 applies to certification of fuel tanks and not to the installation of an inerting system, although fuel tank inerting may be one way to show compliance with § 25.981(c)(1).

FAA Reply: We do not concur. The applicant has proposed to voluntarily comply with § 25.981(c), amendment 25–102, for certification of the performance of an FRM to reduce flammability in the center wing fuel tanks of Model 747 series airplanes. Additionally, as stated in the preamble to these special conditions, the applicant must also ensure that installation of an FRM will meet the ignition source prevention requirements of § 25.981(a) and (b), as well as all the other applicable part 25 regulations. No changes were made as a result of this comment.

Comment: The commenter requests that the 747-Classics effectivity be removed from the special conditions. The commenter says that few 747-Classics remaining in service may fall within the total 3 percent exposure criteria, and failing that should pose a far lower risk for the following reasons:

- The majority of ignition reduction modifications (IRM), including the improved maintenance procedures, will be implemented prior to any reasonable FRM compliance date;
- AD 98–20–40 fuel quantity indicating system protection upgrade has been fully incorporated on all 747-Classics; and
- With the two 737 accidents, it appeared that the center wing tank (CWT) fuel pumps were inadvertently left running with an empty CWT, and although it could not be confirmed that the pumps were at fault, the IRM requirement to automatically (or otherwise) shut pumps off at low pressure will eliminate this possible ignition source.

There may be an argument that the older airplanes are at a greater risk and therefore should be FRM protected, but the historical events and sample in-tank inspections tend to rebuff this proposition.

FAA Reply: We disagree with the commenter that the center wing fuel tank on 747 Classic airplanes falls within the 3 percent fleet average flammability exposure criteria because initial flammability exposure analyses of these airplane models has shown the flammability to be well above 3 percent. We estimate there are currently about 95 747–100, –200, and –300 airplanes in service today in the United States. Though ignition source prevention ADs have been incorporated on these airplanes and additional ADs will be incorporated as a result of SFAR 88 rulemaking, as we said earlier in this document experience demonstrates that all possible ignition sources cannot be determined and reliably eliminated. Reducing or preventing flammable vapors from forming in high flammability fuel tanks will significantly improve fuel tank safety. These special conditions support certification of the applicant's FRM design for possible installation on Boeing Model 747 series airplanes. These special conditions do not mandate any changes to current airplanes. No changes were made as a result of these comments.

Novel or Unusual Design Features

Comment: The commenter requests that the phrase ''by showing that fuel tanks'' in the second paragraph of this discussion be deleted because the beginning of the sentence establishes the requirement to comply with § 25.981(a), and (b). The method of compliance is the applicant's responsibility.

FAA Reply: We do not concur with the commenter. This last phrase provides a condensed explanation to the reader of what is required for compliance with § 25.981(a) and (b). No changes were made as a result of this comment.

Comment: This comment concerns the discussion of how the applicant proposes to operate the FRM. The commenter says the applicant must be allowed the freedom to design the system and must ensure that all features of the FRM are addressed properly so that hazardous conditions do not occur and the system complies with §§ 25.1301 and 25.1309 and other applicable requirements.

Another commenter requests that the system description be replaced by the following to focus on requirements and not prescribe design:

> The proposed FRM uses a nitrogen generation system (NGS). Engine bleed air will flow through an air separation module (ASM) that will separate the air stream into nitrogen-enriched air (NEA), which will be supplied to the center fuel tank, and oxygen-enriched air (OEA), which will be exhausted overboard. The FRM will also include modifications to the fuel vent system. Certain features of the FRM may introduce a hazard to the airplane if not properly addressed.

FAA Reply: We do not concur with the commenters. This section of the special conditions preamble appropriately defines what the novel or unusual design features of the FRM are that require special conditions under § 21.16. No changes were made as a result of these comments.

Comment: This commenter says the special conditions do not adequately address the descent control valve function as it relates to the high flow versus low flow mode. The Monte Carlo analysis is not based on test data or historical data to predict the effectiveness of the NGS on descent.

FAA Reply: We do not concur. The special conditions require that the applicant validate the inputs to the Monte Carlo analysis by ground and flight tests and substantiate that distribution of NEA is effective at inerting the fuel tank for the performance conditions required. No changes were made as a result of these comments.

Comment: It is the commenter's opinion that the proposed 10-day MMEL relief for the system is unjustified. The commenter says all components are Line Replaceable Units (LRU) that can be replaced within ''typical'' turn around time. A long relief time defeats the purpose of the system. If limited dispatch relief is granted, then it should be restricted to conditions (cold temperature) in which development of flammable vapors in the fuel tank is of low probability. The commenter points to AC 25.981–2, paragraph 4(h), which addresses limited operations based on outside air temperature.

FAA Reply: The special conditions do not approve an MMEL dispatch interval. As stated previously, even though the applicant has proposed a 10-day MMEL dispatch interval, the Flight Operations Evaluation Board (FOEB) will determine and approve the appropriate MMEL relief intervals based on data submitted by the applicant. The applicant must show that the fleet average flammability exposure of a tank with an FRM installed is equal to or less than 3 percent, including operating time with an FRM. No changes were made as a result of these comments.

Comment: This commenter says the MMEL procedure is a result of system design (safety system or not, redundancy, etc.) and reliability of the system. It is up to the applicant to design their system to satisfy both the regulations and their customers.

FAA Reply: We concur. The special conditions require the applicant to submit data that show compliance with the special conditions for their proposed MMEL dispatch interval. The FOEB will assess the data in determining if the interval is appropriate. No changes were made as a result of this comment.

Comment: The commenter contends that the existing technology for hollow fiber technology presently has a mean time between failure (MTBF) of less than 2,000 hours, which is different than the 5,000 hours identified in this section.

FAA Reply: To comply with the specific reliability requirements, the applicant will have to consider the MTBF or life limit of the hollow fiber technology in their FRM design. The design and compliance with the special conditions will dictate what the MTBF will be. No changes were made as a result of this comment.

Discussion

Comment: Three commenters contend that the statement ''* * * due to factors such as the limited availability of bleed air and electrical power, it is not considered practical at this time to develop systems for retrofit * * *'' is not appropriate and is incorrect. One commenter says this issue would be better addressed in documentation and discussion rather than this section of the special conditions. The discussion should be limited to the issues considered and the data presented in the proposed special conditions. The second commenter says that on all commercial airplanes during normal operation (all engines operating and all generators operating), excess bleed-air and electrical power is available. The last commenter requests removal of the words ''Since amendment 25–102 was adopted,* * * it is not considered practical at this time to develop systems for retrofit into existing airplane designs that can maintain a non-flammable tank ullage in all fuel tanks or during all operating conditions.'' The commenter says the wording suggests that a more stringent requirement than that established by amendment 25–102 has been demonstrated to be practical. The FAA has not proposed, substantiated, or adopted rulemaking to support this statement. Changes to the requirements of § 25.981(c) are not the subject of these special conditions.

FAA Reply: We do not concur with the commenters but believe clarification is needed to fully understand the context of the statement that is at issue. As stated earlier, the FAA Administrator has made public statements concerning our intention to propose rulemaking that would amend § 25.981(c). During the public process following issuance of any proposal, comments will be welcome. The purpose of this statement in the special conditions is to provide justification for the level of performance required within the proposal. Although the complexity and sizing of inerting technology has been reduced such that it is a viable method for reduction of flammability in fuel tanks, there are still restrictions in existing airplanes today that would limit an inerting system from being 100 percent effective at inerting the fuel tank during all operating conditions. No changes were made as a result of these comments.

Comment: One commenter expresses concern that an FRM that complies with § 25.981(c), amendment 25–102, may not preclude fuel tanks from routinely being flammable under the specific operating conditions present when recent accidents occurred. The commenter says that if the FAA believes the above statement is true, then it has not specified the right regulations. The commenter believes a repeat of the Philippine, TWA, or Thai incidents would be prevented by compliance with § 25.981(c).

FAA Reply: The FRM is intended to add an additional layer of safety for high flammability fuel tanks by reducing the existence of flammable vapors in the center wing tank. It is important to recognize that this system does not totally eliminate flammable vapors in the tank during all operating conditions. The special conditions include requirements that will address specific risk elements for warm day ground and climb profiles where accidents have occurred which is a more stringent requirement than § 25.981(c). The FRM will augment the ignition source prevention measures in substantially reducing the risk for future fuel tank explosions. No changes were made as a result of these comments.

Definition of Inert

Comment: One commenter believes that 12 percent oxygen concentration at sea level cannot be assured unless the oxygen percentage within the ullage of the fuel tank is monitored and measured. The commenter says oxygen monitoring by percentage is needed to verify if the center wing fuel tank is inert per the definition supplied in the special conditions, and to determine if the inerting system is inoperative. The commenter says there is a need to know the oxygen concentration in the center tank for airplanes operated in warmer climates. If NEA is lost, the risk factor needs to be accounted for in the analysis. If it is lost because of a leak surrounding the NGS, there will be a higher than normal oxygen level in that compartment. The commenter would encourage further investigation, testing, and analysis of existing data to support the definition of inert in all locations and all fuel tanks for the Model 747 series airplanes and eventually on the Model 737, 757, 767, and 777 airplanes, as referenced in the ''Novel or Unusual Design Features'' discussion.

Two commenters believe that the level of oxygen concentration should be monitored at the most critical location in the fuel tank to verify adequate system operation. One of the commenters believes that an indication should be generated if the oxygen concentration in the fuel tank rises above the maximum allowable concentration for greater than a specified time. This would prevent transient conditions from generating nuisance indications. The other commenter says that the system indications should monitor adequate system performance throughout the flight profile, which is something a periodic ground check cannot ensure. Besides the obvious safety and reliability benefits, it is not understood how else the reporting requirements of special condition III(c) could be met. Although AC 25.981–2 does not require cockpit indications for an inerting system, this commenter would support rulemaking intended to revise AC 25.981–2.

Two commenters believe that an indication system that displays the inerting system functionality should be available to the flightcrew. Relying solely on preflight or ground crew checks leaves out a valuable resource for monitoring the system status. The flightcrew should be aware if the system is functioning. If it is not, changes in the flight profile should be made to ensure the airplane is out of the regime where the center fuel tank is in the most danger.

FAA Reply: We do not concur with the commenters. There are no requirements in the special conditions for oxygen concentration monitoring, but there is nothing that precludes a monitoring system and associated crew indications from being developed. While monitoring of oxygen concentrations is one means of determining system performance, other indications such as pressure measurements, flow measurements, valve positions etc., as well as periodic functional checks may be used to provide assurance that the system is functional. The concerns listed by the commenters are included in the analysis and testing the applicant must perform to show that the FRM meets the special condition flammability and reliability requirements. No changes were made as a result of these comments.

Comment: The commenter requests the word ''localized'' in the second sentence of the first paragraph in this section be deleted. The commenter also requests that the rest of the paragraph after the second sentence (*i.e.*, ''Currently there is * * * be considered inert'') be deleted. The commenter believes the addition of a requirement to individually address all tank compartments is not in accordance with the principles used to date to develop a practical and commercially viable system that will minimize the average fleet flammability exposure. It is already conservative to estimate flammability based on average fuel temperature because the average fuel temperature is typically higher than the majority of the tank surfaces. This approach represents the theoretical flammability of a tank where all the tank surfaces are at this uniform temperature. In reality, when the fuel temperature is high enough to result in evolution of sufficient vapors to cause a flammable ullage near the fuel surface, the temperatures of the sides and top of the fuel tank are cooler, resulting in condensation that significantly reduces the actual flammability of the tank ullage.

FAA Reply: We concur, in part, with the commenter. We have revised the definition of ''flammable'' in the special conditions to read, ''With respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding (14 CFR part 1, Definitions). A non-flammable ullage is one where the gas mixture is too lean or too rich to burn and/or is inert per the definition below.''

We do not concur with the comment that the bulk average fuel temperature should be used to determine flammability. The ARAC used a bulk average fuel temperature to provide a comparative flammability level for various fuel tanks on different airplane models. The ARAC used a simplified methodology that assumed the fuel tank was one large volume and that the liquid fuel and fuel vapor in the tank would mix, forming a uniform mixture. In this case, using the bulk average fuel temperature would provide a realistic representation of the actual fuel tank flammability.

This simplified approach, however, does not reflect the actual design of some fuel tanks. In reality, some fuel tanks have significantly different flammability exposures within different compartments of the fuel tank due to barriers installed in the tank, to prevent sloshing of fuel. These barriers do not allow significant mixing of the fuel and vapors. For example, some center fuel tanks extend from the center wing box out into the wing. Other tanks located in the center wing box have barriers that create separate compartments within the tank. In these cases, the portion of the fuel tank in the wing or that exposed to a cold air source may be much cooler and little mixing within the different portions of the fuel tank would occur. If the fuel temperature in the part of the tank located in the wing or other colder section were used in the analysis, the results would not represent the actual flammability of those portions of the tank where cooling did not occur. We have therefore modified the special conditions to revise the discussion in appendix 2 to address those airplanes that have significantly different flammability exposures within different compartments of the fuel tank due to the design of the tank, such as a center fuel tank that extends from the center wing box out into the wing. For these fuel tanks, the appendix requires evaluation of the compartment with the highest flammability for each flight phase. We do not expect that determining which compartment to evaluate will require a detailed analysis of each compartment. In most cases, a qualitative assessment, considering ambient temperatures and other relevant factors will be sufficient.

Determining Flammability

Comment: This commenter says the Monte Carlo analysis should also consider the center tank theoretically in an unheated condition, not heated by adjacent equipment.

FAA Reply: We do not concur. The Monte Carlo analysis as used in these special conditions is specific for determining fuel tank flammability exposure and certifying an FRM that reduces the flammability of a specific center wing tank. No changes were made as a result of this comment.

Comment: This commenter points out that in the second paragraph of the ''Flammability'' discussion the FAA says ''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.'' Table 6 in appendix 2 of the special conditions defines lower flammability limits if the applicant chooses to use fewer than 1,000,000 flights. The commenter says the number of runs should be defined as ''when the average results become stable,'' and the criteria for assessing these results should then be 3 percent.

FAA Reply: We do not concur. Monte Carlo analyses in general require the applicant to run a large number of cases for the results to be accurate. The special conditions contain a method for an applicant to run fewer cases if they are able to show that they meet the required 3 percent fleet average and 3 percent warm day flammability exposure limits for the fuel tank under evaluation. No changes were made as a result of this comment.

Comment: The commenter requests that the following sentence be added to the end of the last paragraph of the ''Flammability'' discussion: ''However, fresh air drawn into an otherwise inert tank during descent does not immediately saturate with fuel vapors, and hence localized concentrations above the inert level during descent do not represent a hazardous condition.'' This is because fresh air drawn into the fuel tank through the vent during descent is not flammable, and will not cause the tank to become flammable during descent. Fresh air near the vent has not had the time necessary to mix with the bulk tank ullage, and thus will not be inert. However, the same lack of mixing time also precludes the presence of a flammable vapor level in this same region. Counting these non-hazardous periods as ''flammable'' would increase system size, weight, and associated costs with no benefit.

FAA Reply: We concur and have modified the preamble discussion of ''Determining Flammability'' to add the following sentence: ''However, fresh air drawn into an otherwise inert tank during descent does not immediately saturate with fuel vapors; hence, localized concentrations above the inert level during descent do not represent a hazardous condition.''

Definition of Transport Effects

Comment: One commenter says the FAA statement that the effects of mass loading and the effects of fuel vaporization and condensation with time and temperature changes have been excluded is flawed, because FAA documents clearly indicate that ''transport effects'' are important. Another commenter also believes that the analysis model should include ''transport effects'' as well as flammability effects on heated unusable (empty, 0 quantity indication) fuel in the center wing tank. This second commenter says the fuel temperature within a specific compartment of the tank could be within the flammable range for the fuel type being used if the tank was empty and heat sources were next to the compartment.

FAA Reply: We do not concur with the commenters. As stated in the definition of ''transport effects'' in the special conditions and the earlier discussion, this term includes two physical phenomena that affect the concentration of fuel vapor in the fuel tank ullage. The first is referred to as low fuel conditions or ''mass loading.'' At low fuel quantities there may be insufficient fuel in the fuel tank at a given pressure and temperature for the concentration of fuel vapor to reach the equilibrium level that would form if fuel were added to the tank.

The second is the change in fuel vapor concentration in the fuel tank ullage caused by fuel condensation and vaporization. This change in fuel vapor concentration is caused by temperature variations on the fuel tank surfaces that result in a vapor concentration different from the concentration calculated using the bulk average fuel temperature.

We excluded both of these effects because they were not considered in the original methodology ARAC used to establish the proposed flammability requirements. If this effect had been included in the wing tank flammability exposure calculation, it would have resulted in a significantly lower wing tank flammability exposure benchmark value.

The ARAC analysis also did not consider the effects of the low fuel condition (or ''mass loading''), which would lower the calculated flammability exposure value for fuel tanks that are routinely emptied, such as center wing tanks. As explained earlier, when the amount of fuel is reduced to very low quantities within a fuel tank, there may be insufficient fuel in the tank to allow vaporization of fuel to the concentration that would be predicted for any particular temperature and pressure.

No changes were made as a result of these comments.

Flammability Limit

Comment: The commenter requests that the reference to ''during descent'' be changed to ''after high rate descent'' to more accurately reflect conditions.

FAA Reply: We do not concur. The commenter provided no substantiation to clarify why they believe the tank would be able to maintain an inert ullage during descent mode that is not classified as a high rate of descent. Both the performance of the FRM and the rate of descent may impact the oxygen concentration level in the fuel tank and both need to be considered. No changes were made as the result of this comment.

Comment: The commenter says that the 3 percent exposure criteria, referenced in this discussion, appears to be premised on the good service history of main and non-heated reserve fuel tanks. However, heated center wing tanks (CWTs) make up only a small percentage of the total number of tanks in use. If the exposure times for non-heated tanks are summed, it is likely to be close to the total overall exposure period for heated CWTs. If exposure period were the only criterion, then one would expect to see non-heated tank incidents. It is probable that the operating requirements (fuel remaining in tanks) have as much to do with the good service history as the exposure level. SFAR 88 Ignition Reduction Modifications will significantly reduce the ignition risk of the heated CWT to a level where perhaps they are not quite as safe as the main tanks but on a false premise. If the non-heated tanks had an average 6 percent exposure, it is unlikely that the service history would differ. Setting the exposure design criteria to 3 percent or lower may not be as relevant as indicated in these special conditions, and even a small shift upward could significantly influence the cost of installation and maintenance. A more important criterion could be the fact that many CWT components remain uncovered for the majority of time, with the possibility of an intermittent latent ignition type defect coming into play when inerting is unavailable. Therefore, the commenter states it may be more appropriate to consider additional MMEL limitations to help mitigate whatever is the remaining exposure risk. This may include ensuring that if CWT components fail, power is removed and not reapplied until the component is replaced and/or some fuel is left in the CWT under certain defect conditions. It should also be noted that it is important to ensure that inerting does not become a substitute over time for the quick and effective clearance of CWT defects.

FAA Reply: We agree with the commenter concerning the limitations of ignition source prevention. Minimization of ignition sources, such as component failure, removal of power, etc., was the goal of SFAR 88 but it is recognized that absolute elimination of ignition sources is not possible. Flammability reduction provides a significant improvement in fuel tank safety in conjunction with ignition source prevention but, as such, it is important to recognize that this system will not necessarily eliminate all flammable vapors at all operating conditions. However, the warm day flammability exposure requirements in these special conditions would prevent fuel tank flammability during conditions where the past three fuel tank explosions occurred. By combining the two approaches, the risks for fuel tank explosions can be substantially reduced. Compliance with the special conditions will also ensure that neither the performance nor the reliability of the FRM will be greater than 1.8 percent of the fleet average flammability exposure, thereby further minimizing the exposure risk. The MMEL for each airplane model was reviewed as part of SFAR 88 and limitations on operations. We do not believe that additional MMEL requirements would be needed unless the FRM is unable to meet the performance, reliability, or warm day requirements in the special conditions. No changes were made as a result of these comments.

Specific Risk Flammability Limit

Comment: The commenter says that because the issue of fuel tank flammability is primarily one of specific risk, they do not understand why the Monte Carlo analysis does not include MMEL relief and dispatch with the FRM inoperative in the evaluation of specific risk against the requirement of special condition paragraph II (b).

FAA Reply: We did not include the effect of MMEL in special condition paragraph II (b) because the intent is to address the performance of the FRM under warm day conditions on the ground, in takeoff, and in climb, which are high risk. The fleet average flammability exposure includes the affects of reliability and including this in the warm day (that is, specific risk) is redundant. No changes were made as a result of this comment.

Comment: The commenter requests that reference to ''conducting a separate

Monte Carlo'' be changed to ''analyzing a subset of the fleet average Monte Carlo'' to more accurately reflect how the analysis has been developed.

FAA Reply: We do not agree. The applicant can analyze either a subset of an overall analysis or conduct a separate Monte Carlo for the warm day ground, takeoff, and climb cases. The applicant is still required to run the analysis to meet the fuel tank flammability exposure limit for the number of simulated flights as shown in Table 6 of appendix 2. No changes were made to the special conditions because the method has not been limited.

Inerting System Indications

Comment: The commenter says the four elements (when the FRM is operating and inerts the tank, when the FRM is operating but does not inert the tank, when the FRM is not operating properly and the operator is unaware of the failure, and when the FRM is not operating and is on the MMEL) mentioned in the first paragraph of this discussion should be included for fleet average flammability exposure. Paragraph II (e) of the special condition states that ''sufficient accessibility for maintenance personnel, or the flightcrew, must be provided to FRM status indications that are necessary to meet the reliability requirements of paragraph II (a) of these special conditions.'' The way this special condition is written is unclear and leaves it to the applicant's opinion of what the ''status indication'' should be. The commenter would therefore like to see this special condition explicitly address the four elements mentioned above.

FAA Reply: We do not concur. The special conditions require the overall FRM reliability to meet a minimum standard and allow the applicant to optimize the design. The type of indications that would be required to meet the reliability requirements is design dependent; therefore, the special conditions do not require specific indications. No changes were made as a result of this comment.

Comment: This commenter believes it would be cost beneficial and easier for operators if the look and feel of the FRM indication system is the same across all fleets. Operators already deal with different indication design philosophy across different fleets, so the argument of consistency is not appropriate. Where possible and depending on cost, a strong consideration should be made to align the FRM indication with existing indication philosophy. In the case of the 747–400, this should be by way of an Engine Indication and Crew Alert System (EICAS) status message.

FAA Reply: We do not concur. As stated earlier, the special conditions do not dictate a specific design but rather state that indication and/or maintenance checks will be required to ensure that the performance and reliability of the FRM meets the special condition requirements. The look and feel of an indication system is beyond the scope of these special conditions. No changes were made as a result of these comments.

Comment: The commenter believes that an FRM requires a redundant system to address any future foreseeable events and/or conditions. Consideration should be given to apply the FRM on newly certificated airplanes, and only where it is feasible to existing airplanes.

FAA Reply: We do not concur. As stated earlier, the FRM is intended to be a system that provides an additional layer of protection by reducing the exposure to flammable vapors in the heated center wing fuel tank. This protection, when added to ignition prevention measures, will substantially reduce the likelihood of future fuel tank explosions in the fleet. These special conditions are only applicable to certification of an FRM for the affected 747 series airplanes for which an application was received. No changes were made as a result of these comments.

Comment: The special conditions state that, ''at a minimum, proper function of essential features of the system should be validated once per day by maintenance review of indications or functional checks, possibly prior to the first flight of the day.'' This is a specific implementation and is taken to be for 747 series airplanes only. If the special condition material is intended to be used for other projects, the sentence should be ''proper function of essential features of the system should be monitored.''

FAA Reply: The special conditions require that the FRM for the applicable 747 airplanes meet specific performance and reliability requirements. Various design methods to ensure this may include a combination of system integrity monitoring and indication, redundancy of components, and maintenance actions. The initial 747 FRM design features, as presented to the FAA, would require daily monitoring of system performance to meet the reliability requirements. Daily checks may not be needed on all FRM and are only one way of monitoring proper function of essential system features. Continuous system monitoring by maintenance computers with associated maintenance messages may also be used. A combination of maintenance indication or maintenance check procedures could be used to limit exposure to latent failures within the system, or high inherent reliability may be used to make sure the system will meet the fuel tank flammability exposure requirements.

The type of FRM indications and the frequency of checking system performance (maintenance intervals) must be determined as part of the FRM fuel tank flammability exposure analysis. These special conditions will be used as the starting point for developing special conditions for other airplane models, listed in the preamble, for which the applicant is considering certification of an FRM. No changes were made to these special conditions as a result of these comments because they are applicable to the 747.

Comment: Two commenters question the same discussion in the preamble, specifically the sentence that reads, ''if system maintenance indication is not provided for features of the system essential for proper system operation, system functional checks will be required for these features. They believe that, at a minimum, proper function of essential features of the system should be validated once per day by maintenance review of indications or functional checks, possibly prior to the first flight of the day.'' The comments indicate the commenter interpreted the statement to mean that daily checks are required. One commenter says that accomplishing the functional checks prior to the first flight of the day is not practical, because maintenance personnel are not available at all destinations. It could be 2 to 3 days before the affected airplanes would be at an appropriate location where maintenance is available. The validation check would better align with the operators' maintenance programs if the interval were based on flight hours. The applicant and airplane operators have discussed this topic at length, and believe that an interval of 75 flight hours would provide a conservative validation of the system's functionality and allow the check to be accomplished by qualified maintenance personnel. The commenters also say there is no historical data to support FRM validation only once per day. They recommend continuous monitoring.

FAA Reply: As discussed earlier, we concur with the commenters that the need for daily checks will depend on the FRM design. The preamble discussion was not intended to mandate daily checks by maintenance personnel. As noted earlier, the need for system functional checks and the interval between the checks will be established based on the level of ''system maintenance indication provided for features of the system essential for proper system operation'' and the reliability of the system. If continual system monitoring is provided or features of the system have high inherent reliability, daily checks would not be needed to meet the reliability requirements in these special conditions. As we stated in the preamble, the determination of a proper interval and procedure will follow completion of the certification testing and demonstration of the system's reliability and performance prior to certification. The time interval between system health checks and maintenance will be established by the reliability analysis, any airworthiness limitations, and the FOEB. We agree with the commenter that providing a design with continuous system monitoring is desirable; however, we do not agree that this feature should be required by the special conditions because it would mandate specific design features and not allow design freedom. No change was made as a result of these comments.

Comment: Concerning accomplishment of a daily check for proper function of the FRM, the commenter says past experience has shown that extended ground time and maintenance induced errors can happen. The commenter also contends this is contradictory to the statement that, ''determination of a proper interval and procedure will follow completion of the certification testing * * *.'' The commenter recommends that the maintenance review board (MRB) procedure, outlined in AC 121–22, be used to develop the Instructions for Continued Airworthiness.

FAA Reply: Instructions for Continued Airworthiness are established as part of certification of the FRM to the performance and reliability requirements in these special conditions. The MRB procedure, as outlined in AC 121–22, will be used to define how an MRB will be conducted. No changes were made as a result of these comments.

Comment: Concerning the MMEL dispatch inoperative interval, four commenters believe the proposed MMEL interval of 10 days should be shortened and the FRM be operational to the maximum extent practical. One commenter says 10 days represents approximately 2.74 percent of a year, and contends that the FRM components (bleed-air control valve, ozone converter, heat exchanger, filter, and ASM) can be readily removed and replaced by a line mechanic during a typical turnaround. The commenter believes that several of the FRM components can cause system malfunction (produce low quality NEA) without any indication. These malfunctions cannot be predicted by analysis or by test. A second commenter notes that the FAA and industry have adopted a 3-day MMEL relief interval for other inoperative safety systems, such as flight data recorders, while another commenter states that catastrophic events brought about the development of an FRM; therefore, the importance of such a system is easily seen.

FAA Reply: We do not concur with the commenters regarding setting a specific MMEL interval in the special conditions. The FOEB process, as previously discussed, will determine the appropriate MMEL dispatch interval. No changes were made as a result of these comments.

Comment: One commenter believes that if the reliability analysis shows that a 10-day MMEL will allow the overall fleet flammability exposure limit to meet the requirements listed in the special conditions, then the 10-day MMEL should be acceptable. A second commenter requests clarification that the MMEL relief will be determined using standard methods, and that the reference to warm climates in the last paragraph of this section refers to inclusion in the Monte Carlo analysis and not to a limitation in the MMEL specific to warm ambient temperatures.

FAA Reply: The standard processes (FOEB review), as discussed above, will be used to determine the appropriate MMEL dispatch interval. These same processes may also determine if a limitation is needed in the MMEL for warm day operation based on the results of the analysis. No changes were made as a result of these comments.

Comment: The commenter says that if the FRM is inoperative, there might be some conditions in which the percentage of oxygen concentration is as high as 30 percent while the airplane is in the climb flight profile. An operational consideration might be to transfer fuel into the center tank or to carry extra fuel in that tank until level cruise is attained. This procedure addresses the internal energy sources discussed in current advisory circulars. The commenter contends that whether or not the FRM is in low or high flow mode, it cannot keep up with the need due to pressure and temperature changes and out-gassing of the fuel.

FAA Reply: We do not concur. The special conditions require that the flammability analysis take into account any periods where the FRM is inoperative or does not have the capacity to maintain a non-flammable fuel tank ullage. We agree with the commenter that out-gassing of dissolved air in the fuel may affect the oxygen concentration in the fuel tank during certain flights. These special conditions require that this factor be considered when determining the portion of the flammability exposure evaluation time (FEET) when the FRM cannot maintain a non-flammable ullage. This portion of the fleet average flammability exposure is limited to 1.8 percent. The special condition requirements are intended to provide an additional layer of protection to the existing certification standards that require designs to preclude fuel tank ignition sources. This balanced risk management approach of precluding ignition sources and reducing flammability exposure in certain fuel tanks provides two independent layers for preventing fuel tank explosions in those tanks. No changes were made as a result of these comments.

Comment: The commenter requests that the entire discussion of ''Inerting System Indications'' be reworded. It is the commenter's position that the special conditions should establish the certification requirements not already established by existing part 25 requirements. The commenter says that the reliability requirement for the FRM is clearly established in paragraph II (a)(2) of the special conditions as to not contribute more than 1.8% overall fleet flammability exposure. The commenter believes the required inspections and associated inspection intervals should be developed by the applicant in support of complying with the 1.8% limit. The applicant should have the flexibility to design a system that has high reliability (at higher equipment cost) with fewer inspections required, or lower reliability and higher frequency of inspection with less time allowed for MMEL dispatch. The commenter also believes that this is consistent with § 25.981(c), amendment 25–102, where it specifically states that ''minimize'' means to incorporate practicable design methods to reduce the likelihood of flammable vapors.

FAA Reply: We do not concur. The special conditions do provide the applicant with flexibility to design the FRM either to higher reliability and longer inspection intervals or lower reliability with more frequent inspections, as long as the contributions for either performance of the system or its reliability are not greater than 1.8 percent of the total 3 percent fleet average flammability exposure. The approved maintenance procedures and intervals established by the FOEB will be based on the applicant's fleet average flammability exposure data submitted to the FAA. No changes were made as a result of these comments.

Affect of FRM on Auxiliary Fuel Tank System Supplemental Type Certificates

Comment: The commenter believes the applicant should validate, as part of the certification effort, that the performance and reliability requirements for the FRM are met for any approved combination of auxiliary fuel tank installations. The commenter does not understand how installation of an FRM on an airplane with auxiliary fuel tanks can be adequately assessed ''during development and approval of the service bulletin for the FRM.''

FAA Reply: We concur and have added a requirement in special condition II (a)(3) for the applicant to ''identify critical features of the fuel tank system to prevent an auxiliary fuel tank installation from increasing the flammability exposure of the center wing tank above that permitted under paragraph II (a)(1) and (2) and to prevent degradation of the performance and reliability of the FRM.'' We have also added a requirement under paragraph III (a)(3) to establish airworthiness limitations to address these features.

Disposal of Oxygen-Enriched Air

Comment: One commenter refers to the statement, ''the OEA produced in the proposed design is diluted with air from a heat exchanger, which is intended to reduce the OEA concentration to non-hazardous levels.'' The commenter says that although this is a particular solution to the hazard, it should not be seen as the only solution. The term ''hazardous'' is open to interpretation; thus, this discussion is considered as too design specific.

FAA Reply: We agree with the commenter that there are a number of different means of addressing any hazards associated with the OEA. These special conditions are applicable to the applicant's proposal for certification of their FRM design. The description of the particular design feature noted by the commenter was not intended to limit other means of compliance should another applicant propose an FRM. We will evaluate each FRM based on the proposed design. No changes were made as a result of these comments.

Comment: The commenter requests that the first paragraph of this discussion be replaced with the following: ''The FRM produces both nitrogen-enriched air (NEA) and oxygen-enriched air (OEA). The OEA generated by the FRM could result in a fire hazard if not disposed of properly. Compliance with existing requirements of § 25.863 are sufficient to address potential leakage of OEA due to failures and safe disposal of the OEA during normal operation.'' The commenter requests this change to make OEA leakage compliance requirements consistent with those applicable for other flammable leakage zone items.

FAA Reply: We concur with the commenter that certification of the FRM will require the applicant to evaluate installation of equipment in a flammable fluid leakage zone for compliance with § 25.863. However, compliance with § 25.901 is required to ensure that no single failure or malfunction, or probable combination of failures, will jeopardize the safe operation of the airplane. Depending on where the OEA is discharged, other part 25 regulations might apply. No changes were made as a result of these comments.

Applicability

Comment: The commenter notes that the airplane applicability is not consistent. Furthermore, the commenter says § 25.981(c), amendment 25–102, is only applicable to new type designs, and therefore these special conditions should apply to new type designs and may extend to newly built airplanes. If the special conditions were proposed for other Boeing Model airplanes (737, 777, etc.), the commenter believes the standards established for the 747 airplanes should also be applicable for these models.

FAA Reply: We concur with the commenter that the airplane applicability was inconsistent in certain sections of the proposed special conditions in that these sections excluded the 747–100B and 747–300 series airplanes. We have corrected the applicable sections of the final special conditions to show the applicability as Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes. The applicant has voluntarily proposed to show compliance with amendment 25–102 plus the additional requirements of the special conditions for an inerting system for the affected Boeing Model 747 series airplanes. As stated earlier, these special conditions will be the baseline for the other airplane models for which the applicant plans to seek approval of an FRM. No changes were made as a result of this comment.

Special Conditions

I. Definitions

Comment: The commenter requests the definition for flammable be revised to read as follows:

> *Flammable.* With respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding (14 CFR Part 1, Definitions). A non-flammable ullage is one where the gas mixture is too lean or too rich to burn and/or is inert per the definition of inert below. For the purposes of these special conditions, a fuel tank is considered flammable when the ullage is not inert and the fuel vapor concentration is within the flammable range for the fuel type being used. The fuel vapor concentration of the ullage in a fuel tank shall be determined based on the average fuel temperature within the tank. This vapor concentration shall be assumed to exist throughout all bays of the tank. An exception to this shall be utilized when one or more major portion of the tank is exposed to grossly dissimilar heating conditions. In this situation, the vapor concentration of this major portion shall be determined independently based upon the fuel temperature of this portion.

The commenter requests this change because the wording, as proposed in the notice, is inconsistent with the modeling methods required in appendix 2 of the special conditions. The development of the concept of assessing average fleet flammability exposure using a Monte Carlo analysis was based on the use of an average bulk fuel temperature of the entire center wing fuel tank. This is the parameter that was defined in conjunction with the conclusion that achieving a 3 percent average fleet flammability exposure criteria would be considered equivalent to providing similar characteristics to the type certificated model's unheated aluminum wing tanks when the same fuel is used in the calculation, as required by § 25.981(c). None of the Monte Carlo analytical modeling to date by the FAA, the two ARAC studies, or the Boeing Company have been based on individual tank compartment fuel temperatures. Each of these analyses has been based on the average temperature of the fuel and applying the flammability exposure based on that fuel temperature to all bays. The commenter references FAA Report DOT/FAA/AR–TN99/65 for supporting test data.

FAA Reply: We concur, in part, with the commenter. As stated earlier, we have modified the definition of flammable to ''With respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding (14 CFR part 1, Definitions). A non-flammable ullage is one where the gas mixture is too lean or too rich to burn and/or is inert per the definition of inert below.''

To ensure that flammability of individual bays is accounted for in the Monte Carlo analysis, we have added clarification in appendix 2 that reads:

For the purposes of these special conditions, a fuel tank is considered flammable when the ullage is not inert and the fuel vapor concentration is within the flammable range for the fuel type being used. The fuel vapor concentration of the ullage in a fuel tank shall be determined based on the bulk average fuel temperature within the tank. This vapor concentration must be assumed to exist throughout all bays of the tank. For those airplanes with fuel tanks having different flammability exposure within different compartments of the tank, the flammability of the compartments must be analyzed individually in the Monte Carlo analysis. The highest flammability exposure must be used in the analysis. For example, the center wing fuel tank in some designs extends into the wing and has portions of the tank that are cooled by outside air, and other portions of the tank that are insulated from outside air. Therefore, the fuel temperature is different than the portion of the fuel tank in the wing.

Comment: One commenter says use of the term ''employee'' in the definition for ''hazardous atmosphere'' is questionable. The commenter considers it more appropriate to extend the definition to cover the risk to maintenance personnel, passengers, flightcrew, etc.

FAA Reply: We concur with the commenter and have revised the definition of ''hazardous atmosphere'' to address any person(s).

Comment: A commenter requests clarification of the definition of inert (what is the percentage at sea level to meet the 12 percent or less oxygen limit at 10,000 feet?). The commenter also asks if the NEA supply can keep up with demand through 10,000 feet. The commenter says the altitude should be 15,000 feet because TWA 800 exploded at 13,500 feet. The commenter also says there is conjecture that the oxygen concentration in the fuel tank ullage will have to be less than 10 percent at sea level to keep the oxygen level below 12 percent at 10,000 feet.

FAA Reply: We do not concur. The definition of inert is based on FAA testing as explained previously. No changes were made as a result of these comments.

Comment: In reference to the definition of a Monte Carlo analysis, the commenter notes that the FAA used the ARAC analysis in the model as the means of compliance with the special conditions. The commenter says this analysis did not include transport effects, which they believe should be included, as well as flammability effects on center wing tank heated unusable (empty, 0 quantity indication) fuel. They say the fuel temperature within a specific compartment of the tank could be within the flammable range for the fuel type being used if the tank was empty and heat sources were next to the compartment.

FAA Reply: We do not concur. As explained earlier, we excluded both of the phenomena (mass loading and fuel vaporization and condensation) that are part of the definition of transport effects, because they were not considered by ARAC when they established the flammability requirements. If they had included these effects in the wing tank flammability exposure calculation, the wing tank flammability exposure benchmark value would have been significantly lower, which could result in more restrictive requirements for center wing tank flammability exposure. No changes were made as a result of these comments.

Comment: Two commenters request clarification of the definition of operational time. One commenter proposes the definition be revised to read as follows for consistency with AC 25.981–2 and the Monte Carlo analysis: This commenter says the current definition would not result in a clearly defined number of flights per day for use in the Monte Carlo analysis and would basically define the daily operational time as one continuous period of time.

''*Operational Time.* For the purpose of these special conditions, the time from the start of preparing the airplane for flight (that is, starting and connecting the auxiliary or ground power unit to the aircraft electrical system) through the actual flight and landing, and through the time to disembark any payload, passengers and crew.''

FAA Reply: We concur in part. Because the definition of operational time in these special conditions is not consistent with the definition in 14 CFR part 1, Definitions, we have replaced ''operational time'' with the term ''flammability exposure evaluation time (FEET).'' We have revised the definition to read as follows:

Flammability Exposure Evaluation Time (FEET). For the purpose of these special conditions, the time from the start of preparing the airplane for flight, through the flight and landing, until all payload is unloaded and all passengers and crew have disembarked. In the Monte Carlo program, the flight time is randomly selected from the Mission Range Distribution (Table 3), the pre-flight times are provided as a function of the flight time, and the post-flight time is a constant 30 minutes.

Comment: This commenter believes additional definitions need to be added such as operational time, fleet average, etc., for clarification.

FAA Reply: We concur in part. The definition of operational time is already addressed in Special Condition I. Definitions, and we have added additional definitions for clarification as needed.

II. System Performance and Reliability

Comment: Several commenters request clarification of paragraph II (a)(2). One commenter assumes that the FRM can be non-operational for 1.8 percent of the airplane operational life. This commenter says elsewhere in the special conditions more stringent requirements are implied (for example ''shortest practical MMEL relief''), which is inconsistent. The commenter considers the 1.8 percent requirement to be sufficient. Another commenter requests explanation of the percentage figures quoted in paragraphs II (a), (b), and (c).

FAA Reply: The 1.8 percent maximum contribution requirement for an inoperative FRM is for an airplane fleet, not an individual airplane. The special conditions limit the maximum fleet average flammability exposure to 3 percent. The performance or reliability contributions can be up to 1.8 percent, as long as the overall fleet average flammability exposure does not exceed a total of 3 percent. The contribution for FRM performance would be limited to 1.2 percent if the reliability contribution were 1.8 percent. The 3 percent warm day requirement is a separate performance requirement that must be met for warm day ground, takeoff, and climb flight profiles and therefore does not include the contribution for reliability of the system. All of these requirements establish the minimum safety standards. No changes were made as a result of these comments.

Comment: The commenter refers to the statement in paragraph II (c) that ''the applicant must provide data from ground testing and flight testing'' to show compliance with paragraphs II (a), (b), and (c)(2). The commenter believes that the means of compliance should be left to the applicant. The paragraph should therefore read, ''The applicant must provide appropriate data * * *''

Comment: Another commenter also requests a change to paragraph II(c). This commenter suggests the following: ''The applicant must provide data from analysis and/or testing.'' The commenter says use of analysis and/or testing is consistent with normal processes used to demonstrate compliance with part 25 requirements.

FAA Reply: We do not concur with the commenters. The wording of the special condition is consistent with other regulations where test data is needed to demonstrate compliance. Analysis alone is not considered adequate for demonstrating compliance with the special condition requirements because with this new technology there is not a sufficient experience base from which to derive a reliable analysis. No changes were made as a result of these comments.

Comment: One commenter requests clarification why paragraph II (c) has been included in the requirements listed under paragraphs II (c)(1), II (d), and III (a).

FAA Reply: We infer from the comment that the reference to paragraph II (c) should be removed from paragraphs II (c)(1), II (d), and III (a) and we concur. We have therefore revised the special conditions to change the reference in the noted paragraphs to paragraph II (c)(2).

Comment: The commenter requests that the four elements involved with the fleet average flammability exposure, as referenced in ''Inerting System Indications,'' be included in paragraph II (e).

FAA Reply: We do not concur. The special conditions do not dictate a specific design, but rather state that indication and/or maintenance checks will be required to ensure that the performance and reliability of the FRM meets the special conditions requirements. No changes were made as a result of this comment.

Comment: The commenter recommends that paragraph II (f) be expanded to state that appropriate markings are required for all inerted fuel tanks, tanks adjacent to inerted fuel tanks, and all fuel tanks communicating with the inerted tanks via plumbing. The plumbing includes, but is not limited to, vent system, fuel feed system, refuel system, transfer system and cross-feed system plumbing. NEA could enter adjacent fuel tanks via structural leaks. It could also enter other fuel tanks through plumbing, if valves are operated or fail in the open position. The hazardous markings should also be stenciled on the external upper and lower surfaces of the inerted tank to ensure maintenance personnel are aware of the possible contents of the fuel tank.

FAA Reply: We concur in part. We revised paragraph II (f) to clarify that any fuel tank with an FRM must be marked as required, as well as any confined spaces or enclosed areas that could contain NEA under normal conditions or failure conditions. The special condition already requires the applicant to mark access doors and panels to any fuel tank that communicates with an inerted tank.

Comment: Two commenters say that in paragraph II (g) it is not clear which ''normal'' operating conditions the FAA is referring to, and if this requirement is intended to address any FRM failures, or only hazards related to the oxygen-enriched air. Both consider the criteria specified in this paragraph to be inadequate. One commenter says the FRM installation must be shown to comply with the safety requirements of § 25.1309 (demonstrate that an inverse relationship exists between the probability of an event, failure condition, and its severity). The second commenter requests that paragraph II (g) be revised to read: ''Oxygen-enriched air produced by the nitrogen generation system must not create a hazard during all FRS operating conditions and it must be established that no single failure or malfunction or probable combination of failures will jeopardize the safe operation of the airplane.''

Comment: Another commenter requests paragraph II (g) be revised to read: ''Oxygen-enriched air produced by the nitrogen generation system must not create a hazard during normal operating conditions (refer to 14 CFR 25.863).'' The commenter requests this change to make OEA leakage compliance requirements consistent with those applicable for other flammable leakage zone items.

FAA Reply: We concur, in part, with the commenters. The intent of this requirement is to address any hazards associated with both normal operating and failure conditions and not just when the FRM is operating. This intent was not clear in the original proposal. We have revised paragraph II (g) to state that, ''Any FRM failures, or failures that could affect the FRM, with potential catastrophic consequences must not result from a single failure or a combination of failures not shown to be extremely improbable.'' Note that approval of the FRM design will require the applicant to evaluate installation of equipment in a flammable fluid leakage zone for compliance with § 25.863. However, compliance with the existing general requirements of § 25.901 is required to ensure that no single failure or malfunction or probable combination of failures will jeopardize the safe operation of the airplane.

III. Maintenance

Comment: The commenter requests paragraph III (a) be changed to: ''Maintenance and/or inspection tasks needed to identify items without failure indication, so that FRM reliability does not fall below the values assumed in the Monte-Carlo analysis, must be identified as Airworthiness Limitations.'' The requirement to identify Airworthiness Limitations for all maintenance and/or inspection tasks is unprecedented in part 25 certification and would impose an unjustified burden on operators. The application of this special condition wording to other parts of the fuel system would, in essence, require an Airworthiness Limitation to inspect the flight deck lights for basic indications such as pump low pressure lights and status messages. It is the commenter's position that identifying Airworthiness Limitations only for items without failure indication will ensure that the desired inspections to identify latent failures are accomplished, without an impractical burden on the operators.

FAA Reply: We concur, in part, with the commenter. Paragraph III (a) is not intended to apply to all maintenance and/or inspection tasks, just those necessary to identify failures related to FRM performance and reliability requirements. No changes were made as a result of these comments.

Comment: The commenter requests that paragraph III(c)(1) be changed to: ''Develop and introduce an event monitoring and reporting system acceptable to the primary certification authority.'' The commenter requests this change because the proposed requirement to track inoperative time would result in the introduction of new recordkeeping processes, which, in turn, will result in a significant increase in the maintenance and operational burden on the operators. The commenter accepts that the FRM system reliability should be initially monitored, but the requirement should allow the flexibility for existing operator and reliability reporting systems to be used to evaluate actual in-service system reliability, at practical costs.

FAA Reply: We do not concur. We believe the applicant will be able to gather the required data from operators using existing reporting systems that are currently in use for airplane maintenance, reliability, and warranty claims. We anticipate the operators would provide this information to the applicant through existing business arrangements. No changes were made as a result of these comments.

Comment: One commenter believes initiation of component and/or system modification should also be included in paragraph III (c)(4) for correcting failures of the FRM that increase the fleet flammability exposure. Another commenter says paragraph III (c)(4) is not clear as to whether this statement refers to the 3 percent flammability requirement of paragraph II (a) or II (b), or both. This commenter believes paragraph III (c)(4) should specifically address the requirements of both paragraphs II (a) and II (b) of the special conditions.

FAA Reply: We concur with the commenters that paragraph III (c)(4) needs clarification. We have revised this paragraph to read: ''Develop service instructions or revise the applicable airplane manual, per a schedule agreed to by the FAA, to correct any failures of the FRM that occur in service that could increase the fleet average or warm day flammability exposure of the tank to more than the exposure requirements of paragraphs II (a) and II (b) of these special conditions.''

Comment: The commenter requests that an additional requirement be added that would instruct an applicant to provide training material to the industry to incorporate any new design system. This would include any specific dangers and safety factors. The amendment of all technical documentation, including Airplane Maintenance Manual (AMM), Airplane Flight Manual (AFM), etc., is not enough.

FAA Reply: We do not concur with the commenter. The applicant must provide service bulletins that will instruct the operators how to properly install an FRM, which should include any specific dangers or safety factors that need to be considered during installation. The applicant is also responsible for providing any materials necessary to ensure an operator knows how to properly operate and maintain the system. Training is outside the scope of these special conditions. No changes were made as a result of this comment.

Appendix 1: Monte Carlo Analysis

Comment: The commenter requests the following note be added to paragraph (b)(3): ''**Note:** localized concentrations above the inert level are allowed provided the volume of the non-inert region would not produce a hazardous condition.'' The commenter says the fresh air drawn into the fuel tank through the vent during descent will not be flammable and will not cause the tank to become flammable during descent. The commenter believes that counting these non-hazardous periods as ''flammable'' would increase the system size, weight, and associated costs with no benefit.

FAA Reply: We agree that a note paragraph would be appropriate and have added the following to paragraph (b)(3): ''**Note:** localized concentrations above the inert level as a result of fresh air that is drawn into the fuel tank through vents during descent would not be considered as flammable.''

Comment: The commenter requests the following change to paragraph (b)(5): ''Proposed MMEL/MEL dispatch periods including action to be taken when dispatching with the FRM inoperative.'' The commenter says the MMEL process is outside the scope of the special conditions. The specific MMEL time should be based on fleet data for similar systems, not a prescriptive mandate of 60 hours. The actual inoperative MMEL interval and corresponding fleet exposure used in the Monte Carlo analysis is one of a number of items whose inoperative interval would be substantiated as part of achieving part 25 certification. During any part 25 certification project, providing acceptable substantiating data to the FAA for assumptions and analytical processes is the responsibility of the applicant.

FAA Reply: The establishment of an MMEL dispatch interval will be achieved through the certification process, whereby the Flight Operations Evaluation Board (FOEB) will review the applicable data submitted by the applicant to determine if the proposed dispatch interval is appropriate. However, the special conditions include the requirement in appendix 1, paragraph (b)(5), to allow the applicant to use an inoperative FRM interval that is shorter than the maximum proposed interval of ten days, if they can substantiate that the 3 percent flammability requirement can be met when operating with an inoperative FRM. Otherwise, 60 flight hours must be used in the analysis for a proposed 10-day MMEL dispatch interval. No changes were made as a result of these comments.

Comment: The commenter contends that in paragraph (b)(5) it should be noted that the assumed 60 flight hours for a 10-day MMEL is the ''average'' MMEL/MEL dispatch inoperative period.

FAA Reply: We recognize that not all MMEL inoperative periods will typically occupy the full allowed MMEL dispatch interval. To account for this, the special conditions require an average 60 flight hours to be used in the Monte Carlo analysis for a 10-day MMEL dispatch interval. This is based on using an average airplane utilization of 12 hours per day, and an average of one-half the proposed 10-day MMEL dispatch interval. No changes were made as a result of this comment.

Appendix 2: Atmosphere

Comment: The commenter says that oxygen monitoring would eliminate the need to compute the transitional temperature, as required in this section of appendix 2. This is because the oxygen monitoring system measures the temperature in the tanks and uses that temperature in the calculations to determine the oxygen percentage present.

FAA Reply: From the comment, we infer that the commenter is questioning why a temperature needs to be calculated for the Monte Carlo analysis when an oxygen sensor can be used to measure temperature in the fuel tank. Modeling the atmosphere during climb and descent using the tables in appendix 2 is required to determine the flammability exposure for use in the Monte Carlo analysis. It is not related to possible design features such as an oxygen sensor. No changes were made as a result of this comment.

Comment: The commenter would like to know who would make the decision regarding the use of lower flash point fuels for more than 1percent of the fleet operating time. The commenter asks how this determination will be made to apply to a particular airplane flown with a particular defined flight profile. Another commenter believes there should be allowance for factoring in a higher flash point for fuels if used for more than 1 percent of the fleet operating time.

Comment: A third commenter requests that the 3rd and 4th sentences in paragraph three of the ''Atmosphere'' discussion be changed to:

> Table 2 is based on typical use of Jet A type fuel, with limited TS–1 use. If an airplane fleet is expected to operate with low flash point fuels (such as JP–4) more than 1 percent of its operating time, or intermediate flash point fuels (such as TS–1) more than 10 percent of the fleet operating time, then the Monte Carlo analysis must include fuel property variation acceptable to the FAA for these approved fuels.

The commenter believes this change clarifies that some TS–1 fuel is already included in the Table 2 distribution, and adds a separate usage limit for low and intermediate flash point fuel that would require development of new worldwide fuel type studies only if exceeded. Currently, there are no data available to use for a statistical distribution of non Jet-A type fuels and it is unreasonable to expect an applicant to provide a Monte Carlo analysis incorporating a flammability exposure dataset for these other fuels where the appropriate data is not available. The impact on the flammability analysis of up to 10 percent use of intermediate flash point fuels would be small; therefore, the study is not justified unless it is expected that the use of these fuels would exceed 10 percent.

FAA Reply: We agree, in part, with the commenters. The fuel properties tables in appendix 2 of the special conditions include a distribution of flash points reflecting an FAA survey of jet fuels used in both U.S. domestic and international routes. The tables therefore include an allowance for use of lower flash points fuels. The intent of the Monte Carlo analysis method is to provide a standardized analysis method to compare the flammability of the fuel tank under evaluation to the established flammability limits. The flammability limits were established based on a Monte Carlo analysis using the flash point table in these special conditions. To simplify the standardized analysis, we have deleted the need to consider other fuel flash point distributions from these special conditions.

Appendix 2: Oxygen Evolution

Comment: The commenter asks, if 12 percent or less oxygen percentage is tolerable at 10,000 feet (as opposed to 20.9 at sea level before NEA is available to the fuel tank), what oxygen concentration is needed on the ground at departure if the FRM is not fully effective immediately after engine start? Can the available NEA high flow rate keep up with the possible out gassing of the 30 percent oxygen level in the fuel in order to be at an oxygen level of 12 percent or less at 10,000 feet?

FAA Reply: The flammability requirements in the special conditions will limit the maximum oxygen concentration. We expect that if the FRM were not designed so that the oxygen concentration of the center wing fuel tank ullage is below 12 percent at sea level, it would not meet these requirements. It is also not possible to meet the specific risk requirements in the special conditions for warm day operations if the FRM does not reduce the oxygen concentration level below 12 percent during ground operations. The affects of oxygen evolution during climb must be accounted for in the analysis required by these special conditions. These special conditions do not preclude exceeding the 12 percent oxygen concentrations during transient conditions. For example, the tank may no longer be inert during a high descent rate or during a rapid climb where the tank could be above the 12 percent oxygen level for short periods of time. As previously discussed, we do not believe it is practical to require an FRM that would inert the fuel tank during all operational conditions within the airplane operating envelope. No changes were made as a result of these comments.

Comment: The commenter says the last sentence of this discussion should read, ''The applicant must provide the assumptions relating to air evolution rate'' because provision of substantiated data would not be possible due to the uncertain manner in which air evolves from the fuel during climb.

FAA Reply: We agree with the commenter that air evolution rates are uncertain and can vary from flight to flight depending on the fuel load and the conditions under which the fuel was loaded. However, we do not agree that it will not be possible to provide data to substantiate the air evolution rate for the center wing fuel tank. The FAA has not seen large transients related to air evolution during airplane model testing (FAA Report No. DOT/FAA/AR–01/63, ''Ground and Flight Testing of a Boeing 737 Center Wing Fuel Tank Inerted With Nitrogen-Enriched Air.'' We would expect air evolution rates determined by flight testing with typical fuel loading to be representative of those anticipated in service, so this data should be sufficient to address the effects of air evolution on oxygen concentrations. No changes were made as a result of this comment.

Other

In addition to the changes to the special conditions in response to comments, we made some changes to provide additional clarification in certain areas. Because those changes do not change the intent of the special conditions, they are not included in the discussion of comments.

Applicability

As discussed above, these special conditions are applicable to the Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes. Should the type certificate be amended later to include any other model that incorporates the same or similar novel or unusual design feature, or should any other model already included on the same type certificate be modified to incorporate the same or similar novel or unusual design feature, the special conditions would also apply to the other model under the provisions of § 21.101.

Conclusion

This action affects only certain novel or unusual design features on Boeing Model 747–100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F series airplanes. It is not a rule of general applicability and affects only the applicant who applied to the FAA for approval of these features on the airplane.

List of Subjects in 14 CFR Part 25

Aircraft, Aviation safety, Reporting and recordkeeping requirements.

■ The authority citation for these special conditions is as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

The Special Conditions

■ Accordingly, pursuant to the authority delegated to me by the Administrator, the following special conditions are issued as part of the type certification basis for Boeing Model 747–100/200B/200F/200C/ SR/SP/100B/300/100B SUD/400/400D/400F series airplanes, modified by Boeing Commercial Airplanes to include a flammability reduction means (FRM) that uses a nitrogen generation system to inert the center wing tank with nitrogen-enriched air (NEA).

Compliance with these special conditions does not relieve the applicant from compliance with the existing certification requirements.

I. *Definitions.* (a) *Bulk Average Fuel Temperature.* The average fuel temperature within the fuel tank, or different sections of the tank if the tank is subdivided by baffles or compartments.

(b) *Flammability Exposure Evaluation Time (FEET).* For the purpose of these special conditions, the time from the start of preparing the airplane for flight, through the flight and landing, until all payload is unloaded and all passengers and crew have disembarked. In the Monte Carlo program, the flight time is randomly selected from the Mission Range Distribution (Table 3), the pre-flight times are provided as a function of the flight time, and the post-flight time is a constant 30 minutes.

(c) *Flammable.* With respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding (14 CFR part 1, Definitions). A non-flammable ullage is one where the gas mixture is too lean or too rich to burn and/or is inert per the definition below.

(d) *Flash Point.* The flash point of a flammable fluid is the lowest temperature at which the application of a flame to a heated sample causes the vapor to ignite momentarily, or ''flash.'' The test for jet fuel is defined in ASTM Specification D56, ''Standard Test Method for Flash Point by Tag Close Cup Tester.''

(e) *Hazardous Atmosphere.* An atmosphere that may expose any person(s) to the risk of death, incapacitation, impairment of ability to self-rescue (escape unaided from a space), injury, or acute illness.

(f) *Inert.* For the purpose of these special conditions, the tank is considered inert when the bulk average oxygen concentration within each compartment of the tank is 12 percent or less at sea level up to 10,000 feet, then linearly increasing from 12 percent at 10,000 feet to 14.5 percent at 40,000 feet and extrapolated linearly above that altitude.

(g) *Inerting.* A process where a noncombustible gas is introduced into the ullage of a fuel tank to displace sufficient oxygen so that the ullage becomes inert.

(h) *Monte Carlo Analysis.* An analytical tool that provides a means to assess the degree of fleet average and warm day flammability exposure time for a fuel tank. See appendices 1 and 2 of these special conditions for specific requirements for conducting the Monte Carlo analysis.

(i) *Transport Effects.* Transport effects are the effects on fuel vapor concentration caused by low fuel conditions, fuel condensation, and vaporization.

(j) *Ullage, or Ullage Space.* The volume within the fuel tank not occupied by liquid fuel at the time interval under evaluation.

II. *System Performance and Reliability.* The FRM, for the airplane model under evaluation, must comply with the following performance and reliability requirements:

(a) The applicant must submit a Monte Carlo analysis, as defined in appendices 1 and 2 of these special conditions, that—

(1) Demonstrates that the overall fleet average flammability exposure of each fuel tank with an FRM installed is equal to or less than 3 percent of the FEET; and

(2) Demonstrates that neither the performance (when the FRM is operational) nor reliability (including all periods when the FRM is inoperative) contributions to the overall fleet average flammability exposure of a tank with an FRM installed is more than 1.8 percent (this will establish appropriate maintenance inspection procedures and intervals as required in paragraph III (a) of these special conditions).

(3) Identifies critical features of the fuel tank system to prevent an auxiliary fuel tank installation from increasing the flammability exposure of the center wing tank above that permitted under paragraphs II (a)(1) and (2) of these special conditions and to prevent degradation of the performance and reliability of the FRM.

(b) The applicant must submit a Monte Carlo analysis that demonstrates that the FRM, when functional, reduces the overall flammability exposure of each fuel tank with an FRM installed for warm day ground, takeoff, and climb phases to a level equal to or less than 3 percent of the FEET in each of these phases for the following conditions—

(1) The analysis must use the subset of 80 °F and warmer days from the Monte Carlo analyses done for overall performance; and

(2) The flammability exposure must be calculated by comparing the time during ground, takeoff, and climb phases for which the tank was flammable and not inert, with the total time for the ground, takeoff, and climb phases.

(c) The applicant must provide data from ground testing and flight testing that—

(1) Validate the inputs to the Monte Carlo analysis needed to show compliance with (or meet the requirements of) paragraphs II (a), (b), and (c)(2) of these special conditions; and

(2) Substantiate that the NEA distribution is effective at inerting all portions of the tank where the inerting system is needed to show compliance with these paragraphs.

(d) The applicant must validate that the FRM meets the requirements of paragraphs II (a), (b), and (c)(2) of these special conditions, with any combination of engine model, engine thrust rating, fuel type, and relevant pneumatic system configuration approved for the airplane.

(e) Sufficient accessibility for maintenance personnel, or the flightcrew, must be provided to FRM status indications necessary to meet the reliability requirements of paragraph II (a) of these special conditions.

(f) The access doors and panels to the fuel tanks with an FRM (including any tanks that communicate with an inerted tank via a vent system), and to any other confined spaces or enclosed areas that could contain NEA under normal conditions or failure conditions, must be permanently stenciled, marked, or placarded as appropriate to warn maintenance crews of the possible presence of a potentially hazardous atmosphere. The proposal for markings does not alter the existing requirements that must be addressed when entering airplane fuel tanks.

(g) Any FRM failures, or failures that could affect the FRM, with potential catastrophic consequences must not result from a single failure or a combination of failures not shown to be extremely improbable.

III. *Maintenance.* (a) Airworthiness Limitations must be identified for all critical features identified under paragraph II (a)(3) and for all maintenance and/or inspection tasks required to identify failures of components within the FRM that are needed to meet paragraphs II (a), (b), and (c)(2) of these special conditions.

(b) The applicant must provide the maintenance procedures that will be necessary and present a design review that identifies any hazardous aspects to be considered during maintenance of the FRM that will be included in the instructions for continued airworthiness (ICA) or appropriate maintenance documents.

(c) To ensure that the effects of component failures on FRM reliability are adequately assessed on an on-going basis, the applicant must—

(1) Demonstrate effective means to ensure collection of FRM reliability data. The means must provide data affecting FRM availablity, such as component failures, and the FRM inoperative intervals due to dispatch under the MMEL;

(2) Provide a report to the FAA on a quarterly basis for the first five years after service introduction. After that period, continued quarterly reporting may be replaced with other reliability tracking methods found acceptable to the FAA or eliminated if it is established that the reliability of the FRM meets, and will continue to meet, the exposure requirements of paragraphs II (a) and (b) of these special conditions;

(3) Provide a report to the validating authorities for a period of at least two years following introduction to service; and

(4) Develop service instructions or revise the applicable airplane manual, per a schedule agreed on by the FAA, to correct any failures of the FRM that occur in service that could increase the fleet average or warm day flammability exposure of the tank to more than the exposure requirements of paragraphs II (a) and (b) of these special conditions.

Appendix 1

Monte Carlo Analysis

(a) A Monte Carlo analysis must be conducted for the fuel tank under evaluation to determine fleet average and warm day flammability exposure for the airplane and fuel type under evaluation. The analysis must include the parameters defined in appendices 1 and 2 of these special conditions. The airplane specific parameters and assumptions used in the Monte Carlo analysis must include:

(1) FRM Performance—as defined by system performance.

(2) Cruise Altitude—as defined by airplane performance.

(3) Cruise Ambient Temperature—as defined in appendix 2 of these special conditions.

(4) Overnight Temperature Drop—as defined in appendix 2 of these special conditions.

(5) Fuel Flash Point and Upper and Lower Flammability Limits—as defined in appendix 2 of these special conditions.

(6) Fuel Burn—as defined by airplane performance.

(7) Fuel Quantity—as defined by airplane performance.

(8) Fuel Transfer—as defined by airplane performance.

(9) Fueling Duration—as defined by airplane performance.

(10) Ground Temperature—as defined in appendix 2 of these special conditions.

(11) Mach Number—as defined by airplane performance.

(12) Mission Distribution—the applicant must use the mission distribution defined in appendix 2 of these special conditions or may request FAA approval of alternate data from the service history of the Model 747.

(13) Oxygen Evolution—as defined by airplane performance and as discussed in appendix 2 of these special conditions.

(14) Maximum Airplane Range—as defined by airplane performance.

(15) Tank Thermal Characteristics—as defined by airplane performance.

(16) Descent Profile Distribution—the applicant must use either a fixed 2500 feet per minute descent rate or provide alternate data from the service history of the Model 747.

(b) The assumptions for the analysis must include—

(1) FRM performance throughout the flammability exposure evaluation time;

(2) Vent losses due to crosswind effects and airplane performance;

(3) Any time periods when the system is operating properly but fails to inert the tank;

Note: localized concentrations above the inert level as a result of fresh air that is drawn into the fuel tank through vents during descent would not be considered as flammable.

(4) Expected system reliability;

(5) The MMEL/MEL dispatch inoperative period assumed in the reliability analysis (60 flight hours must be used for a 10-day MMEL dispatch limit unless an alternative period has been approved by the FAA), including action to be taken when dispatching with the FRM inoperative (**Note:** The actual MMEL dispatch inoperative period data must be included in the engineering reporting requirement of paragraph III(c)(1) of these special conditions.);

(6) Possible time periods of system inoperability due to latent or known failures, including airplane system shut-downs and failures that could cause the FRM to shut down or become inoperative; and

(7) Affects of failures of the FRM that could increase the flammability of the fuel tank.

(c) The Monte Carlo analysis, including a description of any variation assumed in the parameters (as identified under paragraph (a) of this appendix) that affect flammability exposure, and substantiating data must be submitted to the FAA for approval.

Appendix 2

I. *Monte Carlo Model.* (a) The FAA has developed a Monte Carlo model that can be used to develop a specific analysis model for the Boeing 747 to calculate fleet average and warm day flammability exposure for a fuel tank in an airplane. Use of the program requires the user to enter the airplane performance data specific to the airplane model being evaluated, such as maximum range, cruise mach number, typical step climb altitudes, tank thermal characteristics specified as exponential heating/cooling time constants, and equilibrium temperatures for various fuel tank conditions. The general methodology for conducting a Monte Carlo model is described in AC 25.981–2.

(b) The FAA model, or one with modifications approved by the FAA, must be used as the means of compliance with these special conditions. The accepted model can be downloaded from the Web site *http://qps.airweb.faa.gov/sfar88flamex.* On this Web site, the model is located under the page ''Flam Ex Resources,'' and is titled ''Monte Carlo Model Version 6a.'' The ''6a'' represents Version 6A. Only version 6A or later of this model can be used. The following procedures, input variables, and data tables must be used in the analysis if the applicant develops a unique model to determine fleet average flammability exposure for a specific airplane type.

II. *Monte Carlo Variables and Data Tables.* (a) Fleet average flammability exposure is the percent of the mission time the fuel tank ullage is flammable for a fleet of an airplane type operating over the range of actual or expected missions and in a world-wide range of environmental conditions and fuel properties. Variables used to calculate fleet average flammability exposure must include atmosphere, mission length (as defined in Special Condition I. Definitions, as FEET), fuel flash point, thermal characteristics of the fuel tank, overnight temperature drop, and oxygen evolution from the fuel into the ullage. Transport effects, including mass loading, flammability lag time, and condensation of vapors due to cold surfaces, are not to be allowed as parameters in the analysis.

(b) For the purposes of these special conditions, a fuel tank is considered flammable when the ullage is not inert and the fuel vapor concentration is within the flammable range for the fuel type being used. The fuel vapor concentration of the ullage in a fuel tank must be determined based on the bulk average fuel temperature within the tank. This vapor concentration must be assumed to exist throughout all bays of the tank. For those airplanes with fuel tanks having different flammability exposure within different compartments of the tank, where mixing of the vapor or NEA does not occur, the Monte Carlo analysis must be conducted for the compartment of the tank with the highest flammability. The compartment with the highest flammability exposure for each flight phase must be used in the analysis to establish the fleet average flammability exposure. For example, the center wing fuel tank in some designs extends into the wing and has compartments of the tank that are cooled by outside air, and other compartments of the tank that are insulated from outside air. Therefore, the fuel temperature and flammability is significantly different between these compartments of the fuel tank.

(c) *Atmosphere.* (1) To predict flammability exposure during a given flight, the variation of ground ambient temperatures, cruise ambient temperatures, and a method to compute the transition from ground to cruise and back again must be used. The variation of the ground and cruise ambient temperatures and the flash point of the fuel is defined by a Gaussian curve, given by the 50 percent value and a ± 1 standard deviation value.

(2) The ground and cruise temperatures are linked by a set of assumptions on the atmosphere. The temperature varies with altitude following the International Standard Atmosphere (ISA) rate of change from the ground temperature until the cruise temperature for the flight is reached. Above this altitude, the ambient temperature is fixed at the cruise ambient temperature. This results in a variation in the upper atmospheric (tropopause) temperature. For cold days, an inversion is applied up to 10,000 feet, and then the ISA rate of change is used.

(3) The analysis must include a minimum number of flights, and for each flight a separate random number must be generated for each of the three parameters (that is, ground ambient temperature, cruise ambient temperature, and fuel flash point) using the Gaussian distribution defined in Table 1. The applicant can verify the output values from the Gaussian distribution using Table 2.

(d) *Fuel Properties.* (1) *Flash point variation.* The variation of the flash point of the fuel is defined by a Gaussian curve, given by the 50 percent value and a ± 1-standard deviation value.

(2) *Upper and Lower Flammability Limits.* The flammability envelope of the fuel that must be used for the flammability exposure analysis is a function of the flash point of the fuel selected by the Monte Carlo for a given flight. The flammability envelope for the fuel is defined by the upper flammability limit (UFL) and lower flammability limit (LFL) as follows:

(i) LFL at sea level = flash point temperature of the fuel at sea level minus 10 degrees F. LFL decreases from sea level value with increasing altitude at a rate of 1 degree F per 808 ft.

(ii) UFL at sea level = flash point temperature of the fuel at sea level plus 63.5 degrees F. UFL decreases from the sea level value with increasing altitude at a rate of 1 degree F per 512 ft.

Note: Table 1 includes the Gaussian distribution for fuel flash point. Table 2 also includes information to verify output values for fuel properties. Table 2 is based on typical use of Jet A type fuel, with limited TS–1 type fuel use.

TABLE 1.—GAUSSIAN DISTRIBUTION FOR GROUND AMBIENT TEMPERATURE, CRUISE AMBIENT TEMPERATURE, AND FUEL FLASH POINT

Temperature in Deg F			
Parameter	Ground ambient temperature	Cruise ambient temperature	Flash point (FP)
Mean Temp	59.95	−70	120
Neg 1 std dev	20.14	8	8
Pos 1 std dev	17.28	8	8

TABLE 2.—VERIFICATION OF TABLE 1

% Probability of temps & flash point being below the listed values	Ground ambient temperature Deg F	Cruise ambient temperature Deg F	Flash point Deg F	Ground ambient temperature Deg C	Cruise ambient temperature Deg C	Flash point (FP) Deg C
1	13.1	−88.6	101.4	−10.5	−67.0	38.5
5	26.8	−83.2	106.8	−2.9	−64.0	41.6
10	34.1	−80.3	109.7	1.2	−62.4	43.2
15	39.1	−78.3	111.7	3.9	−61.3	44.3
20	43.0	−76.7	113.3	6.1	−60.4	45.1
25	46.4	−75.4	114.6	8.0	−59.7	45.9
30	49.4	−74.2	115.8	9.7	−59.0	46.6
35	52.2	−73.1	116.9	11.2	−58.4	47.2
40	54.8	−72.0	118.0	12.7	−57.8	47.8
45	57.4	−71.0	119.0	14.1	−57.2	48.3
50	59.9	−70.0	120.0	15.5	−56.7	48.9
55	62.1	−69.0	121.0	16.7	−56.1	49.4
60	64.3	−68.0	122.0	18.0	−55.5	50.0
65	66.6	−66.9	123.1	19.2	−55.0	50.6
70	69.0	−65.8	124.2	20.6	−54.3	51.2
75	71.6	−64.6	125.4	22.0	−53.7	51.9
80	74.5	−63.3	126.7	23.6	−52.9	52.6
85	77.9	−61.7	128.3	25.5	−52.1	53.5
90	82.1	−59.7	130.3	27.8	−51.0	54.6
95	88.4	−56.8	133.2	31.3	−49.4	56.2
99	100.1	−51.4	138.6	37.9	−46.3	59.2

(e) *Flight Mission Distribution.* (1) The mission length for each flight is determined from an equation that takes the maximum mission length for the airplane and randomly selects multiple flight lengths based on typical airline use.

(2) The mission length selected for a given flight is used by the Monte Carlo model to select a 30-, 60-, or 90-minute time on the ground prior to takeoff, and the type of flight profile to be followed. Table 3 must be used to define the mission distribution. A linear interpolation between the values in the table must be assumed.

TABLE 3.—MISSION LENGTH DISTRIBUTION AIRPLANE MAXIMUM RANGE—NAUTICAL MILES (NM)

Flight length (NM)		Airplane maximum range (NM)									
From	To	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
		Distribution of mission lengths (%)									
0	200	11.7	7.5	6.2	5.5	4.7	4.0	3.4	3.0	2.6	2.3
200	400	27.3	19.9	17.0	15.2	13.2	11.4	9.7	8.5	7.5	6.7
400	600	46.3	40.0	35.7	32.6	28.5	24.9	21.2	18.7	16.4	14.8
600	800	10.3	11.6	11.0	10.2	9.1	8.0	6.9	6.1	5.4	4.8
800	1000	4.4	8.5	8.6	8.2	7.4	6.6	5.7	5.0	4.5	4.0
1000	1200	0.0	4.8	5.3	5.3	4.8	4.3	3.8	3.3	3.0	2.7
1200	1400	0.0	3.6	4.4	4.5	4.2	3.8	3.3	3.0	2.7	2.4
1400	1600	0.0	2.2	3.3	3.5	3.3	3.1	2.7	2.4	2.2	2.0
1600	1800	0.0	1.2	2.3	2.6	2.5	2.4	2.1	1.9	1.7	1.6
1800	2000	0.0	0.7	2.2	2.6	2.6	2.5	2.2	2.0	1.8	1.7
2000	2200	0.0	0.0	1.6	2.1	2.2	2.1	1.9	1.7	1.6	1.4
2200	2400	0.0	0.0	1.1	1.6	1.7	1.7	1.6	1.4	1.3	1.2
2400	2600	0.0	0.0	0.7	1.2	1.4	1.4	1.3	1.2	1.1	1.0
2600	2800	0.0	0.0	0.4	0.9	1.0	1.1	1.0	0.9	0.9	0.8
2800	3000	0.0	0.0	0.2	0.6	0.7	0.8	0.7	0.7	0.6	0.6
3000	3200	0.0	0.0	0.0	0.6	0.8	0.8	0.8	0.8	0.7	0.7
3200	3400	0.0	0.0	0.0	0.7	1.1	1.2	1.2	1.1	1.1	1.0
3400	3600	0.0	0.0	0.0	0.7	1.3	1.6	1.6	1.5	1.5	1.4
3600	3800	0.0	0.0	0.0	0.9	2.2	2.7	2.8	2.7	2.6	2.5

TABLE 3.—MISSION LENGTH DISTRIBUTION AIRPLANE MAXIMUM RANGE—NAUTICAL MILES (NM)—Continued

Flight length (NM)		Airplane maximum range (NM)									
From	To	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
		Distribution of mission lengths (%)									
3800	4000	0.0	0.0	0.0	0.5	2.0	2.6	2.8	2.8	2.7	2.6
4000	4200	0.0	0.0	0.0	0.0	2.1	3.0	3.2	3.3	3.2	3.1
4200	4400	0.0	0.0	0.0	0.0	1.4	2.2	2.5	2.6	2.6	2.5
4400	4600	0.0	0.0	0.0	0.0	1.0	2.0	2.3	2.5	2.5	2.4
4600	4800	0.0	0.0	0.0	0.0	0.6	1.5	1.8	2.0	2.0	2.0
4800	5000	0.0	0.0	0.0	0.0	0.2	1.0	1.4	1.5	1.6	1.5
5000	5200	0.0	0.0	0.0	0.0	0.0	0.8	1.1	1.3	1.3	1.3
5200	5400	0.0	0.0	0.0	0.0	0.0	0.8	1.2	1.5	1.6	1.6
5400	5600	0.0	0.0	0.0	0.0	0.0	0.9	1.7	2.1	2.2	2.3
5600	5800	0.0	0.0	0.0	0.0	0.0	0.6	1.6	2.2	2.4	2.5
5800	6000	0.0	0.0	0.0	0.0	0.0	0.2	1.8	2.4	2.8	2.9
6000	6200	0.0	0.0	0.0	0.0	0.0	0.0	1.7	2.6	3.1	3.3
6200	6400	0.0	0.0	0.0	0.0	0.0	0.0	1.4	2.4	2.9	3.1
6400	6600	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.8	2.2	2.5
6600	6800	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.2	1.6	1.9
6800	7000	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.1	1.3
7000	7200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.7	0.8
7200	7400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.7
7400	7600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.6
7600	7800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.7
7800	8000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.8
8000	8200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8
8200	8400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0
8400	8600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.3
8600	8800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1
8800	9000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8
9000	9200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
9200	9400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
9400	9600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9600	9800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9800	10000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

(f) *Fuel Tank Thermal Characteristics.* (1) The applicant must account for the thermal conditions of the fuel tank both on the ground and in flight. The Monte Carlo model, available on the website listed above, defines the ground condition using an equilibrium delta temperature (relative to the ambient temperature) the tank will reach given a long enough time, with any heat inputs from airplane sources. Values are also input to define two exponential time constants (one for a near empty tank and one for a near full tank) for the ground condition. These time constants define the time for the fuel in the fuel tank to heat or cool in response to heat input. The fuel is assumed to heat or cool according to a normal exponential transition, governed by the temperature difference between the current temperature and the equilibrium temperature, given by ambient temperature plus delta temperature. Input values for this data can be obtained from validated thermal models of the tank based on ground and flight test data. The inputs for the inflight condition are similar but are used for inflight analysis.

(2) Fuel management techniques are unique to each manufacturer's design. Variations in fuel quantity within the tank for given points in the flight, including fuel transfer for any purpose, must be accounted for in the model. The model uses a "tank full" time, specified in minutes, that defines the time before touchdown when the fuel tank is still full. For a center wing tank used first, this number would be the maximum flight time, and the tank would start to empty at takeoff. For a main tank used last, the tank will remain full for a shorter time before touchdown and would be "empty" at touchdown (that is, tank empty at 0 minutes before touchdown). For a main tank with reserves, the term empty means at reserve level rather than totally empty. The thermal data for tank empty would also be for reserve level.

(3) The model also uses a "tank empty" time to define the time when the tank is emptying, and the program uses a linear interpolation between the exponential time constants for full and empty during the time the tank is emptying. For a tank that is only used for longrange flights, the tank would be full only on longer-range flights and would be empty a long time before touchdown. For short flights, it would be empty for the whole flight. For a main tank that carried reserve fuel, it would be full for a long time and would only be down to empty at touchdown. In this case, empty would really be at reserve level, and the thermal constants at empty should be those for the reserve level.

(4) The applicant, whether using the available model or using another analysis tool, must propose means to validate thermal time constants and equilibrium temperatures to be used in the analysis. The applicant may propose using a more detailed thermal definition, such as changing time constants as a function of fuel quantity, provided the details and substantiating information are acceptable and the Monte Carlo model program changes are validated.

(g) *Overnight Temperature Drop.* (1) An overnight temperature drop must be considered in the Monte Carlo analysis as it may affect the oxygen concentration level in the fuel tank. The overnight temperature drop for these special conditions will be defined using:

- A temperature at the beginning of the overnight period based on the landing temperature that is a random value based on a Gaussian distribution; and
- An overnight temperature drop that is a random value based on a Gaussian distribution.

(2) For any flight that will end with an overnight ground period (one flight per day out of an average of "x" number of flights per day, (depending on use of the particular airplane model being evaluated), the landing outside air temperature (OAT) is to be chosen as a random value from the following Gaussian curve:

TABLE 4.—LANDING OAT

Parameter	Landing temperature °F
Mean Temp	58.68

TABLE 4.—LANDING OAT—Continued

Parameter	Landing temperature °F
neg 1 std dev	20.55
pos 1 std dev	13.21

(3) The outside air temperature (OAT) drop for that night is to be chosen as a random value from the following Gaussian curve:

TABLE 5.—OAT DROP

Parameter	OAT Drop temperature °F
Mean Temp	12.0
1 std dev	6.0

(h) *Oxygen Evolution.* The oxygen evolution rate must be considered in the Monte Carlo analysis if it can affect the flammability of the fuel tank or compartment. Fuel contains dissolved gases, and in the case of oxygen and nitrogen absorbed from the air, the oxygen level in the fuel can exceed 30 percent, instead of the normal 21 percent oxygen in air. Some of these gases will be released from the fuel during the reduction of ambient pressure experienced in the climb and cruise phases of flight. The applicant must consider the effects of air evolution from the fuel on the level of oxygen in the tank ullage during ground and flight operations and address these effects on the overall performance of the FRM. The applicant must provide the air evolution rate for the fuel tank under evaluation, along with substantiation data.

(i) *Number of Simulated Flights Required in Analysis.* For the Monte Carlo analysis to be valid for showing compliance with the fleet average and warm day flammability exposure requirements of these special conditions, the applicant must run the analysis for an appropriate number of flights to ensure that the fleet average and warm day flammability exposure for the fuel tank under evaluation meets the flammability limits defined in Table 6.

TABLE 6.—FLAMMABILITY LIMIT

Number of flights in Monte Carlo analysis	Maximum acceptable fuel tank flammability (%)
1,000	2.73
5,000	2.88
10,000	2.91
100,000	2.98
1,000,000	3.00

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