U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: FUEL TANK FLAMMABILITY REDUCTION MEANS

Date: 9/19/08

Initiated by: ANM-112

AC No. 25.981-2A

1. Purpose. This advisory circular (AC) provides information and guidance on compliance with the airworthiness standards for transport category airplanes about limiting the time a fuel tank may be flammable or mitigation of hazards from flammable fuel air mixtures within fuel tanks. This guidance is applicable to transport category airplanes for which a new, amended, or supplemental type certificate is requested, and for which Amendment 25-125 applies. It is also applicable to certain existing design approval holders and certain pending applications for new type certificates, supplemental type certificates and amended type certificates where required by §§ 26.33, 26.35, 26.37, and 26.39, contained in a subpart D to Title 14, Code of Federal Regulations (CFR) part 26, "Fuel Tank Flammability." Guidance on compliance with the associated requirements for operators of affected airplanes that must comply with requirements in 14 CFR parts 121, 125 and 129, to incorporate flammability reduction or ignition mitigation means by specified dates, will be contained in a separate document.

2. Applicability.

a. This guidance provided in this document is for design approval applicants and holders, airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport category airplane type certification engineers and their designees.

b. This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in demonstrating compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

c. This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

3. Cancellation. Advisory Circular (AC) 25.981-2, Fuel Tank Flammability Minimization, dated 4/18/01, is cancelled.

4. Related Documents.

a. Federal Aviation Regulations. The applicable sections of part 25 that prescribe the design requirements for the substantiation and certification about prevention of ignition sources within the fuel tanks of transport category airplanes include:

§ 25.863	Flammable fluid fire protection.
§ 25.901	Installation.
§ 25.954	Fuel system lightning protection.
§ 25.981	Fuel tank ignition prevention.

b. Advisory Circulars (AC). You can get the following FAA ACs from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, or on the internet at: http://www.airweb.faa.gov/rgl.

(1)	AC 25-8	Auxiliary Fuel System Installations.
(2)	AC 20-53B	Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Caused by Lightning.
(3)	AC 25.981-1B	Fuel Tank Ignition Source Prevention Guidelines.
(4)	AC 120-27	Aircraft Weight and Balance Control.
(5)	AC 26-1	Part 26, Continued Airworthiness and Safety Improvements
(6)	AC 25-26	Development of Standard Wiring Practices Documentation

c. Society of Automotive Engineers (SAE) Documents. You can get the following documents from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

(1) SAE AIR 5128, "Electrical Bonding of Aircraft Fuel System Plumbing Systems" (January 1997).

(2) SAE AIR 4170A, "Reticulated Polyurethane Safety Foam Explosion Suppressant Material for Fuel Systems and Dry Bays" (November 1998).

(3) SAE AIR 1662, "Minimization of Electrostatic Hazards in Aircraft Fuel Systems" (October 1984).

d. Military Specifications (MIL).

(1) MIL-B-83054, Baffle and Inerting Material, Aircraft Fuel Tank (March 1984). (Note: this reference provides an extensive list of military specifications about the use of polyurethane foam.) You can get a copy of this document from the Department of Defense, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, or on the internet at http://assist.daps.dla.mil/online/start/.

e. Other.

(1) FAA Document DOT/FAA/AR-98/26, "A Review of the Flammability Hazard of Jet A Fuel Vapor in Civil Transport Aircraft Fuel Tanks" (June 1998). (You can get a copy of this report from the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.fire.tc.faa.gov/pdf/ar98-26.pdf.

(2) Aviation Rulemaking Advisory Committee (ARAC), Fuel Tank Harmonization Working Group, Final Report (July 1998). You can get a copy of this report at the following web site address: http://www.regulations.gov, by inserting the associated docket number (Docket No. FAA-1998-4183) into the advanced docket search function. You can also get a copy of this report at the following web site address: http://www.fire.tc.faa.gov/systems/fueltank/papers.stm.

(3) "Effects of Fuel Slosh and Vibration on the Flammability Hazards of Hydrocarbon Turbine Fuels Within Aircraft Fuel Tanks," Technical Report AFAPL-TR-70-65 (November 1970), Edwin E. Ott. Contact the Air Force Aero Propulsion Laboratory, Airforce Systems Command, Wright-Patterson Air Force Base Ohio.

(4) FAA Document DOT/FAA/AR-99/65, "Mass Loading Effects on Fuel Vapor Concentrations in an Aircraft Fuel Tank Ullage." You can get a copy of this report from the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.fire.tc.faa.gov/pdf/tn99-65.pdf.

(5) FAA Document DOT/FAA/AR-00/19, "The Cost of Implementing Ground-Based Fuel Tank Inerting in the Commercial Fleet." DOT/FAA/AR-00/19 (May 2000). You can get a copy of this report from the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.fire.tc.faa.gov/pdf/00-19.pdf.

(6) FAA Document DOT/FAA/AR-01/6, "Inerting of a Vented Aircraft Fuel Tank Test Article with Nitrogen Enriched Air" (December 2000). You can get a copy of

this report from the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.fire.tc.faa.gov/pdf/01-6.pdf.

(7) "The Effectiveness of Ullage Nitrogen-Inerting Systems against 30-mm High-Explosive Incendiary Projectiles," China Lake Naval Weapons Center, J. Hardy Tyson and John F. Barnes, May 1991. You can get a copy of this report at the following web site address: http://www.regulations.gov, by inserting the docket number associated with this AC (FAA-2005-22997) into the advanced docket search function.

(8) FAA Document DOT/FAA/AR-TN02/79, "Limiting Oxygen Concentrations Required to Inert Jet Fuel Vapors Existing at Reduced Fuel Tank Pressures" (April 2003). You can get a copy of this report from the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.fire.tc.faa.gov/pdf/TN02-79.pdf.

(9) FAA Special Condition, "Boeing Model 747-100/200B/200F/200C/SR/SP/100B/300/100B SUD/400/400D/400F Airplanes; Flammability Reduction Means (Fuel Tank Inerting)," Docket No. NM270; Special Conditions No. 25-285-SC. You can get a copy of these special conditions at the following web site address: http://www.regulations.gov, by inserting the docket number associated with this AC (FAA-2005-22997) into the advanced docket search function.

(10) FAA Document DOT/FAA/AR-07/30, "Jet A Volatility Survey," July 2007. A copy of this report is available through the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.tc.faa.gov/its/worldpac/techrpt/ar0730.pdf.

(11) FAA Document DOT/FAA/AR-05/8, "Fuel Tank Flammability Assessment Method User's Manual" (May 2008), web site address: http://www.fire.tc.faa.gov/systems/fueltank/FTFAM.stm

(12) FAA Document DOT/FAA/AR-04/41, "Evaluation of Fuel Tank Flammability and the FAA Inerting System on the NASA 747 SCA" (December 2004), web site address: http://www.fire.tc.faa.gov/pdf/04-41.pdf.

(13) Aviation Rulemaking Advisory Committee (ARAC), Fuel Tank Inerting Harmonization Working Group, Final Report (February 2002). You can get a copy of this report at the following web site address: http://www.regulations.gov, by inserting the associated docket number (U.S. Department of Transportation (DOT) electronic dockets, Docket No. FAA-2005-22997) into the advanced docket search function. You can also get a copy of this report, at the following web site address: http://www.faa.gov/regulations_policies/rulemaking/committees/arac/media/ec/EC_FT_T2.pdf

(14) FAA Order 8110.104, Responsibilities and Requirements for Implementing Part 26 Safety Initiatives, Effective Date 12/3/07, You can get FAA Orders from the

U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, or available on the internet at: http://www.airweb.faa.gov/rgl.

(15) FAA Memo No. ANM-08-113-001, Policy Statement on Clarification of Maximum Payload Capacity Definition in Design Approval Holder Rules, dated September 12, 2008. You can get a copy on the internet at: http://www.airweb.faa.gov/rgl.

5. Definitions.

a. Auxiliary Fuel Tank is a tank installed to make additional fuel available for increasing the flight range of that airplane. The term “auxiliary” means that the tank is secondary to the airplane’s main fuel tanks, i.e., the functions of the main tanks are immediately available and operate without immediate supervision by the flightcrew in the event of failure or inadvertent depletion of fuel in an auxiliary tank. Auxiliary tanks are usually intended to be emptied of usable fuel during flight and have been installed in various locations including center wing structure, horizontal stabilizers, wings and cargo compartments. Therefore, auxiliary fuel tanks are “normally emptied” fuel tanks as defined below.

b. Main Fuel Tank is defined in § 25.981(b)(3)(iii) as “a fuel tank that feeds fuel directly into one or more engines and holds required fuel reserves continually throughout each flight.” The functions of the main tanks are immediately available and operate without immediate supervision by the flightcrew in the event of failure or inadvertent depletion of fuel in an auxiliary tank. Generally, main tanks are those dedicated to the feed of the engines during engine feed isolation.

c. Normally Emptied, with respect to fuel tanks, is defined in § 26.31(b) as “a fuel tank other than a Main Fuel Tank.” Main Fuel Tank is defined in § 25.981(b), and expanded above.

d. Bulk Average Fuel Temperature is defined in paragraph N25.2(a) of appendix N to part 25 as “the average fuel temperature within the fuel tank, or different sections of the tank if the tank is subdivided by baffles or compartments.”

e. Center Wing Tank (CWT) is a fuel tank located partially or entirely in the center of an airplane's wing box.

f. Design Approval Holder (DAH) is defined in AC 26-1 as the holder of any design approval, including type certificate, amended type certificate, supplemental type certificate, amended supplemental type certificate, parts manufacturer approval, Technical Standard Order (TSO) authorization, letter of TSO design approval, and field approvals. The definition in AC 26-1 adds that in particular contexts, the term DAH may also refer to applicants for design approvals. In the context of this AC, the term DAH applies to applicants for new design approvals and for changes to existing designs, and it applies to holders of design approvals and applicants for design approvals affected by part 26, subpart D.

g. Flammable, with respect to a fluid or gas, means susceptible to igniting readily or to exploding (14 CFR part 1, Definitions). A non-flammable ullage is one where the fuel-air vapor is too lean or too rich to burn or is inert as defined below. As defined in paragraph N25.2(c) of appendix N to part 25, "a fuel tank that is not inert is considered flammable when the bulk average fuel temperature within the tank is within the flammable range for the fuel type being used. For any fuel tank that is subdivided into sections by baffles or compartments, the tank is considered flammable when the bulk average fuel temperature within any section of the tank, that is not inert, is within the flammable range for the fuel type being used.

h. Fleet Average Flammability Exposure is defined in paragraph 25.2(e) of appendix N to part 25 as "the percentage of the flammability exposure evaluation time (FEET) each fuel tank ullage is flammable for a fleet of an airplane type operating over the range of flight lengths in a world-wide range of environmental conditions and fuel properties as defined in this appendix" (appendix N to part 25). Section 25.981(b)(3)(ii) explains this term "means the percent of time each fuel tank ullage is flammable for a fleet of an airplane type operating over the range of flight lengths." Fleet average flammability exposure is the total time the tank is flammable divided by the total FEET.

i. Flammability Exposure Evaluation Time (FEET) is defined in paragraph N25.2(b) of appendix N to part 25 as "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 Flight Length Distribution (Table 2), the pre-flight times are provided as a function of the flight time, and the post-flight time is a constant 30 minutes." Table 2 referenced in this definition is Table 2 of appendix N to part 25.

j. Flammability Envelope is the pressure (i.e., altitude)/temperature domain where the fuel vapor/air mixture is flammable. This flammability envelope is defined in appendix N to part 25, by the upper flammability limit (UFL) and the lower flammability limit (LFL). These flammability limits are dependent on the type of fuel used and vary for different fuel batches that meet the fuel specification. For Jet-A fuels the variation of flash points that are to be used in the analysis are defined in appendix N to part 25. Appendix N also defines the LFL and UFL as a function of altitude and fuel flash point. The flammability envelope for the fuel is defined by the UFL and LFL as follows:

(1) LFL at sea level is the 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 feet.

(2) UFL at sea level is the 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 feet.

k. Flammability Reduction Means (FRM) is any system intended to meet the flammability exposure criteria in appendix M to part 25.

l. Flash Point of a flammable fluid is defined in paragraph N25.2(d) of appendix N to part 25 as "the lowest temperature at which the application of a flame to a heated sample causes the vapor to ignite momentarily, or "flash." The flash point of a fuel is determined using the standardized test method(s) permitted by the fuel specification. Table 1 of appendix N to part 25, provides the Gaussian (or "normal") distribution for the flash point of the standard (Jet-A) fuel to be used in the analysis.

m. Fuel Types approved for use for a given airplane type are listed in the Airplane Flight Manual (AFM) and the type certificate data sheet. Each fuel type has its own properties; those directly related to flammability are "flash point" and "distillation" characteristics. Property differences can occur in different batches of a given fuel type because of variations in the properties of the source crude oil and the refining process used to produce the fuel. The most widely used fuel types are JET-A or JET-A1, per ASTM International Specification D1655, "Standard Specification for Aviation Turbine Fuels." Older airplanes have been approved for use of JET-B (JP-4), per ASTM Specification D6615, "Specification for Jet B Wide-Cut Aviation Turbine Fuel."

n. Gaussian Distribution is defined in paragraph N25.2(f) of appendix N to part 25 as "another name for the normal distribution, a symmetrical frequency distribution having a precise mathematical formula relating the mean and standard deviation of the samples. Gaussian distributions yield bell-shaped frequency curves having a preponderance of values around the mean with progressively fewer observations as the curve extends outward."

o. Hazardous Atmosphere is defined in paragraph N25.2(g) of appendix N to part 25 as "an atmosphere that may expose maintenance personnel, passengers or flightcrew to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a confined space), injury, or acute illness."

p. Inert is defined in paragraph N25.2(h) of appendix N to part 25. It states "the tank is considered inert when the bulk average oxygen concentration within each compartment of the tank is 12 percent or less from sea level up to 10,000 feet altitude, then linearly increasing from 12 percent at 10,000 feet to 14.5 percent at 40,000 feet altitude, and extrapolated linearly above that altitude."

q. Inerting is is defined in paragraph N25.2(i) as "a process where a noncombustible gas is introduced into the ullage of a fuel tank so that the ullage becomes non-flammable."

r. Lean Fuel Vapor/Air Mixture is a fuel vapor/air mixture that contains a concentration of fuel molecules below that which will support combustion.

s. Monte Carlo Analysis is defined in paragraph N25.2(j) of appendix N to part 25 as "the analytical method that is specified in this appendix (appendix N to part 25) as the compliance means for assessing the fleet average flammability exposure time for a fuel tank." Paragraph N25.3(a) requires analysis be performed in accordance with the methods and procedures defined in the User's Manual referenced in paragraph 4e(11) of this AC.

t. Oxygen evolution is defined in paragraph N25.2(k) of appendix N to part 25. It "occurs when oxygen dissolved in the fuel is released into the ullage as the pressure and temperature in the fuel tank are reduced."

u. Rich Fuel Vapor/Air Mixture is a fuel vapor/air mixture that contains a concentration of fuel molecules above that which will support combustion.

v. Warm Day Case is that portion of the Monte Carlo Analysis during ground or takeoff/climb phases of flights that begin with a sea level ground ambient temperature of 80 degrees F (standard day plus 21 degrees F) or above, from the flammability analysis done for overall ground operations or warm day takeoff/climb phases.

w. Standard Deviation is defined in paragraph N25.2(l) of appendix N to part 25 as "a statistical measure of the dispersion or variation in a distribution, equal to the square root of the arithmetic mean of the squares of the deviations from the arithmetic means."

x. Transport Effects is defined in paragraph N25.2(m) of appendix N to part 25 as "the change in fuel vapor concentration in a fuel tank caused by low fuel conditions and fuel condensation and vaporization." The change caused by low fuel conditions is also referred to as "mass loading" (see paragraph 4(e)(4)).

y. Ullage is defined in paragraph N25.2(n) of appendix N to part 25 as "the volume within the fuel tank not occupied by liquid fuel."

z. Equivalent Conventional Unheated Aluminum Wing Tank is defined in § 25.981(b)(3)(i) as "an integral tank in a unheated semi-monocoque aluminum wing of a subsonic airplane that is equivalent in aerodynamic performance, structural capability, fuel tank capacity and tank configuration to the designed wing."

aa. Body Tank is a fuel tank installed entirely inside the fuselage of an airplane in a compartment with no tank surface exposed to outside air flow during flight, e.g., an auxiliary fuel tank installed in the cargo compartment of an airplane. See paragraph 4e(11), "Fuel Tank Flammability Assessment Method User's Manual."

6. Regulatory Background.

a. Amendment 25-11 to part 25 introduced the requirements of § 25.981 about limiting temperatures in fuel tanks to prevent ignition of fuel vapors in the fuel tanks from hot surfaces. Advisory Circular 25.981-1A, which was issued in 1972 (now canceled), provided guidance that included failure modes that should be considered when determining compliance with the fuel tank surface temperature requirements defined in § 25.981.

b. Other sections of part 25 require prevention of ignition sources from lightning (§ 25.954) and from failures in the fuel tank system (§§ 25.901 and 25.1309). Sections 25.901 and 25.1309 set forth the provisions to evaluate the fuel tank system and show that "no single failure or malfunction or probable combination of failures will jeopardize the safe operation of the airplane.…" However, service history has shown that ignition sources have developed in airplane fuel tanks because of external ignition sources, and internal ignition sources resulting from unforeseen failure modes, manufacturing and maintenance errors or factors that were not considered at the time of original certification of the airplane.

c. Section 25.981, as amended by Amendment 25-102, was adopted to provide improved standards for preventing ignition sources within fuel tanks and minimizing the exposure to operation of transport category airplanes with flammable vapors in the fuel tanks. Under Amendment 25-102, the title of § 25.981 was revised to "Fuel tank ignition prevention," and paragraphs (a) and (b) were revised to address the prevention of ignition sources within the fuel tanks. Guidance on these paragraphs is provided in AC 25.981-1B, Fuel Tank Ignition Source Prevention Guidelines (or latest revision). Amendment 25-102 also added a new paragraph (c), which requires minimization of the formation of flammable vapors in the fuel tanks, or mitigation of any hazards if ignition does occur. This provision was included in § 25.981(c), which was intended to require design practices that reduce exposure to operation with flammable vapors in transport category airplane fuel tanks to the lowest practical level.

7. Current Requirements. The Fuel Tank Flammability Reduction (FTFR) rule titled "Reduction of Fuel Tank Flammability in Transport Category Airplanes" is effective as of September 19, 2008. The 2008 FTFR rule included an amendment to part 25 fuel tank flammability requirements, part 26 (Continued Airworthiness and Safety Improvements for Transport Category Airplanes) by adding a new subpart D, Fuel Tank Flammability, and amendments to certain operational rules associated with the subpart D requirements. This AC provides guidance for § 25.981, as amended by Amendment 25-125, and the continuous airworthiness requirements of part 26, subpart D. These rules apply to new certification and to certain existing type design approval holders (DAH). The 2008 FTFR also included operational requirements related to the part 26, subpart D, requirements. Guidance for affected operators will be issued later. The following table summarizes the amendments and the applicability of each amendment. Because of the complexity of these requirements, you should refer to the specific regulations for complete details.

TABLE 1

Summary of Regulatory Changes that were made by the 2008 Fuel Tank Flammability Reduction rule

Summary of Rules		
14 CFR	**Description of Requirement**	**Applies To**
§ 25.5 Incorporation by Reference	Incorporates the Fuel Tank Flammability Users's Manual by reference	
§ 25.981, Fuel Tank Explosion Prevention	Paragraph (a) provides ignition prevention requirements; (b) specifies flammability exposure limits for different fuel tank types and mandates use of fuel tank flammability assessment method; (c) provides the option of using Ignition Mitigation Means (IMM) instead of meeting the paragraph (b) flammability limits; and (d) contains requirements for airworthiness limitation items (ALI), including critical design configuration control limitations (CDCCL), for ignition prevention means, IMM or FRM.	Applicants for TCs for transport category airplanes and design changes to those certificates.
Appendix M, Fuel Tank System Flammability Reduction Means	Establishes performance, reliability and reporting requirements for flammability reduction means (FRM).	Applicants for approval of FRM.
Appendix N, Fuel Tank Flammability Exposure and Reliability Analysis	Defines the fuel tank flammability exposure analysis model (Monte Carlo) including definitions, input variables and data tables that must be used in the analysis.	Any person required to perform flammability exposure analysis.
Part 26	**Continued Airworthiness and Safety Improvements for Transport Category Airplanes**	
§ 26.5 Applicability Table	Provides an overview of the applicability of part 26. It provides guidance in identifying what sections apply to various types of entities. The specific applicability of each subpart and section is specified in the regulatory text. Subpart D addresses fuel tank flammability.	Applicants for TCs, and changes to those TCs for transport category airplanes. Manufacturers of certain airplane models.
Part 26, subpart D	Fuel Tank Flammability.	TCs, and design changes to those TCs for transport category airplanes. Manufacturers of certain airplane models.

§ 26.31, Definitions	Provides definitions of certain terms used in part 26, subpart D.	TCs, and design changes to those TCs for transport category airplanes. Manufacturers of certain airplane models.
§ 26.33, Holders of Type Certificates: Fuel tank safety	Require flammability exposure analysis of all fuel tanks within 150 days after September 19, 2008. If below 7 percent, no flammability reduction required. If above 7 percent, normally emptied, and any portion of tank is located in fuselage, must develop service instructions for installation of an IMM or FRM that meets appendix M to part 25 and must submit ALI by September 20, 2010. If above 7 percent, and other tank type, must develop service instructions to incorporate an IMM (meet § 25.981(c)) or FRM to reduce flammability exposure to 7 percent and must submit ALI by September 20, 2010. Service instructions are required by September 20, 2010.	TC holders. Large transport category passenger-carrying airplanes, with passenger capacity of 30 or more or a payload of 7500 lbs. or more (original TC or later increase).
§ 26.35, Changes to type certificates affecting fuel tank flammability	STC and field approval holders: Require flammability exposure analysis of all normally emptied fuel tanks installed under STC or field approval by September 19, 2009. Require impact assessment of normally emptied fuel tanks installed by STC and field approval on all Airbus airplane models and certain Boeing airplane models (those with normally emptied heated center wing tanks) on IMM or FRM developed by TC holder to determine if any ALI has been compromised by March 21, 2011. Require development of service instructions to correct designs that compromise ALI defined by TC holder by September 19, 2012. Applicants for STCs or amendments to TCs: Require flammability exposure analysis of affected fuel tanks by September 19, 2009, or before certification, whichever occurs later. For changes to existing fuel tank capacity and application made on or after September 19, 2008, must comply with § 26.33. For changes that may increase the flammability exposure of a tank for which § 26.33 requires FRM or IMM and application made on or after September 19,	STC and field approval holders for normally empty fuel tanks for large transport category airplanes, with passenger capacity of 30 or more or a payload of 7500 lbs. or more (original TC or later increase). Applicants for future STCs or amendments to TCs that affect fuel tank system or IMM/FRM on passenger-

	2008, requires impact assessment of fuel tanks and other STCs, on IMM or FRM developed by TC holder to determine if any ALI has been violated by March 21, 2011, or before certification, whichever is later. Applicants for any pending and future fuel tank that is normally empty must comply with the requirements of § 25.981, Amendment 25-125. Require development of service instructions to correct designs that compromise ALI defined by TC holder by March 19, 2012 or before certification, whichever is later.	carrying airplanes.
§ 26.37, Pending type certification projects: Fuel tank flammability	Requires compliance with § 25.981, Amendment 25-125, if the application was made on or after June 6, 2001.	Pending certification projects for large transport category passenger-carrying airplanes.
§ 26.39, Newly produced airplanes: Fuel tank flammability	Requires fuel tanks on affected airplanes (produced under FAA production certificates) for which application is made for original certificates of airworthiness or for export airworthiness approval after September 20, 2010, meet the flammability requirements as stated above for § 26.33.	Certain Boeing airplane models, both passenger carrying and cargo.

b. Section 25.981 together with appendices M and N to part 25 and the Fuel Tank Flammability User's Manual incorporated by reference (see § 25.5), Amendment 25-125, provide flammability limits and the method for determining the flammability of fuel tanks. The flammability limits for fuel tanks that are normally emptied and have any portion of the tank located within the fuselage contour must meet the 3 percent average and 3 percent warm day flammability exposure limits in appendix M to part 25, as required by § 25.981(b)(2). Section 25.981(b) limits the flammability exposure of all other fuel tanks to either 3 percent average, or that of a fuel tank within the wing of the airplane model being evaluated, whichever is greater. If the wing is not a conventional unheated aluminum wing, § 25.981(b) requires the analysis be based on that of an assumed Equivalent Conventional Unheated Aluminum Wing Tank. If a flammability reduction means (FRM), such as nitrogen inerting, is used, additional reliability requirements are provided in appendix M to part 25. Appendix N specifies the requirements for conducting the flammability exposure analysis required to show compliance to § 25.981 and appendix M. Appendix N provides the ability to perform a qualitative analysis for fuel tanks installed in aluminum wings provided it substantiates the fuel tank is a conventional unheated wing tank. Section 25.981(c) retains the option of using ignition mitigation means (IMM), for example reticulated polyurethane foam, to address fuel tank flammability requirements of § 25.981. It also extends the existing requirements for development of critical design configuration control limitations (CDCCL) for ignition prevention, that were formerly in paragraph (b), to any FRM or IMM and places the amended requirement in § 25.981(d).

c. The amendment also includes continued airworthiness and safety improvement requirements that are contained in a new subpart D to part 26. The new subpart D includes §§ 26.33, 26.35, 26.37 and 26.39. These sections specify different compliance requirements for the affected DAHs. The affected airplanes include those with a seating capacity of 30 passengers or more, or a payload of 7500 pounds or more. Appendix 1 of this AC provides a list of affected models, and Appendix 3 of this AC provides guidance on compliance with these requirements. The intent of § 25.981(b) is to require that the exposure to the formation or presence of flammable vapors is limited to specific values for fuel tanks located within the wing and fuselage contour. The flammability limits for the specific tank type are summarized in the following table:

TABLE 2

Summary of Flammability Limits for the Specific Tank Type

<table>
<tr><th rowspan="2">Airplanes Affected</th><th rowspan="2">Category of Action

(Cert. Projects Include TCs, ATCs, & STCs)</th><th rowspan="2">Applicable Regulations</th><th colspan="2">Fleet Flammability Exposure (Percent Exposure Time)</th></tr>
<tr><th>Normally Emptied & Any Portion Inside Fuselage</th><th>All Other Fuel Tanks</th></tr>
<tr><td>All part 25 transports</td><td>Future applications for new TCs</td><td>§ 25.981(b)</td><td rowspan="4">Appendix M

(Flam ≤ 3% Plus 3% warm day limit)</td><td rowspan="4">3 percent
or
equal to conventional unheated aluminum wing tank, whichever is greater</td></tr>
<tr><td rowspan="6">Turbine powered large transports with

Max Pass ≥ 30

or

Max Payload ≥ 7500 Lb
(* See note)
See appendix 1 for list of airplane models</td><td></td><td></td></tr>
<tr><td>Pending TC applied on or after June 6, 2001</td><td>§ 26.37</td></tr>
<tr><td>Pending or Future STC or ATC for normally emptied tanks</td><td>§ 26.35(d)(2)</td></tr>
<tr><td>Future STC or ATC
If changes existing fuel tank capacity</td><td>§ 26.35(d)(3)</td><td rowspan="3">If Flam > 7%,
Do appendix M

Reduce flammability to:
≤ 3% average
and
≤ 3% warm day limit</td><td rowspan="3">Flammability
≤ 7%</td></tr>
<tr><td>Production cut-in
(After September 19, 2010)</td><td>§ 26.39 (Boeing)
& Ops Rules
(Airbus)</td></tr>
<tr><td>Fleet retrofit</td><td>§ 26.33(c)
& Ops Rules</td></tr>
</table>

* Applies to transport category, passenger carrying airplanes for which the state of manufacture issued the original certificate of airworthiness or export airworthiness approval on or after January 1, 1992. Section 26.39 production cut-in applies to both cargo and passenger airplanes.

8. Compliance Demonstration.

a. Showing Compliance with § 25.981(b) or (c). Section 25.981 provides two options for addressing the hazards associated with fuel tank flammability:

- Controlling fuel tank flammability to specified levels, and
- Mitigating the hazards if ignition of the fuel vapors occurs.

(1) The first means, as provided in § 25.981(b), shows that the flammability of a fuel tank does not exceed the limits defined in the regulation. When this method of compliance is used, a flammability analysis is required to establish the flammability of the fuel tank, and incorporation of an FRM in any fuel tank to reduce the flammability of any tank that exceeds the applicable flammability limit. Guidance for determining the flammability of a fuel tank is provided in paragraph 10 of this AC. Guidance for incorporating an FRM, including pressurization of a fuel tank, temperature control of a fuel tank, limiting fuel properties and fuel tank inerting, are provided in paragraph 9 of this AC.

(2) Compliance with § 25.981(b) is not required if the hazards of ignition of fuel vapors are mitigated by use of an Ignition Mitigation Means (IMM) meeting the requirements of § 25.981(c). Guidance for demonstrating compliance using IMM is provided in paragraph 12 of this AC. Examples of IMM include filling the tank with polyurethane foam, metallic foils, demonstrating the structure can withstand an explosion, or explosion suppression systems. Since IMM mitigates the effects of ignition so that it is not hazardous, there is no requirement to determine the fuel tank flammability, if this method is used to demonstrate compliance.

b. Showing Compliance with § 25.981(d). Appendix 2 of this AC includes guidance for establishing CDCCL relating to FRM or IMM for the fuel tank system.

c. Showing Compliance with §§ 26.33 and 26.35. Specific guidance for compliance with the continued operational safety requirements contained in part 26, subpart D is provided in appendix 3 of this AC.

9. General Considerations – Fuel Tank Flammability.

a. Formation of Flammable Vapors. The critical considerations in controlling exposure to operation with flammable mixtures in the tank include the control of formation of flammable vapors and/or oxygen concentration. Factors influencing the formation of flammable vapors include fuel type and properties, fuel temperature, pressure in the tank, and any design feature that significantly increases the potential for fuel mists to be created. The time a fuel tank is flammable determined by the Monte Carlo analysis is based upon the assumption that design features needed to prevent spraying and misting of fuel in the tank have been incorporated into the design so these factors are not considered. Rather, the fuel properties and temperature and pressure in the fuel tank are used to determine when the fuel tank is flammable. General design practices that affect the overall flammability risk are described below. Airplane designs submitted for FAA evaluation will be evaluated against these practices.

b. Design Practices to Minimize Flammability Exposure.

(1) Misting and sloshing. The flammability of fuel vapors in a fuel tank can be dramatically influenced by agitation, sloshing, spraying, or misting of fuel. These processes increase the surface area of the fuel allowing more fuel vapors to evolve from the fuel, which results in a higher concentration of fuel molecules in the ullage space. Design practices that reduce the potential for fuel agitation, sloshing, spraying and misting should be incorporated into the design so that flammability is minimized. Examples of proven design practices include installation of sufficient baffling in the tanks to reduce sloshing, and returning any fuel used to cool fuel pumps to the bottom of the tank. Section 6 of SAE Document AIR 1662 describes recommended design practices for minimizing hazards associated with electrostatic charging in fuel tanks. Several of these practices relate to minimizing the formation of flammable vapors, including:

(a) Introducing fuel at low velocity near the bottom of fuel tanks so that the inlet is covered early in the refueling or fuel transfer process.

(b) Directing the fuel flow onto a grounded conducting surface to reduce electrostatic charge build-up.

(c) Using a balanced distribution system to make sure that all fuel tank bays are filled to equal levels to assist in reducing fuel velocity (this minimizes charge relaxation time and mist formation).

These practices greatly reduce the presence of fuel mist that will broaden the flammability range of the fuel at the lean end and cause flammable vapors at temperatures well below the flash point. Appendix N to part 25, paragraph N25.4(3)(ii), defines the flammability envelope that must be used for the flammability exposure analysis. The flammability envelope is a function of the flash point of the fuel selected by the Monte Carlo flammability assessment methodology defined in paragraph 4e(11) of this AC. This determination if the fuel tank is flammable is based upon the assumption that design precautions described in this paragraph have been implemented.

(2) Fuel temperature is one of the key factors that determine fuel tank flammability in unpressurized fuel tanks approved for use with common Jet A type fuels. The most effective methods for controlling fuel tank temperature may differ between different fuel tanks, according to their exposure to the risk. For instance, fuel tanks located in conventional unheated aluminum wings of subsonic transport category airplanes, with little or no heat input from airplane systems or from other adjacent fuel tanks that have large surface areas that allow cooling of the fuel, have been analyzed and shown to meet the intent of the regulation. Fuel tanks located within the fuselage contours or other tanks located within the wing that do not cool require more design attention. For example, auxiliary fuel tanks located in the cargo compartment or pressurized areas, tanks located in the center wing box, horizontal stabilizer tanks, tanks with small surface areas exposed to airflow, and tanks made from materials that act as insulators, may have less ability to reject heat to ambient air, both on the ground and in flight, and may be subject to heat sources from equipment located nearby in the fuselage such as the air conditioning packs that supply cool air to the cabin. For fuel tanks that, because of installation location and/or other factors, do not meet the applicable flammability limits, an FRM or IMM is needed to comply.

(3) Fuel types**.** The proposal for fuels for an airplane type is submitted to the FAA by the applicant for approval, and once approved the fuels are shown in the AFM. The definitions of LFL and UFL define the fuel temperature at which a fuel tank can be expected to be flammable. From the definitions, it can easily be seen that fuel flash point is key. Currently, Jet-A and Jet-A1 are the predominant fuels used in commercial aviation. Because of this, wing tanks are commonly not flammable as the fuel temperature is typically below the LFL. However, the heat input to any tank can push tanks fueled with Jet-A/A1 into the flammable range. A fuel such as JP-4 has the reverse effect. The flash point is below normal ambient temperatures during ground operations, resulting in more flammability exposure for typical wing tanks and less for tanks that are insulated from outside air, such as CWT. The higher temperature tanks are less flammable because the fuel temperature is above the UFL more of the time, resulting in an over-rich condition.

(a) Appendix N to part 25 defines a typical transport category airplane fuel based upon a survey of fuels drawn from operating airplanes as shown in paragraph 4e(10) of this AC. The fuels include Jet A/A1 flash point distribution and also lower flash point fuels commonly used in China and Russia. This distribution is also included in appendix N to part 25 and the Monte Carlo analysis in the paragraph 4d(11) of this AC. For consistency across applicants, and for simplicity, each applicant is required to apply the distribution defined in appendix N unless the FAA finds that this distribution is not representative of the fuels that could be expected to be used on the particular airplane being evaluated.

(b) If the use of low flash point fuels, such as JP-4, is proposed as an approved fuel, the fuel properties defined in the User's Manual may not provide a representative flammability exposure analysis. Use of JP-4 type fuels on a typical transport category airplane may significantly increase operational exposure to flammable vapors. Therefore, modification of the flammability analysis and incorporation of additional flammability reduction capability, such as improved FRM performance, may be required to mitigate the increased exposure created by continuous use of such fuels.

(4) Fuel tank ullage sweeping is the introduction of air into a fuel tank and dumping the fuel vapor overboard to reduce the concentration of fuel vapors in the ullage. This means would result in significant emission of fuel vapors into the atmosphere and would likely not meet emissions standards, unless these vapors were removed prior to dumping the air into the atmosphere. Ullage sweeping would not likely have a significant effect on the bulk average fuel temperature of the affected fuel tank and it would not decrease the oxygen content of the ullage. Therefore, it would not provide a significant reduction in the flammability exposure as determined by the flammability assessment method required by part 25, appendix N.

(5) Controlling oxygen concentration. The accepted level for tank inerting used by the military is to reduce the oxygen concentration in the tank ullage to less than 9 percent. This is the standard established in the 1950s for a zero flammability risk design because ignition sources (hostile munitions) are a likely event in military missions. The standard precludes "cool flame" ignition, where the pressure rise is relatively low. The actual oxygen concentration needed to prevent a catastrophic fuel tank rupture during an ignition event per FAA testing (reference 4(e)(8)), and military live fire testing using incendiary rounds (reference 4 (e)(7)), is higher. The higher the oxygen concentration, the higher the pressure that is developed in the fuel tank during a combustion event. Therefore, the applicant may establish the acceptable oxygen concentration based upon evaluation of the structural capability and maximum peak pressure of the fuel tank. The oxygen concentration defined in the definitions paragraph of this AC is an acceptable benchmark for transport category airplane fuel tanks inerted with nitrogen, without additional substantiation. The oxygen concentration limit was established using nitrogen enriched air to displace oxygen. The allowable oxygen concentration varies with the type of inerting gas used. If another inerting gas such as carbon dioxide is used the applicant must substantiate the allowable oxygen concentration needed to show compliance.

c. STC and amended TC applicants for design changes to install a Normally Emptied fuel tank must comply with § 25.981 at Amendment 25-125. The guidance in this AC primarily addresses means of compliance with the new tank itself. However, these applicants must also comply with all applicable CDCCLs established by the TC holder.

10. Determining Fuel Tank Flammability.

a. Acceptable Means of Determining the Flammability Exposure. There are two means of establishing the flammability of a fuel tank. The method that is acceptable depends upon the flammability level that the tank is required to meet. Paragraph N25.1(a) of appendix N to part 25 allows for using a qualitative method if it substantiates the fuel tank is a conventional unheated aluminum wing tank. The criteria listed below describe the characteristics of conventional unheated aluminum wing tanks. For all other fuel tanks, the Monte Carlo Model defined in paragraph 4e(11) of this AC must be used as required by appendix N.

(1) Qualitative flammability assessment.

(a) A conventional unheated aluminum wing tank is a conventional aluminum structure, integral tank of a subsonic transport airplane wing, with minimal heating from airplane systems or other fuel tanks and cooled by ambient airflow during flight. Heat sources that have the potential for significantly increasing the flammability exposure of a fuel tank would preclude the tank from being considered “unheated.” Examples of such heat sources that may have this effect are heat exchangers, adjacent heated fuel tanks, transfer of fuel from a warmer tank, and adjacent air conditioning equipment. Thermal anti-ice systems and thermal anti-ice blankets typically do not significantly increase flammability of fuel tanks. For these tanks, a qualitative assessment showing equivalency to the unheated aluminum wing fuel tank may be acceptable when considered with the following:

1 A description of the airplane configuration, (including subsonic, wing construction, etc.),

2 A listing of any heat sources in or adjacent to the fuel tank,

3 The type of fuel approved for the airplane,

4 The tank operating pressure relative to ambient static pressure,

5 The tank is uninsulated and made of aluminum, and

6 The tank has a large aerodynamic surface area exposed to outside air to transfer heat from the tank.

(b) Fuel tanks with an aerodynamic surface area to volume ratio (surface area/volume) greater than 1.0 have been shown to meet these criteria. Fuel tanks with a ratio less than 1 are not considered conventional unheated aluminum wing tanks. The aerodynamic surface area includes the area of the integral aluminum wing fuel tank that is exposed to outside air. It does not include any portion of a fuel tank that is shielded from free stream airflow, such as the front and rear spar, or an area under a fairing or wing thermal blanket.

(c) Wing tanks that do not meet the criteria above for use of the qualitative method must use the Monte Carlo analysis (ref. appendix N). For example, if a fuel tank were made of composites, the applicant would need to show compliance using one of the two alternatives provided in § 25.981(b) for wing tanks. One alternative would require the applicant to conduct an assessment of the fleet average flammability exposure for an equivalent conventional unheated aluminum wing tank meeting the criteria above, on the airplane type for which approval is sought. This would establish the maximum allowable flammability level for the actual composite wing fuel tanks. The second alternative provided in § 25.981(b) is to conduct an assessment of the actual composite wing tanks and demonstrate the fleet average flammability exposure of any tanks does not exceed three percent.

(2) Monte Carlo Analysis. When the compliance demonstration requires demonstrating a fuel tank meets a specific fuel tank flammability or the tank does not meet the qualitative assessment criteria previously discussed, both § 25.981(b)(1) and paragraph N25.3(a) of appendix N to part 25 require the flammability assessment be conducted in accordance with the methods and procedures in the FAA document, "Fuel Tank Flammability Assessment Method User's Manual," (User's Manual) dated May 2008, which is incorporated by reference in § 25.5 for § 25.981 and Appendix N. This document may be obtained from the following web site: (http://www.fire.tc.faa.gov/systems/fueltank/FTFAM.stm**)**. Section 25.5 includes a provision permitting use of later FAA versions of the User's Manual when FAA publishes a notice of the change in the Federal Register.

(a) This analytical method is based upon predicting the fleet average flammability exposure, and the warm day fleet average flammability exposure as applicable, to operation with flammable fuel air vapors in the fuel tank. The fuel tank flammability exposure for the tank being evaluated is calculated for the specific fleet of airplanes of interest for which approval is sought using certain standardized parameters for all airplane models and certain airplane model specific parameters. The flammability exposure calculated by the analysis is then compared to the flammability limits defined in the regulations to determine compliance. The analysis method is therefore a standardized analysis method.

(b) The fuel flash point at a given temperature and pressure is used to determine when the ullage in the tank is flammable. When the fuel temperature at a given altitude is in the range between the LFL and the UFL, the ullage is assumed to instantaneously become flammable. When using a Monte Carlo analysis, that transition is considered to occur instantaneously as pressure and temperature changes. The Monte Carlo Model is based on the assumption that any fuel being loaded during refuel is at ambient outside temperature when determining flammability exposure. Appendix N to part 25 defines the fuel properties used in the Monte Carlo Model. This includes the fuel flash point distribution and the flammability envelope of the fuel that is required to be used for the analysis.

(c) Appendix N to part 25 requires the flammability exposure be determined independently for each fuel tank. For fuel tanks that are subdivided by baffles or compartments, N25.3(a) requires an analysis be performed for each section of the tank. Alternatively, if the applicant can show that one section of the tank always has higher flammability exposure than any other section, the applicant may perform the analysis only of that one section. Within each tank where barriers or walls prevent mixing of the fuel/air mixtures, separate volumes or compartments should be treated independently to determine the worst case flammability exposure for that tank because of temperature variations within different portions of the tank. If FRM based upon inerting is used, oxygen concentration in those compartments of the tank can differ significantly from other compartments in the tank (such as an airplane model that has a center wing box that extends out into the wing, or a compartment in a fuel tank where vent inlets may create differences in temperature or oxygen concentration (if an FRM based on inerting is used)).

(d) It is possible for the critical compartment to change from one compartment of the tank to another compartment during different portions of the flight. In this case, the flammability of the individual compartments would need to be determined throughout the flight and the times when any compartment of the tank is flammable would be included in the overall average flammability calculation.

(e) If a fuel tank is determined to exceed the applicable flammability requirements, the holder may control fuel tank flammability by incorporation of an FRM or IMM. Guidance for FRM is provided in paragraph 11 of this AC.

(3) Developing inputs to the Monte Carlo Model. The Monte Carlo Model, which randomly generates values for uncertain variables over and over, is used to simulate a process where the variables are random within defined distributions. The results of a large number of cases can then be used to approximate the results of the real world conditions. Appendix N to part 25 provides standard distributions and values that must be used when determining fuel tank flammability. Figure 1 shows the parameters that are used by the Monte Carlo Model to determine fuel tank flammability. The outlined, non-shaded boxes identify inputs that are dependent on the fuel tank design and operation and on the FRM design. The shaded boxes identify parameters that are fixed in the Monte Carlo Model.

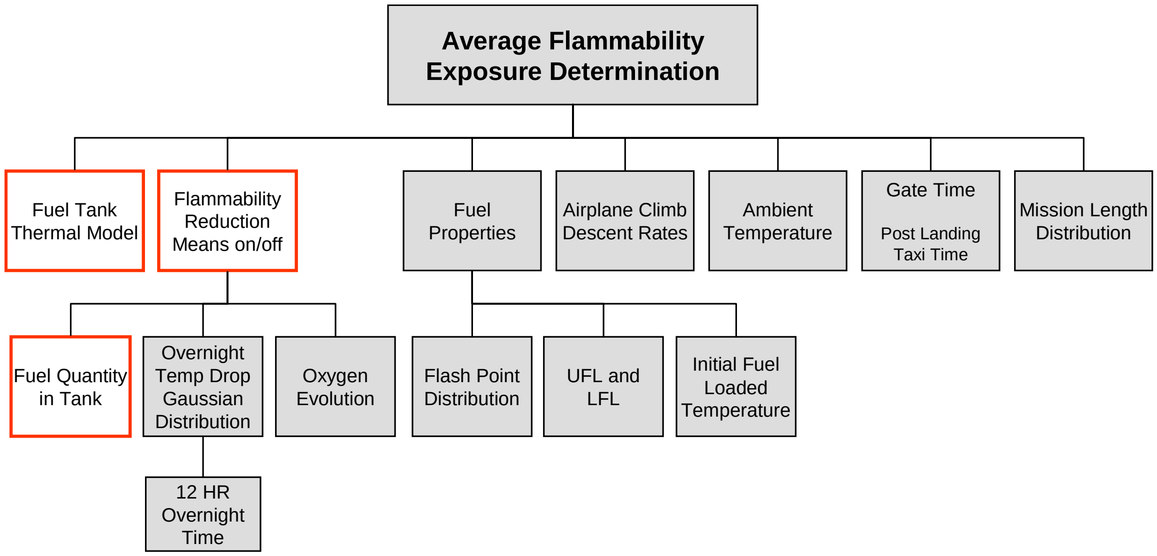

FIGURE 1

Monte Carlo Parameters to Determine Fuel Tank Flammability

(4) Monte Carlo Parameters. The fuel tank thermal model and fuel quantity in the fuel tank are user inputs needed to determine the fuel tank flammability for a fuel tank without an FRM. The performance of an FRM must also be provided by the user if an FRM is installed. User inputs to the Monte Carlo Model and standardized parameters include the following as defined in appendix N to part 25 and in the User's Manual (defined in paragraph 4e(11) of this AC):

(a) Standardized parameters used in the Monte Carlo Model.

1 Cruise ambient temperature, N25.3(b)(1), N25.4 and Table 1 of appendix N.

2 Ground ambient temperature, N25.3(b)(2), N25.4 and Table 1 of appendix N.

3 Fuel flash point, N25.3(b)(3), N25.4 and Table 1 of appendix N.

4 Flight length distribution, in conjunction with the airplane utilization information submitted under Airplane specific inputs below.

5 Airplane climb and descent profiles (paragraph N25.3(b)(5) requires the applicant use the climb and descent profiles defined in the User's Manual.

6 Preflight and post flight gate times; the preflight times are provided as a function of the flight time by the Monte Carlo Model in the User's Manual and the post-flight time is a constant 30 minutes, both as defined by N25.2(b).

7 Oxygen evolution rate (included in model when FRM used, based upon User's Manual as required by N25.3(d)(5)).

8 Overnight temperature change (when FRM is added).

(b) Airplane specific inputs: The airplane specific inputs should reflect the most severe airplane operating conditions or configuration with respect to fuel tank flammability exposure.

1 Airplane cruise altitude.

2 Fuel tank quantities. As discussed in the User's Manual, the FAA Monte Carlo Model has a feature that allows the user to input times when the tank is full and empty so that the fuel quantity in the tank can be modeled. The model assumes a constant rate of fuel use between the specified tank full and empty times and does not account for unique fuel management techniques such as fuel transfer systems that may be incorporated for purposes such as center of gravity (C.G.) management. If fuel quantity affects fuel tank flammability, inputs to the Monte Carlo analysis may need to be modified by the user if the standard model does not provide a realistic representation of the actual fuel quantity within the fuel tank or compartment of the fuel tank throughout each of the flights being evaluated. Input values for this data must be obtained from ground and flight test data or the FAA approved fuel management procedures in the AFM.

3 Airplane cruise mach number.

4 Airplane maximum range. This parameter should be determined assuming a payload equivalent to a load factor of 75 percent for a typical two class passenger configuration for the airplane model, using year-around average passenger weights and standard average baggage and carry-on weights per AC 120-27, "Aircraft Weight and Balance Control," standard day atmosphere, zero wind, long range cruise speed and domestic or international reserves as would apply to the typical operation of the airplane.

5 Fuel tank thermal characteristics. If fuel temperature affects fuel tank flammability, the rule requires that inputs to the Monte Carlo analysis be provided that represent the actual bulk average fuel temperature within the critical compartment of the fuel tank throughout each of the flights being evaluated. For fuel tanks that are subdivided by baffles or compartments, bulk average fuel temperature inputs should be developed for each section of the tank. The temperature in any compartment that results in the highest flammability at any given time should be used in the tank flammability analysis. If one compartment in the tank always has the highest flammability exposure, the temperature in that compartment should be used in the analysis. The rule requires that input values for these data be obtained from ground and flight test data or a thermal model of the tank that has been validated by ground and flight test data. The thermal input data should reflect the most severe airplane operating conditions or configuration.

For example, for fuel tanks located near heat sources such as the airplane environmental conditioning system (ECS), also called air conditioning packs (packs), the maximum allowable number of packs should be running during test and modeling conditions.

6 Maximum airplane operating temperature limit as defined by any limitations in the AFM. This value is obtained from the flight manual for the specific airplane type.

7 Airplane Utilization. The rule requires that the applicant provide data supporting the number of flights per day and the number of hours per flight for the specific airplane model under evaluation. If there is no existing airplane fleet data to support the airplane being evaluated, the applicant must provide substantiation that the number of flights per day and the number of hours per flight for that airplane model is consistent with the existing fleet data they propose to use.

(aa) Fuel tank thermal model. A computer simulation, validated by flight test data, is one way to provide inputs for the model that simulates the thermal behavior of the tank throughout the airplane operating envelope. This model must be provided by the applicant based on the particular characteristics of the particular fuel tank that is being evaluated. The applicant may use the thermal modeling tool incorporated into the Monte Carlo Model if flight test data show that this modeling technique provides conservative prediction of fuel tank temperatures. The Monte Carlo Model includes a feature to use exponential time constants to define the heating and cooling characteristics of a fuel tank. This feature has the capability to input 6 different constants for various conditions that may be present on typical aluminum fuel tanks. While this feature is one method of modeling the fuel tank thermal characteristics so that fuel tank temperatures can be predicted, it is not an acceptable method of modeling the fuel tank if it does not provide accurate results. It may be necessary for the applicant to develop a separate fuel tank temperature model that accurately predicts fuel tank temperatures. Appendix 4 of this AC provides further guidance regarding developing a validated fuel tank thermal model for use in showing compliance for fuel tanks. This guidance will be helpful for use in developing a thermal model for a fuel tank with an FRM.

(bb) Simplified fuel tank thermal model. To simplify the certification process and avoid the need to develop a fuel tank thermal model, if an applicant so chooses, it is acceptable to determine the flammability exposure of a tank with an inerting system added by assuming the fuel temperature is otherwise always between the LFL and UFL.

(cc) Body fuel tank thermal model. If the tank is located entirely inside the fuselage of the airplane in a compartment and no tank surface is exposed to outside air flow during flight, e.g., an auxiliary fuel tank installed in the cargo compartment of an airplane, it is considered a "Body Tank." For these fuel tanks, the Monte Carlo model defined in paragraph 4e(11) allows the calculated temperatures of the fuel tank to be controlled by the temperature of the compartment in which the fuel tanks is installed.

b. Fuel Tank FRM Model. If FRM is used, the rule requires an FAA-approved Monte Carlo Model be used to show compliance with the flammability requirements of § 25.981 and appendix M of part 25. The program must determine the time periods during each flight phase when the fuel tank or compartment with the FRM would be flammable. The following factors must be considered in establishing these time periods:

(1) Any time periods throughout the FEET and under the full range of expected operating conditions, when the FRM is operating properly but fails to maintain a non-flammable fuel tank because of the effects of the fuel tank vent system or other causes.

(2) The effect of any inerting system may be included in this analysis. The applicant should present a description of the system including its control logic, and data to substantiate its performance at lowering the ullage oxygen content to below the inert level defined in appendix N to this part to comply with the applicable average flammability level. Where the system does not provide continuous protection such as a ground based inerting system as described in paragraph 4e(5) of this AC, the degradation of the ullage inerting level with time, altitude, oxygen evolution from the fuel, air inhalation with fuel use or altitude reduction, and possible effects from vent system operation must be addressed.

c. Compliance Report. The results of the analysis described above, together with substantiation data for the assumptions used in the analysis, including test data validating the thermal analysis used, would be included in the compliance report presented to the FAA. If the tank in question requires a demonstration of equivalence, an analysis of a real or hypothetical unheated wing tank on the same airplane must also be presented.

d. Documentation and Validation of Monte Carlo Model. As discussed earlier in paragraph 10, modifications to the Monte Carlo model are limited to the additional features needed to model an FRM, tank thermal characteristics, and fuel management. All modifications to the model's code must be thoroughly documented and validated both through detailed analysis and flight test. The compliance report should include a summary section that lists all modifications.

11. Flammability Reduction Means. The available methods of limiting exposure to operation with a flammable ullage space in the tank include preventing the formation of flammable vapors and/or controlling the oxygen concentration. Factors that directly influence the formation of flammable vapors include the fuel type properties, fuel temperature, pressure within the fuel tank, and any design feature that increases the potential for fuel mists to be created. Design precautions described earlier within this AC to limit misting or sloshing of fuel within a fuel tank should be taken.

Demonstrating compliance when an FRM is used requires modification to the Monte Carlo Model to include a simulation of the FRM performance. The simulation must determine the times during the flight when the FRM is effective at maintaining a non-flammable fuel tank. Factors that need to be considered when developing the simulation are discussed within this section.

a. Managing Heat Transfer to the Fuel Tank. In general, heat sources should not be located in or near fuel tanks, and heating from other sources, such as hydraulic heat exchangers or rejection of heat from engine systems, should be avoided unless features are incorporated to maintain fuel tank flammability equivalent to an unheated wing fuel tank. Locating heat-producing systems away from the tanks should be considered. If this is not a practical solution, installation of an FRM using thermal control may be another option. Possible technical solutions include the use of thermal insulation blankets, and/or providing ventilation and/or dedicated cooling to remove excess heat from the fuel tank or areas adjacent to the tank.

b. Cooling/Ventilation of Fuel Tanks. If the fuel tank is located in an area of the airplane where little or no cooling occurs, such as the center wing box, certain horizontal stabilizers, or auxiliary fuel tanks located in the cargo compartment, ventilation or dedicated cooling may also be an effective means of demonstrating compliance. The cooling/ventilation means should be effective under all operating conditions, including ground and flight operation, considered necessary to achieve the desired goal of showing the tank flammability is equivalent to the unheated wing tanks. Adequate cooling/ventilation may be provided for certain airplane types by means such as installation of an air gap in spaces adjacent to fuel tanks and utilizing cold air source during ground operation to cool the tank, and the use of ram air inlets for in-flight operation to transfer heat from the tank. Other means (e.g., bleeding cool air from the ECS packs into the air gap) may also be effective at providing adequate cooling/ventilation of the tank.

c. Controlling Fuel Tank Pressure. The flammability of the fuel tank is affected by the pressure in the tank. Typical transport category airplane fuel tanks are vented to the atmosphere and operate at or slightly above local ambient pressure. Fuel tanks located within the wing typically operate with a pressure equal to the local static pressure unless features are incorporated to increase the fuel tank operating pressure. Designs have been developed that use pressurization of the wing fuel tanks as a means to transfer fuel. Pressurization of the fuel tanks also provides reduced flammability. Manufacturers have also incorporated National Advisory Committee for Aeronautics (NACA) scoops on the vent outlets of some airplane fuel tank systems to enhance engine suction feed performance. The pressure recovery factor of these scoops varies but in general is in the range of .4 to .6. Therefore fuel tank pressure during flight may be between .5 to 1.25 psi above local static pressure. The increase in tank pressure results in a reduction in fuel tank flammability.

Many recently designed auxiliary fuel tanks, located in pressurized cargo compartments, incorporate structural features that allow utilization of pneumatic pressure to transfer fuel from the fuel tank to the airplane fuel tank system. These tanks typically are designed to operate at the airplane cabin pressure which is normally equivalent to approximately 8000 feet pressure altitude. This results in a significant reduction in fuel tank flammability. Controlling fuel tank pressure is one means of reducing fuel tank flammability. The Body Tank model in the Monte Carlo Model defined in paragraph 4e(11) of this AC has features that allow the user to input a pressure differential relative to ambient pressure so that fuel tank flammability under these conditions can be evaluated.

d. Fuel Tank Ullage Sweeping. A positive ventilation system has been studied to be used to “sweep” the ullage of flammable fuel vapor/air mixtures at a rate that keeps the ullage lean when the fuel temperature and pressure in the tank would otherwise define the tank as being flammable. It is discussed in the ARAC Fuel Tank Harmonization Working Group Final Report in paragraph 4e(2) of this AC. The rule requires that the fuel tank flammability be determined based upon the Monte Carlo analysis, which determines if the fuel tank ullage is flammable based on the fuel temperature and fuel tank altitude (or pressure altitude).

e. Higher Flash Point Fuels. One method of reducing fuel tank flammability is to restrict the fuel type specified in the AFM to higher flash point fuels (e.g., JP-5, 140 degrees F flash point). This method, in combination with other means, may be effective at reducing the exposure. However, as discussed in the ARAC Fuel Tank Harmonization Working Group Final Report in paragraph 4e(2) of this AC, this approach is not considered to be practical at this time. If this method were considered, the applicant would need to request FAA approval for use of a fuel type with a different flash point when conducting the flammability assessment than that required by appendix N to part 25.

f. Oxygen Concentration.

(1) Fuel Tank Inerting. Fuel tank inerting is a highly effective means of reducing or eliminating the flammability exposure within a given tank. This method eliminates flammable vapors by displacing oxygen from the ullage space of the tank with inert gas (reducing the oxygen concentration below the level that would support combustion of flammable vapors). The military has used this method to prevent fuel tank explosions of combat airplanes. While system requirements for commercial applications are different, the development of technology for separation of nitrogen gas from air has allowed the size and weight of inerting systems to be significantly reduced for commercial applications. Additional size and weight reductions may be achieved by new approaches such as catalytic conversion of fuel vapors in fuel tanks to produce carbon dioxide for use as the inert gas that is under development.

(2) Recent technology developments have made it possible to develop inerting systems that use optimized air sources that are part of the initial airplane design. These systems are capable of inerting a fuel tank during normal airplane operating conditions. Older technology airplanes that have limited bleed air sources are less efficient and it may not be practical to provide an inerting system that inerts the tank throughout the flight envelope. On these airplanes a flammability assessment based upon the time the

inerting system is effective, as well as consideration of the fuel tank flammability, may be part of the overall compliance demonstration.

(3) The applicant may show that inerting is only needed for certain missions, for example during warmer days when the fuel ullage would be flammable, or parts of a particular flight to lower the fuel tank vapor/air mixture average exposure to a level that meets the flammability limit. Inerting may be achieved by supplying inert gas from on-board storage bottles, holding either gas or liquid inerting agent, on board inert gas generation systems (OBIGGS), or from a ground storage system if the tank is inerted only on the ground. Nitrogen is currently the inert gas of choice for inerting fuel tanks and the requirements in the § 25.981 address the requirements for use of nitrogen based inerting systems. Use of other gases, such as carbon dioxide, to inert a fuel tank would include many of the same considerations for markings and maintenance procedures. However there may be other considerations that need to be addressed in the certification plan, such as gas absorbed by the fuel and the effect of the gas absorbed on the fuel system performance, such as suction feed performance.

(4) FRM designs that reduce the oxygen concentration to very low levels during cruise and increase the flow of nitrogen enriched air (NEA) into the fuel tank during decent have been found to optimize the design. One nitrogen inerting system designed for retrofit into airplanes with limited air sources has a dual flow mode that takes into consideration the performance of the air separation modules (see paragraph 4e(12) of this AC). During cruise the system operates at low flow mode where high nitrogen concentration NEA is introduced into the fuel tank to lower the oxygen concentration to very low levels. During decent the system is operated in high flow mode where the flow rate of NEA is increased. At high flow rates the nitrogen concentration of the NEA is lower.

(5) Oxygen Level. The accepted practice for tank inerting used by the military for a nitrogen based system is to reduce the oxygen concentration in the tank ullage to less than 9 percent. Data obtained from military testing that was conducted in 1991 (see paragraph 4e(7) of this AC), as well as FAA testing (see paragraph 4e(8) of this AC), shows that 12 percent oxygen concentration at sea level, will provide sufficient protection for transport category airplanes when using nitrogen based systems. As stated in the definitions paragraph of this AC, a fuel tank is considered to be inert when the bulk average oxygen concentration within each compartment of the fuel tank is 12 percent or less from sea level up to 10,000 feet altitude, then linearly increasing from 12 percent at 10,000 feet to 14.5 percent at 40,000 feet altitude, and extrapolated linearly above that altitude.

g. Oxygen Evolution. Fuel loaded on the airplane from sources vented to the atmosphere contains dissolved oxygen. Systems added to inert fuel tanks must take into account the dissolved and entrained oxygen in the fuel when loaded onto the airplane. The applicant can either design the system to allow and compensate for the evolution of the oxygen or include provisions to remove or “scrub” the oxygen from the fuel during refueling. The effect of oxygen that may rapidly evolve from the fuel during pressure reduction conditions, such as during climb, must be accounted for in the Monte Carlo

Model. Section 4.3 of the User's Manual discusses how oxygen evolution should be treated in the Monte Carlo analysis when an FRM using inerting is developed.

NOTE: An FAA ground and flight test program evaluated the effectiveness of inerting a center wing fuel tank with a ground based nitrogen enriched air supply without a closed vent system. The testing included measuring the effects of oxygen evolution. The results of the test program are contained in FAA Report, Ground and Flight Testing of a Boeing 737 Center Wing Fuel Tank Inerted with Nitrogen Enriched Air, Report # DOT/FAA/AR-01/63, (July 2001). The report is available on the internet at http://www.fire.tc.faa.gov/pdf/01-63.pdf.

h. Overnight Temperature Change. As the airplane sits overnight, the temperature will change accompanied by an associated density change of the fuel tank ullage. Usually, the change in temperature is downward from the last flight of the day to the first flight the next day. The result is that the fuel tank will "breathe in" additional air as the ullage density increases. The applicant must take this effect into consideration. Appendix N defines the required distribution the applicant must use in a Monte Carlo analysis to determine the change in temperature. The starting temperature is the temperature of the ullage at the end of the last flight as determined by the validated thermal model. The ending temperature is the ambient outside temperature before the next flight after an overnight temperature change. The applicant must substantiate the number of flights per day for a particular airplane and apply the overnight temperature change effect once "per day" in the FRM module developed by the applicant for the Monte Carlo analysis. Some airplane operations (such as executive jets) result in routine operations with consecutive days of overnight temperature changes that may cause the oxygen concentration in the fuel tanks to be elevated so the tank is no longer inert. The effects of consecutive overnight temperature changes on FRM performance should be provided by the DAH in the airplane operating and maintenance instructions.

i. Other Considerations Related to Oxygen. The applicant should consider any other environmental conditions or airplane system that may have an effect on the oxygen concentration within the fuel tank in question. Some existing fuel tank vent systems are designed to vent to both wing tips. For a fuel tank that may be vented to both sides of the airplane, the applicant must consider the effects of pressure differences across the wing and the resulting cross flow through the tank. Differential pressures created during maneuvers, between the vents located near each wing tip result in significant flow of air through the fuel tank and can result in adverse effects on an FRM that is based upon limiting oxygen concentrations. Installation of check features, such as a lightly loaded check valve in the vent system, or limiting the venting to one vent outlet have been shown to limit cross-flow. Any changes to an existing airplane vent system must meet the associated regulations (e.g., §§ 25.975 and 25.979). For example, one factor that needs to be considered is possible increases in fuel tank bottom pressures during refueling conditions due to any additional pressure losses resulting from modifications to the vent system. When inerting is used as the means of compliance, the inert gas distribution system must be shown to be effective in all compartments of a fuel tank. The design may be optimized by incorporation of features to maintain even distribution of the inerting gas.

j. Compliance Demonstration. Flight test demonstration and analysis will be required to demonstrate the effectiveness of the inerting system (see appendix 5 for information on measurement of oxygen concentrations in airplane fuel tanks). The demonstration should include critical conditions and demonstration that the inerting system reduces the oxygen concentration in the tank to an acceptable level, without leaving pockets of oxygen concentrations above the maximum level within the tank. Where the applicant uses inerting as one part of an overall method to reduce flammability (for example inerting in combination with tank temperature control), the applicant should demonstrate the effectiveness of each part of the overall method independently, as well as in combination to show overall effectiveness at meeting the flammability requirements.

(1) The amount of flight testing that is acceptable for showing compliance depends upon the proposed method of compliance. For example, an applicant may choose to develop an FRM performance model and then substantiate by airplane testing that the model accurately predicts the system performance. An applicant may also choose to define the critical points in the airplane operating envelope and then conduct flight test conditions at the critical points to show compliance.

(2) For an inerting-based FRM that is effective at preventing fuel tank flammability during normal airplane operating conditions, the demonstration that would be needed may be limited to providing substantiation that the distribution system is effective at inerting all sections of the tank, that the system provides adequate flow, and that the reliability of the system meets the overall requirements.

(3) In addition, the applicant must substantiate that the added system meets the installation requirements of part 25.

k. System Reliability Considerations.

(1) The overall time the fuel tank is flammable cannot exceed 3 percent of the Flammability Exposure Evaluation Time (FEET), which is the total time, including both ground and flight time, considered in the flammability assessment defined in appendix N. As a portion of this 3 percent, if flammability reduction means (FRM) are used, each of the following time periods cannot exceed 1.8 percent of the FEET: (a) when any FRM is operational but the fuel tank is not inert and the tank is flammable; and (b) when any FRM is inoperative and the tank is flammable.

(2) Master Minimum Equipment List (MMEL) Interval. Inerting systems designed as a flammability reduction means are considered part of a balanced fuel tank safety approach together with design features incorporated to prevent ignition sources in fuel tanks. These FRM are not considered flight critical and airplanes may be eligible for dispatch under the MMEL with the FRM inoperative. The FAA Flight Operations Evaluation Board (FOEB) will establish the MMEL dispatch relief interval for the FRM

based on data submitted by the applicant to the FAA. This value should reflect the value the applicant uses in the reliability analysis and the requirements of appendix N25.3(d)(2), which states that if dispatch with the system inoperative under the MMEL is requested, the time period assumed in the reliability analysis must be 60 flight hours for a 10-day MMEL dispatch limit unless an alternative period has been approved by the Administrator. The FOEB may accept a system reliability analysis using the Monte Carlo Model. As shown in section 3.2 of the User's Manual, inputs needed to conduct an analysis include, mean time between failures (MTBF) of the FRM, average time to restore the system function after it is placed on the Minimum Equipment List (MEL), and the number of flights before a failed FRM would be detected. These inputs are discussed in more detail in the User's Manual.

(3) Reliability Reporting. The regulation requires that the applicant demonstrate effective means to ensure collection of FRM reliability data so that the effects of component failures can be assessed on an on-going basis. The reporting requirement is contained in appendix M, paragraph M25.5, and applies to applicants and DAH.

(4) The rule requires the TC or STC holder to provide the FAA with summaries of the FRM reliability data in compliance with appendix M to part 25 on a quarterly basis for the first five years after the FRM is installed and operational. After that time, continued quarterly reporting requirements may be replaced with other reliability tracking methods approved by the FAA Oversight Office. The requirement for quarterly reports may be eliminated if the FAA determines that the reliability of the FRM meets, and will continue to meet, the requirements of the rule.

(5) Operators are not required to report FRM reliability information. Type certificate holders are required to gather the needed data and may use existing reporting systems that are currently used for airplane maintenance, reliability, and warranty claims to gather the data from operators using existing business arrangements between the TC holders and the airlines.

(6) The reliability report should include information regarding overall system dispatch reliability, including identification of the component that caused the failure of the system, and the number of days on average the system was placed on the MMEL. The report should be submitted to the FAA Oversight Office by a letter on a quarterly basis as required by the regulation.

l. Indications.

(1) Since inerting systems are considered a safety enhancing system, similar to a flight data recorder, no indication to the flightcrew of the flammability of the fuel tank, and associated flightcrew procedures for fuel tank flammability or oxygen concentration are specifically required by the regulation. The need to provide indication of the FRM status will depend on the particular FRM design. Various design methods may be used to make sure an FRM meets the reliability and performance requirements. These may

include a combination of system integrity monitoring and indication, redundancy of components, and maintenance actions. 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.

(2) The need for FRM indications and the frequency of checking system performance (maintenance intervals) must be determined as part of the FRM fuel tank flammability exposure analysis. The determination of a proper maintenance interval and procedure will follow completion of the certification testing and demonstration of the system's reliability and performance prior to certification or as part of the FAA review process for airplanes manufactured under existing TC or auxiliary fuel tanks under existing STC.

(3) Appropriate maintenance level indications and limitations should be placed in the MMEL to maintain the reliability of the inerting system to the level required by the regulations. For example, maintenance level messages would likely be needed to meet the reliability requirements for an FRM to show when the system is not functioning properly so the inoperative interval that goes into the reliability analysis can be limited to short periods. Installation of an oxygen sensor to measure the oxygen concentration, and appropriate maintenance messages may be needed to meet reliability requirements or may be a desirable feature that may eliminate the need for frequent maintenance checks.

m. Inerting System Safety Considerations.

(1) For inerting systems that generate NEA on board, the waste gas may create additional fire hazards or change the hazards within certain areas of the airplane. Therefore, these effects should be considered a potential hazard to the airplane. By the very nature of the process of separating nitrogen from air, the waste gas will be of a higher concentration of oxygen than normal air. Since higher concentrations of oxygen may lead to a greater likelihood of ignition, given the availability of fuel vapor and a spark, safety assessment and special precautions may be required.

(2) Inerting systems that use combustion or catalytic processes to produce inerting gas typically operate at elevated temperatures that may introduce hazards into the airplane design. These systems must be located and designed such that they comply with airplane fire protection regulations, such as § 25.863, etc.

(3) Special maintenance procedures may be required to meet the reliability and performance requirements for fuel tanks that utilize nitrogen inerting. Maintenance actions that require entry into a fuel tank that contains inert gas or an area adjacent to an inerted fuel tank may be hazardous if appropriate safety precautions are not utilized. The fuel tank should be ventilated and appropriate air source provided. Appropriate warning information should be included in the maintenance manuals and placards placed at fuel tank entry points warning maintenance personnel.

(4) Confined spaces are compartments or enclosures with limited openings for entry and exit, not intended for continuous human occupancy, and only suitable for temporary work such as inspections, maintenance, or repairs. A fuel tank has potential hazards that include toxic chemicals, insufficient oxygen with a concentration that is below 19.5 percent or excess oxygen that is above 23.5 percent, and a flammable gas, vapor, or mist in excess of 10 percent of its LFL. (Reference U.S. Department of Labor Occupational Safety & Health Administration (OSHA), 29 CFR §1910.146(b)). Specific procedures must be in place that identify, control, or eliminate these hazards prior to maintenance personnel entering into fuel tanks.

(5) 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 environmental hazards exist. These hazards exist in any fuel tank (regardless of whether a nitrogen inerting system is installed) and include fire and explosion, toxic and irritating chemicals, oxygen deficiency, and the confinement to the fuel tank itself. To prevent related injuries, operator and repair station maintenance organizations have developed specific procedures for identifying, controlling, or eliminating the hazards of fuel-tank entry. In addition, government agencies have adopted safety requirements for use when entering fuel tanks and other confined spaces. These same procedures along with additional markings would be applied to the reduced oxygen environment likely to be present in and adjacent to an inerted fuel tank.

(6) Confined and Adjacent Space Markings. The addition of a system that utilizes inerting to reduce the flammability of a fuel tank may result in reduced oxygen concentrations due to leakage of the inert gas in locations in the airplane where service personnel would not expect it.

(7) 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. These gases may be under pressure because of the design of the inerting system, and any hazards associated with working in adjacent spaces near the opening, should be identified in the marking of the opening to the confined space.

(8) Introduction of NEA within the fuel tanks creates additional risks because of the possibility of NEA leaking into compartments adjacent to the fuel tanks. Lack of oxygen in these areas could be hazardous to maintenance personnel, and in some cases could affect the passengers, or flightcrew. Existing certification requirements address these hazards. Appendix M25.3(c) requires markings to emphasize the potential hazards associated with confined spaces and areas where a hazardous atmosphere could be present as a result of the addition of FRM. That paragraph requires that the access doors and panels to the fuel tanks with FRMs and to any other enclosed areas that could contain hazardous atmosphere under either normal conditions or failure conditions be permanently stenciled, marked, or placarded to warn of hazards.

(9) Fuel tanks are 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 oxygen concentrations before entering a fuel tank are already required.

(10) Designs currently being implemented 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 allow some ventilation of the spaces adjacent to the FRM. Leakage of NEA into areas adjacent to the FRM equipment or tanks may create a hazard for maintenance personnel. Confined space hazards in the areas adjacent to the fuel tanks should be assumed unless it can be shown that adequate ventilation is provided so air quality for maintenance personnel is assured. Unless the design eliminates this hazard, markings should 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 connected to 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. 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 hazards of fuel vapors and lack of oxygen in and adjacent to the fuel tank.

(11) Markings/placards. The regulation requires that if an inerting system is installed on an airplane, the access doors and panels to the fuel tank(s) and any other enclosed areas that could contain hazardous atmosphere under either normal conditions or failure conditions must be permanently stenciled, marked, or placarded to warn of hazards. These placards would be considered CDCCL and should be included in the required markings section of the maintenance instructions.

The following is an example of wording that may be used:

- Low oxygen content possible during nitrogen generation system operation.
- Obey employer safety procedures.
- Failure to obey may cause injury.

FIGURE 2

Low Oxygen Level Placard

FIGURE 3

Confined Space Placard

12. Ignition Mitigation Means (IMM).

The following are acceptable means to mitigate the effects of an explosion.

a. One means to meet § 25.981 is to protect a tank from structural and systems damage that could prevent continued safe flight and landing of the airplane. This alternative recognizes that an applicant may choose to accept a high flammability exposure in a given tank and to provide additional protection to extinguish or suppress an explosion in a tank if an ignition occurs.

b. The use of appropriate foams to fill the fuel tank and thereby control the pressure rise following an ignition of the fuel vapor/air mixture has been demonstrated to be effective by the United States Air Force (USAF) and other military forces. Foams are in use on several civilian transport category airplane types. Detailed design information regarding use of reticulated polyurethane safety foam for explosion suppression is provided in the report referenced in paragraph 4d(1) of this AC. The applicant may use such a foam installation to satisfy the requirement of § 25.981. The foam type should be demonstrated to be effective in suppressing explosions to a level where structural and system damage is prevented. The applicant should:

(1) Provide data on the foam, including material, pore size, and intended method for installing the foam in the tank.

(2) Address the potential for, and the effects of, degradation of the foam, from any environmental effects and long term aging, on both the airplane and engine fuel systems. If the foam has a limited useful life, particular installation requirements, or other features that are essential for the IMM to perform its intended function, they should be defined as CDCCLs.

(3) Address the effects of the foam installation on fuel system performance, including engine feed, venting, unusable fuel, sump capacity, expansion space capacity, fueling, and defueling, including the effect of the foam on electrostatic buildup in the tank.

(4) Address the effect of the foam installation on the airplane fuel system, as well as the auxiliary power unit (APU) and engine fuel systems, and develop maintenance procedures to ensure the foam is correctly installed, both initially and when reinstalled, if removed for access to the tank.

/s/ Ali Bahrami

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APPENDIX 1

LIST OF § 26.33(a) AFFECTED MODELS/FAA OVERSIGHT OFFICES

TABLE 1-1

Section 26.33(a) Applicable Airplane Models

The following list represents the airplane models determined to meet the applicability criteria of § 26.33(a). This list only represents our best determination at this time and may not be complete. Design approval holders are responsible for identifying all of their airplane models meeting the applicability criteria.

Aerospatiale:	ATR 42, ATR 72
Airbus:	A300, A310, A318, A319, A320, A321, A330, A340, A380
BAE:	BAe-146, BAe Jetstream 4100, ATP, Avro 146
Boeing:	717, 737, 747, 757, 767, 777, MD-80, MD-90, MD-11
Bombardier:	CL-600-2B19 (CRJ-100/200/440), CL-600-2C10 (CRJ-700), CL-600-2D15, CL-600-2D24 (CRJ-900), DHC-8
CASA:	CN-235, C-295
Dornier:	328-100, 328-300
Embraer:	EMB-120, EMB-135, EMB-145, ERJ-170, ERJ-190
Fokker:	F.27 Mk 50, F.28 Mk 0070 and Mk 0100
Saab:	340 (or SF-340), 2000

TABLE 1-2

FAA Oversight Offices

Airplane manufacturer	FAA Oversight Office
Aerospatiale	Transport Airplane Directorate, International Branch, ANM-116
Airbus	Transport Airplane Directorate, International Branch, ANM-116
BAE	Transport Airplane Directorate, International Branch, ANM-116
Boeing	Seattle Aircraft Certification Office
Bombardier	New York Aircraft Certification Office
CASA	Transport Airplane Directorate, International Branch, ANM-116
deHavilland	New York Aircraft Certification Office
Dornier	Transport Airplane Directorate, International Branch, ANM-116
Embraer	Transport Airplane Directorate, International Branch, ANM-116
Fokker	Transport Airplane Directorate, International Branch, ANM-116
Lockheed	Atlanta Aircraft Certification Office
McDonnell-Douglas	Los Angeles Aircraft Certification Office
SAAB	Transport Airplane Directorate, International Branch, ANM-116

APPENDIX 2

DEVELOPING CRITICAL DESIGN CONFIGURATION CONTROL LIMITATIONS - FUEL TANK FLAMMABILITY

1. Introduction. This appendix provides guidance for developing Critical Design Configuration Control Limitations (CDCCL) for fuel tank systems to prevent the fuel tank from exceeding the applicable flammability exposure limits established in the 2008 Fuel Tank Flammability Reduction (FTFR) rule. Guidance for developing CDCCLs to maintain ignition prevention features is located in AC 25.981-1B, Fuel Tank Ignition Source Prevention Guidelines, or the latest revision.

2. Definitions.

a. Aircraft Maintenance Manual (AMM). A manual developed by the manufacturer of a particular airplane that contains information necessary for the continued airworthiness of that airplane.

b. Airworthiness Limitation Item (ALI). Mandatory maintenance of the fuel system that can include CDCCL, inspections, or other procedures determined necessary to ensure, with respect to this AC, the fuel tank flammability exposure does not increase above the certification limits as a result of maintenance actions, repairs, or alterations throughout the operational life of the airplane.

c. Component Maintenance Manual (CMM). A manual developed by a manufacturer that contains information necessary for the continued airworthiness of a particular component.

d. Critical Design Configuration Control Limitations (CDCCL). A limitation requirement to preserve a critical design feature of a flammability reduction system or of the fuel system design that is necessary for the design to meet the performance standards of § 25.981 throughout the life of the airplane model. The purpose of the CDCCL is to provide instructions to retain the critical features during configuration changes that may be caused by alterations, repairs, or maintenance actions.

e. Instructions for Continued Airworthiness (ICA). The information documented in accordance with 14 CFR 25.1529 and 14 CFR part 25, appendix H that includes the applicable methods, inspections, processes, procedures, and airworthiness limitations required to keep the airplane airworthy throughout its operational life.

3. Discussion.

a. Critical Design Configuration Control Limitations include those features of the design that must be present and maintained to achieve the safety level intended by § 25.981 for the operational life of the airplane. Changes to the airplane, such as installing a fuel re-circulation system, hydraulic heat exchanger in the fuel tank, or a heat source adjacent to the fuel tank, may affect fuel tank flammability exposure. A CDCCL would be necessary in this example to prohibit the addition of heat to the fuel tank.

Another example of a CDCCL might be limits on operation with certain fuel types such as JP-4. The CDCCL would also control or prohibit the kinds of modifications to airplanes, like modifications that affect the vent system of a fuel tank that has an FRM installed or the addition of auxiliary fuel tanks that vent into a fuel tank that has an FRM installed, that could adversely change the flammability exposure of fuel tanks to which it may be connected. All fuel tanks subject to the requirements of Amendment 25-125, even those in airplanes that do not have high flammability fuel tanks, will need to have CDCCL defined so that future modifications do not increase the flammability above the regulatory limit. Under part 26, CDCCL must also be provided for fuel tanks required to be modified by FRM or IMM. The application of CDCCL under the FTFR rule is similar to the requirements already applied to fuel tank ignition source prevention in Amendment 25-102 to § 25.981.

b. The FTFR also includes the requirement that visible means identifying CDCCL be present. This is required to prevent alterations to critical features of the system. As the visible identifications are critical to the FRM or IMM system, they are also considered to be CDCCL. Any tampering or removal would be in violation of the CDCCL. These CDCCLs, inspections, or other procedures would be documented as airworthiness limitations in the ICA.

c. The CDCCLs for fuel tank flammability include any information necessary to maintain those design features that have been determined by analysis of the fuel tank system (e.g., fault tree analysis, failure modes and effects analysis) as needed to maintain the performance of the FRM or IMM, or maintain the fuel tank flammability within the limits established by the applicable regulations. AC 25-981-1B (or latest revision) contains additional guidance on how to perform the analysis for ignition prevention CDCCLs. CDCCLs are intended to preclude the occurrence of any maintenance or inspection task or procedure that could result in a failure, malfunction, or defect that would compromise the intended function of the critical part, component or design feature that ensures the fuel tank flammability exposure does not exceed the regulatory limits. This information is essential to ensure that maintenance, repairs, or alterations do not unintentionally violate the integrity of the original type design of the fuel tank system. CDCCLs may be required that define the critical features, such as:

- Flammability exposure of the unheated aluminum wing tank, and associated cooling rate,
- Limits on heat input such as adding heat blankets or additional hydraulic heat exchangers,
- Limits on how an auxiliary fuel tank is integrated with an existing airplane fuel tank system, such as limiting venting into a tank with FRM based upon inerting or transferring warm fuel from the auxiliary tank,
- Limits on airplane systems such as minimum quantity of engine bleed air flow or electricity that is required to supply power to an FRM,
- Limits on use of high volatility fuels such as JP-4,
- Quantity of engine bleed air flow that is used for inerting,

- Limits on penetrations of the fuel tank,
- Limits on any changes to fuel management that may affect FRM,
- Limits on changes to any placards or means used to visibly identify critical design features of the fuel tank system that must not be compromised for the operational life of the airplane,
- Life limits on parts such as polyurethane foam used as an IMM, and the air separation modules used in an inerting system.

d. Airworthiness limitations are part of the ICA. Design approval holders (DAH) need to make available to affected parties pertinent changes to the ICAs. (The term "make available" is used in the same sense that it is used in § 21.50.) The rule is not intended to alter or interfere with the existing commercial relationships between TC holders and these other persons. The FAA anticipates that DAHs would be able to be reasonably compensated for developing these documents, as they are under current practice.

e. The rule requires creation of an Airworthiness Limitations Section (ALS), unless previously established. The ALS is required by current part 25 and includes those items that have mandatory inspection or replacement times related to fuel systems and structure. The ALS is included in the ICA, approved as part of type certification, and distributed with an airplane on delivery. In this way the ALS is visible to all who need it and who would be required to comply with it under §§ 121.917, 125.509 and 129.117. For those airplanes that currently do not have an ALS, the rule requires an ALS only for fuel tank safety related limits. This rule does not require that the ALS for these airplanes include the other requirements for an ALS established under Amendment 25-54 to part 25, or a later amendment. For those DAH or applicants with airplanes certified to Amendment 25-54 or later, the existing ALS would be revised to include the fuel tank system ALI.

f. The ICA developed by the DAH using the guidance in this advisory circular must be approved by the responsible FAA Oversight Office. Those approved instructions are required by related operational rules to be used by operators to develop and propose changes in their maintenance programs and incorporate design changes needed to maintain the fuel tank flammability within the approved limits and to ensure continued airworthiness of certain features of the FRM and IMM for the operational life of the airplane. These changes to the maintenance programs must be reviewed and approved by the operator's designated FAA inspector or Principal Inspector.

4. Development of Critical Design Configuration Control Limitations.

a. The CDCCLs, which are a type of Airworthiness Limitation, are the primary means of managing and controlling the configuration of the FRM, IMM or design features that affect the flammability of any fuel tank that does not require an FRM or IMM. In the context of this AC, CDCCLs provide limitation requirements for configuration management to preserve the integrity of certain critical flammability features of the fuel tank system design. These critical features are essential to ensure fuel tank flammability does not increase above limits defined in the regulations as a result of configuration changes caused by maintenance action, repair, or alteration of those critical features. While initial inspections may be necessary to ensure that a CDCCL has not been compromised (e.g., because of aging, wear, maintenance, alterations, etc.), they are not intended to require repetitive inspections. Rather the intent of the CDCCL is to ensure that all affected maintenance personnel are aware of the need to make sure the configuration identified by the CDCCL is preserved for the operational life of the airplane.

b. The DAH may determine that the CDCCLs are applicable at the individual part level or at the component level. In the context of this guidance, components are assembled from parts. Design approval holders may elect to identify a CDCCL that applies to the component for the purposes of reducing tracking of ALIs that may apply to individual parts of the component. If the component level is used, the design approval holder is responsible for revising the CMM instructions to identify all of the critical features of the component design for approval by the FAA Oversight Office.

c. To identify the parts or components to which the CDCCLs are applicable, the DAH must first conduct a configuration assessment of the fuel tank system design. The purpose is to identify any foreseeable maintenance or inspection actions or other causes that could compromise the configuration of a critical feature of the fuel tank system. In the context of this guidance, foreseeable causes are those that have occurred in service in the past or those that engineering judgment predicts could compromise the critical feature of a part or component of a fuel tank system. The DAH must develop maintenance and inspection instructions to prevent those foreseeable changes to the design configuration of the critical ignition source prevention features.

d. Airworthiness Limitations Section Content. The ALIs should include the following:

- The Limitation Statements shown below,
- A brief description of the flammability reduction, ignition mitigation means features,
- The flammability issue associated with inadvertent changes to the configuration of each of those design features, and
- The reference to maintenance instructions, if applicable, and other information in manuals (such as airplane maintenance, standard wire practices manual, etc.,) that have been revised or created to advise affected personnel of the CDCCLs.

e. Limitation Statement: The Critical Design Configuration Control Limitation statements are as follows:

LIMITATIONS.

(1) The critical features of the parts or components identified in the CDCCLs must be maintained in a configuration identical to an approved type design for the airplane.

(2) Any repairs or overhauls to the critical features of the parts or components that are identified must be maintained in accordance with the design approval holder's maintenance manual or with other acceptable repair or overhaul specifications and parts approved by the FAA Oversight Office specifically for that part or component.

(3) In cases where the critical features of a component are specified, any test equipment or tooling utilized to repair or overhaul the component must be in accordance with the CMM or otherwise comply with 14 CFR 43.13(a) and be substantiated and documented as equivalent.

5. Identification and Awareness of CDCCLs.

a. The DAH should list the parts components or features to which the CDCCLs are applicable for a particular airplane in the service information (e.g., maintenance planning document or special certification item document) documenting the CDCCL. This is the mechanism for identifying critical features and requiring their control. To ensure that the operator introducing a modification or the mechanic is aware of the need to consider these critical features, it will be necessary to insert cross-references in certain documents to comply with the CDCCLs.

(1) The DAH should identify a task with WARNING or CAUTION notes for a component or part that has a critical design feature in the AMM. The operator should incorporate acceptable procedures to ensure compliance with the CDCCLs.

(2) The DAH should include information in standard practices manuals to ensure the CDCCL information is provided to those making modifications or maintaining the type design. (see AC 25-26, Development of Standard Wiring Practices Documentation (11/14/07) for guidance on preparation of these manuals).

(3) The DAH should identify the appropriate CMM. In addition, the design approval holder should ensure that a statement is inserted into both the CMM and the Airplane Maintenance Manual that the component is controlled by the CDCCL and, therefore, that it may be repaired or overhauled only in accordance with the CMM or other acceptable maintenance procedures and parts approved by the FAA Aircraft Certification Office.

(4) These documents should include a statement that the part, component or design feature component is controlled by the CDCCL and, therefore, that it may be

repaired or overhauled only in accordance with the CMM or other acceptable maintenance procedures approved by the FAA Oversight Office.

APPENDIX 3

COMPLIANCE WITH PART 26, SUBPART D, SECTIONS 26.33 AND 26.35

1. <u>Section 26.33 Holders of type certificates: Fuel tank flammability</u>. This section requires TC holders of certain large transport category airplanes described below to analyze the flammability exposure of all their affected airplanes' fuel tanks and develop service instructions for those tanks that exceed limits defined in the rule. For example, a TC holder of an affected airplane with any fuel tank that is determined by the analysis to have high flammability exposure (over 7 percent) is required to develop service instructions for IMM or FRM to reduce the flammability exposure of the fuel tank. If the fuel tank is normally emptied and any portion of the fuel tank is located within the fuselage contour, § 26.33(c)(1)(i) requires the FRM meet the flammability exposure criteria of appendix M of part 25. For all other fuel tanks with a flammability exposure over 7 percent, § 26.33(c)(1)(ii) requires the FRM meet the flammability criteria of appendix M except instead of complying with paragraph M25.1 of the appendix the fleet average flammability exposure may not exceed 7 percent. The affected TC holders would also be required to submit compliance plans for the flammability analysis and the development of service instructions for an FRM or IMM. The due dates for items required by this regulation are as follows:

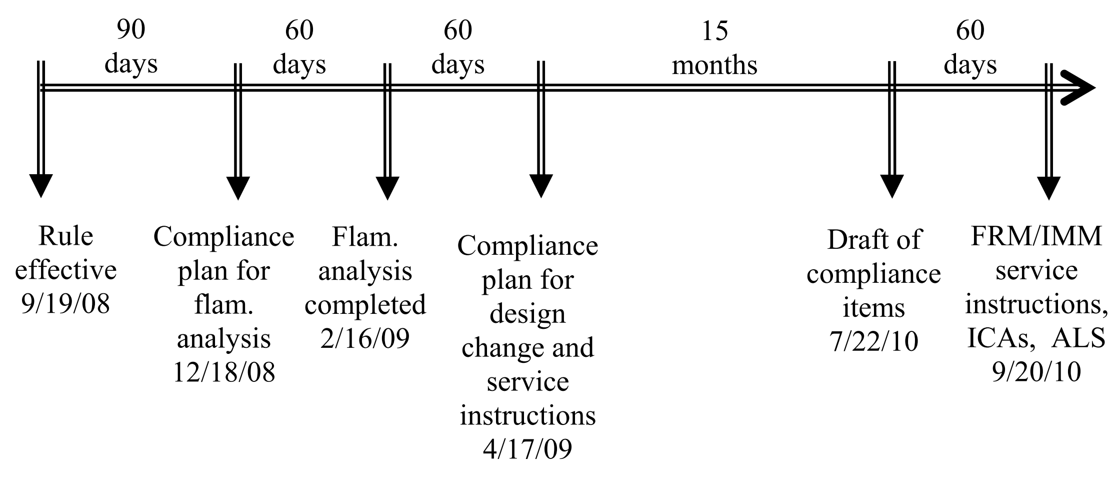

FIGURE 3-1

Compliance Timeline for TC Holders (§ 26.33)

a. Applicability. Section 26.33(a) states that this rule applies to "*U.S. type certificated transport category, turbine-powered airplanes, other than those designed solely for all-cargo operations, for which the State of Manufacture issued the original certificate of airworthiness or export airworthiness approval on or after January 1, 1992, that, as a result of original type certification or later increase in capacity have:*
(1) A maximum type-certificated passenger capacity of 30 or more, or
(2) A maximum payload capacity of 7,500 pounds or more."

(1) The reference to the originally certificated capacity, or later increase in capacity, is intended to address two situations:

(a) In the past, some designers and operators have gotten design change approval for a slightly lower capacity to avoid applying requirements mandated only for airplanes over specified capacities. By referencing the capacity resulting from original certification, this rule removes this possible means of avoiding compliance.

(b) It is also possible that an airplane design could be originally certified with a capacity slightly lower than the minimum specified in this section, but through later design changes, the capacity could be increased above this minimum. The reference to later increases in capacity ensures that, if this occurs, the design would have to meet the requirements of this section.

(2) *Maximum payload capacity* is defined in 14 CFR 119.3, Definitions. Also see the reference in paragraph 4e(15) of this AC.

(3) Foreign Type Certificate Holders. This paragraph applies not only to domestic TC holders, but also to foreign TC holders. In this sense, this section is different from most type certification programs, where foreign applicants typically work with their responsible certification authority, and the FAA relies, to some degree, upon that authority's findings of compliance under bilateral agreements. Since this rulemaking is not harmonized in all cases, the FAA will initially retain the authority to make all the necessary compliance determinations, and where appropriate, may request certain compliance determinations by the appropriate foreign authorities using procedures developed under the bilateral agreements. The compliance planning provisions of this section (discussed later) are equally important for domestic and foreign TC holders and applicants, and we will work with the foreign authorities to ensure that their TC holders and applicants perform the planning necessary to comply with the requirements of this section.

b. Flammability Determination and Service Instructions.

(1) Flammability Analysis. Section 26.33(b) requires holders of TCs for large transport category airplanes to submit a flammability exposure analysis for approval by the FAA oversight office by December 18, 2008. Section 26.33(b)(2) provides an

exception to the flammability analysis requirement for fuel tanks for which the TC holder has notified the FAA that it will provide design changes and service instructions for an FRM or IMM meeting the requirements of § 26.33(c).

(2) Model Variations and Derivatives.

(a) Section 26.33(b) specifies that the flammability analysis must include "*all fuel tanks defined in the type design, as well as all design variations approved under the type certificate that affect flammability exposure*." Design variations that may affect fuel tank flammability could include changing the fuel tank volume or usable fuel capacity, changes in the fuel management procedures, engine changes that might affect parameters such as airplane climb rate or bleed air available if needed by an FRM. Other examples of configuration differences that may affect fuel tank flammability exposure are provided in the discussion of § 26.35. It would also include all modifications and changes mandated by airworthiness directives (AD) that affect fuel tank flammability exposure as of the effective date of the rule. These ADs would only be those issued against any configurations developed by TC holders. This would include any ADs issued against modifications defined by a third party STC installed on affected airplanes. The result would be a configuration that is clearly understood by both industry and the FAA.

(b) An example of a design variation is an airplane certificated with the same model and series designation that could have different maximum takeoff gross weights, changes in fuel tank configuration or engine type or thrust, equipment installations, or passenger versus all-cargo carrying capabilities. Derivatives, in most cases, are those model airplanes that historically incorporate significant design changes from the original approved type design. In general, these derivative models would have to comply with later airworthiness standards for those areas incorporating the significant design changes. The derivative models are listed on the same TC data sheet with the original certificated model. Various segments of industry have also defined these changes as "variants." For the purpose of this regulation, we consider the terms "derivatives" and "variants" to be synonymous.

(3) Service Instructions and Service Bulletins. If the flammability exposure analysis shows that the average exposure for any fuel tank exceeds 7 percent, § 26.33(c) requires the TC holder to develop design changes and service instructions for either FRM or IMM. Modifications incorporated into existing airplanes, including safety related changes (design and/or maintenance) that are mandated by AD, are typically made by operators using service instructions developed by the TC holders. These service instructions are commonly referred to as service bulletins. In this regulation, service instructions must contain sufficient information for the operator to incorporate the design change and any associated procedures and airworthiness limitations. They may include specific step-by-step procedures and information needed by the operator, such as parts lists, drawings, etc. Therefore, the paragraph requires TC holders to develop and submit for approval by the FAA, not just data defining a proposed design change, but a package of complete information that includes all of the information necessary to enable an operator to comply with the operational rules, discussed later. This information should

be formatted and completed to a point similar to what would be submitted to the FAA if the FAA were to be issuing a mandatory action.

(4) Flammability Levels.

(a) The guidance in this paragraph applies to the new FRM or IMM requirements of § 25.981(b) and (c), and appendix M, to existing fuel tanks that exceed 7 percent average flammability exposure. For any fuel tank that is normally emptied and exceeds 7 percent average flammability exposure, if any portion of the tank is located in the fuselage contour, the rule requires TC holders to develop IMM or FRM that reduces the flammability exposure to 3 percent average flammability exposure and 3 percent warm day requirements of appendix M. The warm day requirement would limit the average flammability exposure of the tank for each of the ground, takeoff and climb phases of the airplane operation during warm days to 3 percent average flammability exposure. The flammability exposure limit for these particular tanks has been established in consideration of the service experience that shows these tanks to have a higher risk for fuel tank explosion than other tanks. For all other fuel tanks located in other portions of the airplane (for example, the wing and empennage), the proposal would require TC holders to develop IMM or FRM that reduces the flammability exposure below 7 percent and apply the requirements for an FRM of subparagraph M25.2, M25.3, M25.4 of appendix M if an FRM is selected as the means of compliance. This rule is not expected to result in the need for FRM or IMM in any fuel tanks located in the wings of airplanes in the existing fleet because previous assessments estimate these tanks have flammability exposure below 7 percent. However, the analysis required by this rule may reveal some fuel tanks located within the wing that exceed 7 percent.

(b) The definition of tanks that are normally emptied and auxiliary fuel tanks used in this section are the same as that discussed in the preamble to the flammability reduction rulemaking associated with this AC.

c. Compliance Times.

(1) Section 26.33(d) requires submitting for approval by the FAA oversight office the design changes and service instructions required by § 26.33(c) by September 20, 2010.

(2) The compliance times stated in this section are also used as the basis for the compliance dates for introduction of these systems into the operators' fleets under parts 121, 125, and 129. Extension of the compliance dates for development of the service instructions by the certificate holders would either reduce the amount of time available to operators or delay full deployment of these safety improvements. Incorporation of FRM or IMM will likely require access inside the fuel tanks. Typically fuel tanks are only accessed during heavy maintenance checks that are done on a schedule established during development of the maintenance program. The compliance dates for the operational rules were established to allow a majority of the modifications to be done during these heavy maintenance checks. Introduction of FRM or IMM outside of normally scheduled

maintenance would increase the cost to the operators because extra tank entry and airplane down time would be needed.

d. Critical Design Configuration Control Limitations.

(1) Section 26.33(e) requires that for fuel tanks equipped with FRM or IMM, holders of TCs affected by this section must establish airworthiness limitations consisting of CDCCL, inspections, or other procedures. The purpose of these limitations is, for tanks equipped with FRM, to prevent increasing the flammability exposure of the tanks above that permitted under § 26.33 and, for tanks equipped with IMM, to prevent degradation of the performance of the IMM installed in accordance with this section. Appendix 2 of this AC provides additional guidance regarding development of CDCCL. For example, certain fuel tanks may rely on natural cooling or use of certain fuel types to meet the flammability levels required by the rule. Therefore, CDCCL may be required that define the critical features, such as—

- flammability exposure of the unheated aluminum wing tank,
- cooling rate,
- limits on heat input,
- limits on use of high volatility fuels such as JP-4,
- quantity of engine bleed air flow that is used for inerting,
- limits on penetrations of the fuel tank,
- limits on any changes to fuel management that may affect FRM,
- limits on changes to any placards or means used to visibly identify critical design features of the fuel tank system that must not be compromised for the operational life of the airplane.

(2) Instructions for Continued Airworthiness. As discussed below, airworthiness limitations, such as those in this section, are part of the ICA. Section 21.50 requires that TC holders make changes to the ICA available to persons required to comply with them. As used throughout this notice, the term “make available” is used in the same sense that it is used in § 21.50.

e. Airworthiness Limitations.

(1) Section 26.33(f) requires creation of an ALS, unless previously established. The ALS is required by current part 25 and includes those items that have mandatory inspection or replacement times related to fuel systems and structure. The ALS is included in the ICA, approved as part of certification, and distributed with an airplane on delivery. In this way the ALS is visible to all who need it and who would be required to comply with it under §§ 121.1117, 125.509 and 129.117 of this rule. The current part 25 ALS and ICA requirements apply only to airplane types originally certified after Amendment 25-54 (adopted in 1981) and were developed for structural considerations. As a result, they are not applicable to many current airplanes and do not currently contain information for other systems.

(2) For those TC holders of airplanes that currently do not have an ALS, the regulation only requires establishing an ALS to include fuel tank safety related limits. This would not require that the ALS for these airplanes include the other requirements for an ALS established under Amendment 25-54 to part 25, or a later amendment. For those TC holders or applicants with airplanes certified to Amendment 25-54 or later, the existing ALS would be revised to include the fuel tank system ALI.

f. Compliance Planning.

(1) Historically, the FAA has worked together with the TC holders when safety issues arise to identify solutions and actions that need to be taken. Some of the safety issues that have been addressed by this process include those involving aging aircraft structure, thrust reversers, cargo doors, and wing icing protection. In some cases service instructions have not been developed in a timely manner. While some manufacturers have addressed these safety issues and developed service instructions, others have not applied the resources necessary to develop service instructions in a timely manner. This has caused delay in the adoption of corrective action(s). The compliance planning requirements of § 26.33(g) and (h) are intended to provide TC holders and the FAA with assurance that they understand what means of compliance is acceptable and have taken necessary actions, including assigning sufficient resources, to achieve compliance with this section. This paragraph is based substantially on "The FAA and Industry Guide to Product Certification," which describes a process for developing project-specific certification plans for type certification programs. This Guide may be found in the docket. This planning requirement would not apply to future applicants for TC because, as described in the Guide, this type of planning routinely occurs at the beginning of the certification process. (Additional information is available in the Order referenced in paragraph 4e(14).)

(2) The Guide recognizes the importance of ongoing communication and cooperation between applicants and the FAA. Section 26.33, while regulatory in nature, is intended to encourage establishment of the same type of relationship in the process of complying with this section.

(a) Compliance Plan for Flammability Exposure Analysis. Section 26.33(g) requires submittal of a compliance plan within 90 days after September 19, 2008, for the flammability exposure analysis required by this section. The intent of the proposal is to promote early planning and communication between the certificate holders and the FAA. The affected design approval holders would be required to submit a compliance plan that addresses the following:

1 A proposed schedule, identifying all major milestones, for meeting the flammability analysis compliance date of this rule or a determination that compliance with § 26.33(b) of this section is not required because design changes and service instructions for FRM or IMM will be developed and made available as required by § 26.33.

2 If required, a proposed means of performing a flammability exposure analysis.

(b) Compliance Plan for Design Changes and Service Instructions.

1 Section 26.33(h) requires that each holder of a TC required to comply with § 26.33(c) must submit to the FAA oversight office a compliance plan for their project within 210 days after September 19, 2008. In addition to items corresponding to those required for the compliance plan in § 26.33(g), this plan requires--

(aa) A proposal for submitting a draft of all compliance items required by § 26.33(d), (e) and (f) for review by the FAA oversight office not less than 60 days before the compliance times specified in the rules, and

(bb) A proposed means of compliance with this section, identifying all required deliverables, including all compliance items and all data to be developed to substantiate compliance. If the TC holder has already initiated compliance, the FAA oversight office will review the results of those efforts to ensure that the results are acceptable.

(cc) A proposal for how the approved service information and any necessary modification parts will be made available to affected persons.

2 This section is intended to ensure that affected persons and the FAA have a common understanding and agreement of what is necessary to achieve compliance with this section. Integral to the compliance plan will be the inclusion of procedures to allow the FAA to monitor progress toward compliance. These aspects of the plan will help ensure that the expected outcomes will be acceptable and on time. The schedule for the availability of the service information and any required parts is critical to the affected operators ability to schedule the modification of their airplanes and make changes to their maintenance or inspection programs in accordance with the operational rules. We would expect each TC holder to work with the FAA oversight office to develop a plan to create the required service instructions within the specified time. The plan should include periodic reviews with the FAA office.

3 The success of this fuel tank safety initiative hinges upon the timely development of service instructions and production incorporation of FRM or IMM by the affected certificate holders. If service instructions are not available when required, operators will not be able to begin incorporation of the FRM or IMM into their fleet as their airplanes undergo normally scheduled maintenance checks. Delay in availability of the service instructions could result in the need for operators to do unscheduled maintenance to comply with the operational requirements, resulting in significant unnecessary cost.

g. Section 26.33(j) requires that affected type certificate holders implement the compliance plans, as approved under that section. It allows for revisions to the plans, if approved, but such revisions would still have to result in compliance by the specified compliance dates.

2. Section 26.35 Changes to type certificates affecting fuel tank flammability**:** This section addresses changes to TCs, including installing auxiliary fuel tanks, changes in the capacity of fuel tanks, and changes that may increase the fuel tank flammability exposure of an existing fuel tank that is required by § 26.33(c) to incorporate either a FRM or IMM. An auxiliary fuel tank installed by STC or field approval may result in adverse effects on any FRM or IMM developed by the TC holder as required by § 26.33. This section requires those affected to conduct a flammability exposure analysis of their design, an impact assessment to determine any adverse impact their design may have on tanks for which CDCCL are required, and development of design changes to address adverse changes in flammability exposure. The dates for demonstrating compliance are shown as follow:

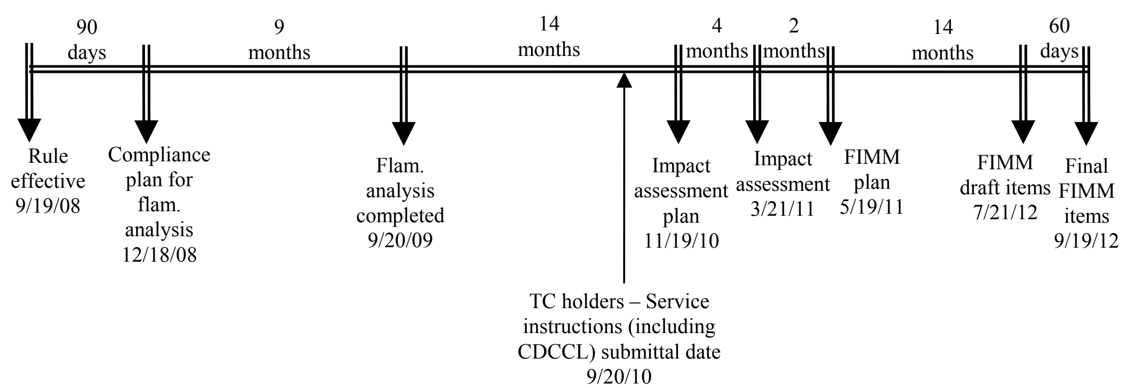

FIGURE 3-2

Compliance Timeline for Holders and Applicants of Changes to Certificates (§ 26.35)

a. Applicability. Paragraph 26.35 (a) states that this section applies to holders and applicants for approvals of the following design changes to any airplane subject to § 26.33(a):

- For holders of STCs or field approvals issued before September 19, 2008, and for applicants for STCs or amendments to TCs applied for before September 19, 2008, if the approval was not issued before

September 19, 2008, this section applies to installation of a Normally Emptied fuel tank.

- For applicants for STCs or amendments to TCs applied for on or after September 19, 2008, this section applies to installation of a Normally Emptied fuel tank, changes to fuel tank capacity, and changes that may increase the flammability exposure of an existing fuel tank for which FRM or IMM is required by § 26.33 (c).

(1) Existing STCs and Field Approvals. For existing STCs and field approvals, this proposal excludes design changes other than for Normally Emptied fuel tank installations. (Field approvals are no longer issued for fuel tank installations.) The meaning of "Normally Emptied" fuel tank is explained earlier in the discussion of § 25.981 and in paragraph 5 of this AC. As discussed in the background section of the preamble to the flammability rulemaking associated with this AC, SFAR 88 included review of all changes to the airplane that could result in the development of ignition sources. We reviewed the fuel system related STCs in the fleet and did not identify any changes that would significantly increase fuel tank flammability. Therefore we have determined that application of this rule to current STC holders, other than those relating to auxiliary fuel tank installations, would not improve fuel tank safety.

(2) Pending Applications for STCs and TC Amendments to TCs. Except for applications that are pending as of September 19, 2008, for installation of Normally Emptied fuel tanks, pending applications for design change approvals were excluded from the final rule. Under § 26.35(d)(2), applicants with pending applications for design changes to install Normally Emptied fuel tanks must comply with § 25.981 at Amendment 25-125.

(3) Future Applicants for STCs or TC amendments.

(a) Auxiliary Fuel Tanks Installed Under STC or amendment to TC. The regulation applies to design changes for which application is made on or after September 19, 2008, to install auxiliary fuel tanks on large transport category airplanes subject to the part 26 rule. The applicability list is included in appendix 1 to this AC. These design changes must be shown to comply with § 25.981, as discussed previously in this AC. For example, the center wing box structure on some versions of certain airplane models did not originally carry fuel, but later models of the airplane may include fuel in these areas. This would be considered to be a change to add a new fuel tank, and compliance with § 25.981 would be required.

(b) Design Changes Affecting Fuel Tank Capacity. An applicant may propose to change the size of sections to an existing fuel wing tank or change the useable fuel capacity in an existing tank. Both increases and decreases in fuel tank capacity must be addressed. Under § 26.35(d)(3), these applicants must comply with the requirements of § 26.33. For example, the applicant must perform a flammability exposure analysis for the modified tank and, if the exposure exceeds 7 percent, the applicant must include FRM or IMM, as required by § 26.33.

(c) Design Changes that May Increase Fuel Tank Flammability Exposure of Tanks for which FRM or IMM are Required. Examples of design changes that may increase fuel tank flammability exposure include installation of hydraulic or electronics system heat exchangers in a fuel tank, installation of heater blankets on the wing, modification of the fuel management that results in changes in fuel tank flammability, installation of a fuel re-circulation system that transfers heat from the engine to the fuel tank, or changes to the flight manual to use lower flash point fuels such as JP-4 or Russian or Chinese fuels. As discussed below, applicants for these types of design changes must perform an impact assessment and, if applicable CDCCL are compromised, develop flammability impact mitigation means.

b. Compliance Times. Section 26.35(b) establishes a timeframe in which the affected persons must submit for approval (to the FAA oversight office) a flammability exposure analysis for their design changes. The rule includes a 12-month timeframe to complete the analysis for existing STCs. Any applicant whose STC or TC amendment is not approved within 12 months after September 19, 2008, would have to complete the analysis before approval.

c. Flammability Analysis.

(1) Supplemental type certificate holders or applicants affected by this section would need to conduct a flammability analysis using the method defined in appendix N of the rule. A number of inputs are required to conduct this analysis. Airplane specific data, such as flight length distributions or airplane climb rate, may not be readily available from the original TC holder. We intend the STC holders to obtain the information by working with the operators of airplanes that have their STC installed. Applicants would need to work with prospective customers. Operators have business agreements with the original TC holders and access to information they obtained when they purchased the airplane. Conservative assumptions or business agreements with the original TC holders are other possible methods of gathering airplane type specific data needed for the analysis.

(2) The flammability analysis required by this § 26.35(b) is intended to identify applications for fuel tank installations that would require incorporation of FRM or IMM or that may increase the flammability exposure of such tanks. As discussed in the preamble to this rule, for existing fuel tank STCs, the flammability analysis is needed to determine if future action should be taken to address auxiliary fuel tanks installed under STCs or field approvals. Additional analysis after obtaining the CDCCL from the TC holder and developing any FIMM, is necessary to demonstrate that the final configuration complies with the applicable flammability analysis requirements and does not violate the CDCCL defined by the original TC holder.

(3) For design changes that may increase the flammability of fuel tanks equipped with FRM or IMM for which compliance with applicable CDCCL must be shown, the purpose of the requirement to perform flammability analyses is to ensure that

the change does not increase flammability exposure in ways that were not anticipated when the CDCCL were developed. If an applicant can show that the design would have no such effect, it may be possible to avoid performance of a full analysis per appendix N through substantiating an equivalent level of safety finding.

d. Impact Assessment.

(1) Section 26.35 requires affected persons[1] to submit for approval (to the FAA oversight office) an impact assessment of the fuel tank system, as modified by their design change. The purpose of this requirement is to identify any features of the modification to the original type design that may violate the critical design configuration control limitations developed by the original TC holder under § 26.33(d). For example, if an FRM that utilizes inerting were incorporated into an airplane, a CDCCL would likely be developed that would limit venting of air into the fuel tank because it could introduce oxygen into the tank, resulting in a flammable vapor space. In this case the STC holder would need to assess its design and identify any violation of the CDCCL identified for the FRM. Results from the analysis would be provided to the FAA in the form of a report or summary letter.

(2) Holders of STCs and field approvals for fuel tanks designed to be normally emptied on airplane models listed in Table 3-1 have to submit the safety assessment by March 21, 2011. This date is six months after the TC holder is required to establish their CDCCLs. Applicants for STCs and for amendments to type certificates whose design changes are not approved within that six-month period would have to submit the assessment before approval of the change. Once the CDCCLs are approved, the TC holder is required to make them available to other affected persons, including those subject to this section.

[1] This refers to STC holders for auxiliary fuel tanks as of September 19, 2008, and future applicants for design changes that may increase flammability exposure of tanks for which FRM or IMM are required.

TABLE 3-1

AFFECTED AIRPLANE MODELS

Model – Boeing
747 Series
737 Series
777 Series
767 Series
757 Series
Model – Airbus
A318, A319, A320, A321 Series
A300, A310 Series
A330, A340 Series

e. Development of Service Instructions. Section 26.35(d) requires development of design changes and service instructions as stated in § 26.35 (d)(1), (d)(2) and (d)(3).

(1) Section 26.35(d)(1) affects persons required to prepare impact assessments, described in the previous paragraph. It includes requirements that apply if the impact assessment shows that a design change compromises any CDCCL applicable to any airplane on which the change is eligible for installation. The holder or applicant would have to develop a means, referred to as a Flammability Impact Mitigation Means (FIMM), to comply with all applicable CDCCLs. FIMM could include either additional design changes or limitations or other procedures. If FIMM are necessary, the applicant or holder would also have to show that their design change, as modified by the FIMM, would still meet the other requirements of this section. For example, § 26.35(d) requires that the flammability analysis for an existing auxiliary fuel tank, as modified by FIMM, would have to be accomplished per § 26.35(b). This paragraph is necessary to ensure that the safety improvements in this rule are not degraded by later design changes.

(2) Section 26.35(d)(2) requires applicants for STCs and amended TCs for installation of a Normally Emptied tank, to meet the requirements of § 25.981 in effect on September 19, 2008 if—

(a) the application is made before September 19, 2008 and the approval was not issued before September 19, 2008, or

(b) the application was made on or after September 19, 2008,

(3) Section 26.35(d)(3) requires applicants for a STC or an amendment to a type certificate made on or after September 19, 2008, that changes the capacity of an

existing tank to comply with the requirements of § 26.33, Holders of type certificates: Fuel tank flammability, as discussed in paragraph 1 of this appendix.

(4) Various methods described in this AC are available for meeting the flammability exposure requirements. The exact modifications needed to comply depend upon specific details of the particular design and choices made by the designers. The most likely solutions include inerting, cooling of the tank, installation of polyurethane foam and pressurizing the tank similar to other tanks that use air pressure for fuel transfer.

f. Compliance Times for Design Changes and Service Instructions**.** Section 26.35(e) establishes timeframes in which holders of STCs and field approvals and applicants for STCs and amendments to TCs must comply with the requirements of § 26.35(d). Supplemental type certificate holders and holders of field approvals would be required to comply by September 19, 2012, which is 24 months after the TC holder compliance date for § 26.33(c). Applicants for STCs and amendments to TCs whose applications are pending on September 19, 2008, would have to comply before the FAA would issue their approval.

g. Compliance Planning. Section 26.35(f) requires compliance plans for the actions required by this section. Compliance planning is discussed earlier in this appendix with guidance for § 26.33. Because STC holders and applicants would need the TC holders' CDCCLs to comply with paragraphs (c) and (d) of this section, the compliance times for submitting those plans provide adequate time after the TC holders are required to comply with § 26.33. The compliance planning dates are given in Table 2 of § 26.35(f), which is shown below.

h. Section 26.35(g) requires that affected holders and applicants implement the compliance plans, as approved under that section. It allows for revisions to the plans, if approved, but such revisions would still have to result in compliance by the specified compliance dates.

TABLE 3-2

COMPLIANCE PLANNING DATES

	Flammability Exposure Analysis Plan	Impact Assessment Plan	Design Changes and Service Instructions Plan
STC and Field Approval Holders	December 18, 2008	November 19, 2010	May 19, 2011

APPENDIX 4

CONSIDERATIONS FOR FUEL TANK THERMAL MODELS

1. The type of thermal model that is needed to show compliance will depend upon the method of compliance selected for the different requirements. For fuel tanks shown to have equivalent flammability to that of an unheated aluminum wing fuel tank, a fuel tank thermal model may not be needed if the qualitative flammability assessment method defined in paragraph 11 of this AC is used. For other tanks where specific flammability levels must be shown, thermal modeling will be needed if fuel temperature affects fuel tank flammability. This appendix provides guidance for validating the thermal modeling of a fuel tank. It is based on using in the Monte Carlo Model defined by the User's Manual (defined in paragraph 4e(11) of this AC). As stated in paragraph 4.1 of the User's Manual, if flight test data or a detailed analysis of the fuel tank's thermal behavior shows that this method cannot yield an accurate representation of the actual fuel tank's fuel temperature profile, then modification of the thermal model code in the Monte Carlo model is necessary.

2. Validating fuel tank thermal coefficients, "Tau," for use in the Monte Carlo Model.

a. When a fuel tank is heated or cooled by a change in air temperature, the response of the fuel temperature is to increase or decrease, respectively, following an exponential decay law. On the ground, air temperature is considered to be ambient temperature at the airplane location, and in flight it will be the Total Air Temperature (TAT) experienced by the airplane. This exponential trend is driven by the temperature difference between the fuel and TAT, and the response of the mass of the fuel and tank. It can be represented by the system exponential decay time constant Tau, and an equilibrium temperature that the fuel temperature will eventually reach. The equilibrium temperature for a totally unheated tank will be very close to the air temperature, and can be expressed as a temperature difference from ambient temperature on the ground and TAT in flight. For this method, the temperature difference will be called Delta T.

b. By taking data from a flight test, the values for Tau and Delta T can be approximated as a function of fuel load and air temperature. This method requires recording fuel tank temperatures and TAT at regular intervals during critical operational ground and flight test conditions so that the fuel tank thermal characteristics can be established.

3. Compliance Testing. Testing should include ground and flight conditions with variable fuel quantities, and any heat transfer from airplane generated sources to the fuel tank at the critical conditions. The Monte Carlo Model includes the capability to use 6 different Tau values, and sufficient testing to confirm the validity of each of the values used in the model should be done. In addition, the thermal characteristics of the critical

portion of the fuel tank relative to formation of flammable vapors should be used in the Monte Carlo Model and validated by the testing. Baffling incorporated into most fuel tanks results in segmented volumes that may significantly affect heat transfer and, therefore, the flammability within the tank volume. If barriers or walls result in separate volumes within the tank and prevent mixing of the fuel and/or vapors in the tank, then each of these volumes should be evaluated independently to determine the worst case exposure for that tank. The validation may include a qualitative assessment of the heat sources (warm fuel transfer, hydraulic heat exchanges, fuel return lines, ECS packs, etc.) and thermal characteristics of different portions of the fuel tank to substantiate critical location for the test evaluation of the Taus.

a. Temperature Measurement. The location of test instrumentation should consider tank configuration and operational factors to determine which locations in the fuel tank require evaluation. The fuel temperature should be measured at critical locations in the tank for each of the critical fuel loading conditions. If an FRM that limits ullage oxygen concentration is included in the design, test instrumentation should be located in critical locations of the ullage to support analysis of the ullage density changes and it's effect on ullage oxygen concentration. The locations of fuel and ullage test temperature sensors should take into consideration any structural barriers or baffles that may divide the tank into regions that may have different thermal characteristics.

b. Test Conditions. The applicant should conduct sufficient ground and/or flight testing that simulates the actual operation of the airplane type so that a validated fuel tank thermal model can be developed that will accurately model the fuel tank. Fuel tank temperatures should be measured so that the change in bulk average fuel temperature in each affected tank on the ground and in-flight versus time can be determined. The minimum number of test conditions needed to validate the thermal modeling of the fuel tank will depend upon the number of variables that may affect the fuel tank temperature. For example, a minimum of two test flights would be required, one representative of a short mission for the airplane and one representative of a long mission for a typical CWT design so that variability in mission length, gate time and fuel quantities could be addressed. The short mission should include at least 30 minutes of ground operation prior to flight, and the long mission at least 90 minutes of ground operation prior to flight. For the entire mission (i.e., from the start-up of airplane systems to completion of the flight), temperatures should be recorded in the test tank(s) at locations to represent the bulk fuel temperature in each separate section of the test tank(s) unless less a qualitative assessment shows that fewer locations can be justified. For this discussion, TAT is used to represent ambient temperature on the ground and TAT in flight. The fuel temperature and TAT should be recorded at least once per minute. The test program should be designed to address the fuel tank thermal response as a function of day type including testing on warm days to understand the fuel tank thermal response when the tank is most likely to be flammable.

4. Example of a Flight Test. The sample flight test shown below is an illustration of how to demonstrate that the bulk average fuel temperature modeling used in the Monte Carlo Model, based upon use of Time Constant Tau, is acceptable for the particular tank

under evaluation. The fight test shown is for a hypothetical aluminum wing tank on a long-range airplane. The data includes operational time before and after the flight as required by the method. The fuel temperature is recorded every minute and the bulk average fuel tank temperature is then determined from the test data. (Data at 10 minute intervals is shown for the example, to save space.) The Tau value is estimated for a full tank and decreased as the fuel is burned off in flight. Using the value of Tau, the tank bulk average fuel temperatures can be estimated using the exponential decay equation, (the term "Fuel Temp" in the equations is an abbreviation for "bulk average fuel temperature"):

$$\text{(Fuel Temp change in time t)/(Fuel Temp-TAT)} = 1\text{-}e^{(-t/Tau)}$$

This can also be written as:

$$\text{Fuel Temp change in time t} = \text{(Fuel Temp-TAT)} \times (1\text{-}e^{(-t/Tau)})$$

The resultant estimated fuel temperature is then compared to the actual and the Tau values corrected until a satisfactory match is obtained. This can be done manually or using a computer solver approach. If there is no heating of the tank, the Tau values can be obtained directly. If there is significant heating of the tank, the equilibrium temperature can be found by increasing the value for TAT to (TAT + Delta T), where Delta T is the tank equilibrium temperature offset from TAT. In this case, both the values for Tau and Delta T must be found for the tank. The Tau used in the Monte Carlo Model should be shown to predict fuel tank temperatures with an error of less than 3 degrees for a period of time not to exceed 5 minutes. If the accuracy does not meet this level, the applicant may choose to use a Tau that is adjusted so that the predicted temperature would be higher and produce a conservative flammability level or propose an alternative method of modeling fuel tank temperatures.

TABLE 4-1

Example of Wing Fuel Tank Flight Test Results (Part 1 of 2)

Shown at 10 minute increments for this example to save space. Should be recorded at 1 minute intervals							Delta T	Estimated Tau	Predicted Temp based on Tau value	Tank Temperature Error
Time	OAT	Mach Number	TAT	Altitude	Fuel Load	Fuel Temp	Fuel Temp TAT			Actual vs. Predicted
Min	Deg. F.		Deg. F,	Ft.	%	Deg. F.	Deg. F.			Deg F.
0	80	0.00	80.0	0	100	80.0	0.0	149.8	80.0	0.0
10	80	0.00	80.0	0	100	80.0	0.0	149.8	80.0	0.0
20	80	0.00	80.0	0	100	80.0	0.0	149.8	80.0	0.0
30	80	0.00	80.0	0	100	80.0	0.0	149.8	80.0	0.0
40	80	0.00	80.0	0	100	80.0	0.0	149.8	80.0	0.0
50	80	0.00	80.0	0	100	80.0	0.0	149.8	80.0	0.0
60	80	0.00	85.9	0	100	80.0	-5.8	149.8	80.0	0.0
70	42.5	0.43	58.2	8750	100	79.5	21.2	149.8	79.4	0.0
80	5	0.57	32.7	17500	100	77.4	44.6	149.8	77.1	-0.2
90	-32.5	0.71	8.5	26250	100	73.9	65.4	149.8	73.4	-0.5
100	-70	0.86	-18.7	35000	100	69.2	87.8	149.8	68.3	-0.8
110	-70	0.86	-18.7	35000	100	63.8	82.5	149.8	62.7	-1.2
120	-70	0.86	-18.7	35000	100	58.8	77.4	149.8	57.3	-1.4
130	-70	0.86	-18.7	35000	100	53.9	72.6	149.8	52.4	-1.6
140	-70	0.86	-18.7	35000	100	49.4	68.1	149.8	47.7	-1.7
150	-70	0.86	-18.7	35000	100	45.1	63.8	149.8	43.3	-1.8
160	-70	0.86	-18.7	35000	100	41.0	59.7	149.8	39.2	-1.8
170	-70	0.86	-18.7	35000	100	37.2	55.9	149.8	35.4	-1.8
180	-70	0.86	-18.7	35000	100	33.6	52.3	149.8	31.8	-1.8
190	-70	0.86	-18.7	35000	100	30.2	48.9	149.8	28.5	-1.7
200	-70	0.86	-18.7	35000	100	26.9	45.6	149.8	25.3	-1.6
210	-70	0.86	-18.7	35000	98	23.7	42.4	146.9	22.4	-1.3
220	-70	0.86	-18.7	35000	94	20.7	39.3	142.2	19.6	-1.1
230	-70	0.86	-18.7	35000	90	17.7	36.4	137.5	16.9	-0.8

TABLE 4-1 (Continued)

Example of Wing Fuel Tank Flight Test Results (Part 2 of 2)

Shown at 10 minute increments for this example to save space Should be recorded at 1 minute intervals							Delta T	Estimated Tau	Predicted Temp based on Tau value	Tank Temperature Error
Time	OAT	Mach Number	TAT	Altitude	Fuel Load	Fuel Temp	Fuel Temp-TAT			Actual vs. Predicted
Min	Deg. F.		Deg F.	Ft.	%	Deg F.	Deg F.			Deg F.
240	-70	0.86	-18.7	35000	87	14.9	33.6	132.8	14.3	-0.6
250	-70	0.86	-18.7	35000	83	12.2	30.9	128.1	11.9	-0.4
260	-70	0.86	-18.7	35000	79	9.7	28.3	123.4	9.5	-0.1
270	-70	0.86	-18.7	35000	76	7.2	25.9	118.7	7.3	0.1
280	-70	0.86	-18.7	35000	72	4.9	23.6	114.0	5.2	0.3
290	-70	0.86	-18.7	35000	68	2.7	21.3	109.3	3.2	0.5
300	-70	0.86	-18.7	35000	65	0.6	19.3	104.6	1.3	0.7
310	-70	0.86	-18.7	35000	61	-1.4	17.3	99.9	-0.4	1.0
320	-70	0.86	-18.7	35000	57	-3.3	15.4	95.2	-2.1	1.2
330	-70	0.86	-18.7	35000	54	-5.0	13.7	90.5	-3.7	1.3
340	-70	0.86	-18.7	35000	50	-6.6	12.0	85.8	-5.1	1.5
350	-70	0.86	-18.7	35000	46	-8.2	10.5	81.1	-6.4	1.7
360	-70	0.86	-18.7	35000	43	-9.6	9.1	76.4	-7.7	1.9
370	-70	0.86	-18.7	35000	39	-10.9	7.8	71.7	-8.8	2.1
380	-70	0.86	-18.7	35000	35	-12.1	6.6	67.0	-9.8	2.2
390	-70	0.86	-18.7	35000	31	-13.2	5.5	62.3	-10.7	2.4
400	-70	0.86	-18.7	35000	28	-14.1	4.5	57.6	-11.6	2.6
410	-70	0.86	-18.7	35000	24	-15.0	3.7	52.9	-12.3	2.7
420	-70	0.86	-18.7	35000	20	-15.8	2.9	48.2	-12.9	2.9
430	-70	0.86	-9.8	33906	17	-16.2	-6.5	43.5	-13.3	3.0
440	-20	0.67	22.1	22969	17	-10.4	-32.5	38.8	-8.1	2.3
450	30	0.48	55.6	12031	16	2.4	-53.2	34.1	4.0	1.7
460	80	0.28	80.0	1094	15	20.8	-59.2	29.9	23.5	2.7
470	80	0.00	80.0	0	15	36.2	-43.8	29.9	40.0	3.8
480	80	0.00	80.0	0	15	47.6	-32.4	29.9	52.3	4.7
490	80	0.00	80.0	0	15	56.0	-24.0	29.9	61.4	5.3

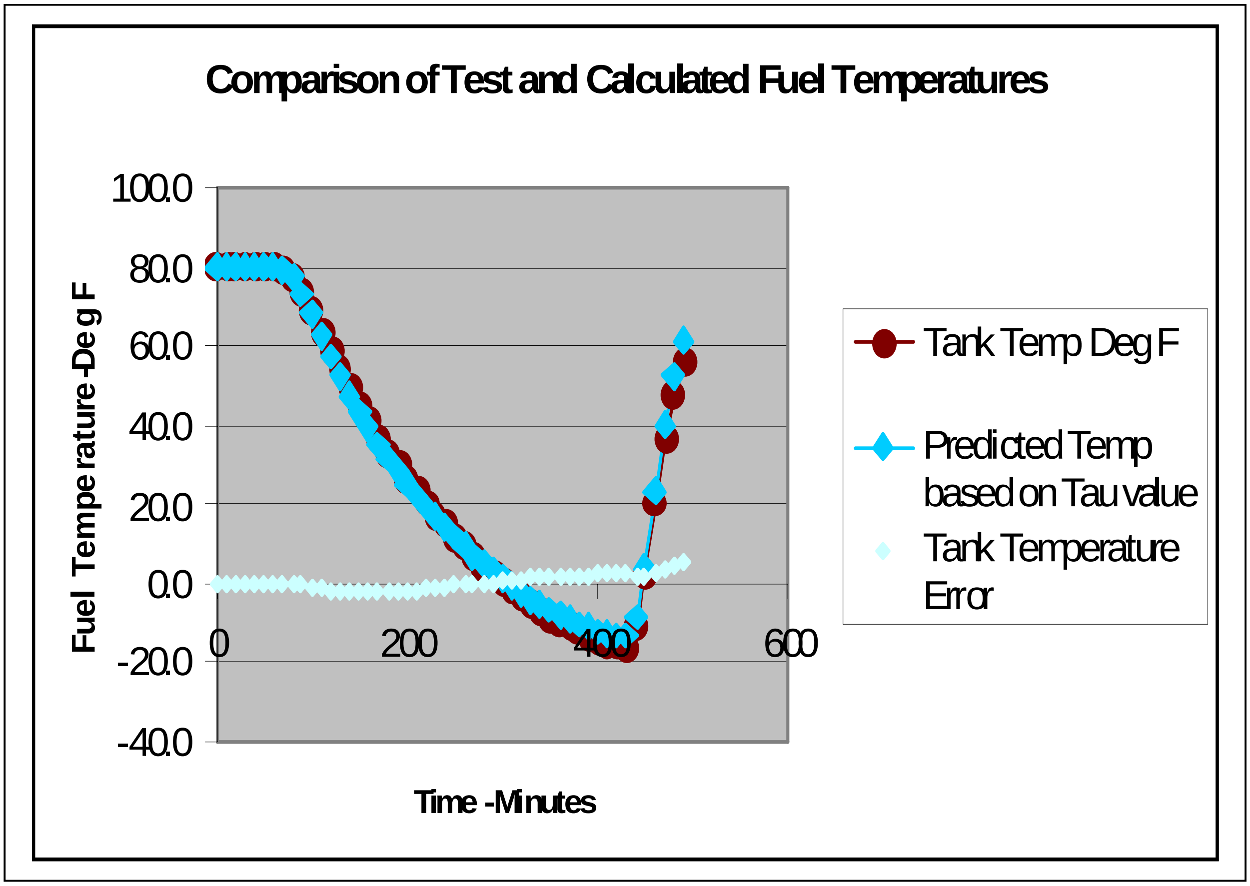

FIGURE 4-1

Comparison of Test and Calculated Fuel Temperatures

5. Compliance Reporting. In order to show the fuel tank temperature modeling is acceptable using this method, the compliance report should include plots of the flight test data, as well as the predicted fuel tank temperatures and the associated error between the predicted temperature and those measured during the flight test.

APPENDIX 5

MEASUREMENT OF OXYGEN CONCENTRATION IN AIRPLANE FUEL TANKS

1. Introduction.

a. Background on Oxygen.

(1) Oxygen is the element most associated with life on our planet. It has an atomic number of 16 and is classified as an oxidizer, which means it reacts readily with other elements and is key to many reactions taking place. Oxygen is essential to every living thing. Air is a mixture made of 99.9 percent oxygen and nitrogen existing primarily on the molecular level in a single bond with itself, thus we use the chemistry term O_2 when describing oxygen and N_2 when describing nitrogen.

(2) Measuring oxygen in a given environment is accomplished by exposing a gas sample to a sensor designed to give feedback for a changing amount of oxygen in the sample. The various sensing technologies rely on one of several different natural properties of oxygen to change the voltage in a circuit, or more directly, the number of counts on an A/D converter. Virtually all oxygen sensors do not sense the volume percentage of oxygen in a sample, but rather, the partial pressure of oxygen in the gas sample in question. The analyzer is then calibrated for volume percent oxygen given a fixed sample pressure, flow, and temperature.

b. Types of Oxygen Sensors.

(1) Most sensing technologies work on some type of chemical reaction. A galvanic cell is a sensor containing a small amount of a liquid solution that reacts with oxygen, retained within a permeable membrane. The gas sample is exposed to the sensor membrane and oxygen from the sample enters or leaves the sensor solution to create equilibrium. The solution in these sensors is separated by an anode and cathode. A fixed current source changes the voltage across the anode and cathode given a changing amount of oxygen in the sensor solution (see Reference 1 of paragraph 4 of this appendix). This voltage can be converted to a fixed output with a voltage divider and some linearizing circuitry. Some sensors simply have a piece of chemical compound (i.e., zirconium oxide) reacting between two electrodes. When a gas sample is exposed to the quantity of compound, the oxygen in the sample reacts with the compound and changes the voltage across the electrodes (see Reference 2 of paragraph 4 of this appendix).

(2) Virtually all sensors have a finite life, due to the fact that the reactants and solutions degrade and dilute over time. It is possible to measure oxygen with a truly non-consumable sensor. One commercially available oxygen analyzer uses the principals of paramagnetism of oxygen to measure the volume concentration of oxygen. Because

oxygen becomes magnetic when exposed to a magnetic field and the other constituents of air (nitrogen, carbon dioxide, and water vapor) do not, it is possible to make a detector that is sensitive to the amount of paramagnetic oxygen in an otherwise diamagnetic mixture of gases. In the case of the Rosemount 755R paramagnetic oxygen analyzer, a dumbbell-shaped, nitrogen-filled, hollow glass sensing body, wrapped with a single platinum wire, is suspended on a platinum/nickel alloy ribbon. When the sensing body is surrounded by a gas sample, "magnetic buoyancy" occurs creating a torque on the dumbbell. The current required to counteract the torque and restore the dumbbell to its null position is directly proportional to the amount of paramagnetic gas (oxygen) in the sample (see Reference 3 of paragraph 4 of this appendix).

(3) Some sensors do not require a dedicated gas sample to be removed from the environment to be measured, and thus can be used in situ, or literally in place. Some of these sensors work on the fluorescence properties of light, which change with partial pressure of oxygen in a given environment. These sensors detect changing fluorescence properties (intensity, time decay, etc.) of the light reflected from a coherent source using a spectrometer (see Reference 4 of paragraph 4 of this appendix). This measurement method is best applied in a controlled environment as the process is very sensitive to changes in temperature and pressure and all in situ methods impose unique calibration problems. In general, sensors that are reacting with oxygen make poor in situ sensors due to their propensity to consume oxygen in the general area of the measurement causing a type of sensor drift during measurements of quiescent environments.

2. Choosing a Measurement Method. To choose a measurement method several considerations must be made. The quantity of data as well as the number of gas sample locations required will determine the method of acquiring oxygen concentration for a flight test. The primary methods of measuring the oxygen concentration in a fuel tank ullage applied to date are continuous sampling, in situ measurements, and discrete sample measurements. Each primary method of measurement has an analyzer/sensor technology that is best applied given the measurement requirements. Each sensor and analyzer combination will have specific gas sample requirements. In the case of in situ measurements, sensitive sensors and fiber optic cables may need special protection. Discrete (individual) measurements made during any test always require the carefully choreographed and documented actions of test personnel during the test. This can lead to problems with post-test analysis of the data if information becomes lost or mishandled. Virtually all instrumentation has an effect on the environment being measured. Regardless of the method used to measure oxygen concentration, care should be taken to minimize the sampling system impact on the ullage oxygen concentration. Ullage samples drawn from the fuel tank for measurement should be returned if possible to the tank in locations that minimize the effect of the samples taken for measurement. The analysis presented for compliance should include the effect of the instrumentation on the results.

a. Continuous Sampling. The ideal measurement of oxygen concentration in a fuel tank environment is instantaneous and continuous. This, however, is not very practical as some finite time is required to sample ullage gas and excite a particular sensor. By keeping gas sample lines short and small (diameter), while maintaining a relatively high sample flow rate, a gas sample system with a relatively short response time can be developed. Traditional sensors generally have a response time between 500 ms and 5 seconds, depending upon the technology applied.

(1) Flow Through Sensor System.

(a) One such method of continuous sampling was developed and applied by the FAA using flow through galvanic cells and a pressure regulated sample train. The sample train uses a powerful pump to draw a gas sample from the ullage sample location in question, through a forward pressure regulator, which regulates the pressure on the input of the sample train to a vacuum pressure lower than the lowest expected pressure in the sample environment (2.73 psia or 141 Torr @ 40,000 feet). The gas sample is then pumped up to a pressure to that just above sea level (14.7 psia or 760 Torr), allowing the gas sample to flow through a flow meter, the galvanic sensor, and then a check valve. Lastly, the gas sample passes through a pressure controller that regulates the back pressure to a fixed value that can be maintained throughout the flight cycle. This pressure is critical to maintaining the calibration of the analyzer with the galvanic cell sensor. The gas sample can then be returned to the ullage to allow for a minimal effect on the sample environment.

(b) Calibration of this measurement methodology is accomplished easily by having a selector valve in the sample train before the input pressure regulator. The sample train is completely pressure regulated, providing calibration gas to the system input, allowing time for the system to stabilize, and adjusting the analyzer gain allows for calibration. It is best to check for adherence of your oxygen measurement system to a wide variety of calibration gases at least once before and after a test program. This is accomplished by calibrating in the traditional manner, and then checking several other calibration gases with different oxygen concentrations within the measurement range of the testing.

(c) When applying this measurement method to an airplane flight test, care must be taken to preclude liquid fuel or vapors from entering the cabin from the fuel tank gas sample lines. Traditionally, all sample lines are double walled and the shroud (outer wall) space is vented overboard to the exterior of the cabin. Leak checks of both the line and shroud prior to testing are essential. The measurement system sample volume should be isolated from the fuel tank with flash arrestors in the event of a failure that creates an ignition within the measurement system itself. Most oxygen sensors operate on very low power; however, complete isolation of the sensor, and other sources of energy within the sample system, from the fuel tank is essential in the event of a failure that could create a reaction within any portion of the flammable sampling system.

(d) The sampling of liquid fuel should be precluded by use of float valves on the ends of each sample tube in the fuel tank. Also, in the event of a failure that allowed liquid fuel into the sample lines, fuel should be prevented from entering the measurement system with either an automatic float shut-off switch or a warning system that allows for the operator to shut-down the sample system. The measurement system itself should also be shrouded and ventilated to allow for protection of the cabin environment in the case of a sample train leak. During ground operation, when natural suction is not available from the cabin exterior, the measurement system housing should also be continuously purged.

(e) A complete description of the galvanic cell continuous sample system applied by the FAA for the purposes of studying in-flight fuel tank inerting is given in Reference 5 from section 4 of this appendix.

(2) Flow-by Sensor System.

(a) Some sensors react significantly with the sample, and therefore may not be appropriate for returning the sample to the tank. A method of applying this type of sensor to a fuel tank environment is to create a volume flow sample train similar to the one described in the previous section. A small amount of this sample is then removed from the loop, in the positive pressure portion of the flow train, allowed to flow through the reacting sensor in question, and then deposited overboard. Minimizing the flow to the sensor helps minimize the effect of the consumed sample and creates a safer environment should the reaction of the ullage sample with the sensor become hazardous. It may be necessary to remove flammable fuel tank vapors from the sample gas to safely apply some sensors for measuring ullage gas.

(b) Calibration of this measurement methodology is accomplished easily by having a selector valve in front of the sensor housing, outside of the primary sample loop. Care must be taken to ensure that the calibration gases flow through the sensor at same pressure and flow rate as the flow by sample. The flow-by sensor should stabilize quickly, allowing for adjustment of the analyzer gain. Again, it is best to check for adherence of your oxygen measurement system to a wide variety of calibrations gases at least once before and after a test program.

(c) Ensuring safety of a flow-by sensor installation is done much in the same manner as described in the previous section. Special care may need to be taken to ensure the reaction between the sensor and the ullage gas sample remains completely benign to the measurement system and the aircraft in general. It is for this reason that high energy sensors have not been applied to in-flight measurement applications. Whatever installation is chosen, careful analysis and application is required, within the confines of the regulations, to minimize risk in accordance with the individual program plan developed.

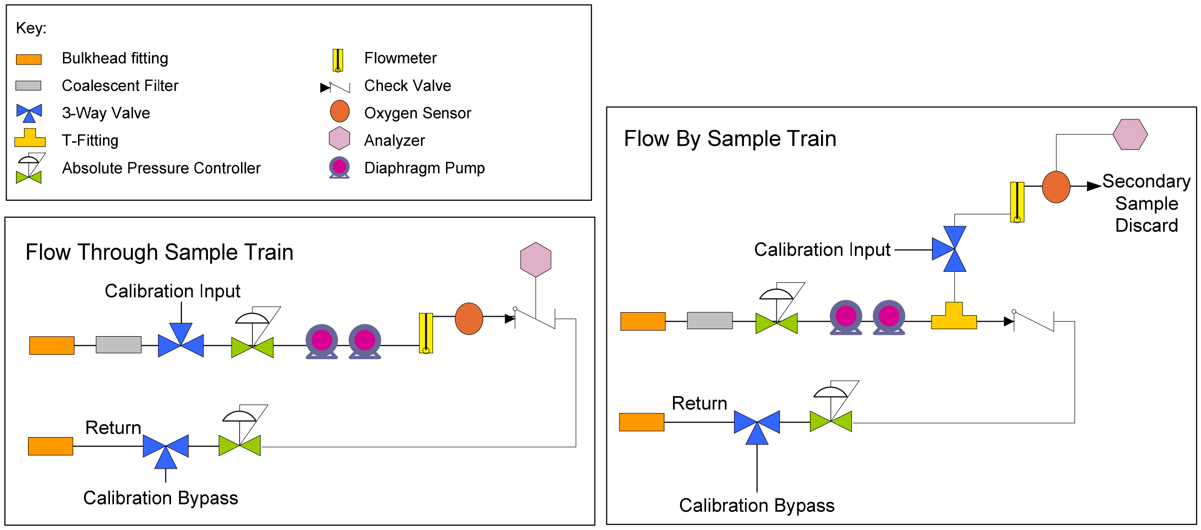

FIGURE 5-1

Block Diagrams of Flow Through and Flow Bypass Sample Systems

b. In Situ Measurements.

(1) Application of in situ sensors for measuring fuel tank ullage oxygen concentration has been applied and observed by the FAA on a limited basis. However, recent advances in application of these sensor technologies make them a viable option for future in-flight oxygen concentration measurement in a fuel tank ullage. Optical methods such as fluorescence quenching are attractive to apply to measurements in fuel tanks due to the intrinsically safe nature of the energy required for the sensor, and in situ methods in general alleviate the need to remove flammable ullage gas from the fuel tank for sampling.

(2) Each in situ sensor will have its own unique installation issues due to the sensor size and shape, as well as any environmental limitations such as temperature. Routing of any fiber optic cables will need to be within the requirements for the cable.

(3) The main difficulty with applying in situ sensors is the need to calibrate the sensor in place. This is not practical on a daily basis in an airplane fuel tank. This is complicated by the fact that optical methods generally have a very nonlinear response and need to be calibrated for a changing ullage temperature. In previous applications of fluorescence quenching sensors, the calibration was done in a controlled environment using multiple gases at multiple temperatures. The system was then installed in the tank and each channel was then “normalized” to a baseline intensity using air at some middle calibration temperature. This proved to be problematic given the variable of the baseline intensity of the different channels between the lab and airplane.

(4) To alleviate this, a sleeve assembly could be fabricated for the sensor that allows the sensor to be immersed in calibration gas through the sleeve, deposited from the outside of the fuel tank, to allow for daily checking of the calibration for several

gases. At the very least, the sensors would need to be validated at a single point before every flight. This has been accomplished in the past by having the inert gas generation system create a fixed oxygen concentration gas for an extended period of time. This will eventually stabilize the tank at a single oxygen concentration and temperature to allow for validation of each sensor in the tank. It is easy to see that this could quickly become expensive and time consuming if the calibration had to be checked multiple times and/or with multiple gases on a daily basis.

(5) Safety requirements for equipment located within a fuel tank such as in situ measurement systems are already established in the existing § 25.981 and related sections (See AC 25.981-1B (or latest revision). These safety requirements establish limitations on power required for instruments installed and places limitations on materials for use in fuel tanks. Part 25 addresses analysis of failure modes in general (§ 25.1309) and sets general installation requirements (subpart F). The power required for any sensor installed in a fuel tank needs to be calculated to be less than the minimum ignition energy prescribed by the FAA for fuel tank installations. Any cables that need to be installed should be routed in accordance with standard industry practices within the requirements of all airworthiness regulations. Each individual installation needs to be analyzed and evaluated for risk within the confines of the regulations and agreed upon by all project stakeholders.

c. Discrete Sampling**.** Although not desirable, it is possible to evaluate the capability of a particular inerting system to allow for protection of a given fuel tank without acquiring continuous oxygen concentration data throughout a complete flight cycle. This may be because of advances in ullage oxygen concentration modeling or because of the existence of a large quantity of previously acquired data for a similar inerting system and application. Regardless, collection of discrete samples at several critical times for a few different ullage locations can provide a complete picture of capability of an inerting system to maintain an inert ullage in a specified fuel tank during a flight cycle for some applications. Discrete methods may provide a cost advantage over continuous sampling measurements and can be considerably less complex if large quantities of gas samples are not required. The primary methods of acquiring discrete samples are through vacuum bottle sampling or through single point calibration and sampling.

(1) Vacuum Bottle Sampling.

(a) One method of acquiring discrete ullage gas samples at various times is by the use of vacuum sample bottles, which are previously cleaned, evacuated, and hermetically sealed. Vacuum bottles are generally used by plumbing several bottles in series. Each bottle has an individual hand operated valve to let in a gas sample, to the desired sample line, which is located within the ullage of the fuel tank in question. Each vacuum sample bottle in the series will provide a single, discrete gas sample in time at that particular ullage sample location. A vacuum sample bottle generally has a second vacuum bottle adjacent to it which is deployed (valve opened) before deploying the actual vacuum sample bottle. This is done to "update" the sample line with a fresh ullage gas sample before opening the sample bottle to acquire the gas sample.

(b) Each sample location will have an associated series of vacuum sample bottles, depending upon the number of samples required and the individual test setup. Typically these bottles are analyzed after completion of the test for oxygen content and whatever additional gas analysis is desired, by a laboratory that specializes in this kind of gas sample. It is critical to have a simple, well documented, plan for gas sampling to ensure that test personnel acquire the required gas samples at the appropriate time and allow for adequate documentation. As is always the case with human/test interaction, a series of procedures and checks are required to minimize the possibility of human error.

FIGURE 5-2

Vacuum Bottle Sample System Installed on an NTSB Test Aircraft

(c) The primary safety concerns with a vacuum bottle sample system are similar to those for a continuous sample system. All sample lines penetrating the pressurized bulkhead should be leak checked and shrouded to preclude the possibility of ullage gas or fuel entering the cabin. Additionally, each sample bottle series should be housed in a shroud which is ventilated overboard to the cabin exterior. The advantage of analyzing the gas samples after the flight test is that no additional safety features are required to protect the aircraft fuel tank from the potential ignition source of a sensor or associated gas sample regulation equipment.

(2) Single Point Calibration and Sampling.

(a) It is possible to use an analyzer and sample train to obtain discrete oxygen concentration measurements during a flight test. This can be accomplished by rapidly calibrating an analyzer sensor with a calibration sample gas, and then exposing the sensor to the desired ullage gas sample. This method would probably only be effective for measuring the oxygen concentration at times and tank locations with a relatively stable pressure, temperature, and oxygen concentration within the fuel tank ullage.

(b) All of the safety considerations associated with single point calibration and sample methods are identical to those of continuous sampling methods. For this reason alone, it may not be desirable to apply this methodology to a flight test scenario. Most of the cost and complexity of a gas sample system installation for a flight test environment is attributable to the safety features (sample line shrouds, box ventilation system, and system safety analysis). To apply these methods and not install the additional equipment to continuously sample, at a relatively small cost and complexity, does not seem cost effective. Again, every installation and application needs to be analyzed for certification requirements, data ranges, and program risk, within the confines of the regulations, to ensure a successful, cost effective flight test.

3. Selections of Sample Locations. The primary consideration when selecting the location and number of gas sample ports is the physical geometry of the fuel tanks, as well as the compartmentalization of the fuel tank. The two types of fuel tanks considered are single bay tanks and multiple bay tanks.

a. Single Bay Fuel Tanks.

(1) Single bay fuel tanks have a single volume, broken up only by structural members, which do not impede the flow of gases inside the tank. It is possible to select a single gas sample location that is representative of the entire ullage average oxygen concentration, but without prior measurements during similar inerting testing or extensive computation calculations, it is difficult to ensure a single measurement location is representative of the entire ullage. For fuel tanks where air enters the fuel tank during descent, a continuous measurement of ullage oxygen concentration during a specified aircraft descent profile is essential to determining the level of protection afforded the tank by the inerting system and is the best measure of the sizing of inerting system for the specified fuel tank. The critical sampling location would typically be located near where outside air enters the tank. Therefore if a single sampling location is proposed, substantiation that the selected sampling location will provide oxygen measurements that demonstrate the tank is inert must be provided.

(2) Measurements too close to the airplane vent (air deposit) or the NEA deposit nozzle can provide a biased measure of the average ullage oxygen concentration. It is possible that during the mixing of NEA and vent air into the tank, brief pockets of

high or low oxygen concentration ullage gas may exist within the ullage. Without compartmentalized bay walls, these pockets will be transient and difficult to identify. Mixing can be problematic in the vertical direction (between the top and bottom of the tank), particularly when considering low flow rates of air or NEA entering a tall thin fuel tank. If a fuel tank has associated radiant heat on the bottom (heated CWT), this problematic mixing will be small in nature and short lived.

(3) At the end of every test the aircraft fuel tank ullage will have a measured average ullage oxygen concentration after the aircraft has come to a complete stop and the inerting system has been shut off. By continued examination of this average over a period of 20-60 minutes during the operation of the aircraft air cycle machines (bottom heat), good vertical mixing can be validated. Any change in the average ullage oxygen concentration after the test is complete, with no additional air or NEA is entering the tank, can only be caused by changing oxygen concentration readings due to the mixing of the resulting ullage constituency. Again, without prior knowledge, the only way to ensure the inerting system is appropriate for the aircraft fuel tank is by the continuous measure of oxygen concentration at several strategic locations within the ullage during an appropriate descent flight test.

b. Multiple Bay Fuel Tanks.

(1) Multiple bay tanks are fuel tanks broken into several smaller volumes by solid or nearly solid web structures. These structures can be somewhat limited in their partitioning with large openings and extensive gaps between the web and the tank structure as is the case with many wing fuel tanks. These web structures can also be very solid in nature, with the only large openings being doors removed during maintenance and small web gaps for equalizing fuel and ullage gas, making a very compartmentalized tank.

(2) Fuel tanks with relatively open partitions may only require a few gas sample locations across many bays to allow for the accurate measurement of the overall fuel tank ullage average. Previous research highlighting inert gas distribution behavior during ground inerting may be beneficial to determining the number and location of gas sample ports. However this is not a guarantee of good air redistribution given the different nature of the NEA deposit and the vent opening. In the end, several more oxygen concentration sample locations may be necessary to allow for validation of inert gas distribution and ullage gas mixing during certain flight tests. These additional sample locations can be utilized when the mixing of the tank needs to be examined or validated using oxygen measurement channels redundant at that time.

(3) In the case of very compartmentalized fuel tanks, inert gas distribution may be problematic, depending on the sizing of the inerting system and the NEA deposit scheme selected. This generally requires at least one gas sample in each compartment, with long thin compartments perhaps requiring two gas sample locations. Bays that have a large vertical height, while still remaining relatively thin, may require an additional sample port at the bottom of the bay. Again, any differences in the oxygen concentration

of the top and bottom of an ullage compartment will be transient in nature, but the knowledge of this behavior may allow for an explanation of an unusual measurement obtained and could allow for the validation of fuel tank inerting models being utilized.

4. References.

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