U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Flammable Fluid Fire Protection

Date: D R A F T

Initiated By: AIR-624

AC No: 25.863-X

This advisory circular (AC) describes acceptable means, but not the only means, for showing compliance with the flammable fluid fire protection requirements of title 14, Code of Federal Regulations (14 CFR) part 25, with particular emphasis on § 25.863, *Flammable fluid fire protection* and § 25.1187, *Drainage and ventilation of fire zones*.

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1 PURPOSE.

This AC describes acceptable means, but not the only means, of showing compliance with the flammable fluid fire protection requirements of part 25, with particular emphasis on §§ 25.863 and 25.1187. The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies.

1.1 General Flammable Fluid Fire Protection.

Section 25.863 addresses fire protection for areas of the airplane into which flammable fluids or vapors might leak, and requires an applicant to provide means to minimize the probability of ignition of leaked flammable fluids and the hazard if ignition occurs. The purpose of this AC is in part to provide guidance for showing compliance with § 25.863, taking into account the various foreseeable types of fluids, leakage, and ignition scenarios. This AC further standardizes policy regarding the following:

1.1.1 The relationship of § 25.863 with the more general requirements of §§ 25.901(c) and 25.1309(b);

1.1.2 Definitions of, and the relationship between, ignition probability and hazard minimization; and

1.1.3 Role of drainage and ventilation in showing compliance with § 25.863.

1.2 Flammable Fluid Fire Protection in Designated Fire Zones.

This AC provides guidance on what factors should be considered in the design of flammable fluid drainage systems and ventilation systems, and describes a means of showing compliance with the sections of part 25 that address these systems.

1.2.1 Sections 25.1181 through 25.1207 prescribe design features and performance standards for flammable fluid fire protection of designated fire zones.

1.2.2 Section 25.1187 addresses the accumulation of flammable fluids and flammable vapors within designated fire zones. The accumulation of flammable liquids can be minimized by safely draining it away from the airplane, both in flight and on the ground. Adequate ventilation reduces the accumulation, and in many instances the formation, of flammable vapors.

1.2.3 Section 25.1187 requires that each part of each designated fire zone have complete drainage and effective ventilation to minimize the hazards that may result if any component containing flammable fluid fails or malfunctions.

2 APPLICABILITY.

2.1 The guidance in this AC is for airplane manufacturers, modifiers, foreign regulatory authorities, Federal Aviation Administration (FAA) Aircraft Certification Service engineers, and the Administrator's designees.

2.2 Conformity with the guidance is voluntary only and nonconformity will not affect rights and obligations under existing statues and regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as "should," "may," and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. If the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the FAA may require additional substantiation as the basis for finding compliance.

3 RELATED DOCUMENTS.

The following regulatory and advisory materials are related to this AC:

3.1 Regulations.

The following sections of 14 CFR part 25 are related to this AC. The full text of these regulations can be downloaded from the U.S. Government Printing Office e-CFR website. A paper copy can be ordered from the Government Printing Office, Superintendent of Documents, Attn: New Orders, PO Box 371954, Pittsburgh, PA, 15250-7954.

- Section 25.729(f), *Retracting mechanism-Protection of equipment on landing gear and in wheel wells*.
- Section 25.855(e), *Cargo or baggage compartments*.
- Section 25.859, *Combustion heater fire protection*.
- Section 25.863, *Flammable fluid fire protection*.
- Sections 25.901(b)(2) and (c), *Installation*.
- Section 25.954, *Fuel system lighting protection*.
- Section 25.967, *Fuel tank installations*.
- Section 25.981, *Fuel tank explosion prevention.*
- Section 25.1091(d)(1), *Air induction*.
- Sections 25.1121(b) and (d), *Exhaust System–General*.
- Section 25.1163(b), *Powerplant accessories*.
- Section 25.1181, *Designated fire zones; regions included*.
- Section 25.1182, *Nacelle areas behind firewalls, and engine pod attaching structures containing flammable fluid lines*.

- Section 25.1183, *Flammable fluid-carrying components*.
- Section 25.1185(c), *Flammable fluids*.
- Section 25.1187, *Drainage and ventilation of fire zones*.
- Section 25.1189, *Shutoff means*.
- Section 25.1191, *Firewalls*.
- Section 25.1192, *Engine accessory section diaphragm*.
- Section 25.1193, *Cowling and nacelle skin*.
- Section 25.1195, *Fire extinguishing systems*.
- Section 25.1207, *Powerplant Fire Protection – Compliance*.
- Section 25.1309, *Equipment, systems, and installations*.
- Section 25.1435(c), *Hydraulic systems*.

3.2 **Advisory Circulars (ACs).**

The following ACs are related to the guidance in this AC. The latest version of each AC at the time of publication of this AC is identified below. If any AC is revised after publication of this AC, you should refer to the latest version for guidance, which can be downloaded from the Internet at www.faa.gov/regulations_policies/advisory_circulars.

- AC 20-53C, *Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Caused by Lightning*, dated September 24, 2018.
- AC 20-135, *Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria*, dated October 11, 2018.
- AC 25-8, *Auxiliary Fuel System Installations*, dated May 2, 1986.
- AC 25-16, *Electrical Fault and Fire Prevention and Protection*, dated April 5, 1991.
- AC 25-19A, *Certification Maintenance Requirements*, dated October 3, 2011.
- AC 25.901-X, *Safety Assessment of Powerplant Installations*.
- AC 25.954-1, *Transport Airplane Fuel System Lightning Protection*, dated September 24, 2018.
- AC 25.981-1D, *Fuel Tank Ignition Source Prevention Guidelines*, dated September 24, 2018.
- AC 25.1309-1B, *System Design and Analysis*.
- AC 43.13-2B, *Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair*, dated March 3, 2008.

3.3 **Technical Standard Orders (TSO).**

TSO-C53a, *Fuel and Engine Oil System Hose Assemblies*. Technical Standard Orders can be obtained from the Federal Aviation Administration (FAA), Aircraft Certification Service, Aircraft Engineering Division (AIR-120), 800 Independence Ave., SW, Washington, D.C. 20591.

3.4 **Technical Publications.**

3.4.1 Latest version of RTCA, Inc.[1] (RTCA) Document DO-160, *Environmental Conditions and Test Procedures for Airborne Equipment*. This document can be obtained from the RTCA Inc., 1150 18th Street NW, Suite 910, Washington, DC. 20036; by completing the Document Order Form and faxing it to (202) 833-9434; or on the Internet at https://my.rtca.org/nc_store.

3.4.2 *Handbook of Aviation Fuels Properties*, Coordinating Research Council (CRC) Document 530. This document can be obtained from the Society of Automotive Engineers, Inc., General Publications Department, 400 Commonwealth Drive, Warrendale, PA 15096.

3.4.3 Kuchta, Joseph M., *Summary of Ignition Properties of Jet Fuels and Other Aircraft Combustible Fluids*, Air Force Aero Propulsion Laboratory Technical Report AFAPL-TR-75-70, US. Bureau of Mines PMSRC, 1975. This document can be obtained from the National Technical Information Service (NTIS), US. Department of Commerce, Springfield, VA 22151.

3.4.4 Parts, Leo, *Assessment of the Flammability of Aircraft Hydraulic Fluids*, Air Force Aero Propulsion Laboratory Technical Report AFAPL-TR-79-2055, July 1979. This document can be obtained from the National Technical Information Service (NTIS), US. Department of Commerce, Springfield, VA 22151.

3.4.5 Kuchta, Joseph M., and Clodfelter, Robert G., *Aircraft Mishap Fire Pattern Investigation*, Air Force Aero Propulsion Laboratory Technical Report AFWAL-TR-85-2057, August 1985. This document can be obtained from the National Technical Information Service (NTIS), US. Department of Commerce, Springfield, VA 22151.

3.4.6 Clodfelter, Robert G., *Hot Surface Ignition and Aircraft Safety Criteria*, SAE International[2] (SAE), Paper 901950, October 1990. This document can be obtained from the SAE Customer Service Department, Phone (877) 606-7323.

3.4.7 SAE International, *Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft*, Aerospace Standard AS1241D.

[1] Previously known as the Radio Technical Commission for Aeronautics.
[2] Previously known as the Society of Automotive Engineers.

4 DEFINITIONS.

Note: The following definitions apply to the requirements of §§ 25.863 and 25.1187 when using the guidance in this AC. You should not assume that these definitions apply to the same or similar terms used in other regulations or ACs. The FAA has not defined terms for which standard dictionary definitions apply. Appendix A provides additional information pertaining to flammability, ignition, and fire characteristics of aircraft fluids.

4.1 Airplane Operating and Environmental Conditions.

Any conditions, or combination of conditions, expected to be encountered:

4.1.1 Throughout the full normal operating envelope of the airplane, as defined by the Airplane Flight Manual, together with any modification to that envelope associated with abnormal or emergency procedures and any anticipated crew action; and

4.1.2 Under the anticipated external and internal airplane environmental conditions, as well as any additional conditions, where equipment and systems are assumed to "perform as intended" when complying with the requirements of § 25.1309 or other applicable regulations.

4.2 Autogenous Ignition Temperature (AIT).

The minimum temperature at which an optimized flammable vapor and air mixture will spontaneously ignite under particular laboratory test conditions. Sometimes referred to as the minimum auto-ignition temperature.

4.3 Baffle Rib.

A vapor barrier or dam that segments the leading or trailing edge of the wing such that leaking flammable fluids (liquid or vapor) are controlled to reduce the likelihood of ignition. Baffle ribs provide a means to control drainage and ventilation within zones, and divert fluids away from the fuselage thereby limiting propagation of fire.

4.4 Designated Fire Zone (DFZ).

Areas that have been designated as fire zones are listed in § 25.1181 as the engine power section, the engine accessory section, the Auxiliary Power Unit (APU) compartment, any fuel burning heater (or combustion equipment described in § 25.859), the compressor and accessory sections of turbine engines, and the combustor, turbine and tailpipe sections of turbine engine installations that contain lines or components carrying flammable fluids.

4.5 Fire Zone.

A flammable fluid leakage zone that contains a nominal ignition source.

Note: While typically any Designated Fire Zone will also qualify as a "Fire Zone" under this more generic definition, other areas of the airplane may also be considered "Fire Zones." The means to protect the airplane from the hazardous effects of a fire within these other “Fire Zones” may differ from that prescribed for Designated Fire Zones under part 25, Subpart E.

4.6 **Flammability Limit**.

The flammability limit is the highest and lowest concentration of fuel in air by percent volume that will sustain combustion. A fuel to air mixture below the lower limit is too lean to burn while a mixture above the upper limit is too rich to burn. The flammability limit varies with altitude and temperature and is typically presented on a temperature vs. altitude plot.

4.7 **Flammable Fluid**.

Flammable, with respect to a fluid (liquid or vapor), means susceptible to igniting or to exploding. This includes any fluid that can burn, e.g., fuels, hydraulic fluid (including phosphate ester based fluids such as “Skydrol”), petroleum and synthetic oils, and some ice protection fluids.

4.8 **Flammable Fluid Leakage Zone**.

Any area where flammable liquids or vapors are not intended to be present, but where they might exist due to leakage from flammable fluid carrying components (e.g., leakage from tanks, lines, etc.).

4.9 **Flash Point**.

The minimum temperature at which a flammable liquid will produce a flammable vapor/air mixture at sea level ambient pressure per the applicable fluid specifications and test procedures.

4.10 **Flammable Fluid Ignition Source**.

A heat source, which is anticipated to occur under the Airplane Operating and Environmental Conditions, which has sufficient temperature and/or energy to initiate combustion of the flammable fluid in question.

4.11 **Foreseeable Event.**

A foreseeable event is an event that has occurred in service in the past, or is physically possible and is not extremely improbable.

4.12 **Maximum Allowable Surface Temperatures.**

A temperature 50 °F below the autogenous ignition temperature, which without further substantiation, can be conservatively considered not to be an ignition source per general industry/FAA practice.

4.13 **Nominal Ignition Source**.

A flammable fluid ignition source, which is not associated with a failure condition.

4.14 **Potential Ignition Source**.

A flammable fluid ignition source, which is associated with a failure condition.

4.15 **Telltale Drain**.

A drain outlet system that allows identification of a leaking accessory in a compartment that contains many accessories or a manually activated device, used to determine whether fluid has flowed through a drain line or shroud.

4.16 **Vapor Barrier**.

A barrier installed to confine liquid or vapor within a fire zone or flammable fluid leakage zone.

5 DEMONSTRATING COMPLIANCE WITH § 25.863, FLAMMABLE FLUID FIRE PROTECTION.

5.1 Applicability and Zone Classification.

5.1.1 Applicable Areas.

Section 25.863 is applicable to areas of the airplane that could be exposed to flammable fluid leakage from airplane systems. The origin of the leakage could be a different area of the airplane than the area exposed. Section 25.863 applies to flammable fluid leakage caused by a crash or wheels-up landing, engine or APU rotor non-containment, engine case burst or burn through, and catastrophic failure of primary structure. Other regulations in part 25 also address these failure conditions. Consequently, the applicant can generally infer compliance with § 25.863 from compliance with these more specific part 25 regulations. The “minimization” means delineated herein are applicable to these failure conditions only to the extent required by the more specific regulations.

5.1.2 Inapplicable Areas.

The following areas or situations, which are addressed by other regulations, generally do not need to be considered in demonstrating compliance with § 25.863:

5.1.2.1 Areas normally containing flammable fluid, such as the interior of flammable fluid system tanks, components, and plumbing; and

5.1.2.2 Flammable fluids not associated with airplane systems, such as those contained in cargo, baggage, personal possessions, and cabin stores.

5.1.3 Identification of Flammable Fluid Leakage Zones.

5.1.3.1 Section 25.863(d) requires the applicant to identify and define each area where flammable fluids or vapors might escape by leakage from a fluid system.

5.1.3.2 Applicants must also consider the possible sources and paths of fluid leakage, and means to detect leakage, as required by § 25.863(b)(1). The applicant should conduct an analysis of leak sources and leak paths to determine which areas should be classified as flammable fluid leakage zones. The applicant should take into account both liquid and vapor paths within the zone, and from adjacent zones.

5.1.3.3 If analysis is insufficient to predict whether an area is exposed to flammable fluid exposure, the applicant can conduct testing per paragraph 6.5 of this AC, or the applicant can conservatively assume that the area has been exposed to the leakage. When analyzing failures that cause leakage, applicants should consider the anticipated failure sequence.

5.1.3.3.1 For example, leakage due to cracks or sealant degradation in integral fuel tanks would be expected to progress to a low-rate-seeping and dripping-type leaks. Such leaks may be detectable before reaching higher leakage rates.

5.1.3.3.2 Contrarily, leaks involving high-pressure fluid lines and components could progress fairly rapidly to a spray-type leak. These types of leaks can be more critical than a higher rate streaming-type leak, especially for fluids with high flash points. Spraying flammable fluid is more easily ignited, and the applicant should consider reduced ignition temperatures when establishing whether components can be assumed to not be an ignition source within the zone being assessed.

5.1.4 Sections of This AC Related to Flammable Fluid Fire Protection.

Paragraph 5.2 below discusses hazard minimization concepts, paragraph 5.3 discusses various tools available for flammable fluid fire protection, and paragraph 5.4 discusses applicability of the hazard minimizations concepts and tools to various airplane areas, flammable fluid types, and scenarios. Figure 1 presents a flow chart for determining compliance of a particular area with § 25.863.

Note: In this figure, references in parentheses, e.g., (4.4), refer to the relevant paragraphs of this AC.

Figure 1. Flow Chart for § 25.863 Compliance

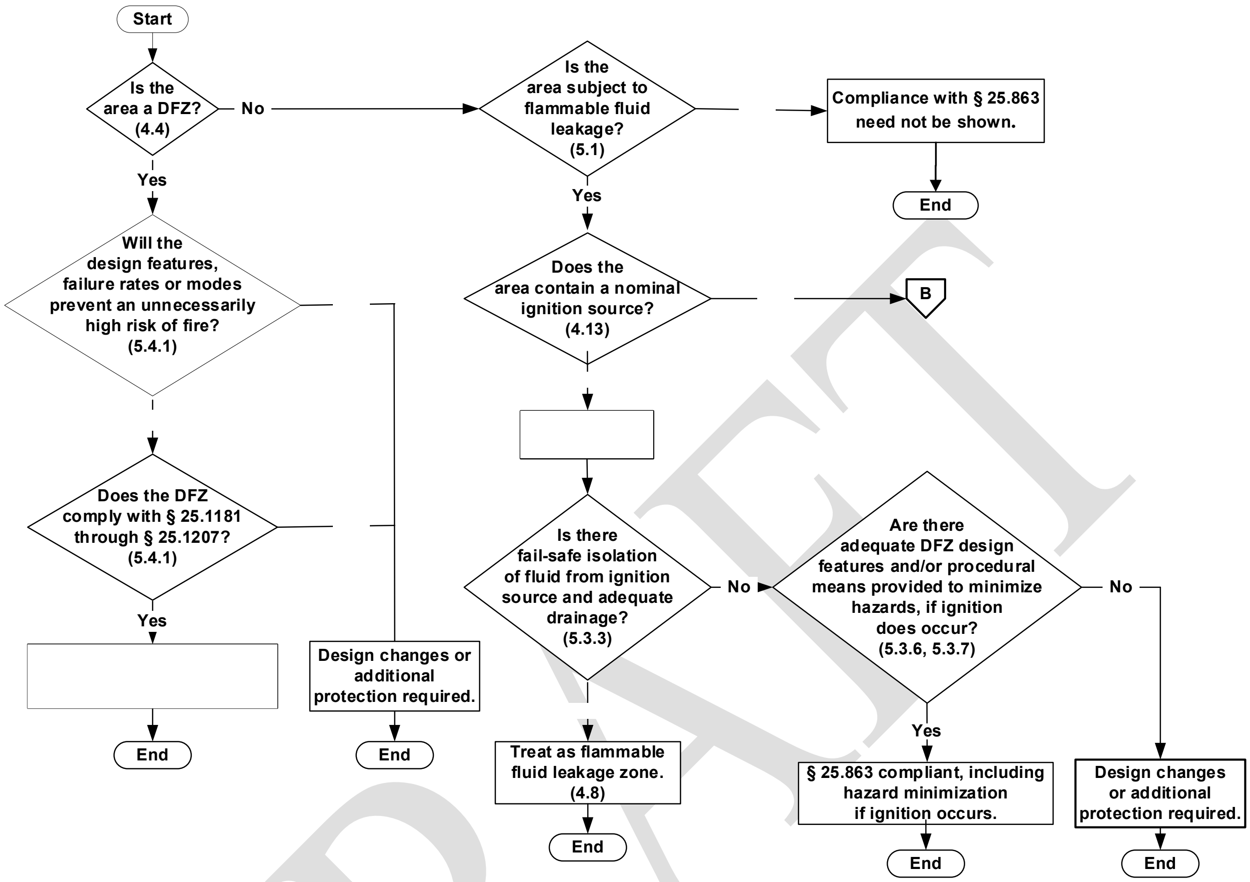
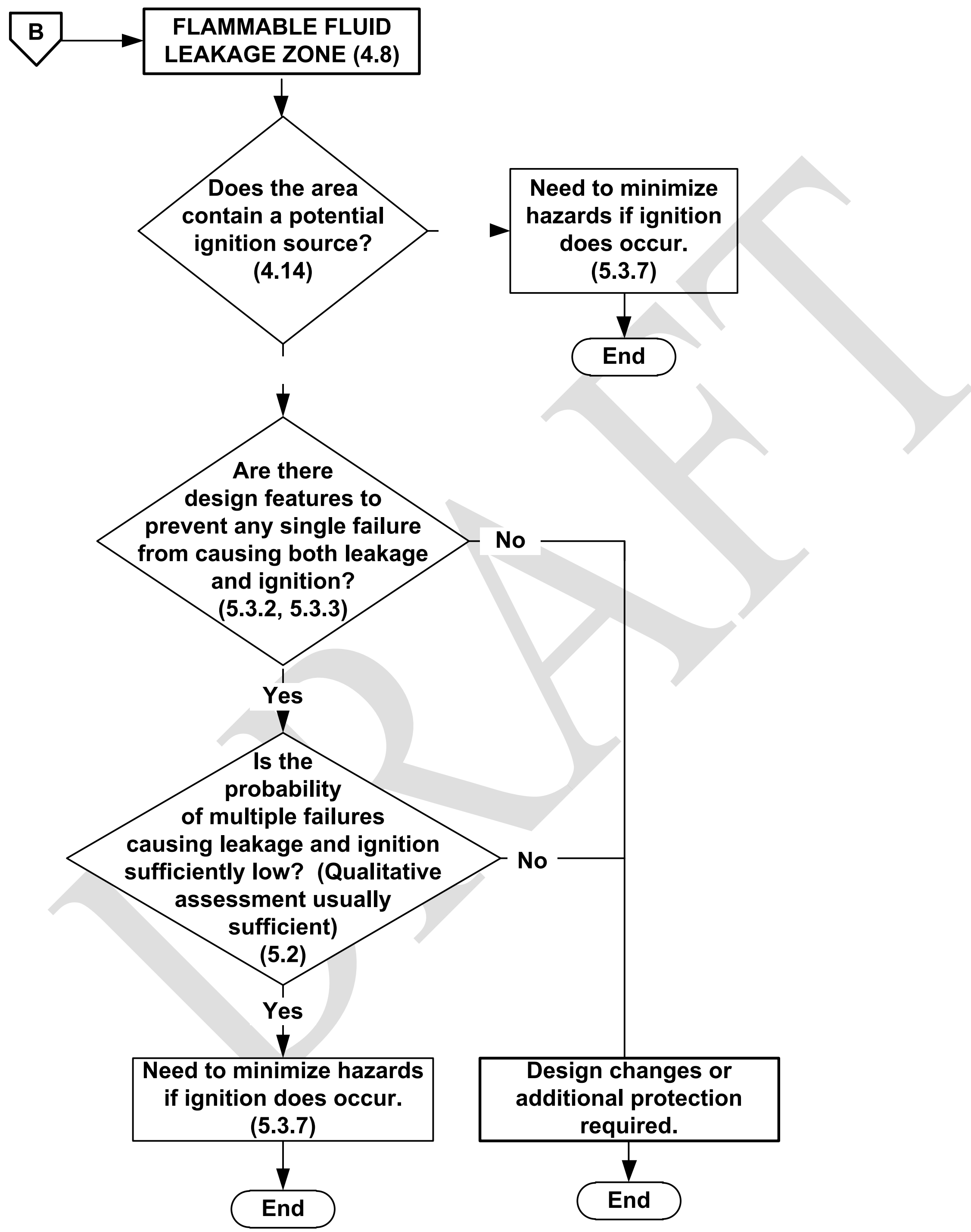


Figure 1. Flow Chart for § 25.863 Compliance (continued)



5.2 Hazard Minimization and Relationship of § 25.863 with §§ 25.901(c) and 25.1309(b).

5.2.1.1 Hazard minimization is doing what is technologically feasible and economically practical to eliminate or further reduce the hazard, given the current state of the art in design at the time of application. As a minimum, since the hazards associated with flammable fluids are not excepted from §§ 25.901(c) or 25.1309, acceptable flammable fluid fire protection must comply with the related requirements of §§ 25.901(c) and 25.1309.

5.2.2 Compliance Methods for §§ 25.901(c) and 25.1309.

5.2.2.1 For the powerplant installation, a system safety assessment should be used to show compliance with the requirements of §§ 25.901(c) and 25.1309(b). The compliance methodology for § 25.901(c) should be consistent with the latest version of AC 25.901-, *Safety Assessment of Powerplant Installations*.

5.2.2.1.1 For ignition sources related to fuel systems and areas adjacent to fuel tanks, the compliance methodology to show compliance with the requirements of §§ 25.901(c) and 25.1309(b) should be consistent with AC 25.981-1D, *Fuel Tank Ignition Source Prevention Guidelines*.

5.2.2.1.2 For ignition sources related to lightning, the compliance methodology to show compliance with the requirements of §§ 25.901(c) and 25.1309(b) should be consistent with AC 25.954-1, *Transport Airplane Fuel System Lightning Protection*.

5.2.2.2 For airplane systems, a system safety assessment should be used to show compliance with the requirements § 25.1309(b). The compliance methodology should be consistent with the latest version of AC 25.1309-1, *System Design and Analysis*.

5.2.2.2.1 Failure conditions resulting from ignition of flammable fluid (liquid or vapor) leakage must be shown to meet the probability objective (e.g., remote, extremely remote or extremely improbable) corresponding to the classification according to the severity of the failure condition effects, as described in AC 25.1309-1.

5.2.2.3 A quantitative analysis is not always necessary, and in some cases, a numerical assessment might not be practical due to issues such as the lack of failure rate data; therefore, a qualitative assessment can be appropriate.

5.2.2.4 Service experience has shown that the single most important aspect of these requirements is the prevention of catastrophic effects due to a single failure. This means to show compliance with the requirements of §§ 25.901(c) and 25.1309(b), applicants must ensure single failures, such as a wire chafing on a tube, do not cause both a leak and an ignition source.

5.2.2.5 Service experience has also shown that single failures in combination with latent failure conditions can have potentially hazardous or catastrophic effects. Applicants must ensure single failures, such as a leak, cannot occur when there is an ignition source present under normal or latent failure conditions.

5.2.2.6 The compliance methodology for failure conditions resulting from ignition of flammable fluid (liquid or vapor) that could require the crew to take appropriate corrective action concerning unsafe system operating conditions, per § 25.1309(c), should be consistent with the latest version of AC 25.1309-1, *System Design and Analysis*.

5.2.2.7 Wherever technologically feasible and economically practical, the probability of ignition and the resulting hazards should be further minimized in showing compliance with § 25.863. While compliance can be shown, it is often not practical, given the current state of the art at the time of application, to further reduce the probability of ignition and the resulting hazards below the levels required to meet §§ 25.901(c) and 25.1309(b).

5.2.2.7.1 Therefore, in the case where it is shown that it is not practical to further reduce the probability of ignition and the resulting hazards and compliance is shown for §§ 25.901(c) and 25.1309(b), further minimization is not required.

5.2.2.7.2 However, in some cases it might be practical to further reduce the probability of ignition and the resulting hazards even though compliance can be shown for §§ 25.901(c) and 25.1309(b) without further minimization. In these cases, § 25.863 requires the probability of ignition and the resulting hazards be further reduced.

5.3 General Protection Considerations for Demonstrating Compliance with § 25.863.

5.3.1 Ventilation and Drainage.

5.3.1.1 Unlike the requirements for designated fire zones in § 25.1187, drainage and ventilation are not specifically required for compliance with § 25.863. However, one primary means of mitigating fires from leaked flammable fluids is to prevent the accumulation of flammable liquids by safely draining the liquids away from the airplane, both in flight and on the ground, and to prevent the accumulation of flammable vapors as well as the formation of a flammable mixture by providing adequate ventilation. The degree of effectiveness of drainage and ventilation in minimizing ignition probability and hazard if ignition occurs varies with the type of fluid leakage characteristics and ignition scenario(s). In addition, drainage is useful for detection of slow leaks to avoid prolonged exposure or progress to a more severe leak. Several examples of the effectiveness of drainage and ventilation for various situations are shown in table 1 below.

5.3.1.2 For cases where drainage or ventilation is determined to be effective in minimizing the probability of ignition of the fluids and vapors, and the resultant hazards, applicants should consider the guidelines in section 6 of this AC.

Table 1. Drainage and Ventilation Effectiveness

Condition	Drainage Effectiveness	Ventilation Effectiveness
Slow leak and/or limited leakage quantity of a fluid with a relatively low flash point in relationship to compartment and fluid temperature.	Drainage is effective in limiting size and duration of pools (and fires) and in leak detection and repair, although leak detection may not be effective for very small leaks.	Ventilation is effective in prevention of explosive ignition and should minimize probability of flammable vapor contact with an ignition source.
More rapid leak and/or higher leakage quantity of a fluid with a relatively low flashpoint in relationship to compartment and fluid temperature.	Drainage effectiveness reduces as leak rate increases relative to flow capability of drains. Drainage is effective in leak detection.	Ventilation effectiveness becomes less as vapor formation rate increases relative to ventilation rate.
Non-spray type leak of a fluid with a relatively high flashpoint in relationship to compartment and fluid temperature.	Not generally susceptible to ignition of pools, so that drainage may be less beneficial in prevention, but still limits magnitude if ignition occurs. **Note**: Assumes pool not heated by a fire. Drainage is effective in leak detection.	Not generally susceptible to flammable vapor formation so that ventilation may not be beneficial.
Spray-type leak.	Limited effectiveness in preventing fire if the spray contacts an ignition source, but still limits magnitude if ignition occurs. Drainage is effective in leak detection.	Limited effectiveness if the spray contacts an ignition source.

Note: Relatively high flashpoint in relationship to compartment or fluid temperature means a significant difference on the order of 150 ºF (83 ºC). Based on this criterion, all fuels, alcohols, and petroleum based oils or hydraulic fluids will generally be considered relatively low flashpoint in at least portions of the operating envelope. Synthetic oils and hydraulic fluids may be considered relatively high flashpoint, depending on the assessment of flashpoint in relationship to compartment or fluid temperature. See appendix A of this AC for additional fluid data.

5.3.2 Separation of Leakage from Ignition Sources.

5.3.2.1 Separation of leakage and ignition sources is a fundamental tool in minimizing the probability for ignition, particularly with respect to preventing a single failure from causing both leakage and ignition.

5.3.2.2 Analysis should substantiate separation of leakage sources and ignition sources.

5.3.2.3 Arc faults between electrical wires and metallic lines carrying flammable fluids have punctured the line and ignited the leaking fluid, resulting in serious fires. A high-pressure spray leak can cause damage to adjacent components, such as wiring, and result in a fire. Acceptable means of compliance to address these types of failures can include the following:

5.3.2.3.1 Wherever possible, locate wires above or level with the fluid lines and not in the same vertical plane. This positioning reduces the likelihood that flammable fluid leakage impinges upon wiring and that any hot materials liberated due to wire arcing are less likely to fall onto and melt into flammable fluid lines.

5.3.2.3.2 Where possible, put splash shields between leakage locations, such as connectors, and ignition sources.

5.3.2.3.3 Avoid running wiring parallel to flammable fluid lines wherever possible. When wiring is run parallel to or crosses flammable fluid lines, maintain as much separation as possible and/or provide adequate fail safe clamping features.

5.3.2.4 Adequate physical separation should be maintained in the "as-built" configuration to ensure any wire bundle failure and/or flammable fluid leakage will not create a hazard. Based on in-service experience, unless other acceptable positive means of isolating the wiring and plumbing is provided, the minimum clearance between wiring and lines carrying flammable fluid should not be less than one inch under any anticipated failure conditions. This clearance accounts for the relative motion of the airplane structure due to wing deflection, engine movement and manufacturing tolerances.

5.3.2.5 Applicants should address failure conditions including, but not limited to:

5.3.2.5.1 Failed clamps, brackets, or other attachments in the plumbing and wiring.

5.3.2.5.2 Wire or plumbing failures whereby the location of these components could deviate sufficiently from their normal routing to violate the separation provided.

5.3.2.5.3 Other ignition sources (e.g., hot gas components, energy storage devices, and mechanical components) that cannot be acceptably prevented should also be effectively separated or otherwise isolated from flammable fluid leakage. The adequacy of the prevention and/or isolation means should be evaluated under all anticipated operating conditions. This should include any anticipated failure of any “explosion proof,” “pneumatic,” or “electrical” component within any flammable fluid leakage zone.

5.3.3 Isolation of Leakage from Ignition Sources (Nominal and Potential).

5.3.3.1 Isolating flammable fluid leakage from ignition sources consists of constructing physical barriers to prevent leakage (including vapors) from coming into contact with ignition sources. Isolating high-pressure leaks from ignition sources is especially important in the design.

5.3.3.2 Acceptable means of isolation include installing shrouds around plumbing and components that carry flammable fluid, double-walled fuel tanks, and transparent[1] secondary coatings on integral tanks. These fuel tank coatings prevent leakage from sealant leaks or structural cracks but permit detection of these leaks.

5.3.3.3 The volume between the fluid boundary and the isolation means should not contain any ignition sources. It should be ventilated and drained to either outside the airplane or another area where the presence of flammable fluid leakage will be detected before the isolation means is compromised. Isolation is normally accepted as a means of compliance with § 25.863, provided the following criteria are met:

5.3.3.3.1 The isolation means is capable of handling any expected leakage without leaking or failing itself.

5.3.3.3.2 The isolation means should remain intact and effective between normal inspections and/or overhauls.

5.3.3.3.3 Drainage of fluid from the isolated volume exit complies with § 25.863 and is reasonably detectable during ground, pre-flight, or routine inspection.

5.3.3.3.4 In areas in which there is a nominal ignition source, and a fluid leak is expected to result in a fire, no single failure (including structural failure) will cause both a leak and failure of the isolation means.

5.3.3.4 Partial isolation can be effective in some situations to minimize the probability of ignition and the resultant hazard if ignition occurs. For example, baffle ribs in the wing leading edge allow the leakage to drain without migrating to other areas.

[1] Transparent coating installed on structure provides a secondary barrier that prevents leakage of fuel or fumes into the pressurized areas of the airplane that should be assumed to contain ignition sources. The coatings are flexible and stretchable. These coatings should be carefully applied and maintained. Damage to the coatings has been observed due to personnel walking on surfaces where the coatings were installed. Damage has also occurred when preloaded fasteners have failed and caused tears in coatings as well as a breach of the tank, resulting in a fuel leak into the passenger compartment. The coating has also been damaged due to impingement of hot air from environmental control system duct leakage. Installation errors where the coating was not properly applied have also been observed. Transparency of the coatings is typically required to allow inspection of the primary structure to detect possible cracking so that latent failure of the primary fuel barrier is addressed.

This measure decreases the probability of ignition and the size of any resulting fire. Another example is using wiring conduits or other local shielding to minimize the possibility of leakage contacting potential ignition sources. This example particularly applies to situations involving high flash point fluids where the main ignition hazard involves a pressurized spray.

5.3.4 Qualification of Components to be Located in Flammable Fluid Leakage Zones.

5.3.4.1 Applicants should demonstrate that components located in flammable fluid leakage zones are not nominal ignition sources. The components should be qualified for use within flammable fluid leakage zones by identifying the appropriate qualification criteria and then demonstrating compliance with those criteria.

5.3.4.2 Electrical components could be qualified using the explosion-proof requirements in the latest version of AC 25-16, *Electrical Fault and Fire Prevention and Protection*; or § 9 of RTCA Document DO-160;or BS 3G-100, *Specification for General Requirements for Equipment for Use in Aircraft*. However, applicants might need to take into account additional considerations summarized in the note below.

5.3.4.3 Other components must be free of potential arcing or friction ignition sources as required by § 25.981. They must have maximum surface temperatures with an acceptable margin (usually 50 °F) below the autogenous ignition temperature of the flammable fluid that could exist within the zone as required by § 25.981.

5.3.4.4 The necessary compliance showing for components to be qualified as not being ignition sources in failure conditions (including any anticipated latent failure condition that could occur) will vary depending upon the failure modes and probability, the leakage and ignition scenario involved, and the proposed means of minimizing the probability of ignition.

Note: Determining the potential for equipment to create an ignition source could involve considerations beyond the criteria in § 9 of RTCA DO-160 for the following reasons:

Category A: Explosion-proof requirements might not be applicable for all equipment. They do not address the ignition potential of faults in wiring connecting to the equipment.

Category E or H: Equipment testing is necessary to show that there is no potential for ignition in flammable fluid leakage areas under normal operating conditions for showing compliance with § 25.863. However, testing is also necessary to consider ignition potential and probability under fault conditions.

Note: The FAA generally accepts the use of a maximum acceptable surface temperature of 50 ºF below the applicable fluid autogenous ignition temperature (i.e., approximately 400 ºF/200 ºC for jet fuels).

However, in certain cases manufacturers have substantiated that the conditions (e.g., ambient pressure, dwell time, and fuel type) within certain flammable fluid leakage zones, safely allow surface temperatures closer to the AIT. For example, the FAA has approved pneumatic bleed duct surface temperatures up to 450 ºF, with a transient excursion of up to 500 ºF for a maximum of two minutes. The excursion above 450 ºF occurs only during failure conditions such as an engine high stage pneumatic bleed valve failure or duct rupture. These elevated temperatures were accepted because the design had compensating features. These compensating features included a flight deck indication of over-temperature, associated procedures to shutoff the overheated system, insulated ducts, zone ventilation airflow, which produces a lean fuel-to-air mixture and an automatic over-temperature shutoff of the pneumatic system so that the temperature cannot exceed the accepted 450 ºF value for more than two minutes.

5.3.5 <u>Cooling Air Ducts.</u>

The cooling air supply and/or discharge for any electrical, electronic, or mechanical equipment should be conveyed within the airplane and discharged from the airplane so it does not create a hazard if the equipment fails and creates any potential ignition sources (e.g., hot gases, flames, or friction sparks). This may require the cooling duct to be fireproof and/or insulated.

5.3.6 <u>Detecting, and Accommodating Hazard Conditions.</u>

Monitoring for, detecting, and accommodating conditions that could contribute to a flammable fluid ignition hazard is a common and effective aid in minimizing that hazard. Condition monitoring and accommodations can take many diverse forms, including:

5.3.6.1 Looking for and detecting overboard drainage of flammable fluids during the pre-flight walk-around inspections. When combined with suitable dispatch restrictions when such leakage is noted, this type of condition monitoring can help minimize the exposure times associated with detectable leakage.

5.3.6.2 Overcurrent and/or overheat protection and condition monitoring within flammable fluid tanks, pumps and/or other flammable fluid carrying components (see AC 25.981-1D, *Fuel Tank Ignition Source Prevention Guidelines*). This type of condition monitoring can help minimize the hazards associated with exceedingly hot flammable fluids and/or fluid system components (e.g., ignition of flammable fluids within the fluid system and leakage of hot flammable fluids). Overcurrent and/or overheat protection and condition monitoring can include thermal switches that automatically shut off flammable fluid pumps when they overheat, and indicators that monitor the temperature of fluid in tanks, which combined with operating limitations and flightcrew procedures, trigger isolation of overheating fluid systems. When an overcurrent or overheat condition is sensed, accommodations are triggered either automatically or through flightcrew indications and procedures.

5.3.6.3 Fire and/or overheat monitoring within a flammable fluid leakage zone. This monitoring most commonly occurs within designated fire zones. When a fire or overheat condition is sensed, accommodations are triggered either automatically or through flightcrew indications and procedures. For example, a warning is triggered in the flight deck and the flightcrew follow established procedures to minimize the fire hazard. These established procedures may include shutting off the flow of flammable fluids and/or ventilation air into the zone, releasing fire extinguishing agent into the zone, shutting off the airflow into a burst environmental control system or engine-bleed air duct, etc.

5.3.6.4 Detection and accommodation of other conditions known to cause flammable fluid leakage, ignition sources, reduced ventilation or drainage, loss of some flammable fluid fire protection means, or otherwise contribute to a flammable fluid ignition hazard. Detection and accommodation of these conditions may include the following:

5.3.6.4.1 Installing circuit breakers to stop arcing due to shorted power wires.

5.3.6.4.2 Conducting inspections and functional tests to detect clogged drainage provisions.

5.3.6.4.3 Selecting closed as the fail-safe state for cooling air valves.

5.3.6.4.4 Creating procedures to detect failures within the fire detection means.

5.3.6.4.5 Periodically conducting maintenance to ensure fire-extinguishing capability.

5.3.7 <u>Protection If Ignition Occurs.</u>

5.3.7.1 In addition to minimizing the probability of ignition, § 25.863(a) requires that the resultant hazards be minimized if ignition does occur. As discussed in paragraph 5.2 of this AC, this requirement is in addition to the safety requirements of §§ 25.901(c) and 25.1309(b). However, the applicant's demonstration of what is technologically feasible and economically practical may constrain these mitigations depending upon the current state of the art at the time of application and the technology level of the applicable product, in cases where the applicant is proposing to modify an existing airplane design.

5.3.7.2 Designated fire zones require the protection means of § 25.1181 through § 25.1207, which provide the required hazard minimization if ignition occurs (see paragraph 5.4.1 of this AC).

5.3.7.3 Nacelle areas behind firewalls and pod attaching structures containing flammable fluid lines require the protection means outlined in § 25.1182, which provide the required hazard minimization if ignition occurs (see paragraph 5.4.3 of this AC).

5.3.7.4 Other fire zones (containing a nominal ignition source), wheel well, and occupied areas are discussed further in paragraphs 5.4.2, 5.4.4, and 5.4.5 of this AC.

5.3.7.5 For flammable fluid leakage zones, the following provisions have been generally accepted as minimizing the hazard if ignition occurs:

5.3.7.5.1 Provide ventilation in areas to minimize the amount of flammable vapors in the zone.

5.3.7.5.2 Provide ventilation to minimize the probability of the ignition causing an explosion.

5.3.7.5.3 Provide a means to shut off ventilation airflow, following flight deck indication of a fire.

5.3.7.5.4 Provide the maximum practical amount and effectiveness of drainage to minimize leakage volume available to a fire and provide detection to minimize multiple flight exposure to a leak. This may vary by area, type of fluid, and quantity of fluid. For example, it is usually not practical to drain pressurized areas in-flight. While this lack of drainage capability may be acceptable for low quantities of high-flashpoint fluids, other means of preventing the accumulation of leakage such as drained shrouds would be necessary for low-flashpoint fluids.

5.3.7.5.5 If some residual undrained fluid is present, or if drainage is not practical for all phases of flight, consider what would happen if that residual undrained fluid ignited. The applicant should pay special attention to how the fluid might aid in the spread of a fire, and the potential effects on critical structure and systems as well as other flammable fluid systems. The applicant should consider independently caused fires as an ignition source, with respect to creating or igniting the leakage, so that the ignition would increase the hazard by adding to the size or intensity of the fire or causing it to spread to other areas.

5.3.7.5.6 If the above means do not adequately minimize the hazard, the applicant should consider additional practical means. The applicant should consider if the protection means already in place could be improved or if additional protection means are necessary, such as those used to protect designated fire zones.

5.4 Section 25.863, Compliance Considerations for Different Airplane Areas.

5.4.1 <u>Designated Fire Zones (DFZs).</u>

5.4.1.1 Section 25.1181(b) requires DFZs to comply with § 25.863 and other regulations. However, in most cases compliance with the fire protection requirements (§ 25.1181 to § 25.1207) of 14 CFR part 25, Subpart E, will also provide compliance with § 25.863. Given that the FAA assumes DFZs will have nominal ignition sources within them, the emphasis here is on minimizing the hazardous effects of fire.

5.4.1.2 If design features result in an unusually high probability of fire, additional methods may be required to show compliance with § 25.863. For example, attaching an electrical power feeder cable to a fuel feed pipe would not comply with § 25.863, even within a DFZ.

5.4.2 Other Fire Zones.

Other fire zones are those that are subject to flammable fluid leakage and contain a nominal ignition source. Wheel wells, discussed further in paragraph 5.4.4 of this AC, are typically one example, but there may be others for specific airplane designs. As previously discussed in paragraph 5.3.3 of this AC, one acceptable means of compliance is isolation so that the zone is no longer subject to leakage and therefore is no longer classified as a fire zone. In the event that this means of compliance is not practical, the applicant should consider and apply various means of protection prescribed for designated fire zones as appropriate.

5.4.3 Areas Adjacent to Designated Fire Zones.

5.4.3.1 Areas adjacent to DFZs can include pylon, strut, and nacelle areas behind the firewall; fan cowls that are not designated fire zones; and areas adjacent to many different types of APU compartments. In some cases, the nacelle areas may include wheel wells.

5.4.3.2 The firewall boundary may constitute an ignition source in the case of a fire in the DFZ. The FAA has accepted several means of addressing § 25.863 with respect to this situation:

5.4.3.2.1 Use insulation, compartmentalization, or other means so that firewall surfaces of these areas do not become hot enough to be an ignition source for the fluids (liquid, vapors and mist) involved.

5.4.3.2.2 Substantiate that the fire in the DFZ will not itself cause flammable fluid leakage in the adjacent area. This substantiation needs to include consideration of any anticipated latent failure of the firewall (e.g., loss of a segment of bulb seal or a fastener failure leaving a hole through which fire could escape and cause damage to flammable fluid carrying components in the adjacent zone.) The substantiation should also consider any foreseeable source of fire more severe than that for which the firewall was qualified (e.g., high pressure “torch-like” fire immediately adjacent to the firewall or a fire that involves a halide metal, such as magnesium). Ensure that the combined probability of the fire and an independent failure causing flammable fluid leakage meets both the applicable fail-safe requirements of §§ 25.901(c) and 25.1309(b) and the minimization criteria discussed above. Include the anticipated degree of latent leakage and resulting ignition susceptibility and effects.

Note: Substantiation of the absence of latent leakage sufficient to cause a hazard for this option could be difficult, depending on airplane size, configuration, and leakage flow paths.

5.4.3.3 Section 25.1182 specifies fire protection requirements for some of these areas (e.g., nacelle areas behind firewalls and engine pod attaching struts). The applicant should consider design features that address these requirements in showing compliance with § 25.863. However, showing compliance with the requirements of § 25.1182, while it might reduce the probability of ignition, does not necessarily also show compliance with § 25.863 because § 25.1182 does not address minimizing the probability of ignition.

5.4.4 Wheel Wells.

5.4.4.1 Wheel wells generally contain flammable hydraulic fluid, may be subject to fuel leakage, can contain nominal ignition sources (e.g., hot surface ignition source resulting from brake usage or dragging brakes) and require specific single failure consideration with respect to tire burst, tire tread debris and flailing.

5.4.4.2 Due to the wide variety of designs, providing herein an acceptable means of compliance for each specific design is not practical. However, the following is a list of design features that have been used in various combinations for hazard minimization and compliance:

5.4.4.2.1 Design considerations required to show compliance to § 25.729(f) (considerations for wheel and tire failures and brakes overheat).

5.4.4.2.2 Installation of fluid systems, especially fuel, so that leakage does not enter the wheel well.

5.4.4.2.3 Inherent drainage and ventilation provided by not using completely sealed wheel well doors.

5.4.4.2.4 Volumetric fuses on brake lines or other brake design features to limit amount of hydraulic fluid that can feed a brake fire.

5.4.4.2.5 Means, such as shrouds, to minimize the probability that leaking flammable liquids would contact a hot brake surface.

5.4.4.2.6 Installation of a wheel well overheat/fire detector combined with procedures to extend the gear or otherwise cool/extinguish the fire if an overheat/fire is detected.

5.4.4.2.7 Installation of brake temperature indication combined with procedures to not retract the gear (or extend the gear if retracted) until the brake temperatures are within limits.

5.4.4.2.8 Mechanical shielding or sleeves on electrical wire bundles.

5.4.5 Occupied/Pressurized Areas.

5.4.5.1 Passenger and crew compartments, and adjacent areas (e.g., pressurized avionics, baggage or cargo areas), should be assumed to contain nominal ignition sources such as carry-on articles and galley service equipment. To the extent practicable, avoid installing flammable fluid tanks, lines, and other components that carry flammable fluid within these areas.

5.4.5.2 Further, § 25.967(e) requires fuel tanks and lines to be isolated from personnel compartments by fuelproof and fumeproof secondary barriers.[2] An accepted practice for compliance with § 25.863 within personnel compartments is to isolate lines and other components that carry flammable fluid by means of drained vapor-proof and liquid-proof enclosures (e.g., shrouding). If tanks (in their isolation enclosures) are located in baggage or cargo compartments, § 25.855(e) requires features to prevent baggage or cargo from moving during operation and damaging the tank or other components carrying flammable fluids.

5.4.5.3 While providing less protection than the previously-described shrouding method, unshrouded installations within personnel compartments and adjacent areas have been found acceptable provided these areas contain:

5.4.5.3.1 Fluids with a higher flash point (e.g., MIL-H-83282, MIL-H-87257, and phosphate esters).

5.4.5.3.2 Auto-ignition temperatures that are much higher than compartment and component temperatures.

5.4.5.3.3 Provisions to keep spray-type leakage from contacting any nominal or potential ignition source. These provisions can include installation routing and using adjacent structures or a dedicated shield to obstruct spray paths.

5.4.5.3.4 Drainage provisions should be used to minimize puddling and maximize detectability of leaks, although the design may be acceptable for drainage to not occur when the airplane is pressurized depending upon the situation, such as potential leakage rates and quantities.

5.4.5.4 Air inlets for personnel compartments and adjacent areas, including those used or present during non-pressurized flight, should not ingest flammable fluid leakage from another part of the airplane in showing compliance with § 25.1091(d)(1).

5.4.6 Areas Containing Electrical and Electronic Equipment.

Note: The considerations in the paragraphs below apply to all electrical or electronic equipment subject to flammable fluid leakage. However, the complexity and practicality of failure analysis is magnified in areas with large amounts of electronic or electrical

[2] AC 25-8, *Auxiliary Fuel Systems Installations,* provides guidance on compliance with requirements for installing fuel tanks and lines within the pressurized compartments.

equipment because of the number of components, wire bundles, failure conditions, and related concerns involved.

5.4.6.1 If the airplane contains dedicated electronic and electrical equipment bays that are isolated from exposure to flammable fluid leakage, such isolation means might satisfy § 25.863. However, applicants would need to show that these areas are not exposed to flammable fluid leakage from other parts of the airplane, such as through cooling or pressurization airflow paths.

5.4.6.2 Liquid Glycol based electrical component cooling systems have been installed that may leak and produce residue that is flammable, or may be absorbed by adjacent insulation and cause the insulation to fail flammability requirements. Applicants should evaluate and account for failure modes of these types of systems in design and maintenance requirements.

5.4.6.3 The applicant should address unique failure modes introduced by batteries installed within the pressurized compartment. The applicant should apply guidance in this AC to any battery installation that could be impacted by leakage of flammable fluids or vapors.

Note: The FAA has applied project-specific requirements for lithium battery installations, in the form of special conditions.

5.4.6.4 When it is necessary to prevent exposure of certain areas to flammable fluid leakage from adjacent areas, the FAA has accepted designs with ventilation that provides a positive pressure differential between the compartment and the adjacent area.

5.4.6.5 Some areas of the airplane (e.g., tail cones and nose compartments) may contain both significant amounts of electrical and electronic equipment, and potential flammable fluid leakage sources. In these cases, the applicant must demonstrate compliance with § 25.863.

5.4.6.6 The applicant must minimize the probability that flammable fluids will spray or leak directly into or onto electrical and electronic equipment, to comply with § 25.863, because electrical and electronic equipment constitute a possible ignition source. The applicant should locate equipment away from potential leaks or install spray and/or leakage barriers in showing compliance with § 25.863.

5.4.6.7 The applicant should use drainage to minimize puddling and maximize detectability of leaks.

5.4.6.8 Zonal analysis and physical minimization should show that all flammable fluid components are protected against single failures causing both a leak and an ignition source (see paragraph 5.2). Where traditionally accepted design practices are utilized, meeting the following additional provisions usually provides adequate assurance that the multiple failure requirements are met.

5.4.6.9 For fuel or lower-flashpoint hydraulic fluids (e.g., MIL-H-5606):

5.4.6.9.1 Use the isolation provisions discussed in paragraph 5.3.3 of this AC; or

5.4.6.9.2 For one-piece lines with large design margins (including lines with permanent fittings of integrity equivalent to the line), the applicant should substantiate that the electrical/electronic equipment will not be a nominal ignition source, per paragraph 5.3.4 of this AC, and that the compartment has adequate drainage and ventilation.

5.4.6.9.3 For hydraulic fluids with a higher flashpoint (e.g., MIL-L-23282, MIL-L-87257, and phosphate esters), the applicant should substantiate that there is a large margin between the temperature of the electrical/electronic equipment in normal operation and that required for ignition.

5.4.7 Areas Containing Hydraulic System Components.

5.4.7.1 Areas containing hydraulic system components are generally susceptible to hydraulic fluid leakage. These areas can also contain nominal ignition sources (e.g., hot surfaces).

5.4.7.2 Due to the number of substantially different type designs, providing acceptable means of compliance herein for each type is not practical. Nevertheless, applicants should use the following in various combinations to minimize the probability of ignition and any resulting hazards:

5.4.7.2.1 Design precautions taken to limit the hydraulic fluid quantity susceptible to be spilled.

5.4.7.2.2 Minimize the number of couplings and use permanent couplings (e.g., swaged) wherever possible.

5.4.7.2.3 Locate components that carry flammable fluid so as to minimize the potential for flammable fluid leakage to contact ignition sources.

5.4.7.2.4 Design features to keep flammable fluid leakage, including spray type leakage, away from ignition sources (e.g., dedicated shield, shroud, and spray covers).

5.4.7.2.5 Provide adequate drainage paths to minimize puddling and maximize detectability of leaks.

5.4.7.2.6 Provide adequate ventilation to minimize the hazards from flammable vapors (temperature reduction and purging).

5.4.7.2.7 Install temperature indications where abnormally high temperatures would increase the flammable fluid fire hazard (e.g., hydraulic fluid tanks, high power consumption electrical equipment, and other potential ignition sources). Where practicable, provide potential sources of overheating with an automatic cut-off device (e.g., hydraulic pump overheat/over-current cut-off).

5.4.7.2.8 Install low-level indicators on hydraulic tanks that cause appropriate automatic/manual procedures to be applied.

5.4.7.2.9 Ensure the safe discharge of electrostatic charges by using appropriately bonded components including earthed, screened conductor wires.

6 DEMONSTRATING COMPLIANCE WITH § 25.1187, DRAINAGE AND VENTILATION OF FIRE ZONES.

6.1 Applicability.

The drainage and ventilation requirements of § 25.1187 apply to designated fire zones, to nacelle areas immediately behind the firewall per § 25.1182, to each portion of any engine pod attaching structure containing flammable fluid lines per § 25.1182, and to engine cowlings per § 25.1193.

6.2 Drainage.

The applicant may demonstrate compliance with § 25.1187 by test (see paragraph 6.5 of this AC), through a combination of testing and analysis, or by analysis (see paragraph 6.3).

6.3 Drainage Analysis.

In some cases, the applicant can show that leakage from unintended places and impingement on other parts of the airplane is clearly not possible. In these cases, the applicant can show compliance by analysis alone. Section 25.1187(a)(1) requires the analysis show that the drainage system will perform under all intended sustained flight conditions. The applicant must substantiate that unfavorable pressure gradients do not exist under normal flight conditions so that the drainage system will function as intended. The applicant should conduct tests as described in paragraph 6.5 of this AC if the drainage analysis cannot be validated.

6.4 Purposes of Drainage Analysis.

The purposes of drainage analysis are to:

6.4.1 Establish where leaks might occur and introduce measures to minimize leak rates where possible.

6.4.2 Determine the anticipated maximum leakage rates for each leakage source.

6.4.3 Confirm that adequate drainage is provided in the necessary locations.

6.4.4 Identify where the drained fluid (both liquid and vapor) goes and show that no additional fire hazard occurs.

6.4.5 Potential Failures.

The applicant should conduct the drainage analysis to evaluate the safety implications of the potential leak sources for each flammable leakage zone. The analysis should include foreseeable failures which can result in large uncontrolled leaks that exceed the drainage system design flow rate. Examples of large uncontrolled leaks are engine fuel supply line coupling failures due to over-tightening or mis-assembly of the coupling without the packing (o-ring), unsecured fuel filters, high-pressure fuel line failure due to fatigue cracking, and secondary fuel/vapor barrier failure due to cracking or misapplication.

6.4.6 Requirements/Inclusions.

Some key considerations for performing drainage assessments include:

6.4.6.1 The applicant should establish the proper drainage rate based on analysis of potential leaks sources within the flammable fluid leakage zone.

6.4.6.2 The failure conditions caused by maximum anticipated leakage must comply with §§ 25.901(c) and 25.1309(b).

6.4.6.3 Typically, drainage systems should provide adequate capacity to handle fluid flow rates that could occur if a single seal fails or high-pressure lines crack.

6.4.6.4 Drainage rates may also need to accommodate drainage of fluid trapped downstream of firewall shutoffs in a timely manner. This accommodation must meet the requirements of § 25.1189(e).

6.4.6.5 The FAA does not typically expect that drainage systems be capable of accommodating large leaks since they will be mitigated in other ways in showing compliance with § 25.901(c). For example, the FAA certified many current airplanes based on demonstration of a drainage system flow capacity of one gallon per minute. This rate was established by analysis of the maximum leak possible when one o-ring seal was omitted from a fuel line coupling. Conversely, drainage rates traditionally do not accommodate the very large leakage rate that would result from the total separation of a main fuel feed line or hose. This is because the foreseeable failure modes of main fuel lines and hoses are traditionally limited to progressive failures whereby the resulting leakage can be detected and safely accommodated before complete separation occurs.

6.4.6.6 The applicant must provide means to assure that leakage rates will not exceed the drainage capacity, to provide the “complete” drainage required by § 25.1187(a). These means could include, but are not limited to:

6.4.6.6.1 Installing telltale drains that provide maintenance awareness of small leaks.

6.4.6.6.2 Installing fail-safe features on connections (e.g., shrouds around couplings, double attachment of fuel filters, and reduced flow areas around seal retention plates within couplings to restrict flow if a seal fails).

6.4.6.6.3 Isolating high-pressure leak source drains from low pressure leak source drains to preclude back flow into low pressure systems.

6.4.6.6.4 Locating of drain lines away from heat sources that are of sufficient temperature to cause clogging due to residual carbon build-up (coking).

6.4.6.6.5 Installing of graduated/increased area drain screens over drain inlets to preclude clogging by debris, and drain line design to prevent ice clogging. One example of a drain screen used for this purpose is a “finger screen” that extends vertically from the drain inlet, and allows passage of fluid if debris collects around the base of the screen.

6.4.6.7 Manufacturing discrepancies have resulted in airplane drain problems, such as failure of the drainage or sealing systems to perform their intended function. The drainage system analysis should also establish that type design manufacturing and inspection processes and procedures are in place to ensure that necessary sealing provisions perform their intended function. Similarly, instructions for continued airworthiness per § 25.1529 should ensure that this capability is retained in service.

6.4.6.8 After performing the leak source analysis, the applicant should evaluate the consequences of a maximum foreseeable leak to ensure that a hazardous condition is not created. Sealing of compartments should be adequate to allow build-up of fluids without migration of fluid into areas where ignition could occur. The location of flammable fluid overboard drain outlets is critical in providing a design that minimizes ignition of leaked fluids following drainage. The following guidelines can be useful in locating flammable fluid drain outlets:

6.4.6.8.1 Arrange overboard drain outlets so flammable fluids do not collect on the airplane when the airplane is stationary on the ground.

6.4.6.8.2 Drain outlets should be located downstream of areas where drained fluid may reenter the airplane in any operating condition where it could cause an additional fire hazard.

6.4.6.8.3 Outlets must be designed and located to meet the lightning requirements of §§ 25.581 and 25.954.

6.4.6.8.4 Evaluate outlet location and line routing to ensure there are no restrictions because of water traps that result in the accumulation of water or ice.

6.4.6.8.5 Prevent fire hazards created by flammable fluid exiting a drain and impinging or running along the outside of the airplane by extending the drain mast beyond the boundary layer. Installation of a vortex generator on the drain mast upstream of the outlet may facilitate dispersion of the fluid and eliminate hazardous impingement on the airframe.

6.5 **Drainage Test.**

Typically, testing is needed to validate elements of the analysis and demonstrate that compartment sealing and drainage provisions remain effective under representative operating conditions throughout the flight envelope. As with any FAA certification test program, the applicant submits a certification plan proposing analysis methods and test conditions. The FAA approves this plan before it will conform test articles or witness tests. Both ground and flight tests are normally needed.

6.5.1 Simulating Leakage.

6.5.1.1 Install a system to dispense test fluid in the airplane. Nozzles are located to spray into areas where potential leaks could occur. Disperse the spray in a manner representative of the potential leakage sources so that any unintended leakage paths will be apparent. Fluid spray bars consisting of a flexible tube with perforations have been used in the past to simulate leakage from flammable fluid lines. The selection of test fluid spray rates and dispersion patterns should be adequate to support the objectives of the testing. Measurement of pressure gradients during flight testing is also sometimes used to validate the drainage capacity analysis in paragraph 6.3 of this AC.

6.5.1.2 An FAA airworthiness representative normally witnesses the ground and flight tests. Take photos of the airplane prior to the flight test to show the dye sensitive coating application. Take post-test photos to document the drainage patterns and to substantiate compliance. Video is also helpful in recording test results.

6.5.1.3 While there are no simple universally-accepted criteria for what constitutes a "hazardous quantity," the applicant should take the following guidance into account:

6.5.1.3.1 The location of all significant amounts of "undrained" fluid should be identified.

6.5.1.3.2 The drainage paths should not create a hazard.

6.5.1.3.3 There should be no indication of excessive puddling.

Note: Individual puddles should be smaller than 1.5 fluid ounces (4.1 cl.).

6.5.1.3.4 The quantity of undrained fluid should be minimized.

Note: One measure that the FAA has accepted for reasonably small volumes of test fluids is when over 90 percent of the test fluid is recovered within 10 minutes, and there is no practicable means to further reduce the undrained volume.

6.5.1.3.5 The undrained fluid should not be located such that it substantially contributes to the probability of flammable fluid ignition or the resulting hazard should ignition occur.

6.5.2 Static Ground Test.

The purpose of the ground test is to demonstrate that no hazardous quantities of fluid can be trapped within a fire zone and to assess the overall suitability of the drainage paths. As a minimum, the applicant should perform this test in a normal ground attitude. However, the applicant should take into account the effects of other attitudes either by analysis or by additional testing. The applicant should perform this test by:

6.5.2.1 Determining the amount(s) and location(s) where dyed fluid (usually water or a water/glycol mixture) should be introduced to adequately wet the area under test and making suitable provisions to do so.

6.5.2.2 Coating the area under test with a dye-exposing substance, such as powdered soap or a suitable paint to provide a means to visualize both the adequacy of “wetting” and the drainage characteristics in critical areas.

6.5.2.3 Introducing the pre-determined measured amount(s) of dyed fluid.

Note: Typically between 1 and 4 U.S. gallons (4 to 15 liters) distributed around each potential leakage source) and measuring the amount of fluid that is recovered from the compartment drains.

6.5.2.4 Computing the net undrained fluid, inspecting the area under test, and making an adequate accounting of the location of all the fluid.

6.5.2.5 Establishing that the undrained fluid is not a hazardous quantity. (See paragraph 6.5.1.3 in this AC for further guidance).

6.5.2.6 Complete a successful ground test before the flight test demonstration of the drainage system. If necessary, dry the system after the ground test to prevent freezing.

6.5.3 Flight Test.

6.5.3.1 The applicant should perform a flight test to demonstrate that the intended drainage paths and compartment seals are effective under all anticipated operating conditions, such as those listed in the paragraphs below, and to show that no fluid migrates to, or impinges on, an area of the airplane where it would create an additional hazard. The flight test should also verify the assumptions in the ventilation analysis:

6.5.3.1.1 Review the spray nozzle arrangement with the FAA airworthiness representative prior to the test flight. Applicants have used flow rates of one U.S. gallon (4 liters) per minute from each spray nozzle, however, it may be necessary for the applicant to show varying rates or nozzle arrangements to simulate high pressure leakage patterns and provide coverage of the entire drainage zone. The spray rates need not necessarily match anticipated leakage rates, as the test purpose is to determine acceptable drainage distribution and paths. In fact, excessive spray rates could make the tests less effective due to washing away of the detection compound.

6.5.3.1.2 Establish the flow rate based on results of the leak source analysis, and the suitability for leak path detection. When necessary, accomplish determination of drainage rate by methods such as ground test measurement or analysis corrected for flight test measured differential pressures, or direct in-flight observation and correlation of fluid spray injection versus drainage.

6.5.3.1.3 Calibrate the actual flow rate and drainage system function prior to the test. If pneumatic bleed is used for pressurization of the test fluid dispensing system, the applicant should establish the altitude and flight effects of pressure differentials on the flow rates to assure proper flow rates are achieved.

6.5.3.1.4 Use the total volume of dyed fluid sprayed into each zone along with the duration of the test conditions to validate the actual flow rate achieved during the flight test conditions.

6.5.3.2 The test fluid should allow testing at anticipated temperatures such that the test fluid will not freeze during the flight test conditions. If the various compartments are to be tested simultaneously, spray different colored dye into each compartment to identify the source of the drained fluid. A dye exposing substance such as powdered soap or a suitable paint provides a means to visualize the drainage impingement in critical areas. Coat internal and external surfaces of the airplane where fluid impingement or re-entry are possible with the dye sensitive material. Flight through visible moisture (including clouds) should be avoided to preclude washing away the soap and the dye drainage pattern.

6.5.3.3 Due to the difficulty in predicting complex airflow patterns and the number of different flight test conditions required, numerous flight test conditions are usually required. Spray test fluid for 30 to 120 second test intervals during all critical flight conditions. Critical flight conditions include:

- Takeoff;
- Climb;
- Cruise;
- Sideslips;
- Turns;
- Descent;

- Approach with gear extended;
- During the flap transition to the extended position during the dye dump condition;
- Landing with reverse engine thrust; and
- Landing without reverse engine thrust.

6.5.3.4 Evaluation of the drainage test results is often subjective in nature, but the FAA typically considers drainage of fluid into the following areas unacceptable:

6.5.3.4.1 Passenger compartment and cargo compartment.

6.5.3.4.2 APU compartment.

6.5.3.4.3 APU exhaust. Special design precautions may be required such as a drip fence to guide fuel leakage away from the exhaust nozzle.

6.5.3.4.4 APU inlet. Uncontrolled drainage into the inlet may result in an inability of the APU fuel control to maintain control of the APU resulting in overspeed.

6.5.3.4.5 Engine inlets or exhaust systems.

6.5.3.4.6 Any other fire zone.

6.5.3.4.7 Accessory compartments or areas where nominal ignition sources are expected to exist at the time of the leak, such as the battery compartment, electronics bays, or logo lights.

6.5.3.4.8 Wheel wells containing a nominal ignition source.

6.5.3.4.9 Another compartment of the same engine or APU installation.

6.5.3.4.10 A compartment containing an oxygen reservoir.

6.5.3.4.11 Any other area where an ignition source (including those caused by latent or anticipated failures) is expected to exist while exposed to leaked fluid.

6.5.3.5 The applicant should schedule testing accordingly as test results may necessitate a redesign of fluid drainage systems. Relocation of drain masts, extension of drain masts, installation of vortex generators on the end of the drain mast, installation of drip fences to deflect flammable fluids away from critical areas, and implementation of revised sealing procedures or modification of seal designs have been required on some airplanes in order to obtain a satisfactory result.

6.6 **Ventilation.**

6.6.1 Analysis.

Section 25.1187 requires the applicant to show that fire zones are ventilated in order to prevent the accumulation of flammable vapors, so that, should a leak occur, the likelihood of ignition is minimized. Accepting that there may often be pockets of stagnation in a fire zone and some conditions where effective ventilation flow cannot be provided, the FAA accepts a minimum target of five bulk volume air changes per minute as being effective in reducing the formation of a combustible mixture from a leak that does not form a flammable fluid mist. However, the FAA accepts that this target may not always be achievable during ground operations. The applicant should validate analytically determined ventilation rates using flight test results by measuring pressures within each zone and calculating airflow rates using known areas and the differential pressures. Ventilation can also be inferred by analyzing the fire extinguisher concentration dissipation rate measured during fire extinguishing tests, provided that the resulting ventilation rate is corrected for critical flight conditions using validated analytical methods or test data.

6.6.2 Test.

The drainage flight testing presented in paragraph 6.5 of this AC should also be used to verify the assumptions in the ventilation analysis.

Appendix A. Aircraft Flammable Fluid Flammability, Ignition, and Fire Characteristics

A.1 GENERAL.

Aircraft flammable fluid flammability, ignition, and fire characteristics can vary widely depending on the fluid, type of leakage involved, and ambient conditions in the area subject to leakage. This appendix provides basic information on the characteristics that applicants should consider in addressing flammable fluid fire protection. The referenced paragraphs, in this appendix, to other parts of this AC provide additional information; complete information for all fluids or scenarios could require further research or testing.

A.2 FLAMMABILITY.

A fluid is flammable when its vapor mixes with air within a certain range of mixture concentrations. For equilibrium conditions, the flammability of the fuel is a function of the fuel and air temperature. The following table shows characteristics of typical aircraft fluids.

Table A-1. Aircraft-fluid characteristics

Fluid	Flammability Range		Flash Point at Sea Level	
	Vol. %	Reference	ºF	Reference
Fuels				
Aviation Gasoline	1.3-7.1	See paragraph 3.4.2	-49	See paragraph 3.4.2
JET B, JP-4	1.3-8.2		0	
JET A, JET A-1, JP-8	0.6-4.7		100 minimum	Spec.
TS-1	–	–	80 minimum	–
Diester Oils				
MIL-L-7808	1.0-12.0	MSDS[1]	437	See paragraph 3.4.5
MIL-L-23699			440	
Petroleum Hydraulic Fluids				
MIL-H-5606	–	–	180 minimum	Spec.
Synthetic Hydrocarbon Hydraulic Fluids				
MIL-H-83282	–	–	401 minimum	Spec.
MIL-H-87257	–	–	338 minimum	

[1] Material Safety Data Sheet from one or more fluid suppliers.

Fluid	Flammability Range		Flash Point at Sea Level	
	Vol. %	**Reference**	**ºF**	**Reference**
Phosphate Ester Hydraulic Fluids				
Skydrol 500	–	–	360 minimum	See paragraph 3.4.5
Type IV Class 1[2]	–	–	320 minimum	See paragraph 3.4.7
Type IV, Class 2	–	–	320 minimum	See paragraph 3.4.7
Type V[4]	–	–	300 minimum	See paragraph 3.4.7
Anti-Icing Fluids				
Isopropyl Alcohol	2.0-12.7	MSDS[1]	53-60	MSDS[1]
AL5 (TKS Fluid)			129-138	

A.2.1 Factors Related to Flammability.

Several additional factors related to flammability are as follows:

A.2.1.1 Equilibrium mixtures, or mixtures corresponding to laboratory procedures, do not usually exist in situations involving aircraft fluid leakage.

A.2.1.2 The actual lower flammability limit is typically 10-20 °F lower than the flash point, as the flash point procedure involves downward flame propagation instead of upward. Fluid at the flash point will not necessarily sustain flame. Specifications include a fire point that is somewhat higher than the flash point.

A.2.1.3 A pressurized spray can be flammable at lower temperature than represented by the flash point. An extreme example is the starting of an engine at -40 °F or colder using JET A fuel. The flammability strongly relates to the degree of atomization and ignition energy, which can be several orders of magnitude larger than minimum ignition energy.

A.2.1.4 A mixture that is non-flammable (too lean) at sea level can become flammable at higher altitude. An example is JET A, for which the lower flammability limit decreases about 0.8 °F per 1,000 feet. Similarly, a mixture that is flammable at sea level can become too rich at increased altitude.

A.2.1.5 Due to non-uniform mixtures, ventilation may not completely eliminate a flammable condition. If a leak forms a flammable or too rich non-flammable mixture or spray at

[2] Designation per SAE AS1241D.

the source, it is unlikely that ventilation will completely eliminate the flammability, although it may reduce the flammable volume further away from the source.

A.2.2 **Ignition Properties.**

A.2.2.1 General.

Ignition of a flammable vapor depends on the mixture concentration, ambient pressure, and the size, duration and temperature of the ignition source. This can range from an extremely small, short duration, high temperature source such as a voltage spark, to a large, long duration, lower temperature source such as a large hot surface. Mixtures are most easily ignited when they are at or slightly rich of the ideal stoichiometric mixtures and when they are at higher ambient pressures, such as at sea level instead of at altitude.

A.2.2.2 Voltage Sparks.

A voltage spark consists of a spark arising from a voltage difference strong enough to jump the gap between two electrical conductors. It is accepted that the minimum ignition energy for hydrocarbon fluids under ideal conditions is approximately .20 millijoules, although research indicates that this value is statistical and ignition may only occur on the order of 1 in every 1,000 attempts. Similar data for high flash point synthetic fluids is not readily available, however, it is noted that the environmental conditions necessary to obtain ideal mixture conditions would be extreme. Energy is given by the ideal formula:

$$E = 1/2CV^2$$

A.2.2.2.1 Where E is Energy (joules); C is Capacitance (farads) and V is Electrical Potential (volts).

A.2.2.2.2 In an actual case, the presence of inductance and resistance in the circuit makes it difficult to determine the actual energy in the spark gap. In non-ideal conditions, such as near the lean limit, or in a mist, or at high altitude, ignition energy can be as much as three or more orders of magnitude higher (i.e., in the 1-10 joule range). Research, particularly in the fuel system lightning strike field, indicates that electrical ignition sources are much more likely to be the break spark or arc types as discussed below. However, research emphasis has been put on ignition energies for voltage sparks because they are more easily quantified.

A.2.2.2.3 While AC 25.981-1D describes 200 micro-joules as the minimum ignition energy for typical hydrocarbon fuels, it also advises (at least, for fuel tank ignition protection) that the applicant applies an appropriate factor of safety when using this value. In the AC 25.981-1D case, a factor of safety of 10 is suggested.

A.2.2.3 Break Sparks and Arcs.

A break spark consists of continuing current across a gap between two electrical conductors, which were originally in contact with current flowing, such as a switch opening. A simplified formula for the energy is:

$$E = 1/2LI^2$$

A.2.2.3.1 Where E is Energy (joules); L is Inductance (henrys) and I is Current (amps).

A.2.2.3.2 This does not account for duration factors that may be influenced by such parameters as current, voltage, rate and amount of separation. The minimum ignition energies with break sparks are typically two to ten times larger than those for capacitive sparks, although the difference may be less with very fine wires and rapid separations such that heat losses to the conductor surfaces are minimized.

A.2.2.3.3 An arc consists of ejection of molten conductor material where the current greatly exceeds the conductor capacity. It may be difficult to distinguish between break sparks and arcs in some typical examples, such as shorting the terminals of a battery or a high voltage conductor in contact with a tube, since the elements of limited contact area may produce arcs, while intermittent contact may produce break sparks.

A.2.2.3.4 Finally, in many, but not all, situations, such as the two examples given above, discussions of minimum ignition energy can be somewhat academic since energy release can be large enough that there is no doubt an ignition source is present.

A.2.2.4 Friction Sparks.

Friction sparks result from molten metal ejection or localized hot surfaces as a result of severe abrasion or impacts of certain metals on other hard surfaces. Research indicates that aluminum has low friction spark potential but that the potential for ignition of hydrocarbon fluids exists with other common aircraft metals such as titanium, various steel alloys, and magnesium. Ignitions have occurred at bearing pressures as low as 20-50 psi and rubbing speeds below 73 feet per second. The potential for friction sparks in a failure scenario would vary considerably with the specific design and failure mode characteristics of that scenario.

A.2.2.5 Autogenous and Hot Surface Ignition.

The phenomenon of ignition by the contact of a flammable mixture with a hot surface is complex. The lowest ignition temperatures obtainable are through laboratory testing to various AIT procedures, in which the fluid sample is introduced in a heated vessel such that the fluid, its vapor, and the surrounding air are all influenced by the vessel temperature, and the conditions inside the vessel vary in a complex time-dependent manner. Ignition delays can be up to 5 minutes, depending on the procedure.

A.2.2.5.1 Although AIT tests produce minimum ignition temperatures and can be considered safe, with a suitable margin, the necessary conditions may not exist in realistic aircraft flammable fluid ignition scenarios. The closest scenario would be when the hot surface is a large proportion of the compartment surface and when there is minimum airflow. Much research has been conducted into ignition temperatures for other conditions such as hot manifolds, rods, wires, etc., showing a significant increase in hot surface ignition temperature as the hot surface size decreases.

A.2.2.5.2 Hot surface ignition temperatures increase with an increase in compartment airflow. However, available data indicate the relationship is not strong.

A.2.2.5.3 A maximum surface temperature in a flammable leakage zone of AIT - 50°F is accepted as not being an ignition source by the regulatory authorities. Demonstrating that a surface temperature above AIT -50 °F is not an ignition source due to factors such as hot surface geometry, compartment conditions, ventilation rates, flammable fluid leakage rates and specific flammable fluid properties (other than AIT), while technically feasible, is often difficult to validate.

A.2.2.5.4 There have been instances where surface temperatures exceeding the AIT -50°F have been deemed acceptable, when showing that ignition sources have been minimized. In these limited instances, factors such as flight condition, time duration of the elevated temperature, flight deck indication, automatic system response to elevated temperatures, and probability of failure scenario have been given consideration as providing acceptable risk mitigation.

A.2.2.5.5 The applicant is encouraged to coordinate acceptable validation methods for surface temperatures in excess of the AIT -50 °F in a flammable leakage zone with regulatory authorities as early in the design process as possible.

A.2.2.5.6 The following table is a summary of AIT. This table also shows Hot Manifold Ignition Temperatures, which may be useful to an applicant in proposing an alternate means of compliance.

Table A-2. Fuel Ignition Temperatures

Fluid	Minimum AIT In Air (°F)				Hot Manifold Ignition Temperature (°F)		
	Atmospheres			Reference	Spray	Stream	Reference
	0.25	0.05	1.0				
Fuels							
Aviation Gasoline	–	1030	825	See paragraphs 3.4.3, 3.4.5	–	–	–
JET B, JP-4	1060	830	445	See paragraphs 3.4.3, 3.4.5	–	920–1300	See paragraph 3.4.6
JET A, JET A-1, JP-8	1100	865	445	See paragraphs 3.4.3, 3.4.5	–	900–1200	
Diester Oils							
MIL-L-7808	–	–	735	See paragraph 3.4.5	1500	1010–1300	See paragraph 3.4.6
MIL-L-23699	–	–	775			1100	
Petroleum Hydraulic Fluids							
MIL-H-5606	1033	820	437	See paragraph 3.4.5		730–960	3.4.6
			656			630–1080	
Synthetic Hydrocarbon Hydraulic Fluid							
MIL-H-83282	–	–	653 minimum	Spec.	1250	630–1080	See paragraph 3.4.6
Mil-H-87257	–	–	469	Testing per ASTM 2155[3]	–	–	–
Phosphate Ester Hydraulic Fluids							
Skydrol 500	–	–	950	See paragraph 3.4.5	1500	1440	See paragraph 3.4.6
Type IV Class 1[4]	–	–	750 minimum	See paragraph 3.4.7	1500	1300	See paragraph

[3] AFP Associates Inc. Testing per ASTM E659 conducted by the Air Force at Wright Patterson resulted in an AIT of 482°F.
[4] Designation per SAE AS1241D.

Fluid	Minimum AIT In Air (°F)				Hot Manifold Ignition Temperature (°F)		
	Atmospheres			Reference	Spray	Stream	Reference
	0.25	0.05	1.0				
							3.4.7
Type IV, Class 2[4]	–	–	900 minimum	See paragraph 3.4.7	1500	1300	See paragraph 3.4.7
Type V[4]	–	–	750 minimum	See Paragraph 3.4.7	1500	1300	See paragraph 3.4.7
Anti-icing fluids							
Isopropyl alcohol	–	–	750–810	MSDS[5]	–	–	–
AL5 (TKS fluid)	–	–			–	–	–

A.2.3 **Hot-Gas Ignition.**

Hot-gas ignition can occur when jets of hot gas are discharged into a flammable mixture. Available data (see paragraph 3.4.7 of this AC) indicates significantly higher ignition temperatures than for hot surfaces of comparable size, as follows:

Table A-3. Hot Gas Ignition Temperatures

Hot Air Jet Dia. (in.)	Ignition Temperature, °F		
	N-Hexane	JP-6	MIL-L-7808
1/8	1910	1985	1605
1/4	1630	1670	1530
3/8	1450	1500	1410
1/2	1280	1410	1250
3/4	1210	1290	1210

[5] Material Safety Data Sheet from one or more fluid suppliers.

A.3 FIRE CHARACTERISTICS

A.3.1 General.

Testing and service experience have shown that fire characteristics associated with leaking flammable fluids can vary depending on the type of leak, type of fluid, and environmental conditions in the affected compartment. Characteristics of various types of fires and resulting considerations are discussed below.

A.3.2 Explosive Ignition.

A.3.2.1 Explosive ignition can occur when the flammable mixture becomes distributed, to some degree of uniformity, throughout the compartment prior to ignition. Maximum pressure under worst-case conditions (mixture at or slightly rich of stoichiometric, uniform mixture distribution, absence of long, narrow or convoluted propagation paths) is about eight times the initial absolute pressure. Explosive ignition can also occur with a flammable mist distributed within a compartment, but peak pressures are likely to be considerably lower.

A.3.2.2 Explosive ignition is likely to occur with more volatile flashpoint fluids, and is unlikely to occur with high flash point fluids unless the fluid and compartment temperatures are higher than the flashpoint.

A.3.2.3 It is noted that the ignition source may likely be remote from the leak source, contributing to the build-up of a flammable mixture leading to explosive ignition.

A.3.2.4 Historically, prevention of explosive ignition has been addressed by compartment ventilation. Ventilation is most effective in this regard for relatively small leak rates of volatile fluids.

A.3.3 Spray Fires.

A.3.3.1 Spray fires occur when a spray resulting from a small pressurized leak, such as a pinhole, contacts an ignition source. The most important characteristic of spray fire is that ignition can occur at temperatures well below the flashpoint, although at higher ignition energies and surface temperatures than an ideal air/fuel mixture. Ignition is a characteristic of the degree of atomization provided by the pressure and leak source. An extreme example, representing on-purpose design rather than a failure condition, is turbine engine light-off at temperatures as low as -40 °F using fuel with a flash point higher than 100°F.

A.3.3.2 Service experience shows that spray ignition may be particularly likely to occur in the case of a high energy electrical wire chafing against a pressurized fluid tube, as the electrical discharge to the tube is capable of creating both a small spraying leak and an intense ignition source. This can create a potentially hazardous fire in at least some higher flash point fluids, such as MIL-H-83282, although the intensity or completeness of combustion may not be as great as with more flammable fluids.

A.3.3.3 SAE AS1241D prescribes a spray test for phosphate ester hydraulic fluids (e.g., Skydrol), using a flame as the ignition source, which requires that either the fluid will not ignite or will extinguish after an initial flash. This specification only covers a specified range of conditions. Sustained ignition has been observed in fire tests involving higher pressures and finer sprays. Therefore, additional testing may be required if it is necessary to characterize the spray ignitability of phosphate ester hydraulic fluids. Sustained burning of phosphate ester hydraulic fluids has been observed in in-service events, even after the originating flame ignition source has been removed from the fire. The burning hydraulic fluid spray fire can create an environment where the fire is self-sustaining.

A.3.3.4 Historically, prevention of spray fires has been accomplished by a combination of isolation of potential leak sources from ignition sources, and/or ensuring the potential ignition sources are not sufficiently energetic to be an actual ignition source for the fluid involved.

A.3.4 Pool Fires.

A.3.4.1 Pool fires consist of burning at the surface of a pool of flammable fluid, which has collected in the bottom of a compartment. They may also include burning along the leakage stream or drip path between the leak source and the pool.

A.3.4.2 Pool fires can occur outside the flammable range of the fluid involved. However, this condition generally requires a more energetic ignition source, such as an existing flame, capable of raising the temperature of a pool surface, and a slower rate of spread along the pool surface. For example, tests have shown a spread rate of approximately 10 meters/minute for JET A at 80 °F compared to a flame spread rate of 220 meters/minute for JET B at the same temperature.

A.3.4.3 Tests have shown that with a remote streaming source exposed to a flame, that pool fires occur readily with fluids of equal or lower flash point than MIL-H-5606, but are much less likely to occur with higher flash point fluids at temperatures well below the flash point.

A.4 IGNITION SOURCES.

The following table gives examples of nominal and potential ignition sources, which need to be considered for § 25.863 compliance. The list is not to be considered definitive for any airplane model; the actual nominal and potential ignition sources will be determined by the proposed design.

Table A-4. Ignition Source Types and Mechanisms for Ignition

Ignition Source Type	**Ignition Mechanism**			
	Hot surface - Temperature >AIT-50 °F	Sparking or arcing.	Naked Flame.	Hot Fluid (Air).
Nominal	Engine/APU casing. Exhaust ducting. High pressure bleed duct. Brakes. Electrical equipment. Passenger areas.	Electrical terminals - non-sealed. Electrical equipment. Passenger/cargo areas.	Exhaust gas. Passenger areas.	
Potential	Engine accessory gearboxes. Engine starters. Electrical cable - normal insulator. Electrical cable - in conduit. Electrical cable bundle/loom. Bleed duct. Electrical terminals - non-sealed. Electrical terminals – sealed. Firewall. Air cycle machine. Electrical equipment. Frictional heating. Passenger/cargo areas.	Electrical cable - normal insulator. Electrical cable - in conduit. Electrical cable bundle/loom. Electrical terminals - non-sealed. Electrical terminals - sealed. Electrical equipment. Frictional sparks. Passenger/cargo areas. Lightning - voltage sparks. Lightning - thermal sparks. Lightning - edge glow.	Torching flame. Electrical cable bundle/loom. Electrical equipment. Engine/APU surge. Tailpipe fire. Passenger/cargo areas.	Bleed duct.