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of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Fuel Vent Fire Protection

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This advisory circular (AC) provides information and guidance concerning compliance with the airworthiness standards for transport category airplanes pertaining to flame arrestors and other means of preventing fuel tank explosions caused by ignition of vapors outside the fuel tank vents.

If you have any suggestions for improvements or changes, you may use the template provided at the end of this AC.

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1 **PURPOSE.**

This advisory circular (AC) provides information and guidance concerning compliance with Federal Aviation Administration (FAA) requirements in Title 14, Code of Regulations (14 CFR) 25.975(a)(7) and related regulations for preventing fuel tank explosions caused by ignition of vapors outside the fuel tank vents.

2 **APPLICABILITY.**

2.1 The guidance in this AC is for airplane manufacturers, modifiers, foreign regulatory authorities, and FAA transport airplane type certification engineers and their designees.

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

2.3 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, existing regulatory requirements.

3 **RELATED DOCUMENTS.**

3.1 **Sections of 14 CFR.**

- § 25.863, *Flammable fluid fire protection.*
- § 25.867, *Fire protection: other components.*
- § 25.901, *Installation* [paragraphs (b)(2) and (c)].
- § 25.954, *Fuel system lightning protection*.
- § 25.963, *Fuel tanks: general.* [paragraphs (d) and (e)(2)].
- § 25.981, *Fuel tank ignition prevention.*

3.2 **FAA ACs.**

The following ACs are current at the time of publication of this AC. You should use the latest version for guidance. You can view and download the latest version on the FAA website.

- AC 25-8, *Auxiliary Fuel System Installations*, dated May 2, 1986.

- AC 20-53B, *Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Caused by Lightning*, dated June 5, 2006.
- AC 20-135, *Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria*, dated February 6, 1990.
- AC 25.981-1C, *Fuel Tank Ignition Source Prevention Guidelines*, dated September 19, 2008.
- Draft AC 25.863-1, *Flammable Fluid Fire Protection.* Available on page 17 of the final report of the FAA Aviation Rulemaking Advisory Committee (ARAC), Transport Airplane and Engine Issue Area, Powerplant Installation Harmonization Working Group: Task 5 – Powerplant Fire Mitigation Requirements. Available on the FAA website.

3.3 **Technical Publications.**

- Hill, Richard and George R. Johnson, *Investigation of Aircraft Fuel Tank Explosions and Nitrogen Inerting Requirements During Ground Fires*, FAA Technical Report No. FAA-RD-75-119. Washington, D.C.: U.S. Department of Transportation, 1975.
- FAA Technical Report ADS-18, National Technical Information Service (NTIS), *Lightning Protection Measures for Aircraft Fuel Systems*. Springfield, VA: U.S. Department of Commerce, 1964.
- Military Standard, *Environmental Engineering Considerations and Laboratory Test Methods*, MIL-STD-810G w/Change1, Method 511.6 Procedure II. Philadelphia, PA: U.S. Department of Defense, 2014.
- RTCA, Inc., *Environmental Conditions and Test Procedures for Airborne Equipment*, RTCA/DO-160G. Washington DC: RTCA, Inc., 2010.
- Coordinating Research Council, Inc., *Handbook of Aviation Fuel Properties*. Atlanta, GA: CRC, Inc., 2004.
- Kuchta, Joseph M., *Summary of Ignition Properties of Jet Fuels and Other Aircraft Combustible Fluids*, Technical Report AFAPL-TR-75-70. Springfield, VA: U.S. Department of Commerce, 1975.

4 DEFINITIONS.

- **Autogenous Ignition (Auto-Ignition) Temperature (AIT).** The minimum temperature at which an optimized flammable vapor and air mixture will spontaneously ignite when heated to a uniform temperature in a normal atmosphere without an external source of ignition, such as a flame or spark.
- **Flammability Limit.** The highest and lowest concentration of fuel-in-air-by-volume percent 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-versus-altitude plot.

- **Flash Point.** The minimum temperature at which a flammable liquid will produce flammable vapor at sea level ambient pressure.
- **Flame Holding.** The ability of a flame arrestor to halt the propagation of a flame front through a passage.
- **Ignition Source.** A source of sufficient energy to initiate combustion of a fuel-air mixture. Hot surfaces that can exceed the auto-ignition temperature of the flammable vapor under consideration are considered to be ignition sources. Electrical arcs, electrical sparks, and friction sparks are also considered ignition sources if sufficient energy is released to initiate combustion.
- **Stoichiometric Ratio.** The ratio of fuel to air corresponding to the condition in which the available amounts of fuel and oxygen completely react with each other thereby resulting in combustion products containing neither fuel nor oxygen.

5 BACKGROUND.

In its final report published in 1980, the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee ("the committee") established the value of installing flame arrestors in fuel tank outlets and vent lines as a result of a review of transport category airplane accident history. The committee reviewed worldwide transport airplane accidents involving post-crash fuel tank explosions that had occurred since 1964 and concluded that, with existing technology, the potential for post-crash explosion hazards could be reduced. The committee evaluated methods to address fuel tank explosions such as fuel tank inerting, fuel vent flame arrestors, or surge tank explosion suppression systems. The committee determined fuel vent flame arrestors were the most practical method available at that time. This method is used in many current airplanes to delay propagation of ground fires and the subsequent explosions, which provides additional time for safe evacuation of passengers and crew. Advancements in technology since the committee recommendations have resulted in installation of inerting systems in many currently produced transport airplanes models and surge tank fire suppression systems in several airplane models to prevent propagation of fire resulting from lightning. To ensure all transport airplane models have means to prevent fuel tank explosions from outside ignition sources, § 25.975(a)(7) at Amendment 25-143 issued June 7, 2016 (81 FR 41200, June 24, 2016), requires fuel tank vent systems to prevent explosions, for 2 minutes and 30 seconds, caused by propagation of flames from outside the tank through the fuel tank vents when any fuel tank vent is continuously exposed to flame.

6 ACCEPTABLE MEANS OF COMPLIANCE.

Acceptable means of compliance to § 25.975(a)(7) include:

- Flame arrestors in the fuel tank vents that prevent flame propagation into the fuel tank (see section 7 of this AC);

- Fuel tank inerting systems, exceeding the basic requirements of § 25.981, that prevent fuel tank explosions[1] (see paragraph 9.1 of this AC);
- Fuel tank pressurization systems or features of the system that result in a closed vent system that are effective in preventing a fuel tank explosion during all operating (e.g., taxi, takeoff, landing, refueling, etc.) and post-crash fire conditions (see paragraph 9.2 of this AC); and
- Fuel tank or vent system fire suppression systems that prevent a fuel tank explosion with a fire present at the fuel tank vent outlet for the required 2 minutes and 30 seconds (see paragraph 9.3 of this AC).

7 FLAME ARRESTORS.

7.1 This section describes the use of flame arrestors as a means of meeting the 2 minute and 30 second time requirement defined in § 25.975(a)(7). The guidance is based on evaluating the flame arrestor performance during critical case conditions anticipated to occur when fire is adjacent to the fuel tank vent outlet. The flame arrestor should meet the performance described in this AC during post-crash ground fires or other fire scenarios such as those resulting from fuel leakage due to fuel tank damage or fuel spilled during refueling mishaps.

7.2 Flame arrestors meeting the standards defined in this AC may not be effective at preventing propagation of fires that may occur following lightning strikes near the fuel tank vent outlet. Ignition of fuel vapors near the vent outlet caused by lightning results in a high speed pressure wave that can travel through the flame arrestor without sufficient time for the heat transfer necessary for the flame arrestor to quench the flame front. Instead, fuel tank vent lightning protection may be addressed as discussed in AC 20-53, *Protection of Aircraft Fuel Systems against Fuel Vapor Ignition Caused by Lightning*, which is based on locating vents outside lightning strike zones of the airplane. While airplane manufacturers have used flame arrestors to address lightning protection in several instances, they needed dedicated testing considering unique design features to demonstrate the effectiveness of the installation. The guidance in this AC is intended to address compliance with § 25.975(a)(7) and is not intended to be used as guidance for showing compliance to the lightning protection requirements in § 25.954.

7.3 Installation of flame arrestors in the airplane fuel vent system will impact fuel tank vent system performance. The applicant should account for factors such as the introduction of a flow restriction and associated increase in pressure drop during refueling system failure conditions, as well as the impact of environmental conditions such as icing and

[1] Fuel tank inerting systems meeting § 25.981 would not necessarily be adequate for demonstrating compliance to § 25.975 because § 25.981 does not require the fuel tank ullage to be fully inert at all times. If inerting is used as the means of compliance to § 25.975, the inerting system must be effective at preventing flame that is present at the vent outlet from propagating to the fuel tank. The applicant should show this during normal operating conditions, all foreseeable ground fire conditions (e.g., from refueling, refueling overflow, etc.), and post-crash ground fire conditions.

lightning, when requesting approval of the fuel tank installation. Compliance means for these considerations are not addressed in this AC. General fuel system guidance is provided in AC 20-53 and AC 25-8, *Auxiliary Fuel Systems Installations*.

7.4 Past flame arrestor performance test results indicate the critical condition for evaluating the effectiveness of the flame arrestor occurs when the flame front contacts the surface of the flame arrestor, which results in heating of the flame arrestor. As the flame arrestor is heated, the ability of the flame arrestor to absorb energy may be reduced, resulting in its inability to quench the flame. Once this occurs, the flame will then pass through the flame arrestor resulting in flashback. It is important to realize that flashback through heated flame arrestor channels, which are normally quenching, should not be confused with auto-ignition or hot surface ignition. Flashback will occur when the rate of heat loss to the channel wall is insufficient to quench the flame. In this case, the wall acts as an inadequate heat sink and not as an ignition source. The flame retains sufficient heat energy to pass to the upstream side of the flame arrestor.

7.5 Flame propagation past the flame arrestor may also occur due to the ignition of flammable vapors by hot surfaces. The time it takes for the assembly surfaces on the internal side of the flame arrestor, including the line and housing, to be heated above the AIT of the flammable vapor mixture could be the limiting factor in establishing the effectiveness of the flame arrestor assembly. The ignition of combustible mixtures by hot surfaces (auto-ignition) involves different phenomena than the phenomena involved in flashback as discussed in paragraph 7.4 of this AC. For auto-ignition to occur, a portion of the combustible gas must dwell near a hot surface for a time, such that chemical heat evolution is produced in a volume in excess of heat dissipation to the surroundings. The maximum dwell time (commonly termed “ignition lag”) is a function of the heat transfer characteristics of the gas and heat source, as well as the kinetics of the combustion process. For this reason, the surface area and shape of the hot surface, and the flow field around the heat source, are critical factors in determining whether ignition will occur.

7.6 The test conditions defined in this AC are intended to evaluate the effectiveness of flame arrestors during two conditions. The first condition is the ignition, by an external source, of flammable vapors at the fuel tank vent outlet. The flame arrestor should be effective at stopping the initial propagation of flame. The second condition is a continuous flow of vapor exiting the fuel vent. The flame arrestor should hold the flame without passing the flame to the upstream portion of the vent system. The applicant should determine the critical test conditions following review and analysis of the particular flame arrestor installation and its characteristics.

7.7 The conditions under which the flame arrestor should be effective include those where flammable fluid vapors are exiting the fuel tank at flow rates varying from no flow, typically occurring during normal ground operations, to high-flow conditions, typically occurring during refueling or when the fuel tank is heated due to ground fire following an accident.

7.8 The applicant should conduct an analysis to determine pass/fail criteria for the airplane-specific flame arrestor installation. The analysis should include consideration of hot surface ignition when determining whether the flame arrestor assembly meets the explosion prevention requirement of 2 minutes and 30 seconds. Maximum flame arrestor installation surface temperatures and the flame arrestor surface temperatures should be established when meeting the requirement. The applicant should consider the velocity of the flammable fluid vapor on the surface of the flame arrestor and the duct sidewall upstream (tank) side of the flame arrestor. Provided that a uniform vapor velocity is present (no stagnation areas), a heat source whose temperature exceeds the AITs quoted for static conditions (typically 450 °F) will not cause ignition in the flame arrestor installation. Data in the *Handbook of Aviation Fuels Properties* (reference paragraph 3.3 of this AC) show the relationships between velocity and AITs. Test results from developmental testing of flame arrestors installed in fuel vent lines have shown that ignition will not occur provided the center of the flame arrestor remains below 700 °F. However, this temperature limit may not be appropriate for other surfaces in the flame arrestor installation where a uniform flammable vapor flow is not present. The applicant should analyze the flame arrestor design to determine the critical locations and fuel vapor flow conditions that result in the highest surface temperatures, and run an adequate number of test conditions to validate the analysis.

8 DEMONSTRATING COMPLIANCE USING FLAME ARRESTORS.

8.1 Flame arrestor performance is influenced by installation effects that may cause variation in critical parameters such as the speed of flame front and the temperature of surfaces. The applicant should account for installation effects in demonstrating compliance. The applicant may choose to show compliance with § 25.975(a)(7) by testing a complete, conformed production installation of the flame arrestor (including the upstream and downstream ducting). Alternatively, the applicant may request FAA approval to use other tests and analysis of the flame arrestor and the installation as a means of compliance.

8.2 The applicant may propose using flame arrestor elements from a supplier. The supplier may have previously qualified an element to flame propagation requirements without consideration of the design of the airplane into which the flame arrestor will be installed. The applicant should conduct tests to show that they have accounted for any effects of installation, including flame front speeds and duct sidewall temperatures. Fuel types for these tests differ and should be established as discussed in paragraph 8.3.1.3 of this AC prior to conducting any testing.

8.3 Flame Arrestor Installation Test.

8.3.1 Test Setup.

Figure A-1 shows a schematic of the test setup. The test setup involves mounting the flame arrestor element in a tube configuration representative of the airplane installation. The speed of the flame front that travels down the fuel vent system tubing toward the flame arrestor is a critical factor in the flame propagation performance of the flame arrestor. The flame front will accelerate down the tubing, so higher velocities will occur as the flame arrestor is located farther away from the fuel tank vent outlet. Therefore, the shape and diameter of the tubing and its length from the fuel tank vent inlet to the flame arrestor should be representative of the production configuration, unless the flame arrestor element was previously found to comply in an installation where the flame speed reaching the flame arrestor was higher. In addition, the orientation of the flame arrestor in the fixture is a critical parameter for the compliance demonstration. For instance, the flame holding performance of a flame arrestor installation that faces downward, so a ground fire impinges on its face, will have shorter flame holding capability than a flame arrestor that is mounted horizontally.

8.3.1.1 **Test Fixture Features.**

The applicant should consider the following features in designing the flame arrestor test fixture:

1. Orient the element to simulate the actual airplane installation.
2. Cut viewing sections into the pipe upstream and downstream of the flame arrestor element and cover it with transparent material to provide visual access to the element.
3. Locate igniters upstream and downstream of the element.
4. Locate thermocouples in the duct to measure incoming flammable mixture temperature and vapor temperatures downstream of the flame arrestor element.
5. Install thermocouples on the surface of the center of the flame arrestor element’s upstream face and on the surface of the upstream side of the duct.
6. Incorporate a pressure relief feature in the upstream portion of the system to relieve explosive pressures when ignition of the upstream flammable fluid vapor occurs.
7. Mix air that is at a temperature higher than the boiling point of the fuel being used (see paragraph 8.3.1.3 of this AC) with fuel, and introduce it at the inlet of the tube.
8. Vary fuel-air ratios by adjusting the respective fuel vapor and air supply rates.

8.3.1.2 **Test Equipment.**

The test equipment should include:

1. Test article, including flame arrestor and the downstream section of the vent system assembly that meets production specifications.
2. A section of ducting representative of the production flame arrestor installation.
3. A means of generating a supply of fuel vapor at preselected fuel-to-vapor air ratios and various flow rates.

4. A window for observing upstream and downstream conditions during the test. This means should allow determination of the location of the flame front relative to the flame arrestor.
5. A means to measure temperatures on the upstream duct surfaces and flame arrestor.
6. A means to measure fuel vapor mixture temperatures both upstream and downstream of the flame arrestor.
7. A means to relieve explosive pressure upstream of the flame arrestor.
8. Ignition sources for igniting the explosive mixture upstream and downstream of the flame arrestor.

8.3.1.3 **Fuel Type.**

8.3.1.3.1 The applicant should establish the critical fuel type for the test based on a review of the approved fuels for the airplane model. The applicant should use fuels in the test that have representative characteristics of the critical fuel approved for use in the airplane. The use of hexane as a representative fuel for kerosene fuels such as Jet A and TS-1 has been acceptable. Hexane (C_6H_{14}) is readily available and easily manipulated in the gaseous state, so it is typically a fuel of choice. The AIT for hexane of 433 °F closely simulates that of Jet A kerosene fuel, with an AIT of 435 °F, and JP-4 with an AIT of 445 °F.

Note: The applicant should not use fuels with higher AITs, such as propane, for the flame arrestor element test because ignition on the back side of the flame arrestor would not be adequately evaluated.

8.3.1.3.2 Table A-1 summarizes the properties of hexane and provides an example of the method for calculating the stoichiometric relationship of hexane needed for the test.

8.3.1.3.3 The applicant may use propane for flame arrestor installation testing where AIT is not a critical parameter for the test. For example, testing of a simulated production flame arrestor installation to validate that temperatures of portions of the installation within the fuel tank remain below the maximum permitted fuel tank surface temperature (typically 400 °F) would be acceptable, provided the applicant or supplier has previously shown the flame arrestor element meets the flame holding requirements.

8.3.1.3.4 Table A-3 summarizes the properties of propane as provided in the FAA Technical Report ADS-18, *Lightning Protection Measures for Aircraft Fuel Systems*, (see paragraph 3.3 of this AC) and provides an example of the method for calculating the stoichiometric ratio of propane.

8.3.1.4 **Thermocouples.**

The applicant should use bare junction 1/16- to 1/8-inch metal-sheathed, ceramic-packed, chromel-alumel thermocouples with nominal 22 to 30 AWG (American wire gage) size conductors or equivalent. The applicant should not use an air-aspirated, shielded thermocouple. Experience has shown that 1/16-inch thermocouples may provide more accurate calibration than 1/8-inch thermocouples; the 1/16-inch thermocouples are therefore recommended.

8.3.1.5 **Test Specimen.**

The test specimen should be a production component that conforms to the type design intended for certification.

8.3.2 Test Conditions.

Two types of tests are typically needed to demonstrate compliance: one for flame propagation prevention in a static vent vapor flow condition, and one for flame holding in a continuous vapor flow condition. These conditions provide a conservative demonstration of fuel tank vent fire protection capability with respect to delaying flame front propagation through the fuel vent flame arrestor installation during ground fire conditions.

8.3.2.1 **Flame Propagation Tests (Static).**

This test demonstrates the element's flame arresting performance in a static condition at the critical fuel mixture condition of 1.15 ± 0.05 stoichiometric. This mixture is based on FAA-sponsored tests done by Atlantic Research, documented in the *Lightning Protection Measures for Aircraft Fuel Systems* report. The report shows curves of flame arrestor equilibrium temperature for various air-flow ratios as a function of percent stoichiometric fuel-air ratio (see Figure A-2 in this AC). These curves maximize at about 1.10 to 1.20 stoichiometric. The curves indicate higher temperatures occur at lower flow rates.

8.3.2.1.1 Establish the Mixed Flow.

Close fuel and air valves. Ignite the mixture downstream of the element. Verify that flame did not propagate through the flame arrestor by observation through the viewing window. Verify the upstream mixture is combustible by energizing the upstream igniter and observing ignition of the upstream mixture. The applicant should repeat this test a minimum of 5 times at this mixture as is done with explosion proof testing.

8.3.2.1.2 Flame Front Velocity.

The velocity of the flame front as it reaches the flame arrestor can significantly influence the effectiveness of the flame arrestor at preventing flame propagation. The flame front velocity increases as the flame travels down a vent line containing flammable vapors. The velocity of the flame front is installation-dependent and influenced by the vent line length, diameter, and flow losses between the ignition source and flame arrestor. The test configuration should include consideration of these critical features. If an applicant proposes to use a previously approved flame arrestor element in a new installation with different vent line length and diameter than previously tested, the applicant should account for these installation differences in the compliance demonstration. The applicant may need to conduct a separate test to demonstrate that the flame arrestor is effective in the installed configuration.

8.3.2.2 **Flame Holding Tests.**

The purpose of this test is to show that a flame present at the fuel tank vent outlet, when a continuous flow of flammable vapor is exiting the vent, will not propagate into the fuel tank. The test conditions for this test are based on test results documented in the *Lightning Protection Measures for Aircraft Fuel Systems* report that resulted in the highest flame arrestor temperature. Run this test at a 1.15 stoichiometric fuel-air ratio. The flammable vapor flow rate that achieves a velocity of 0.75 to 1.0 feet per second (ft/s) across the flame arrestor is the range where flame arrestor failure occurred in the shortest time in development testing. Adjust the flow to achieve a velocity of 0.75 ft/s (+.25, -0 ft/s) across the flame arrestor and ignite it downstream of the flame arrestor. Determine and establish the location of the flame front by viewing through the viewing window. Determine the position of the flame front and adjust the vapor flow rate such that the flame front contacts the downstream flame arrestor face, resulting in the greatest rate of heating of the flame arrestor surface. Take care to maintain the flammable vapor flow rate at a constant value throughout the test so as to maintain the correct fuel–to–air ratio.

8.3.2.2.1 Flame Arrestor Element Maximum Surface Temperatures.

Monitor the temperature at the upstream center of the flame arrestor during the flame holding test; it is required to stay below 700 °F for 2 minutes and 30 seconds. Data from developmental testing show that the temperature of the center of the upstream flame arrestor face at which failure (propagation of the flame) occurred was typically above 700 °F, which is well above the AIT of JP-4 fuel vapor of 445 °F as established during no-flow conditions. The upstream flame arrestor temperature can go well above the AIT without causing upstream ignition because of the high local velocity. For this reason, hexane, with an AIT of 433 °F, is used for the flame arrestor element test.

8.3.2.2.2 Flame Arrestor Installation and Vent System Maximum Surface Temperatures.

The compliance demonstration must include a showing that flames present at the vent outlet will not propagate into the fuel tank for 2 minutes and 30 seconds. If the flame arrestor installation or any vent system components that are exposed to the flame are installed in locations where ignition of flammable vapors could result in the propagation of the fire into the fuel tank, the applicant must show ignition of the fuel vapors will not occur. This may require installation of additional surface temperature instrumentation as part of the compliance demonstration test. The applicant should establish temperature limits for any components of the vent or flame arrestor assembly that are located in spaces where flammable vapors may be present based on the location of the components in relation to the fuel tank. AC 25.981-1C provides guidance for establishing a maximum allowable surface temperature within the fuel tank (the tank walls, baffles, or any components) that provides a safe margin, under all normal or failure conditions, that is at least 50 °F (27.7 °C) below the lowest expected AIT of the approved fuels. The AIT of fuels will vary because of a variety of factors (e.g., ambient pressure, dwell time, fuel type, etc.). As stated in AC 25.981-1C, the AIT accepted by the FAA without further substantiation for kerosene fuels, such as Jet A, under static sea level conditions, is 450 °F (232.2 °C). This results in a maximum allowable surface temperature of 400 °F (204.4 °C) for an affected component surface of a fuel tank. The ARAC draft AC 25.863-1, *Flammable Fluid Fire Protection*, (see paragraph 3.2 of this AC) provides similar guidance that limits surface temperatures in flammable fluid leakage zones to AIT-50 °F. The ARAC draft AC also provides guidance for allowing somewhat higher surface temperature limits in flammable fluid leakage zones in certain cases where the applicant can substantiate the higher temperature limits. The applicant should monitor and record surface temperatures for any components where the analysis-established limits were required and show the surface temperatures remain below the established limits.

8.3.3 Pass/Fail Criteria.

8.3.3.1 The flame arrestor installation should meet the following performance criteria, as described in paragraph 8.3.2 of this AC:

- Static propagation test.
- Minimum flame holding time of 2 minutes and 30 seconds.
- Installation-dependent maximum surface temperature limits established for any flame arrestor and vent system components located in fuel tanks or flammable fluid leakage zones that are determined to be a potential source of propagating the external vent flame to the fuel tank.

8.3.3.2 After completing the flame arrestor tests noted above, the applicant should carefully examine the integrity of the flame arrestor structure. Suppliers have constructed flame arrestors from one flat and one corrugated stainless steel sheet that are rolled up and placed into a flanged casing. This construction produces a series of small passages. Structural integrity of the coiled sheet metal is maintained by either rods that cross at the front and rear face of the coil or by brazing or welding of the coiled sheet metal at various points around the surface. Flame arrestors have failed the test when the flame passed across the flame arrestor because structural integrity was lost during the test due to weld or brazed joint failures. Damage of flame arrestor assembly components is acceptable if the flame arrestor installation prevents flame propagation during the test, and the maintenance requirements specify the flame arrestor must be repaired or replaced following an event where the flame arrestor was exposed to flame.

8.3.4 Related Qualification and Installation Considerations.

This section does not contain an all-inclusive list of applicable qualification considerations. The tests should show that each component performs its intended function within the environment where it is installed. The applicant should establish design-specific qualification requirements in addition to the items listed in this section.

8.3.4.1 **Vibration**.

Test the flame arrestor for the vibration environment of the installation.

8.3.4.2 **Icing.**

Installation of a flame arrestor will likely introduce a point in the vent system where icing is likely. The applicant should account for this effect in the vent system design by either installing pressure relief provisions that protect the tank from excessive pressure differentials, or by showing that icing or clogging of the flame arrestor with ice is not possible.

8.3.4.3 **Fuel Tank Bottom Pressures.**

In many cases, applicants have established the size of fuel tank vent systems, and associated fuel tank refueling rates, based on the bottom pressure of the fuel tank after failure of the refueling system shutoff system and the resulting fuel overflow of the tank through the vent system. However, installation of a flame arrestor or modifications to the vent system may result in increased tank bottom pressures. Therefore, if an applicant adds a flame arrestor to a fuel vent, or modifies an existing flame arrestor, the applicant should evaluate the effects of these changes on tank bottom pressure, and adjust refueling rates to maintain fuel tank bottom pressures within the limits that were established by the fuel tank structural analysis.

8.3.4.4 **Lightning.**

The applicant must show the fuel tank vent system installation complies with § 25.954. AC 20-53B provides guidance in meeting those requirements. FAA Technical Report ADS-18 (see paragraph 3.3 of this AC) provides factors the applicant should consider when developing fuel tank vent lightning protection features.

9 DEMONSTRATING COMPLIANCE USING FUEL TANK INERTING, FUEL TANK PRESSURIZATION, AND FIRE SUPPRESSION SYSTEMS.

9.1 Fuel Tank Inerting.

An applicant's use of fuel tank inerting systems to show compliance with § 25.975(a)(7) requires demonstrating that the design prevents fuel tank explosions during all operating (e.g., taxi, takeoff, landing, refueling, etc.) and post-crash fire scenarios. To comply with § 25.981, inerting systems are not required to inert the fuel tanks during all operating conditions. Therefore, if an applicant proposes an inerting system as the means of compliance to § 25.975(a)(7), the system would need to have additional capability to prevent fuel tank explosions during all operating conditions. For example, inerting systems found compliant with § 25.981 typically allow the fuel tanks to become flammable during refueling operations, and when the inerting system is inoperative. The applicant would need to address these conditions in order to ensure that the system continues to meet the requirements of § 25.975(a)(7).

9.2 Fuel Tank Pressurization Systems.

Fuel tank pressurization systems or features of the system that result in a "closed" vent system may become inoperative during an accident or the subsequent post-crash fire scenario. If the applicant proposes fuel tank inerting or pressurization as the means of compliance with § 25.975(a)(7), the applicant must show these means are effective in preventing a fuel tank explosion during all operating (e.g., taxi, takeoff, landing, refueling, etc.) and post-crash fire conditions.

9.3 Fire Suppression Systems.

Fuel tank or vent system fire suppression systems typically are activated by a light sensor and discharge a fire suppressant agent that is only effective for a short period of time. Demonstrating compliance using this technology would require showing effectiveness at preventing a fuel tank explosion with a fire present at the fuel tank vent outlet for a minimum of 2 minutes and 30 seconds.

Appendix A. Example of Calculation for Fuel-to-Air Ratio

Table A-1. Combustion Properties of Hexane

Property	Value
Heat of Combustion, BTU/lb.	19,200
Molecular weight	86.17
Limits of inflammability in air (% by volume) percent:	
Lower	1.2
Upper	7.4
Flash point	-7 °F
Boiling point	156 °F
Auto-ignition temperature	433 °F
Vapor pressure at 70 °F (psia)	2.5

Note: The combustion of hexane and oxygen is written as:

$$2\ C_6 H_{14} + 19\ O_2 = 14\ H_2O + 12\ CO_2$$

For every 2 moles of hexane consumed, 19 moles of oxygen are required for complete combustion with no residual oxygen. Thus, 172.34 gm of hexane require 19 x 32.00 = 608 gm of oxygen or 2627.48 gm of air, which is 23.14 percent by weight oxygen. Hence, the weight of air to weight of hexane required for stoichiometric burning (i.e., complete combustion of hexane with no excess oxygen) is 15.24. A 1.15 fraction of stoichiometric mixture of air and hexane has an air-to-fuel weight ratio of:

$$\frac{2627.48}{1.15 \times 172.34} = 13.2$$

Table A-2. Fuel-to-Air Mixtures for Flame Arrestor Tests

Condition	JP-4 Percent by Volume	JP-4 Fuel/Air Mass Ratio	Hexane Percent by Volume	Hexane Fuel/Air Mass Ratio
Lean limit	0.90	0.035	1.3	0.04
Between lean limit and stoichiometric	1.10	0.045	1.7	0.05
Stoichiometric	1.58	0.065	2.2	0.0658
1.15 Stoichiometric	1.82	0.074	2.5	0.07567
Between stoichiometric and rich limit	3.0	0.15	6.3	0.2
Rich limit	6.16	0.23	8.0	0.26

Table A-3. Combustion Properties of Propane

Property	Value
Heat of combustion (298K), kcal/gm-mole	530.6
Flammability limits in air (% by volume), percent	
Lower	2.2
Upper	9.5
Flame temperature (stoichiometric in air, STP), °C	1925
Quenching diameter,* inches	0.11
Minimum spark ignition energy,* millijoules	0.027
Critical velocity gradient for flashback,* sec-1	600
Laminar flame speed,* cm-sec	40

*Applicable to 1.1 stoichiometric propane-to-air at standard temperature and pressure (STP).

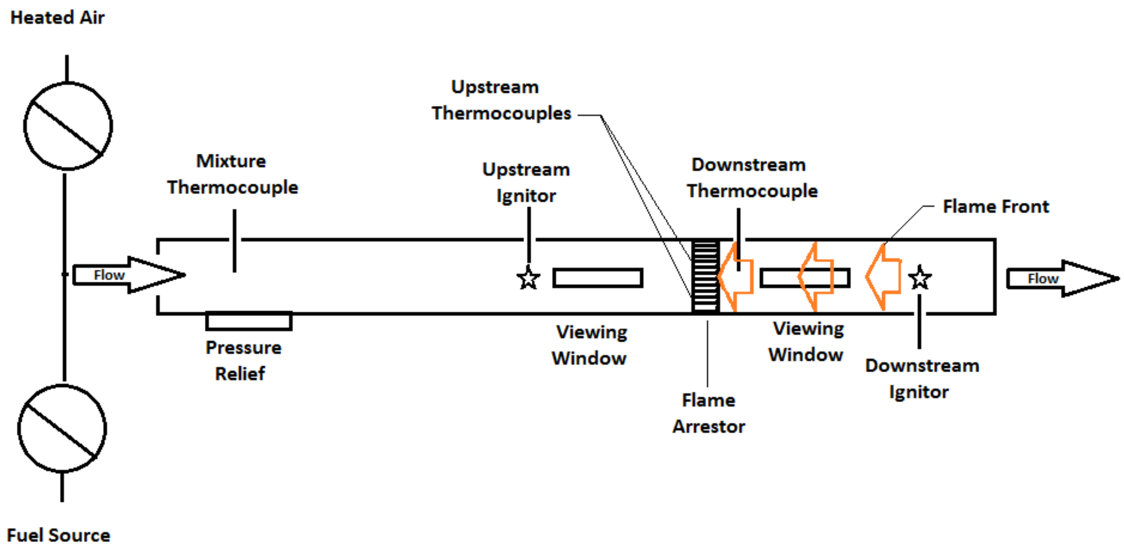
Note: The combustion of propane and oxygen is written as:

$$C_3H_8 + 5\,O_2 = 4\,H_2O + 3\,CO_2$$

For every mole of propane consumed, 5 moles of oxygen are required for complete combustion with no residual oxygen. Thus, 44.09 gm of propane require 5 x 32.00 = 160 gm of oxygen or 691.44 gm of air, which is 23.14 percent by weight oxygen. Hence, the weight of air to weight of propane required for stoichiometric burning (i.e., complete combustion of propane with no excess oxygen) is 15.7. A 1.15 fraction of stoichiometric mixture of air and propane has an air-to-fuel weight ratio of:

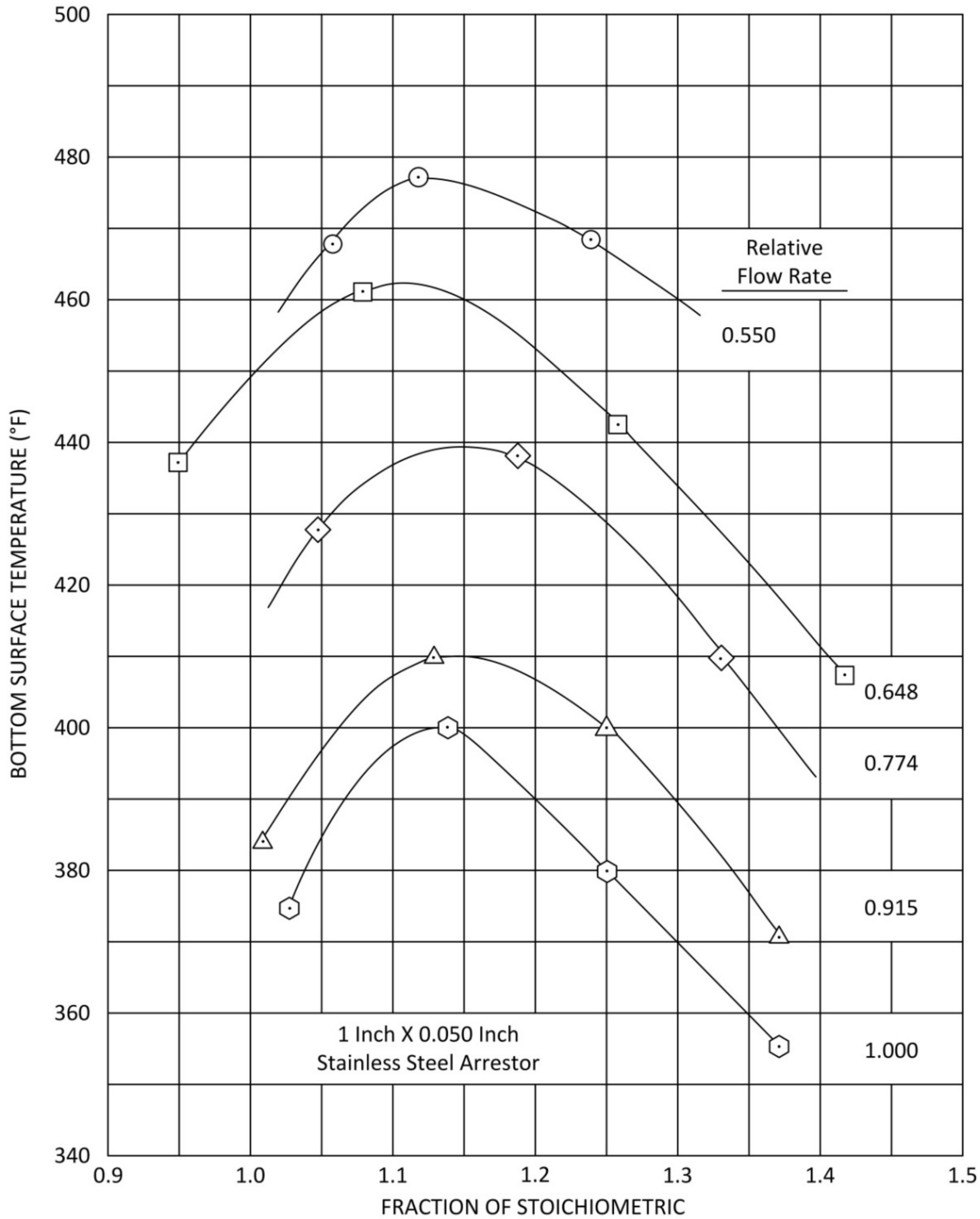
$$\frac{691.44}{1.15 \times 44.09} = 13.7$$

Figure A-1. Fuel Tank Vent Flame Arrestor Test Schematic



Note: This test schematic is not intended to represent an acceptable test configuration for project-specific compliance testing. The test installation, including the length and diameter of downstream vent line and the orientation of the flame arrestor will have a significant impact on the effectiveness of the flame arrestor. Therefore, the test configuration should be representative of the actual airplane installation. Additional surface temperature measurements may be needed if the flame arrestor is installed in a location where ignition of flammable vapors could lead to propagation of the external vent fire into the fuel tank. For example, a vent flame arrestor could be installed adjacent to a fuel surge tank, such that hot surfaces of the flame arrestor or vent system could cause ignition of flammable vapors and propagation of the fire into the fuel tank. Additional surface temperature data would be needed to demonstrate that surface temperature limits are not exceeded.

Figure A-2. Flame Arrestor Surface Temperature at Various Flow Rates and Stoichiometric Mixture Ratios[2]



[2] FAA Technical Report ADS-18, *Lightning Protection Measures for Aircraft Fuel Systems* (see paragraph 3.3 of this AC).

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR500-Coord@faa.gov or (2) faxing it to the attention of the Aircraft Certification Service Directives Management Officer at (202) 267-3983.

Subject: AC 25.975-1, Fuel Vent Fire Protection Date: ____________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph ____________ on page ______________ .

☐ Recommend paragraph ____________ on page ___________ be changed as follows:

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: ______________________________ Date: ____________________