6.3.1.5. Test specimen.

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

6.3.2. Test conditions.

Two types of tests are typically needed to demonstrate compliance: one for flame propagation prevention in a static vent vapour flow condition, and one for flame holding in a continuous vapour 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.

6.3.2.1. Flame propagation test (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 the flame arrestor equilibrium temperature for various air–flow ratios as a function of the per cent stoichiometric fuel–air ratio (see Figure A-2 in this AMC). These curves maximise at about 1.10 to 1.20 stoichiometric. The curves indicate that higher temperatures occur at lower flow rates.

6.3.2.1.1. Establish the mixed flow.

Close the fuel and air valves. Ignite the mixture downstream of the element. Verify that flames did not propagate through the flame arrestor by observing it through the viewing window. Verify that the upstream mixture is combustible by energising the upstream igniter and observing the 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.

6.3.2.1.2. Flame front velocity.

The velocity of the flame front as it reaches the flame arrestor can significantly influence the effectiveness of the flame arrestor in preventing flame propagation. The flame front velocity increases as the flame travels down a vent line containing flammable vapours. The velocity of the flame front is installation-dependent and influenced by the length and diameter of the vent line, and by flow losses between the ignition source and the 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 a different length or diameter of the vent line 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.

6.3.2.2. Flame-holding test.

The purpose of this test is to show that a flame present at the fuel tank vent outlet, when a continuous flow of flammable vapour 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 vapour 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 during development testing.

Adjust the flow to achieve a velocity of 0.75 ft/s (+ 0.25, – 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 it through the viewing window.

Determine the position of the flame front and adjust the vapour 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 vapour flow rate at a constant value throughout the test so as to maintain the correct fuel-to-air ratio.

6.3.2.2.1. Flame arrestor element maximum surface temperatures.

Monitor the temperature at the upstream centre of the flame arrestor during the flame-holding test; it is required to stay below 370 °C/700 °F for the first 2 minutes and 30 seconds after the ignition. Data from developmental testing show that the temperature of the centre of the upstream flame arrestor face at which failure (i.e. propagation of the flame) occurred was typically above 370 °C/700 °F, which is well above the AIT of JP-4 fuel vapour of 229 °C/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 of the vapour. For this reason, hexane, with an AIT of 223 °C/433 °F, should be used for the test of the flame arrestor element.

6.3.2.2.2. Flame arrestor installation and vent system maximum surface temperatures.

The compliance demonstration must show that flames present at the vent outlet do not propagate into the fuel tank during the first 2 minutes and 30 seconds after ignition. If the flame arrestor installation or any vent system components that are exposed to the flame are installed in locations where the ignition of flammable vapours could result in the propagation of the fire into the fuel tank, the applicant must show that ignition of the fuel vapours does not occur. This may require the 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 vapours may be present, based on the location of the components in relation to the fuel tank. AMC 25.981 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 30 °C/50 °F 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.). The AIT accepted by EASA without further substantiation for kerosene fuels, such as Jet A, under static sea level conditions, is 232 °C/450 °F. This results in a maximum allowable surface temperature of 200 °C/400 °F for an affected surface of a fuel tank component. Higher surface temperature limits in flammable fluid leakage zones may be allowed in certain cases where the applicant can substantiate that the higher temperature limits are acceptable. The applicant should monitor and record surface temperatures for any components where the analysis-established limits were required, and should show that the surface temperatures remain below the established limits.

6.3.3. Pass/fail criteria.

6.3.3.1. The flame arrestor installation should meet the following performance criteria, as described in paragraph 6.3.2 of this AMC:

It should pass the static propagation test;

It should have a minimum flame-holding time of 2 minutes and 30 seconds;

Installation-dependent maximum surface temperature limits should be established for any flame arrestor and vent system components located in fuel tanks or flammable fluid leakage zones that are determined to be potential sources that could propagate the flame from the external vent to the fuel tank.

6.3.3.2. After completing the flame arrestor tests noted above, the applicant should carefully examine the integrity of the structure of the flame arrestor. 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 faces 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 failures of welds or brazed joints. Damage to components of the flame arrestor assembly is acceptable if the flame arrestor installation prevents flame propagation during the test, and the maintenance requirements specify that the flame arrestor must be repaired or replaced following an event where the flame arrestor was exposed to flame.

6.3.4. Related qualification and installation considerations.

This paragraph 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 paragraph.

6.3.4.1. Vibration.

Test the flame arrestor in a vibration environment representative of the installation.

6.3.4.2. Icing.

Installation of a flame arrestor will probably 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.

6.3.4.3. Fuel tank bottom pressures.

In many cases, applicants have established the size of fuel tank vent systems, and the associated fuel tank refuelling rates, based on the bottom pressure of the fuel tank after failure of the refuelling system shut-off 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 the tank bottom pressure, and adjust the refuelling rates to maintain the fuel tank bottom pressures within the limits that were established by the fuel tank structural analysis.

6.3.4.4. Lightning.

The applicant must show that the fuel tank vent system installation complies with CS 25.954. AMC 25.954 provides guidance in meeting those requirements. FAA Technical Report ADS-18 (see paragraph 2.2 of this AMC) provides factors that the applicant should consider when developing features to protect fuel tank vents from lightning.

7. Demonstrating compliance using fuel tank inerting, fuel tank pressurisation, and fire suppression systems

7.1. Fuel tank inerting.

An applicant's use of fuel tank inerting systems to show compliance with CS 25.975(a)(7) requires them to demonstrate that the design prevents fuel tank explosions during all operating conditions (e.g. taxiing, take-off, landing, refuelling, etc.) and post-crash fire scenarios. To comply with CS 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 with CS 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 CS 25.981typically allow the fuel tanks to become flammable during refuelling 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 CS 25.975(a)(7).

7.2. Fuel tank pressurisation systems.

Fuel tank pressurisation 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 pressurisation as the means of compliance with CS 25.975(a)(7), the applicant must show that these means are effective in preventing a fuel tank explosion during all operating conditions (e.g. taxiing, take-off, landing, refuelling, etc.) and post-crash fire conditions.

7.3. Fire suppression systems.

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

[Amdt 25/21]

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

ED Decision 2018/005/R

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) per cent: Lower Upper	 1.2 7.4
Flash point	– 22 °C/– 7 °F
Boiling point	69 °C/156 °F
Auto-ignition temperature (AIT)	223 °C/433 °F
Vapour pressure at 21 °C/70 °F (Pa/psia)	17 237/2.5

Note: The equation for the combustion of hexane and oxygen is written as:

2 C6 H14 + 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 g of hexane require 19 × 32.00 = 608 g of oxygen or 2 627.48 g of air, which is 23.14 per cent by weight oxygen. Hence, the ratio of the weight of air to the 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:

$$\frac{2627.48}{1.15 \times 172.37} = 13.2$$

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

Condition	JP-4 Per cent by Volume	JP-4 Fuel-Air Mass Ratio	Hexane Per cent 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 (298 °K), kcal/g-mole	530.6
Flammability limits in air (% by volume), per cent: Lower Upper	 2.2 9.5
Flame temperature (stoichiometric in air, STP)	1 925 °C/3 497 °F
Quenching diameter,* cm/in	0.28/0.11
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 equation for 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 g of propane require 5 × 32.00 = 160 g of oxygen or 691.44 g of air, which is 23.14 per cent 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

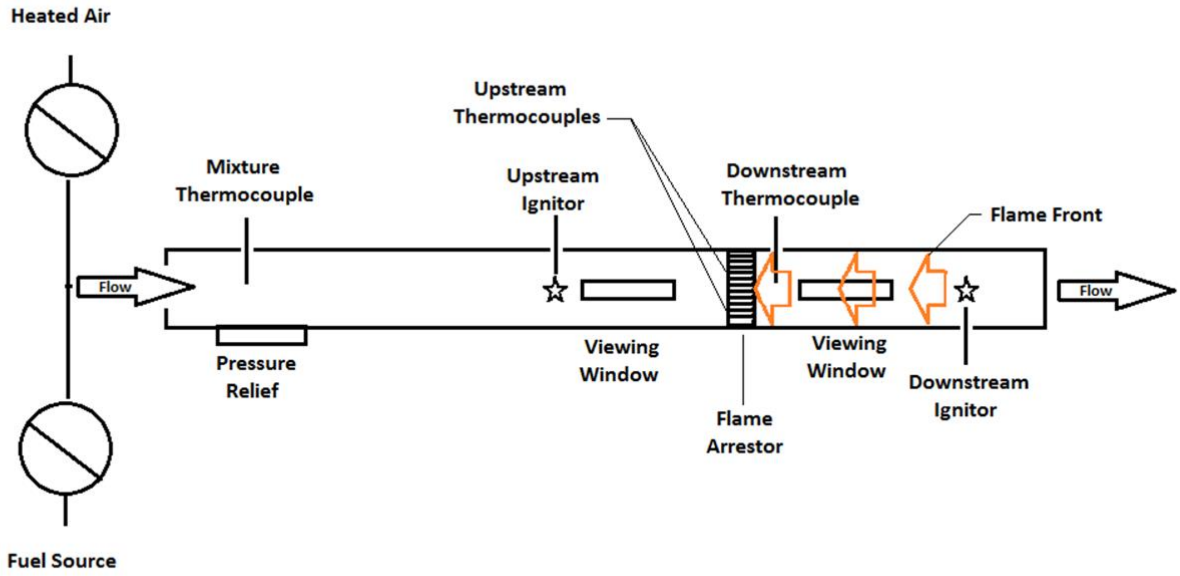
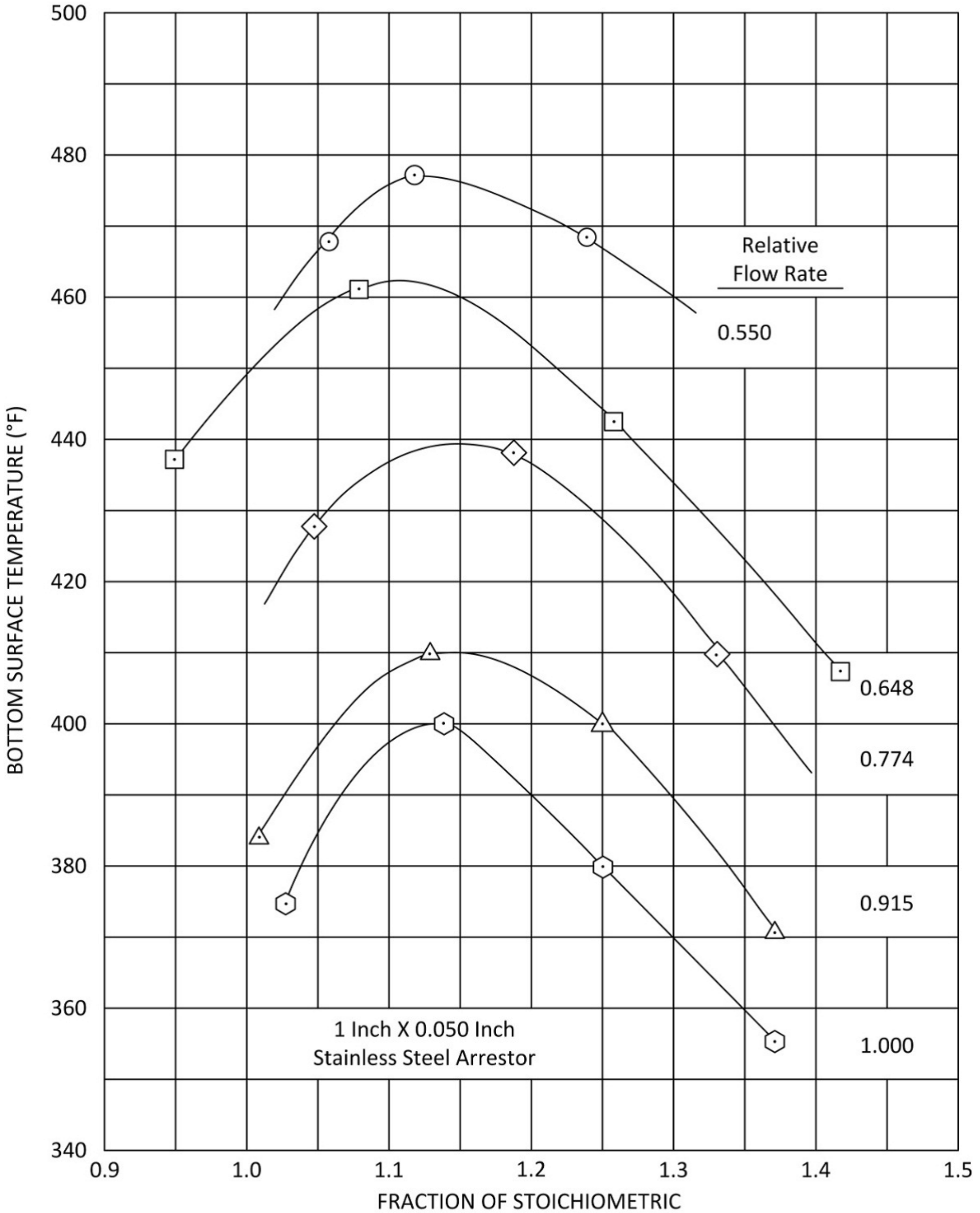


*Figure A-2. Flame Arrestor Surface Temperature at Various Flow Rates and Stoichiometric Mixture Ratios**



* FAA Technical Report ADS-18, Lightning Protection Measures for Aircraft Fuel Systems (see paragraph 2.2 of this AMC).

[Amdt 25/21]

CS 25.977 Fuel tank outlet

ED Decision 2003/2/RM

(a) There must be a fuel strainer for the fuel tank outlet or for the booster pump. This strainer must –

(1) Reserved.

(2) Prevent the passage of any object that could restrict fuel flow or damage any fuel system component.

(b) *Reserved*.

(c) The clear area of each fuel tank outlet strainer must be at least five times the area of the outlet line.

(d) The diameter of each strainer must be at least that of the fuel tank outlet.

(e) Each finger strainer must be accessible for inspection and cleaning.

CS 25.979 Pressure fuelling system

ED Decision 2016/010/R

(See AMC 25.979)

For pressure fuelling systems, the following apply:

(a) Each pressure fuelling system fuel manifold connection must have means to prevent the escape of hazardous quantities of fuel from the system if the fuel entry valve fails.

(b) An automatic shut-off means must be provided to prevent the quantity of fuel in each tank from exceeding the maximum quantity approved for that tank. This means must –

(1) Allow checking for proper shut-off operation before each fuelling of the tank; and

(2) Provide indication, at each fuelling station, of failure of the shut-off means to stop the fuel flow at the maximum quantity approved for that tank.

(c) A means must be provided to prevent damage to the fuel system in the event of failure of the automatic shut-off means prescribed in sub-paragraph (b) of this paragraph.

(d) The aeroplane pressure fuelling system (not including fuel tanks and fuel tank vents) must withstand an ultimate load that is 2·0 times the load arising from the maximum pressures, including surge, that is likely to occur during fuelling. The maximum surge pressure must be established with any combination of tank valves being either intentionally or inadvertently closed. (See AMC 25.979(d).)

(e) The aeroplane defuelling system (not including fuel tanks and fuel tank vents) must withstand an ultimate load that is 2·0 times the load arising from the maximum permissible defuelling pressure (positive or negative) at the aeroplane fuelling connection.

[Amdt 25/18]

AMC 25.979(d) Pressure fuelling systems

ED Decision 2003/2/RM

1 Pressure fuelling systems, fuel tanks and the means preventing excessive fuel pressures, should be designed to withstand normal maximum fuelling pressure of not less than 345 kN/m^2 (50 psi) at the coupling to the aeroplane.

2 Pressure fuelling systems should be so arranged that the fuel entry point is at or near the bottom of the tank so as to reduce the level of electrostatic charge in the tank during fuelling.

CS 25.981 Fuel tank explosion prevention

ED Decision 2020/024/R

(a) No ignition source may be present at each point in the fuel tank or fuel tank system where catastrophic failure could occur due to ignition of fuel or vapours. This must be shown by:

(1) Determining the highest temperature allowing a safe margin below the lowest expected auto-ignition temperature of the fuel in the fuel tanks.

(2) Demonstrating that no temperature at each place inside each fuel tank where fuel ignition is possible will exceed the temperature determined under sub-paragraph (a)(1) of this paragraph. This must be verified under all probable operating, failure, and malfunction conditions of each component whose operation, failure, or malfunction could increase the temperature inside the tank.

(3) Except for the ignition sources due to lightning addressed by CS 25.954, demonstrating that an ignition source could not result from each single failure, from each single failure in combination with each latent failure condition not shown to be extremely remote, and from all combinations of failures not shown to be extremely improbable, taking into account the effects of manufacturing variability, ageing, wear, corrosion, and likely damage.

(b) Fuel tank flammability

(1) To the extent practicable, design precautions must be taken to prevent the likelihood of flammable vapours within the fuel tanks by limiting heat and energy transfer (See AMC 25.981(b)(1)).

(2) Except as provided in sub-paragraph (4) of this paragraph, no fuel tank Fleet Average Flammability Exposure level may exceed the greater of:

(i) three percent, or

(ii) the exposure achieved in a fuel tank within the wing of the aeroplane model being evaluated. If the wing is not a conventional unheated aluminium wing, the analysis must be based on an assumed Equivalent Conventional Unheated Aluminium Wing (see AMC 25.981(b)(2)).

The Fleet Average Flammability Exposure is determined in accordance with appendix N of CS-25.

(3) Any active Flammability Reduction means introduced to allow compliance with sub-paragraph (2) must meet appendix M of CS-25.

(4) Sub-Paragraph (2) does not apply to a fuel tank if following an ignition of fuel vapours within that fuel tank the aeroplane remains capable of continued safe flight and landing.