those located in direct lightning attachment zones. The CDCCLs should identify these critical fastener features and refer to the structural repair manual (SRM) for approved fastener lists and approved installation processes for these fasteners.

5.1.2.2 Fuel tube electrical isolation segments can be used to limit induced lightning currents on the fuel tubes, especially on aeroplanes with carbon-fibre composite fuel tank structures. Maintenance, alterations, or repairs of the fuel tube system should maintain the lightning current limits provided by the fuel tube isolation segments. A limitation may specify that the fuel tube isolation segments are required for lightning protection, that replacements must also meet the electrical isolation requirements of the original design, and electrical bonding straps must not bridge the isolation segments.

5.1.2.3 Fuel tank access doors have the potential for lightning-related sparking inside the tank as a result of a direct lightning strike or a conducted lightning current. The doors may incorporate specific protection features such as electrically conductive gaskets, electrically insulating seals, and multiple fasteners. The limitation may specify that the presence and integrity of the gaskets, seals and fasteners should be verified when the access doors are installed. Electrical bonding measurements may be required to verify that the electrical resistance between the access door and adjacent structure is less than a specified value.

5.1.2.4 Sealant can provide caps over fasteners or fillet seals applied where structural parts are joined within the fuel tank. Poor sealant adhesion or sealant damage could degrade the protection against lightning ignition sources. The limitation may specify that the integrity of the sealant must be verified in the areas of the fuel system where maintenance or alterations take place. Cracked, peeling, or missing sealant could indicate that the integrity of the protection is compromised.

5.1.2.5 The minimum spacing between metal fuel tubes, hydraulic tubes, and conduits and adjacent structure may be specified to prevent lightning-related arcing. In addition, electrically insulating bushings or grommets may be installed to prevent lightning-related arcing between fuel system components and structures. The limitation may specify that the presence and integrity of the bushings or grommets must be verified in the areas of the fuel system where maintenance or alterations take place, and that the minimum clearance between fuel tubes, hydraulic tubes, or conduits and adjacent structure or components must be verified in areas where maintenance or alterations take place.

5.1.2.6 Fittings for metal hydraulic tubes, nitrogen inerting tubes, and fuel tubes may be installed through the fuel tank walls. These fittings must conduct induced-lightning currents and prevent voltage or thermal sparks within the tank between the fittings and the fuel tank structure. The limitation may require verifying that the electrical bonding resistance does not exceed a specified value if the fittings are repaired, reinstalled, or altered, and that the integrity and electrical bonding resistance of any required bonding straps must be verified as well.

5.1.2.7 Self-bonding couplings that rely on physical contact between the coupling and fuel tubes may be used to provide electrical bonding. Anodised coatings applied to the fuel tubes could degrade the electrical bonding. The coatings used on the tubes and couplings could be identified as a CDCCL to maintain acceptable electrical bonding.

5.1.2.8 Fuel quantity sensing probes and in-tank wiring may require electrical isolation from the adjacent fuel tank structure to prevent lightning-related arcing between the probes, wiring, and structure. The isolation may be provided by electrically non-conductive probe clamps, or non-conductive caps on the ends of the probes. The wiring protection may be provided by separation from the structure. The limitation may specify that the presence and integrity of the non-conducting clamps or end caps, and the wiring separation must be verified in the areas of the fuel system where maintenance or alterations take place.

5.1.3 CDCCLs are intended to identify only the critical features of a design that must be maintained. A CDCCL has no interval, but establishes configuration limitations to protect the critical design features identified in the CDCCL. CDCCLs can also include requirements to have placards installed on the aeroplane with information about critical features. For certain equipment, critical protection may be provided by components. These critical protection features must be identified as CDCCLs and should be listed in the component maintenance manual (CMM) to provide awareness to maintenance and repair facilities.

5.1.4 Certain CDCCLs apply to elements of fuel system components. As such, the maintenance of those critical features may be covered in a CMM. When Airworthiness Limitations need to call out aspects of CMMs, it is a best practice to limit the CDCCL-controlled content to only those maintenance tasks directly impacting a CDCCL feature, rather than requiring the complete CMM to be a CDCCL.

5.2 Mandatory replacement times, inspection intervals, and related inspection and test procedures

5.2.1 To comply with CS 25.954(d), mandatory replacement times, inspection intervals, and the related inspection and test procedures must be developed for the lightning protection features identified in paragraphs 2.3 and 2.6 of this AMC. Mandatory replacement times, inspection intervals, and the related inspection and test procedures must be included in the Airworthiness Limitations Section of the ICA.

5.2.2 To ensure lightning protection is retained over the service life of the aeroplane, references to these mandatory replacement times, inspection intervals, and the related inspection and test procedures are normally included in the maintenance manuals (e.g., the AMM, SRM, SWPM) and service bulletins that provide maintenance personnel with standard practices for continued airworthiness.

5.2.3 When developing maintenance and service inspection techniques, a review of similar aeroplane designs and their service histories should be conducted to focus on the areas where past experience has shown there is a potential for affecting lightning protection features.

5.2.4 When developing procedures to remove and reinstall fuel tank access panels, applicants should include instructions to maintain or restore the lightning protection features such as sealants, fastener assemblies (structural joints), nut plates, bonded parts, insulators, conductive parts, etc.

5.2.5 The applicant should validate the intended maintenance tasks performed in the fuel tank systems and confirm that they do indeed provide protection and avoidance of damage to the lightning protection features. The applicant should ensure that the proper parts and materials are specified in the maintenance tasks.

5.2.6 The lightning design specialist should participate in the determination of the maintenance program necessary for fuel tank lightning protection.

5.2.7 Lightning protection features that are not anticipated to degrade during the life of the aeroplane, and are identified as inherently reliable, do not require mandatory maintenance for compliance with CS 25.954(d), but should be identified to EASA. The integrity of conductive primary structures is an example of such features. A claim that lightning protection features are not anticipated to degrade during the life of the aeroplane when exposed to the effects of the environment, ageing, wear, corrosion, and likely damage must be substantiated and supported by data.

5.2.8 If a protection feature could degrade over the life of the aeroplane, it must be maintained using approved inspections and procedures consistent with the requirements of CS 25.954(d).

Appendix A. Definitions

The following definitions apply to the lightning protection of fuel tanks and systems of CS 25.954 and the guidance in this AMC.

A.1 ATTACHMENT POINT.

A point where the lightning flash contacts the aeroplane.

A.2 CONTINUED SAFE FLIGHT AND LANDING.

The aeroplane can safely abort or continue a take-off, or continue controlled flight and landing, possibly using emergency procedures. The aeroplane must do this without requiring exceptional pilot skill or strength. Some aeroplane damage may occur because of the failure condition or on landing. The pilot must be able to land the aeroplane safely at a suitable airport.

A.3 CRITICAL DESIGN CONFIGURATION CONTROL LIMITATIONS (CDCCLs).

A limitation requirement to preserve a critical design feature of a fuel system that is necessary for the design to meet the performance standards of CS 25.954 (and/or CS 25.981) throughout the life of the aeroplane model. The purpose of the CDCCL is to provide instructions to retain the critical features during configuration changes that may be caused by alterations, repairs, or maintenance actions.

A.4 CRITICAL LIGHTNING STRIKE.

As defined by CS 25.954(a)(1), a critical lightning strike is a lightning strike that attaches to the aeroplane in a location that, when combined with the failure of any design feature or structure, could create an ignition source.

A.5 ESCAPES.

Production or maintenance errors that can be anticipated to occur that could render the fault tolerance, or lightning protection ineffective.

A.6 EXTREMELY IMPROBABLE FAILURE CONDITION.

Refer to the definition provided in Section 7 of AMC 25.1309 (qualitative and quantitative terms).

A.7 FAULT-TOLERANT DESIGN.

A design that precludes fuel systems ignition sources even when a fault is present.

A.8 FUEL SYSTEMS.

As defined by CS 25.954(a)(2) a fuel system includes any component within either the fuel tank structure or the fuel tank systems and any aeroplane structure or system components that penetrate, connect to, or are located within a fuel tank.

A.9 FUEL TANK STRUCTURE.

Includes structural members of the fuel tank such as aeroplane skins, access panels, joints, ribs, spars, stringers, and the associated fasteners, brackets, coatings and sealant.

A.10 FUEL TANK SYSTEMS.

Tubing, components, and wiring that penetrate, are located within, or connected to the fuel tanks.

A.11 INTRINSICALLY SAFE.

Fuel system design elements that provide effective lightning protection with no foreseeable failure modes that would render them ineffective. These design elements have no failures or combinations of failures that can result in an ignition source. This can be due to reliable design or to a very low lightning voltage or current in that specific location.

A.12 LIGHTNING FLASH.

The total lightning event. It may occur in a cloud, between clouds, or between a cloud and the ground. It can consist of one or more return strokes, plus intermediate or continuing currents.

A.13 LIGHTNING STRIKE.

Attachment of the lightning flash to the aeroplane.

A.14 LIGHTNING STRIKE ZONES.

Aeroplane surface areas and structures that are susceptible to lightning attachment, dwell times, and current conduction.

A.15 LIGHTNING STROKE (RETURN STROKE).

A lightning current surge that occurs when the lightning leader (the initial current charge) makes contact with the ground or another charge centre. A charge centre is an area of high potential of opposite charge.

A.16 PRACTICALITY.

A balance of the available means, economic viability, and proportional benefit to safety.

A.17 RELIABLE DESIGN.

A reliable design is a design that provides lightning protection features that are not anticipated to degrade during the life of the aeroplane.

A.18 RELIABLE FAULT TOLERANCE.

A fault-tolerant fuel system design is a design that precludes ignition sources in the fuel system even when a fault is present; 'reliable' means that the system has the ability to maintain the effectiveness of the protection features over the service life of the individual aeroplane.

A.19 REMOTE.

Refer to the definition provided in Section 7 of AMC 25.1309 (qualitative and quantitative terms).

A.20 SYSTEMS.

Systems include fuel, mechanical, hydraulic, electrical, and electrical wiring interconnection system (EWIS) components that penetrate, are located within, or connected to the fuel tanks.

Appendix B. Section 4 Examples

B.1 EXAMPLES FOR PARAGRAPH 4.1.2.1

The design elements or features for which providing fault-tolerant prevention of lightning ignition sources should be practical include the:

1. Installation of rivets and bolts in aluminium structures that are well bonded through processes that ensure the fastener/hole fit, fastener and hole quality, and installation practices;

2. Installation of bolts in composite structures that are well bonded through processes that ensure control of the fastener/hole fit, fastener and hole quality, and installation practices and with additional design features to distribute current, such as foil or mesh at the material surface; and the

3. Installation of lightning protective sealant or cap seals over fastener heads/ends located inside fuel tanks, where necessary.

B.2 EXAMPLES FOR PARAGRAPH 4.1.2.2

The design features or failures for which providing fault-tolerant prevention of lightning ignition sources could be impractical include:

1. Fatigue cracking within structural elements such as spars, skins, stringers, and ribs. Typically, material controls, manufacturing controls, established material allowables, design margins, and life-cycle tests make the occurrence of significant cracking rare.

2. Failures of fasteners highly loaded in tension that lead to separation of the fasteners or parts of the fasteners from the hole, or gapping of the heads or nuts of the fasteners, and the consequent failure of a cap seal. Typically, manufacturing controls, design margins, and life-cycle tests make the occurrence of broken bolts rare.

3. The installation of double cap seals or structurally reinforced cap seals to retain a bolt that fails under tension, resulting in a cascading failure of the cap seals.

4. Damage that may go undetected by scheduled or directed field inspection, and manufacturing defects in composite structures.

B.3 EXAMPLES FOR PARAGRAPH 4.1.2.3

Some examples of practical design, manufacturing, and maintenance processes are listed below. Although these practices themselves are not considered to be independent features for providing fault tolerance, they are measures to minimise the likelihood of failures, or measures necessary to support the assumptions about failure modes or rates in a safety analysis.

1. A structured design review process (as described in this AMC) to ensure that all the relevant design features are reviewed to identify the critical design areas, critical processes, and associated testing and analysis requirements.
2. Engineering review of the proposed design to identify the failure modes that may occur because of manufacturing errors or escapes, maintenance errors, repairs or alterations, ageing, wear, corrosion, or likely damage.
3. Engineering review of manufacturing processes to identify the failure modes that may occur because of manufacturing errors or escapes.
4. Engineering review of service history records to identify the failure modes that may occur because of production escapes, maintenance errors, repairs or alterations, ageing, wear, corrosion, or likely damage.
5. Implementation of practical manufacturing and quality control processes to address the issues identified through the required engineering reviews.
6. For non-fault-tolerant locations, quality control processes that require inspections of critical features by a person other than the person that performed the manufacturing work.
7. Provisions in the ICA to identify cautions in maintenance documents regarding lightning protection features, as well as life limits or repetitive inspections for non-fault-tolerant features. For any penetration into the fuel tank, or any structural damage within the fuel tank, the SRM should specify the repair methods that maintain the lightning protection features.
8. Mandatory maintenance actions necessary to ensure compliance is maintained with the lightning protection requirements should be included in the Airworthiness Limitations Section of the ICA as required by Section H25.4 of Appendix H to CS-25.

B.4 EXAMPLE FOR PARAGRAPH 4.2.5.3

The following is an example of an assessment process addressing the potential for non-fault-tolerant fuel tank structural cracking. To assess the risk due to non-fault tolerance for structural cracks, the following should be accomplished:

B.4.1 Determine whether the structure in this zone is susceptible to fatigue cracking. If it is susceptible to fatigue cracking, determine the minimum size of crack that could be a source for arcing. This crack length should then be compared with the inspection methods used for compliance with CS 25.571 (Damage Tolerance), to determine the ability to detect and/or the probability of detecting a crack of this size.

B.4.2 If the Airworthiness Limitations required for compliance with CS 25.571 are already sufficient to ensure that the probability is remote (unlikely to occur on each aeroplane — see AMC 25.1309) that a crack will grow to a sufficient size and gap in excess of that necessary to cause sparking during a lightning event, then no lightning-related Airworthiness Limitations are required. The probability of this remote condition occurring, together with the remote probability of a critical lightning strike, make these combinations not foreseeable.

B.4.3 As part of the damage-tolerance evaluation, an analysis should be performed to determine the duration of time (in flight cycles) it will take for a crack of minimum arcing size to grow to the minimum detectable length. This crack propagation rate should then be used along with the probability of detection for the specified inspection method to determine the exposure time. That exposure time is the number of flight cycles an aeroplane may be exposed to before an ignition source due to a structural failure (crack, failed fastener, etc.) occurs.

B.4.4 If the Airworthiness Limitations necessary to support compliance with CS 25.571 cannot ensure that the likelihood of a crack in excess of the size that would cause sparking is remote, and the crack would not be readily detectable within a few flights due to fuel leaks, then this condition must be included in the risk assessment of non-fault-tolerant conditions. Further, any practical maintenance inspection should be made to minimise the exposure time. A low probability combined with a short exposure time may be necessary to demonstrate that a catastrophic ignition is extremely improbable, i.e., it is not anticipated to occur during the entire operational life of all the aeroplanes of one type.

[Amdt 25/26]

CS 25.955 Fuel flow

ED Decision 2016/010/R

(See AMC 25.955)

(a) Each fuel system must provide at least 100% of the fuel flow required under each intended operating condition and manoeuvre. Compliance must be shown as follows:

(1) Fuel must be delivered to each engine at a pressure within the limits specified in the engine type certificate.

(2) The quantity of fuel in the tank may not exceed the amount established as the unusable fuel supply for that tank under the requirements of CS 25.959 plus that necessary to show compliance with this paragraph.

(3) Each main pump must be used that is necessary for each operating condition and attitude for which compliance with this paragraph is shown, and the appropriate emergency pump must be substituted for each main pump so used.

(4) If there is a fuel flowmeter, it must be blocked and the fuel must flow through the meter or its bypass. (See AMC 25.955(a)(4).)

(b) If an engine can be supplied with fuel from more than one tank, the fuel system must –

(1) Reserved.

(2) For each engine, in addition to having appropriate manual switching capability, be designed to prevent interruption of fuel flow to that engine, without attention by the flight crew, when any tank supplying fuel to that engine is depleted of usable fuel during normal operation, and any other tank, that normally supplies fuel to that engine alone, contains usable fuel.

[Amdt 25/18]

AMC 25.955(a)(4) Fuel flow

ED Decision 2003/2/RM

The word 'blocked' should be interpreted to mean 'with the moving parts fixed in the position for maximum pressure drop'.

CS 25.957 Flow between interconnected tanks

ED Decision 2003/2/RM

If fuel can be pumped from one tank to another in flight, the fuel tank vents and the fuel transfer system must be designed so that no structural damage to the tanks can occur because of overfilling.

CS 25.959 Unusable fuel supply

ED Decision 2003/2/RM

The unusable fuel quantity for each fuel tank and its fuel system components must be established at not less than the quantity at which the first evidence of engine malfunction occurs under the most adverse fuel feed condition for all intended operations and flight manoeuvres involving fuel feeding from that tank. Fuel system component failures need not be considered.

CS 25.961 Fuel system hot weather operation

ED Decision 2003/2/RM

(a) The fuel system must perform satisfactorily in hot weather operation. This must be shown by showing that the fuel system from the tank outlets to each engine is pressurised, under all intended operations, so as to prevent vapour formation, or must be shown by climbing from the altitude of the airport elected by the applicant to the maximum altitude established as an operating limitation under CS 25.1527. If a climb test is elected, there may be no evidence of vapour lock or other malfunctioning during the climb test conducted under the following conditions:

(1) Reserved.

(2) For turbine engine powered aeroplanes, the engines must operate at take-off power for the time interval selected for showing the take-off flight path, and at maximum continuous power for the rest of the climb.

(3) The weight of the aeroplane must be the weight with full fuel tanks, minimum crew, and the ballast necessary to maintain the centre of gravity within allowable limits.

(4) The climb airspeed may not exceed –

(i) Reserved.

(ii) The maximum airspeed established for climbing from take-off to the maximum operating altitude.

(5) The fuel temperature must be at least 43.3 °C (110 °F).

(b) The test prescribed in sub-paragraph (a) of this paragraph may be performed in flight or on the ground under closely simulated flight conditions. If a flight test is performed in weather cold enough to interfere with the proper conduct of the test, the fuel tank surfaces, fuel lines, and other fuel system parts subject to cold air must be insulated to simulate, insofar as practicable, flight in hot weather.

CS 25.963 Fuel tanks: general

ED Decision 2016/010/R

(See AMC 25.963)

(a) Each fuel tank must be able to withstand, without failure, the vibration, inertia, fluid and structural loads that it may be subjected to in operation. (See AMC 25.963(a).)

(b) Flexible fuel tank liners must be approved or must be shown to be suitable for the particular application.

(c) Integral fuel tanks must have facilities for interior inspection and repair.

(d) Fuel tanks must, so far as it is practicable, be designed, located and installed so that no fuel is released in or near the fuselage or near the engines in quantities sufficient to start a serious fire in otherwise survivable emergency landing conditions, and:

(1) Fuel tanks must be able to resist rupture and to retain fuel under ultimate hydrostatic design conditions in which the pressure P within the tank varies in accordance with the formula:

$$P = K\rho g L$$

where:

P = fuel pressure in Pa (lb/ft^2) at each point within the tank

L = a reference distance in m (ft) between the point of pressure and the tank farthest boundary in the direction of loading.

ρ = typical fuel density in kg/m^3 (slugs/ft^3)

g = acceleration due to gravity in m/s^2 (ft/s^2)

K = 4.5 for the forward loading condition for fuel tanks outside the fuselage contour

K = 9 for the forward loading condition for fuel tanks within the fuselage contour

K = 1.5 for the aft loading condition

K = 3.0 for the inboard and outboard loading conditions for fuel tanks within the fuselage contour

K = 1.5 for the inboard and outboard loading conditions for fuel tanks outside of the fuselage contour

K = 6 for the downward loading condition

K = 3 for the upward loading condition

(2) For those (parts of) wing fuel tanks near the fuselage or near the engines, the greater of the fuel pressures resulting from subparagraphs (i) and (ii) must be used:

(i) the fuel pressures resulting from subparagraph (d)(1) above, and:

(ii) the lesser of the two following conditions:

(A) Fuel pressures resulting from the accelerations as specified in CS 25.561(b)(3) considering the fuel tank full of fuel at maximum fuel density. Fuel pressures based on the 9.0g forward acceleration may be calculated using the fuel static head equal to the streamwise local chord of the tank. For inboard and outboard conditions, an acceleration of 1.5g may be used in lieu of 3.0g as specified in CS 25.561(b)(3); and:

(B) Fuel pressures resulting from the accelerations as specified in CS 25.561(b)(3) considering a fuel volume beyond 85% of the maximum permissible volume in each tank using the static head associated with the 85% fuel level. A typical density of the appropriate fuel may be used. For inboard and outboard conditions, an acceleration of 1.5g may be used in lieu of 3.0g as specified in CS 25.561(b)(3).

(3) Fuel tank internal barriers and baffles may be considered as solid boundaries if shown to be effective in limiting fuel flow.

(4) For each fuel tank and surrounding airframe structure, the effects of crushing and scraping actions with the ground should not cause the spillage of enough fuel, or generate temperatures that would constitute a fire hazard under the conditions specified in CS 25.721(b).

(5) Fuel tank installations must be such that the tanks will not rupture as a result of an engine pylon or engine mount or landing gear, tearing away as specified in CS 25.721(a) and (c).

(See AMC 25.963(g).)

(e) Fuel tanks must comply with the following criteria in order to avoid hazardous fuel leak:

(1) Fuel tanks located in an area where experience or analysis indicates a strike is likely, must be shown by analysis supported by test, or by test to address penetration and deformation by tyre and wheel fragments, small debris from uncontained engine failure or APU failure, or other likely debris (such as runway debris).

(2) All fuel tank access covers must have the capacity to withstand the heat associated with fire at least as well as an access cover made from aluminium alloy in dimensions appropriate for the purpose for which they are to be used, except that the access covers need not be more resistant to fire than an access cover made from the base fuel tank structural material.

(See AMC 25.963(e).)

(f) For pressurised fuel tanks, a means with failsafe features must be provided to prevent the build-up of an excessive pressure difference between the inside and the outside of the tank.

(g) (Reserved)

[Amdt 25/3]
[Amdt 25/14]
[Amdt 25/18]

AMC 25.963(a) Fuel tanks: General

ED Decision 2003/2/RM

Precautions should be taken against the possibility of corrosion resulting from microbiological contamination of fuel.