European Union Aviation Safety Agency

Notice of Proposed Amendment 2020-01

Regular update of CS-25

RMT.0673

EXECUTIVE SUMMARY

The objective of this Notice of Proposed Amendment (NPA) is to reflect the state of the art of large aeroplane certification and improve the harmonisation of CS-25 with the Federal Aviation Administration (FAA) regulations. To that end, this NPA proposes amendments to CS-25 following the selection of non-complex, non-controversial, and mature subjects.

In particular, this NPA proposes amendments in the following areas:

Item 1: Go-around handling qualities and performance;

Item 2: Minimum control speeds;

Item 3: Fuel tank and system lightning protection;

Item 4: Cabin safety (various topics);

Item 5: Electronic AFMs – computation of misleading primary information;

Item 6: On-board weight and balance systems;

Item 7: Air conditioning systems;

Item 8: Flight guidance systems;

Item 9: Primary flight displays during unusual attitude and declutter modes;

Item 10: Lightning protection and electrical bonding and protection against static electricity; and

Item 11: Operation without normal electrical power.

Overall, these proposals would provide a moderate safety benefit, would have no social or environmental impacts, and would provide some economic benefits by streamlining the certification process.

Action area:	Regular updates/review of rules		
Affected rules:	CS-25		
Affected stakeholders:	Design approval holders — large aeroplanes		
Driver:	Efficiency/proportionality	**Rulemaking group:**	No
Impact assessment:	None	**Rulemaking Procedure:**	Standard

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1. About this NPA

1.1. How this NPA was developed

The European Union Aviation Safety Agency (EASA) developed this NPA in line with Regulation (EU) 2018/1139[1] (the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the European Plan for Aviation Safety (EPAS)[3] under Rulemaking Task (RMT).0673. The text of this NPA has been developed by EASA. It is hereby submitted to all interested parties[4] for consultation.

1.2. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[5].

The deadline for submission of comments is **20 April 2020.**

1.3. The next steps

Following the closing of the public commenting period, EASA will review all the comments received.

Based on the comments received, EASA will develop a decision that amends the Certification Specifications (CSs) and Acceptable Means of Compliance (AMC) for Large Aeroplanes (CS-25).

The comments received on this NPA and the EASA responses to them will be reflected in a comment-response document (CRD). The CRD will be published on the EASA website[6].

1 Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (OJ L 212, 22.8.2018, p. 1) (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1535612134845&uri=CELEX:32018R1139).

2 EASA is bound to follow a structured rulemaking process as required by Article 115(1) of Regulation (EU) 2018/1139. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

3 https://www.easa.europa.eu/document-library/general-publications?publication_type%5B%5D=2467

4 In accordance with Article 115 of Regulation (EU) 2018/1139 and Articles 6(3) and 7 of the Rulemaking Procedure.

5 In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

6 https://www.easa.europa.eu/document-library/comment-response-documents.

2. In summary — why and what

2.1. Why we need to change the rules — issue/rationale

The aviation industry is complex and rapidly evolving. CSs and AMC need to be updated regularly to ensure that they are fit for purpose, cost-effective, and can be implemented in practice.

Regular updates are issued when relevant data is available following an update of industry standards, feedback from certification activities, or minor issues raised by the stakeholders.

Item 1: Go-around handling qualities and performance

a) CS 25.143(b)(2) – Sudden failure of the second critical engine

At Amendment 21 of CS-25, CS 25.143(b)(2) was amended with the addition of 'go-around' in the list of flight phases to be taken into account.

This amendment to CS 25.143(b)(2) was proposed in NPA 2017-06 as part of the actions aimed at reinforcing the demonstration of longitudinal controllability and authority at low speed in all phases of flight, including go-around, having in mind that some aeroplanes are able to conduct a go-around with two failed engines despite this being not required by CS-25.

The Flight Test Harmonisation Working Group (FTHWG) (established by the FAA Aviation Rulemaking Advisory Committee) in which EASA is represented, has been tasked to recommend appropriate revisions to go-around all engine operative (AEO) and one engine inoperative (OEI) regulatory and advisory material (topic 18, 'Go-Around Handling Qualities & Performance' identified in the FTHWG work plan).

Discussions among the FTHWG topic 18 members revealed that the change to CS 25.143(b)(2) could create an unjustified burden on applicants and EASA for the demonstration of compliance, without any demonstrated significant safety benefit, given the low probability of and exposure time to a dual engine failure. Furthermore, if an applicant decides to include the operational capability and the related operational procedures for such go-arounds with two failed engines, it must anyway demonstrate the handling qualities and AFM procedures in accordance with the other CS-25 specifications.

b) AMC 25.101(g) – Go-around with OEI

AMC 25.101(g) does not provide sufficient guidance with respect to unacceptable go-around flight profiles. This has been addressed through the FTHWG recommendations under topic 18 and a recommendation to amend AMC 25.101(g) has been made.

c) AMC 25.143(b)(4) – Go-around manoeuvres

Chapter 2.1 of AMC 25.143(b)(4) states that 'the risk of a somatogravic illusion is high when encountering single or combined high values of pitch attitude (nose-up), pitch rate and longitudinal acceleration, associated with a loss of outside visual references'.

Discussions within the FTHWG under topic 18 concluded that longitudinal acceleration effects might be the main contributor to the vertigo effect experienced by flight crews during high thrust/weight ratio go-arounds. This is not clearly reflected in the statement mentioned above.

Item 2: Minimum control speeds

EASA AMC 25.149 does not provide expanded definitions or test technique guidance for the determination of V_{MCL} and V_{MCL-2} as are provided in FAA Advisory Circular (AC) 25-7D. Only $V_{MCL(1out)}$ and $V_{MCL-2(2\ out)}$ are addressed in AMC 25.149(f) and AMC 25.149(g) respectively.

Item 3: Fuel tank and system lightning protection

On 20 September 2018, the FAA published a final rule amending Part-25 and entitled 'Transport Airplane Fuel Tank and System Lightning Protection'[7].

The final rule [Docket No. FAA-2014-1027; Amendment No. 25-146], which amends paragraphs §25.954, §25.981, and Appendix H to Part-25, became effective on 19 November 2018.

Summary:

'The FAA is amending certain airworthiness regulations for transport category airplanes regarding lightning protection of fuel systems. This action is relieving in several ways. It removes the requirement for manufacturers to provide triple-redundant fault tolerance in lightning protection. It removes regulatory inconsistency by establishing a single standard for lightning protection of both fuel tank structure and fuel tank systems. It establishes a performance- based standard that the design and installation of fuel systems prevent catastrophic fuel vapor ignition caused by lightning and its effects. This performance-based standard allows applicants to choose how to provide the required level of safety. This action requires airworthiness limitations to preclude the degradation of design features that prevent catastrophic fuel vapor ignition caused by lightning. Its intended effects are to align airworthiness standards with industry's and the FAA's understanding of lightning, and to address issues of inconsistency and impracticality that applicants experienced with previous lightning protection regulations.'

The FAA also published:

— Advisory Circular (AC) 25.981-1D 'Fuel Tank Ignition Source Prevention Guidelines' dated 24 September 2018;

— Advisory Circular (AC) 25.954-1 'Transport Airplane Fuel System Lightning Protection' dated 24 September 2018; and

— Advisory Circular (AC) 20-53C 'Protection of Aircraft Fuel Systems Against Vapor Ignition Caused by Lightning' dated 24 September 2018.

Item 4: Cabin safety

Item 4.1: Emergency demonstration

EASA CS-25 Appendix J on emergency demonstration does not provide a value regarding the exterior ambient light to be used.

[7] Federal Register Volume 83, Number 183

Item 4.2: References to FAA AC 25-17A

Several AMC in Book 2 of CS-25 refer to FAA Advisory Circular (AC) 25-17A. This AC was revised with Change 1 dated 24/5/2016.

Item 4.3: References to FAA AC 25-562-1B and AC 20-146

AMC 25.562 on Emergency landing dynamic conditions refers to FAA Advisory Circulars AC 25.562-1B and AC 20-146. These ACs have been respectively revised to AC 25.562-1B Change 1 and AC 20-146A.

Item 4.4: Floor surfaces – standards for friction measurement

The AMC to CS 25.793 and CS 25.810(c) currently refer to FAA AC 25-17A, which itself refers to two MIL standards for friction measurement. However, other standards exist that are acceptable to EASA.

Item 4.5: Emergency exit arrangement – naïve subject testing for the opening of passenger-operated exits

The current AMC 25.809 does not address the testing of emergency exits to be operated by passengers.

Item 4.6: Emergency egress assisting means and escape routes – deployment and inflation tests

AMC 25.810 refers to FAA AC 25-17A. However, this AC does not provide guidance on the minimum number of assisting means (slide) deployment and inflation tests to be conducted on the aeroplane.

Item 4.7: Life-preserver stowage provisions

CS 25.1411(f) requires that each life preserver must be within easy reach of each seated occupant. There is no AMC providing support for the demonstration of compliance.

Item 4.8: Emergency egress assisting means installed in non-pressurised compartments

Emergency egress assisting means that are installed in non-pressurised compartments are exposed to extremely cold conditions during flight. The exposure to very low temperatures typically has two effects on the assisting means: it reduces the energy available in pressurised cylinders used for the inflation systems of escape slides, and more energy is required to inflate the escape slide because the inflatable material is stiffer. The combination of these two effects affects the performance of the assisting means and this has to be taken into account when designing these systems. This topic is not specifically addressed in CS and AMC 25.810. Means of Compliance have been provided for this topic on certification projects in certification review items (CRIs)..

Item 4.9: Emergency evacuation

AMC 25.810(c)(2) makes reference to FAA Advisory Circular (AC) 20-38A. However, this AC was cancelled on 16 October 2017.

Item 5: Electronic AFM – computation of misleading primary information

In AMC 25.1581, Appendix 1 on 'Computerised Aeroplane Flight Manual', paragraph 6.a dealing with software integrity, the following statement is provided:

'The computation of hazardously misleading primary information such as take-off speeds, landing approach speeds, engine thrust or power, engine limit data or other related aeroplane performance data, should be improbable (as defined in CS 25.1309).'

However:

— The term 'improbable' is not defined in AMC 25.1309; this term dates back to JAA Advisory Material Joint (AMJ) 25.1309.

— Using the term 'improbable' may lead some industry stakeholders to directly make the assumption that the severity of this failure condition is consistent with a major failure condition at the aeroplane level, although a normal safety analysis could consider a more severe effect at the aeroplane level.

Item 6: On-board weight and balance systems

CS-25 does not provide a reference to an acceptable standard which may be used for the design and certification of an on-board weight and balance system.

Item 7: Air conditioning system

During the consultation of NPA 2018-05 (Regular update of CS-25 - 2018), comment 20 from the SNPL FRANCE ALPA technical committee highlighted the potential benefit of clarifying how applicants should implement the following point of the amended AMC 25.831(a) related to operating with the air conditioning system 'off':

'*There should be a means to annunciate to the flight crew that the air conditioning system is selected to 'off'*.'

In CRD 2018-05, EASA responded that a proposal would be made in the next NPA 'Regular update of CS-25'.

Item 8: Flight guidance system

At CS-25 Amendment 4 (effective 27 December 2007), CS 25.1329 was broadly amended and the following requirement was created as sub-paragraph (l):

'The autopilot must not create an unsafe condition when the flight crew applies an override force to the flight controls.'

AMC N°1 to CS 25.1329, Chapter 8.4.1 'Autopilot', provides the following:

'1) The autopilot should disengage when the flight crew applies a significant override force to the controls. The applicant should interpret "significant" as a force that is consistent with an intention to overpower the autopilot by either or both pilots. The autopilot should not disengage for minor application of force to the controls (e.g., a pilot gently bumping the control column while entering or exiting a pilot seat during cruise).

(…)

2) If the autopilot is not designed to disengage in response to any override force, then the response shall be shown to be safe (CS 25.1329 (l)). Under normal conditions, a significant transient should not

result from manual autopilot disengagement after the flight crew has applied an override force to the controls (CS 25,1239(d)).

NOTE: The term "override force" is intended to describe a pilot action that is intended to prevent, oppose or alter an operation being conducted by a flight guidance function, without first disengaging that function. One possible reason for this action could be an avoidance manoeuvre (such as responding to a ACAS/TCAS Resolution Advisory) that requires immediate action by the flight crew and would typically involve a rapid and forceful input from the flight crew.

Sustained application of an override force should not result in a hazardous condition. Mitigation may be accomplished through provision of an appropriate Alert and flight crew procedure.'

These provisions are harmonised with the equivalent FAA regulatory provisions.

A serious incident occurred on 15 December 2014 in the vicinity of Sumburgh Airport, Shetland (UK) and involved a Saab 2000, registration G-LGNO.

The aeroplane was inbound to land on Runway 27 at Sumburgh when the pilots discontinued the approach because of bad weather to the west of the airport. As the aeroplane established a southerly heading, it was struck by lightning. When the commander made nose-up pitch inputs, the aeroplane did not respond as he expected. After reaching 4 000 ft AMSL, the aeroplane pitched to a minimum of 19 ° nose down and exceeded the applicable maximum operating speed (V_{MO}) by 80 kt, with a peak descent rate of 9 500 ft/min. The aeroplane started to climb after reaching a minimum height of 1 100 ft above sea level.

Recorded data showed that the autopilot had remained engaged, contrary to the pilots' understanding, and the pilots' nose-up pitch inputs were countered by the autopilot pitch trim function, which made a nose-down pitch trim input in order to regain the selected altitude.

The investigation conducted by Air Accidents Investigation Branch (AAIB) UK concluded as follows:

'(…)the alerting system on the Saab 2000 proved ineffective in this incident. Aural and visual alerting systems are less effective in situations when a flight crew is under stress, and if the flight crew is overriding the autopilot there is a high probability that they are doing so because of an unusual and possibly stressful situation. It is questionable whether any alerting system in this incident could have raised sufficient awareness among the flight crew to cause them to disengage the autopilot manually. It would be safer if the AC and AMC did not permit mitigation via an alerting system, and instead required the autopilot to disengage following a force override. Most new airliner designs appear to be following this route.'

The following safety recommendation was issued to EASA (and the same one to the FAA):

UNKG-2016-054: 'It is recommended that the European Aviation Safety Agency amend the Acceptable Means of Compliance for Certification Specification 25.1329 to ensure that requirement 25.1329(l) can only be met if the autopilot automatically disengages when the flight crew applies a significant override force to the flight controls and the auto-trim system does not oppose the flight crew's inputs.'

Item 9: Primary flight displays during unusual attitude and declutter modes

The investigation of the accident to Bombardier CL-600-2B19, registration SE-DUX, in Sweden, on 8 January 2016, found that the erroneous attitude indication on primary Flight Display (PFD) 1 was caused by a malfunction of Inertial Reference Unit (IRU) 1. The pitch and roll comparator indications of the PFDs were removed when the attitude indicators displayed unusual attitudes (PFD declutter function in unusual attitude).

The following safety recommendation was addressed to EASA:

SR SWED-2016-005: 'EASA is recommended to ensure that the design criteria of PFD units are improved in such a way that pertinent cautions are not removed during unusual attitude or declutter modes. *(RL 2016:11 R3)*'.

Item 10: Lightning protection and electrical bonding and protection against static electricity

The references to industry standards used in AMC 25.581 (Lightning protection) and AMC 25.899 (Electrical Bonding and Protection Against Static Electricity) are not at the last revisions and, therefore, need to be amended. EASA has provided recurrent means of compliance in CRIs to allow applicants to use more recent revisions of these standards.

Furthermore, some acceptable industry standards are missing from these AMCs. Such standards have been provided to applicants in a generic interpretative material CRI entitled 'Lightning protection direct effects'.

Item 11: Operation without normal electrical power

EASA currently uses a generic means of compliance CRI that complements the content of AMC 25.1351(d). Such a generic CRI causes an administrative burden to the applicants and EASA.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 1 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Section 2.1.

The specific objective of this proposal is to amend CS-25 based on the above selection of non-complex, non-controversial, and mature subjects, with the ultimate goal being to increase safety.

2.3. How we want to achieve it — overview of the proposals

Item 1: Go-around handling qualities and performance

a) CS 25.143(b)(2) – Sudden failure of the second critical engine

The existing CS 25.149(g) specifications are considered sufficient to address the effect of a second engine failure before or during approach.

EASA therefore agrees with the FTHWG proposal to remove 'go-around' from CS 25.143(b)(2).

b) AMC 25.101(g) – Go-around with OEI

The FTHWG recommended a text change to amend AMC 25.101(g). EASA proposes to implement it.

c) AMC 25.143(b)(4) – Go-around manoeuvres

The FTHWG proposed changes to clarify the fact that longitudinal acceleration effects might be the main contributors to the vertigo effect experienced by flight crews during high thrust/weight ratio go-arounds. EASA proposes to implement this recommendation.

Item 2: Minimum control speeds

EASA proposes to amend AMC 25.149(f) and (g) in harmonisation with the corresponding section of FAA AC 25-7D.

Item 3: Fuel tank and system lightning protection

EASA proposes to amend CS 25.954, CS 25.981, AMC 25.954, AMC 25.981 in harmonisation with the FAA documents mentioned above in Chapter 2.1.

Item 4: Cabin safety topics

Item 4.1: Emergency demonstration

FAA Part 25 Appendix J requires that emergency evacuation tests are conducted with exterior ambient light levels not exceeding 0.3 foot-candles prior to the activation of the aeroplane emergency lighting system. EASA has accepted this value during certification projects.

Therefore, EASA proposes to amend CS-25 Appendix J, paragraph (a) to harmonise with the corresponding FAA Part 25 Appendix J paragraph (a).

Item 4.2: References to FAA AC 25-17A

EASA proposes to update the references in CS-25 to FAA Advisory Circular (AC) 25-17A and replace these by references to AC 25-17A Change 1, dated 24.5.2016, which is the current version of the AC.

Item 4.3: References to FAA AC 25-562-1B and AC 20-146

EASA proposes to update the references to AC 25.562-1B and to AC 20-146 and replace these by references to AC 25.562-1B Change 1 and AC 20-146A respectively.

Item 4.4: Floor surfaces – standards for friction measurement

EASA proposes to revise the AMC to CS 25.793 and CS 25.810(c) to introduce a list of standards for friction measurement accepted by EASA in certification projects.

Item 4.5: Emergency exit arrangement – naïve subject testing for the opening of passenger-operated exits

EASA proposes to create AMC to 25.809(c) and (e) to address naïve subject testing for the opening of passenger-operated exits, reflecting the current and past practice for certification of this type of exit.

Item 4.6: Emergency egress assisting means and escape routes – deployment and inflation tests

EASA proposes to create AMC 25.810(a)(1)(v) to indicate that at least one test should be conducted on the aeroplane (compatibility test), thereby reflecting what has been performed during EASA certification projects.

Item 4.7: Life-preserver stowage provisions

EASA proposes to create AMC 25.1411(f) to introduce the retrievability testing procedure currently included in ETSO-C127b (aircraft seating systems) for all life vest container installations. New life vest retrieval standards were introduced in this ETSO taking into account the lessons learned from the accident to Airbus A320 registration N106US, on 15.1.2009, on the Hudson River (USA).

Item 4.8: Emergency assisting means installed in non-pressurised compartments

EASA proposes to amend AMC 25.810 to ensure that applicants take into account the effect of in-flight very low temperature conditions affecting the performance of emergency assisting means installed in non-pressurised compartments. The content of the previously issued CRI (MoC) has been taken into account.

Item 4.9: Emergency evacuation

EASA proposes to delete the reference to FAA Advisory Circular (AC) 20-38A in AMC 25.810(c)(2).

Item 5: Electronic AFM – computation of misleading primary information

EASA proposes to replace the above mentioned text in AMC 25.1581, Appendix 1, paragraph 6.a by a new statement reflecting the need to assess the potential safety effect at the aeroplane level, and use this assessment as a basis when determining the AFM software architecture and level of integrity.

Item 6: On-board weight and balance systems

EUROCAE published document ED-263 ‘Minimum Operational Performance Standard for Onboard Weight and Balance Systems’ dated June 2019.

ED-263 may be used by applicants and EASA to support the design and certification of on-board weight and balance systems (OBWBS) on CS-25 large aeroplanes. The standard addresses Class II OBWBS, i.e. advisory systems which are used by the flight crew for comparison with the gross weight and centre of gravity information provided to them by ground operations services (e.g. load sheets).

EASA proposes to add a reference to this standard in CS-25 by creating a new AMC.

Item 7: Air conditioning system

EASA proposes to clarify in AMC 25.831(a) that an indication of the status of the system is not sufficient, but that an alert should be triggered after the end of the allowed limited time period if the air conditioning system is still in the 'off' position.

Item 8: Flight guidance system

EASA reviewed AMC N°1 to CS 25.1329 in cooperation with the FAA (review of AC 25.1329 at Change 1) while considering the AAIB UK report and safety recommendation mentioned in 2.1 above.

EASA proposes to amend AMC N°1 to CS 25.1329 in order to:

— Address the safety recommendation regarding the automatic trim response during a pilot override. Although it is not accepted that compliance with CS 25.1329(l) can only be shown if the autopilot automatically disengages, it is proposed to provide clarification with regard to potential hazards for systems without automatic disengagement: the automatic trim should not oppose the flight crew's commands in any manner that would result in unacceptable aeroplane motion, and mitigation may be accomplished through the provision of an appropriate alert and flight crew procedure, and

— Bring clarification regarding the autopilot disengagement aural alert: it should sound for at least a single cycle even when the autopilot is disengaged by a pilot.

Item 9: Primary flight displays during unusual attitude and declutter modes

EASA proposes to amend AMC 25-11 to clarify that some alerts should remain visible when the primary flight displays declutter. Guidance is therefore proposed to indicate that any fault that can contribute to, or cause, misleading presentations of primary flight information, should have its failure message, flag, or comparative monitoring alert, remain on the primary flight display or in the primary field of view during declutter modes, to prevent it being masked or removed.

Item 10: Lightning protection and electrical bonding and protection against static electricity

EASA proposes to amend AMC 25.581 and AMC 25.899 in order to refer to the current revisions of the mentioned industry standards, and to add other industry standards that are accepted by EASA.

Item 11: Operation without normal electrical power

EASA proposes to introduce the content of the generic means of compliance CRI into the existing AMC 25.1353(d).

2.4. What are the expected benefits and drawbacks of the proposals

The proposed amendments reflect the state of the art of large aeroplane certification and improve the harmonisation of CS-25 with the FAA regulations. Overall, this would provide a moderate safety benefit, would have no social or environmental impacts, and would provide some economic benefits by streamlining the certification process.

3. Proposed amendments and rationale in detail

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in blue;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1. Draft Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (Draft EASA Decision amending CS-25)

Item 1: Go-around handling qualities and performance

It is proposed to remove 'go-around' from CS 25.143(b)(2), as the existing CS 25.149(g) specifications are considered sufficient to address the effect of a second engine failure before or during approach.

Amend CS 25.143(b) as follows:

CS 25.143 General
(…)

(b) (See AMC 25.143(b) and (b)). It must be possible to make a smooth transition from one flight condition to any other flight condition without exceptional piloting skill, alertness, or strength, and without danger of exceeding the aeroplane limit-load factor under any probable operating conditions, including:

(…)

(2) For aeroplanes with three or more engines, the sudden failure of the second critical engine when the aeroplane is in the en-route, approach, ~~go-around,~~ or landing configuration and is trimmed with the critical engine inoperative;

(…)

It is proposed to amend AMC 25.143(b)(4) to better reflect the fact that longitudinal acceleration effects might be the main contributors to the vertigo effect experienced by flight crews during high thrust/weight ratio go-arounds.

Amend AMC 25.143(b)(4) as follows:

AMC 25.143(b)(4)
Go-around Manoeuvres
(…)

2.1 Somatogravic illusions

It is considered that the risk of a somatogravic illusion is high when encountering high longitudinal acceleration ~~single~~ or combined high values of pitch attitude (nose-up), pitch rate and longitudinal acceleration, associated with a loss of outside visual references.

(…)

It is proposed to amend AMC 25.101(g) to provide guidance with respect to acceptable go-around flight profiles, as follows:

AMC 25.101(g)

Go-around

~~In showing compliance with CS 25.101(g), it should be shown at the landing weight, altitude and temperature (WAT) limit, by test or calculation, that a safe go-around can be made from the minimum decision height with:~~

~~— the critical engine inoperative and, where applicable, the propeller feathered,~~

~~— a configuration and a speed initially set for landing and then in accordance with the go-around procedures, using actual time delays and, except for movements of the primary flying controls, not less than 1 second between successive crew actions,~~

~~— the power available,~~

~~— the landing gear selection to the 'up' position being made after a steady positive rate of climb is achieved.~~

~~It should be noted that for Category 3 operation, the system will ensure the aircraft is over the runway, so any go-around will be safe with the aircraft rolling on the runway during the manoeuvre. Hence, AMC 25.101 (g) is only relevant to or necessary for decision heights down to Category 2 operations.~~

1. General

CS 25.101(g) requires that procedures for the execution of balked landings and missed approaches associated with the conditions prescribed in CS 25.119 and CS 25.121(d) must be established. Also, as required by CS 25.1587(b)(4), each AFM must contain the procedures established under CS 25.101(g), including any relevant limitations or information in the form of guidance material. The landing climb gradient determined under CS 25.119 conditions, the approach climb gradient determined under CS 25.121(d) conditions, and the additional operating limitations regarding the maximum landing weight established in accordance with CS 25.1533(a)(2) must be consistent with the established balked landing and missed approach procedures (CS 25.101(g)) provided in the aeroplane flight manual (AFM). In order to demonstrate the acceptability of the recommended missed approach and balked landing procedures, the applicant should conduct demonstrations (by flight test or pilot-in-the-loop simulator tests) to include a one engine inoperative go-around at a weight, altitude, temperature (WAT)-limited or simulated WAT-limited thrust or power condition.

The applicant should conduct the demonstrations at WAT-limited conditions that result in the greatest height loss and/or longest horizontal distance to accelerate to the scheduled approach climb speed. Alternatively, the applicant may conduct testing at simulated WAT-limited conditions (with reduced thrust or power on the operating engine) and use the resulting time delays for each crew action in a subsequent off-line simulation/analysis in accordance with the procedures below. Although compliance with CS 25.101(g) and (h) and CS 25.121(d) are not directly linked with the criteria for the approval of weather minima for approach, the minimum decision height for initiating a go-around is dependent upon the weather minima to be approved. In addition, a steeper climb gradient and the associated lower WAT-limited landing weight may be associated with CAT II operations. As such, if CAT II weather minima approval is expected, the applicant should conduct the go-around demonstration and/or analysis consistent with both CAT I and II operations for the associated decision height and WAT-limited thrust or power condition (or a critical combination thereof).

2. Procedures

The go-around demonstration specified in Chapter 1 of this AMC can be conducted at an altitude above the normal decision height/altitude (for test safety), with the height loss in the manoeuvre used to show that ground contact prior to the runway threshold would not occur if the manoeuvre was initiated at the decision height/altitude. Flight testing, simulation and/or analysis at a range of (WAT limit or simulated WAT limit) conditions throughout the approved envelope should be conducted to assess the height loss relative to the decision height/altitude consistent with the criteria for the weather minima to be approved (or higher as constrained by AFM limitations). At least one flight test or pilot-in-the-loop simulator test should be conducted at a WAT-limited condition to assess the OEI go-around procedure and establish the time delays used for any subsequent analysis/simulation.

In addition, the assessment of the go-around procedure should include consideration of the horizontal distance (based upon the minimum go-around trajectory) needed to establish the minimum engine-out climb gradient required by CS 25.121(d) or a steeper gradient as required by specific weather minima operational criteria. It should be shown by flight test, simulation and/or analysis that the aeroplane would remain above the profile illustrated in Figure 1 below when the go-around is evaluated at the critical WAT limit condition (up to the structural maximal landing weight) and flown in accordance with the one-engine-inoperative (OEI) go-around procedure.

This provides a minimum design standard trajectory for a missed approach with one engine inoperative and does not constitute a means to ensure obstacle clearance. It does not preclude additional missed approach procedures that may be developed to satisfy operational requirements, including special or complex missed approach path requirements. The operator should seek approval from their national aviation authority to use the additional procedures and data.

(a) In accordance with CS 25.101(h), the established procedures for executing balked landings and missed approaches must:

(i) Be able to be consistently executed in service by crews of average skill,

(ii) Use methods or devices that are safe and reliable, and

(ii) Include allowance for any time delays in the execution of the procedures that may reasonably be expected in service (including the recovery of full go-around thrust or power if equipped with a reduced go-around (RGA) thrust or power function that requires manual override), but should not be less than one second between successive flight crew actions, except for movements of the primary flying controls.

(b) The flight test demonstration(s), simulation and/or analysis should be made with:

(i) All engines operating (AEO) and the thrust or power initially set for a 3 degree approach, and the configuration and final approach airspeed consistent with the AEO landing procedure (not more than V_{REF} + 5 kt) in zero wind conditions,

(ii) Application of available go-around thrust or power at the selected go-around height (initially the RGA thrust or power level, if so equipped, followed by either automatic or manual selection of full go-around thrust or power in accordance with the established missed approach and engine failure AFM procedures) with simultaneous failure of the critical engine (or with a simulated engine failure, including the effects on dependent systems), and

(iii) The high lift system, pitch attitude, engine/propeller controls and airspeed adjusted to achieve the conditions consistent with CS 25.121(d), in accordance with the established missed approach and engine failure AFM procedures. The landing gear should be selected to the 'up' position only after a positive rate of climb is achieved. If the use of automatic features (autopilot, auto-throttle, flight director, etc.) is included in the procedure, these features should be considered during the demonstration.

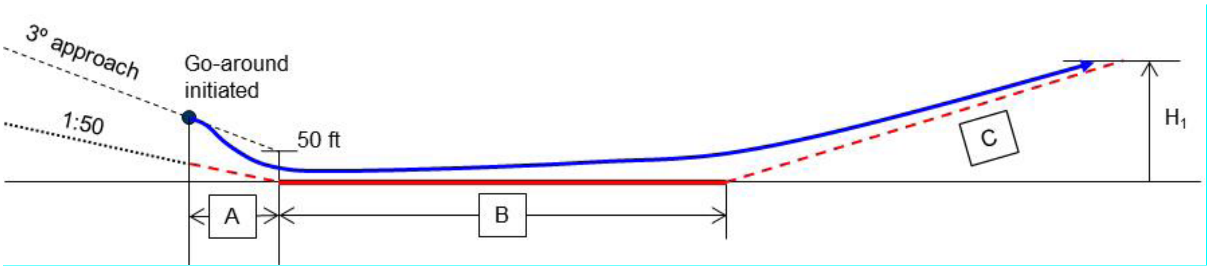


Figure 1. Trajectory Assessment for OEI Go-around

Segment A: From the initiation of go-around at the decision height/altitude to the runway threshold – remain above a 1:50 (2.0 %) plane extended to the runway threshold for clearance of airport obstacles.

Segment B: From the runway threshold plus a distance defined by 40 seconds * V_{T_appr}, not more than the distance indicated in the table below – remain above ground height.

Field Elevation (ft)	**Distance (ft)**
0-3 048 m (0-10 000 ft)	3 048 m (10 000 ft)
>3 048 m (> 10 000 ft)	= Field Elevation

Segment C: A straight line from the end of Segment B at ground height with a gradient defined by CS 25.121(d)(1) or a steeper gradient as required by specific weather minima operational criteria, up to a height, H1 – remain above the line.

Where:

V_{T_appr} is the true airspeed for the normal recommended AEO approach speed in zero wind at the flight condition being assessed (not more than V_{REF} + 9.3 km/h (5 kt) CAS).

H_1 is the height above the runway elevation where the aeroplane has achieved the approach climb configuration and stabilised on the approach climb speed out of ground effect (1x the wing span), not less than the height at which the go-around was initiated.

Item 2: Minimum control speeds

It is proposed to amend AMC 25.149(f) and (g) to harmonise with the corresponding section of FAA Advisory Circular AC 25-7D, because the current AMC 25.149 does not provide an expanded definition or test technique guidance for the determination of V_{MCL} and V_{MCL-2}.

Amend AMC 25.149(f) as follows:

AMC 25.149(f)
Minimum Control Speeds during Approach and Landing (V_{MCL})

(a) CS 25.149(f) is intended to ensure that the aeroplane is safely controllable following an engine failure during an all-engines-operating approach and landing. From a controllability standpoint, the most critical case usually consists of an engine failing after the power or thrust has been increased to perform a go-around from an all-engines-operating approach.

(b) To determine V_{MCL}, the flap and trim settings should be appropriate to the approach and landing configurations, the power or thrust on the operating engine(s) should be set to the go-around power or thrust setting, and compliance with all V_{MCL} requirements of CS 25.149(f) and (h) must be demonstrated.

~~1~~ (c) At the option of the applicant, a one-engine-inoperative landing minimum control speed, $V_{MCL\ (1\ out)}$, may be determined in the conditions appropriate to an approach and landing with one engine having failed before the start of the approach. In this case, only those configurations recommended for use during an approach and landing with one engine inoperative need be considered. The propeller of the inoperative engine, if applicable, may be feathered throughout.

~~2~~ The resulting value of $V_{MCL\ (1\ out)}$ may be used in determining the recommended procedures and speeds for a one-engine-inoperative approach and landing.

Amend AMC 25.149(g) as follows:

AMC 25.149(g)
Minimum Control Speed~~s~~ with Two Inoperative Engines during Approach and Landing (V_{MCL-2})

(a) For aeroplanes with three or more engines, V_{MCL-2} is the minimum speed for maintaining safe control during the power or thrust changes that are likely to be made following the failure of a second critical engine during an approach initiated with one engine inoperative.

(b) In accordance with CS 25.149(g)(5) for propeller-driven aeroplanes, the propeller of the engine that is inoperative at the beginning of the approach may be in the feathered position. The propeller of the more critical engine must be in the position it automatically assumes following an engine failure.

(c) Tests should be conducted using either the most critical approved one-engine-inoperative approach or landing configuration (usually the minimum flap deflection), or at the option of the applicant, each of the approved one-engine-inoperative approach and landing configurations. The following demonstrations should be conducted to determine V_{MCL-2}:

(1) With the power or thrust on the operating engines set to maintain a -3 ° glideslope with one critical engine inoperative, the second critical engine is made inoperative and the remaining operating engine(s) are advanced to the go-around power or thrust setting. The V_{MCL-2} speed is established with the flap and trim settings appropriate to the approach and landing configurations, the power or thrust on the operating engine(s) set to the go-around power or thrust setting, and compliance with all the V_{MCL-2} requirements of CS 25.149(g) and (h) must be demonstrated.

(2) With the power or thrust on the operating engines set to maintain a -3 ° glideslope, with one critical engine inoperative:

(i) Set the airspeed at the value determined in paragraph (c)(1) above and, with a zero bank angle, maintain a constant heading using trim to reduce the control force to zero. If full trim is insufficient to reduce the control force to zero, full trim should be used, plus control deflection as required; and

(ii) Make the second critical engine inoperative and retard the remaining operating engine(s) to minimum available power or thrust without changing the directional trim. The V_{MCL-2} determined in paragraph (c)(1) is acceptable if a constant heading can be maintained without exceeding a 5 ° bank angle and the limiting conditions of CS 25.149(h).

(iii) Starting from a steady straight flight condition, demonstrate that sufficient lateral control is available at V_{MCL-2} to roll the aeroplane through an angle of 20 ° in the direction necessary to initiate a turn away from the inoperative engines in not more than five seconds. This manoeuvre may be flown in a bank-to-bank roll through a wings-level attitude.

~~1~~ (d) At the option of the applicant, a two-engine-inoperative landing minimum control speed, $V_{MCL-2\ (2\ out)}$ may be determined in the conditions appropriate to an approach and landing with two engines having failed before the start of the approach. In this case, only those configurations recommended for use during an approach and landing with two engines inoperative need be considered. The propellers of the inoperative engines, if applicable, may be feathered throughout.

~~2~~ The values of V_{MCL-2} or $V_{MCL-2\ (2\ out)}$ should be used as guidance in determining the recommended procedures and speeds for a two-engine~~s~~-inoperative approach and landing.

Item 3: Fuel tank and system lightning protection

It is proposed to amend CS 25.954, CS 25.981, AMC 25.954, AMC 25.981 in order to harmonise them with the FAA final rule [Docket No. FAA-2014-1027; Amendment No. 25-146], which amends paragraphs §25.954, §25.981, and Appendix H to Part-25, and with the corresponding Advisory Circulars (AC) 25.981-1D 'Fuel Tank Ignition Source Prevention Guidelines' dated 24 September 2018, and AC 25.954-1 'Transport Airplane Fuel System Lightning Protection' dated 24 September 2018,

Amend CS 25.954 by replacing its content with the following text:

CS 25.954 Fuel system lightning protection

(See AMC 25.954)

(a) For the purposes of this paragraph—

(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.

(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.

(b) The design and installation of a fuel system must prevent catastrophic fuel vapour ignition due to lightning and its effects, including:

(1) Direct lightning strikes to areas having a high probability of stroke attachment;

(2) Swept lightning strokes to areas where swept strokes are highly probable; and

(3) Lightning-induced or conducted electrical transients.

(c) To comply with sub-paragraph (b) of this paragraph, catastrophic fuel vapour ignition must be extremely improbable, taking into account the flammability, critical lightning strikes, and failures within the fuel system.

(d) To protect design features that prevent catastrophic fuel vapour ignition caused by lightning, the type design must include critical design configuration control limitations (CDCCLs) identifying those features and providing information to protect them. To ensure the continued effectiveness of those design features, the type design must also include inspection and test procedures, intervals between repetitive inspections and tests, and mandatory replacement times for those design features used in demonstrating compliance with sub-paragraph (b) of this paragraph. The applicant must include the information required by this sub-paragraph in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by CS 25.1529.

Amend CS 25.981 as follows:

CS 25.981 Fuel tank ~~ignition~~ explosion prevention

(See AMC 25.981)

(a) (…)

(3) ~~Demonstrating that an ignition source does not result from each single failure and from all combinations of failures not shown to be Extremely Improbable as per 25.1309. (See AMC 25.981(a))~~

Except for 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.

(…)

(d) ~~Critical design configuration control limitations (CDCCL), inspections, or other procedures must be established, as necessary, to prevent development of ignition sources within the fuel tank system pursuant to subparagraph (a) of this paragraph, to prevent increasing the flammability exposure of the tanks above that permitted under subparagraph (b) of this paragraph, and to prevent degradation of the performance and reliability of any means provided according to subparagraphs (a) or (b)(4) of this paragraph. These CDCCL, inspections, and procedures must be included in the Airworthiness Limitations Section of the instructions for continued airworthiness required by CS 25.1529. Visible means of identifying critical features of the design must be placed in areas of the aeroplane where foreseeable maintenance actions, repairs, or alterations may compromise the critical design configuration control limitations (e.g., colourcoding of wire to identify separation limitation). These visible means must also be identified as CDCCL.~~

To protect design features that prevent catastrophic ignition sources within the fuel tank or fuel tank system according to sub-paragraph (a) of this paragraph, and to prevent increasing the flammability exposure of the tanks above that permitted in sub-paragraph (b) of this paragraph, the type design must include critical design configuration control limitations (CDCCLs) identifying those features and providing instructions on how to protect them. To ensure the continued effectiveness of those features, and prevent degradation of the performance and reliability of any means provided according to sub-paragraphs (a) or (b) of this paragraph, the type design must also include the necessary inspection and test procedures, intervals between repetitive inspections and tests, and mandatory replacement times for those features. The applicant must include information required by this sub-paragraph in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by CS 25.1529. The type design must also include visible means of identifying critical features of the design in areas of the aeroplane where foreseeable maintenance actions, repairs, or alterations may compromise the CDCCLs.

Amend Appendix H as follows:

Appendix H

Instructions for Continued Airworthiness

(…)

H25.4 Airworthiness Limitations Section

(a) (…)

(2) ~~Reserved~~ Each mandatory replacement time, inspection interval, related inspection procedure, and all the critical design configuration control limitations approved under CS 25.981 for the fuel tank system.

(…)

(6) Each mandatory replacement time, inspection interval, and related inspection and test procedure, and each critical design configuration control limitation for each lightning protection feature approved under CS 25.954.

Amend AMC 25.954 by replacing its content with the following text:

AMC 25.954

Fuel System Lightning Protection

1 PURPOSE

This AMC describes the tasks that should be accomplished to show compliance with CS 25.954 for lightning protection of the aeroplane fuel system. These tasks may be accomplished in a different order than that listed below, and some tasks may require iterations.

This AMC also provides a method of compliance appropriate for reliable fault-tolerant and non-fault-tolerant protection for lightning ignition sources. Any non-fault-tolerant lightning protection in an aeroplane fuel system will, in order to comply with the method of compliance set forth in this AMC, need a thorough assessment for the likelihood of failures, lightning strikes and attachment locations, and fuel tank flammability.

2 APPROACH TO COMPLIANCE

2.1 Summary

The method in this AMC divides the design features for fuel system lightning protection into three categories: intrinsically safe, fault tolerant, and non-fault tolerant. It also describes how applicants should develop material for the Airworthiness Limitations Section of the ICA.

2.1.1 Guidance for incorporating intrinsically safe design features into the fuel tank system is provided in paragraph 2.9.4.1.

2.1.2 Section 3 provides guidance on compliance with CS 25.954(b) for fault-tolerant lightning protection designs.

2.1.3 Section 4 provides guidance on compliance with CS 25.954(b) for non-fault-tolerant lightning protection designs.

2.1.4 Section 5 provides guidance on developing CDCCLs and other tasks that must be placed in the Airworthiness Limitation Section of the ICA.

2.2 Compliance tasks

The applicant should accomplish the following tasks to comply with CS 25.954:

— Identify the design features and elements of the fuel system that require lightning assessment (paragraph 2.3);
— Determine the lightning strike zones (paragraph 2.4);
— Establish the aeroplane lightning environment (paragraph 2.5);
— Develop a lightning protection approach and design lightning protection features (paragraph 2.6);
— Identify the potential failures of the design and protection features (paragraph 2.7);
— Identify the potential ignition sources associated with the design features and potential failures (paragraph 2.8);
— Perform a safety assessment to determine fault tolerance and non-fault tolerance (paragraph 2.9);
— Provide reliable fault-tolerant protection for lightning ignition sources (paragraph 3);
— Assess non-fault-tolerant protection for lightning ignition sources (paragraph 4); and
— Establish the airworthiness limitations (paragraph 5).

2.3 Identify the design features and elements of the fuel system that require lightning assessment

To comply with CS 25.954(b), the applicant should identify the fuel system design features and elements for the fuel tank structure, system components, and equipment that require lightning assessment to show that the ignition of fuel vapour within the systems due to lightning and its effects is prevented. The design features and elements may be categorised into design groups that share characteristics that have similar lightning protection performance. The applicant should provide a detailed description of the fuel system, including:

— Structural members and fasteners exposed to direct and swept lightning attachment;
— Structural joints and fasteners exposed to conducted-lightning current resulting from lightning attachment;
— Access doors, vents, drain valves, fuel filler ports, and other parts and components of the fuel system exposed to direct lightning attachment or conducted lightning currents; and
— Electrical, mechanical, hydraulic, and fuel plumbing system installations within the fuel tank or connected to the fuel tanks exposed to direct lightning attachment or conducted lightning current.

2.4 Determine the lightning strike zones

Lightning strike zones define locations on the aeroplane where lightning is likely to attach and structures that will conduct lightning current between lightning attachment points. The applicant should determine the lightning strike zones for the aeroplane configuration, since the zones will be dependent upon the aeroplane geometry and operational factors. Lightning strike zones often vary from one aeroplane type to another.

EUROCAE document ED-91A, 'Aircraft Lightning Zoning', dated January 2019 and the equivalent SAE ARP5414B dated December 2018, are acceptable standards providing guidelines on determining the lightning strike zones for the aeroplane, the areas of direct lightning strikes, areas of swept lightning strokes, and areas of conducted electrical transients. When determining the probability of lightning attachment to certain regions of the aeroplane, applicants should use data from similar aeroplane configurations to substantiate any assumed strike attachment rate for the region.

2.5 Establish the aeroplane lightning environment

The fuel tank structure, system components, and equipment that are located in lightning zones 1 and 2 should be designed for lightning direct-attachment waveforms. EUROCAE document ED-84A, 'Aircraft Lightning Environment and Related Test Waveforms', dated July 2013, and the equivalent SAE ARP5412B dated January 2013, are acceptable standards providing guidelines on acceptable lightning current and voltage waveforms for lightning zones 1 and 2. The fuel tank structure, system components, and equipment that are exposed to conducted currents should be assessed to determine the appropriate lightning current and voltage waveforms and amplitudes, using the conducted current waveforms for zone 3 in EUROCAE ED-84A/SAE ARP5412B. The applicant may use analyses or tests to assess the conducted currents and voltages for the structure, system components, and equipment. Margins should account for any uncertainty of the analysis or test. Simple analyses of the lightning currents and voltages should incorporate larger margins than the lightning currents and voltages that were calculated using detailed computational models that have been validated by tests.

2.6 Develop a lightning protection approach and design lightning protection features

The applicant should develop the lightning protection approach and design lightning protection features required to provide effective lightning protection for all the fuel system design features and elements identified in paragraph 2.3 of this AMC. See paragraphs 3.2 and 4.1.2 for further guidelines on how to demonstrate an effective protection. The lightning protection features can include specific installation requirements, such as hole-size tolerance for fasteners or surface cleaning for sealant application. Other lightning protection features can include specific protection components, such as metal mesh incorporated into the outer surface of composite structures. The design should provide reliable lightning protection that prevents lightning–related ignition sources if a potential failure occurs in the lightning protection features. When possible, the design should place fuel system components—such as fuel tank vents, drain valves, jettison tubes, filler ports, and access doors—in lightning attachment zone 3, so they are less likely to be exposed to direct lightning attachment.

2.7 Identify potential failures of the design and protection features

2.7.1 The applicant should:

— identify potential failures, due to causes that include manufacturing escapes*, operational deterioration**, and accidental damage***, that may lead to the loss or degradation of lightning protection;

— identify design elements that could degrade the effectiveness of lightning protection through analysis or test;
— identify failures through detailed review of manufacturing processes, material properties, structural design, systems design, and reliability and maintainability processes;
— use available manufacturing discrepancy reports, in-service failure reports, and developmental tests to identify potential failures; and
— account for failures such as structural cracking, corroded or failed electrical bonding features, and mis-installed electrical bonding features that occur during manufacturing or maintenance.

**Manufacturing escapes for fuel tank structure include fastener selection issues (incorrect fastener sizes, types, finishes, or coatings), fastener assembly issues (misalignment, incorrect torque, hole size or quality, missing or extra washers), and installation issues (inadequate or improperly adhered sealant, missing cap seals, incorrectly installed electrical bonds). Manufacturing escapes for fuel system components and equipment include design configuration issues (incorrect fasteners, wrong or missing clamps or brackets, inadequate or improperly adhered sealant, missing or incorrect finishes), bonding issues (a missing or improperly installed electrical bond or wiring shield), and clearance issues (insufficient tube or wiring clearance to adjacent systems or structure)*.

***Structural failures due to operational deterioration during intended operation include broken or cracked elements (fasteners or washers), corrosion, degradation of applied materials (sealants, fastener head coating, edge glow protection, or bonded joints), and fatigue issues (loose fasteners or structural cracks). System failures due to operational deterioration include failures of support features (loss of fasteners, brackets, or clamps that support tubes, EWIS or components) and degradation of electrical bonds, wire insulation or shielding due to corrosion, ageing, or wear*.

****Structure or system failures due to accidental damage include impact from foreign object debris (FOD) or inadvertent damage incurred during alterations, repairs, or inspections*.

2.7.2 The severity or types of failures should be defined and can be based on service history, where appropriate, and laboratory test data. The failure severity should be consistent with or bounded by the assumptions made for the structural and systems certification analyses. The severity or types of failures due to manufacturing escapes should be based on manufacturing discrepancy reports, such as rejection tags, manufacturing process escape assessments, and assessments of process improvements.

2.7.3 Manufacturing variability and environmental conditions should be considered in conjunction with failures. Combining worst-case conditions for all manufacturing variabilities and environmental conditions is overly conservative and not necessary. Failures due to operating or environmental conditions other than those required for certification need not be considered. Combinations of failures where one failure also causes a second failure to occur should be considered as a single failure condition (i.e., a common cause or cascading failure).

2.8 Identify potential ignition sources associated with the design features and potential failures.

2.8.1 Fuel system fasteners, structure, equipment, and components that are exposed to direct lightning attachment in lightning zones 1 and 2 should be assessed using the lightning waveforms identified in paragraph 2.5 of this AMC. Fuel system fasteners, structure, equipment, and components should also be assessed for conducted lightning currents. If the aeroplane uses novel or unusual materials, structure, or configurations, the applicant should evaluate the fuel system fasteners, structure, equipment, and components on the outside surface of the aeroplane located in lightning zone 3 using the nominal zone 3 direct lightning attachment waveforms defined in EUROCAE ED-84A/SAE ARP5412B. The use of materials for fuel tank structure that are not highly conductive is considered unusual. Lightning attachment in zone 3 is defined as unlikely in EUROCAE document ED-91A, 'Aircraft Lightning Zoning', dated January 2019 and the equivalent SAE ARP5414B dated December 2018, so the evaluation need not consider failures in combination with such an attachment, but should demonstrate that no catastrophic effect will occur when no failures are present.

2.8.2 The following paragraphs list ignition source types and examples of how ignition sources might occur:

2.8.2.1 Voltage sparks are the result of the electrical breakdown of a dielectric between two separated conductors. Voltage sparking might occur, for example, between the fastener and its hole or through an insulation layer between the base of a nut and a conductive surface. A voltage spark could occur between a fuel tube and the adjacent structure if the separation is insufficient or the bonding to minimise the voltage potential has failed. If this spark is exposed to fuel vapour, an ignition may result. Laboratory tests have shown that the minimum ignition energy in a voltage spark required to ignite hydrocarbon fuel vapour is 200 microjoules*.

** The 200-microjoule level comes from various sources. The most quoted is from Lewis and von Elbe's book, Combustion, Flames and Explosions of Gases (Florida: Academic Press, Inc., 1987; (orig. publ. 1938)). It has a set of curves for minimum ignition energy for the various hydrocarbon compounds in jet fuel, and they all have similar minimum ignition energy levels of greater than 200 microjoules*.

2.8.2.2 Thermal sparks are the result of burning particles emitted by the rapid melting and vaporisation of conductive materials carrying current through a point contact. Thermal sparks can occur when there is a small contact area between a fastener and the hole material, or between a fastener collar and the underlying structure. Thermal sparks can occur at a point contact between a fuel tube and the adjacent structure if the contact point conducts a high current. When sealant or caps are used to contain sparks, failures could result in the internal pressures from the heat of thermal sparks that force hot particles past the sealant or cap, resulting in sparks in the fuel vapour area.

2.8.2.3 Analyses and tests indicate that a small piece of steel wool will ignite a flammable mixture when a transient current of approximately 100 milliamperes (mA) peak is applied to the steel wool*.

** This data was from testing performed by the FAA Technical Center, Report DOT/FAA/AR-TN05/37, Intrinsically Safe Current Limit Study for Aircraft Fuel Tank Electronics. Applicants may conduct testing to substantiate alternate values*.

2.8.2.4 Edge glow includes voltage or thermal sparks that occur at the edges of carbon-fibre composite material when lightning current and voltage cause a breakdown of the resin between fibres. Failures of the protection features to prevent edge glow should be identified.

2.8.2.5 Fuel vapour ignition due to lightning near fuel vent outlets can result in flame propagation into the fuel system. When lightning attaches near fuel vent outlets, ignition of fuel vapour results in a high-speed pressure wave that can travel through the flame arrestor without sufficient time for the flame arrestor to quench the flame front. The vent outlets should be located outside the lightning direct-attachment zones of the aeroplane. If the vent outlets are located in lightning direct-attachment zones, flame arrestors have been used to prevent lightning-ignited fuel vapour from propagating into the fuel system. Specific lightning tests and unique design features are typically needed to demonstrate the lightning-protection effectiveness for these installations. (Lightning effects are not addressed in the fuel tank vent fire protection requirements of CS 25.975(a)(7).

2.9 Perform a safety assessment to determine fault tolerance and non-fault tolerance

2.9.1 The applicant should perform a safety assessment to determine whether the fuel system design provides acceptable fuel system lightning protection based on the design features and potential ignition sources due to failures of the design features identified in the previous steps. The applicant may perform the safety assessment on groups of fuel system design elements and lightning protection features with similar physical and electrical characteristics. For non-fault-tolerant features, an assessment must show, per CS 25.954(c), that the sum of the probability of failures from potential ignition sources in combination with the probability of a critical lightning strike and the fuel tank being flammable does not exceed extremely improbable. The applicant should provide its rationale for assigning design elements and lightning protection into groups.

2.9.2 The safety assessment should address all the fuel system design elements identified in paragraph 2.3 of this AMC, the lightning environment at the locations for those elements identified in paragraphs 2.4 and 2.5 of this AMC, and the failures identified in paragraph 2.7 of this AMC. The applicant should also use the safety assessment to identify where analyses or tests are necessary to demonstrate the prevention of fuel system ignition sources.

2.9.3 The applicant should use a rigorous and structured safety assessment approach. The structured safety assessment and associated fault-tolerance assessment and test reports should be part of the substantiating data. Failure modes and effects analyses are acceptable structured safety assessment tools, particularly for non-fault tolerant lightning protection features. All the failure modes and effects analyses (FMEAs) and fault tree analyses (FTAs) should be included and thoroughly annotated. The applicant should substantiate and document all the assumptions used in performing the safety assessment.

2.9.4 The safety assessment should divide all the lightning protection features of the fuel system into the following three categories:

2.9.4.1 Intrinsically safe lightning protection

Some fuel system design elements 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. The applicant should identify any intrinsically safe fuel system design elements. An example of an intrinsically safe design element would be highly conductive fuel tank skins with sufficient thickness to ensure that lightning attachment to the skin will not result in hot-spot or melt-through ignition sources in the tank. Another example would be a structural element designed with sufficient margins that fatigue cracking is not foreseeable. A third example could be fasteners or joints located in the fuel tank structure where the lightning current density is so low that an ignition source will not result even when failure conditions are present.

2.9.4.2 Fault-tolerant lightning protection

Fuel system design elements that are not intrinsically safe and require design features to provide lightning protection should be designed so that a failure associated with these elements or features will not result in an ignition source. Reliable fault-tolerant lightning ignition source prevention, in combination with the fuel tank flammability control required by CS 25.981 and the statistics of lightning strikes to aeroplanes, is acceptable for showing compliance with CS 25.954(c). Detailed guidance for showing compliance for reliable fault-tolerant lightning protection is provided in Section 3 of this AMC.

2.9.4.3 Non-fault-tolerant lightning protection

Experience has shown that it is impractical to provide fault tolerant features, or indication of failures, for some failures that occur in the aeroplane structure. Certain fuel system design elements and lightning protection features could have conditions where a single failure of these elements or features results in an ignition source when combined with a critical lightning strike. These fuel system design elements, lightning protection features, and failures require detailed and thorough safety assessment to determine whether the fuel system design complies with CS 25.954(b). It is likely that the aeroplane fuel system design and lightning protection can have only a very small number of these non-fault-tolerant lightning protection conditions and still show that the risk of a catastrophic event is extremely improbable to comply with CS 25.954(c). Section 4 of this AMC provides more detailed guidelines for showing compliance for non-fault-tolerant lightning protection.

3 PROVIDE RELIABLE FAULT-TOLERANT PROTECTION FOR LIGHTNING IGNITION SOURCES

3.1 Provide fault-tolerant lightning protection

Fault-tolerant lightning protection for ignition sources on fuel tank structure and systems has been shown to be generally practical and achievable. Compliance with CS 25.954(b) for most fuel system elements (equipment, components, and structure) that are not intrinsically safe should be demonstrated by showing that the lightning protection is effective, reliable, and fault-tolerant.

3.2 Demonstrate effective fault-tolerance

3.2.1 The substantiation process should involve tests or analyses on fuel system design elements and features on which faults are induced. These tests and analyses should address both lightning direct attachment to the fuel system design elements and features and conducted lightning currents on them, as applicable. Where tests are performed, the following steps outline an approach to reduce the number of tests by grouping the design elements and features and associated failures. In each step, the assumptions should be documented.

3.2.2 The test process can be summarised in four steps:

1. Select the test articles that will be used for assessing fault tolerance. A design review may be used to develop groups or for classification of the fuel system design elements and features. For example, fasteners could be grouped by types of fasteners (such as rivets, bolts, and collars). The groups could be differentiated by materials (such as aluminium, steel, titanium, stainless steel, etc.), or by manufacturing processes (such as interference fit holes, cap seals, insulating laminate plies, material thickness, etc.).

2. Assess faults (including ageing, corrosion, wear, manufacturing escapes, and any foreseeable in-service damage) to determine the worst-case failures that could render the fault tolerance ineffective. Determination of the worst-case failures should be justified with engineering tests, previous certification tests, analyses, service experience, or published data.

3. Determine the lightning current amplitudes and waveforms in the fuel system design elements and features due to direct lightning attachment and conducted lightning currents, as applicable. The lightning environments were previously identified in the hazard assessment above.

4. Conduct tests using the current amplitudes and waveforms derived from step 3 and the faults defined in step 2 to demonstrate that the design prevents ignition sources when a fault occurs.

3.2.3 Assessment of systems failure conditions generally involves first assessing the result of the failure condition. For example, the loss of a means of electrical bonding at a systems tank penetration may cause higher current or voltage on components located within the fuel tank. The loss of a wire bundle shield or shield termination may also cause higher voltage in the fuel systems. Assessment of these effects may involve analyses, tests, or a combination of test and analysis. Scaling based on the relative distances from attachment locations, distances for structural conductors, lengths of systems elements, etc., may all be necessary to establish the worst-case threats.

3.2.4 Computational analyses or tests of representative tank sections may be used to determine the lightning current and voltage amplitudes and waveforms within the fuel system. The applicant should determine the currents, voltages, and associated waveforms that are expected on each feature or element of the fuel system, and use these current and voltage waveforms for tests on representative fuel system parts, panels, or assemblies. Analyses should be validated by comparisons of analysis results with test results from fuel system configurations that are similar to the fuel system to be certified. The applicant should apply appropriate margins based on the validation results.

3.2.5 The applicant should conduct lightning tests using test articles that acceptably represent the relevant aspects of the proposed aeroplane fuel system features and elements. The test articles should incorporate the identified failures needed to demonstrate fault-tolerant lightning protection. When performing these tests, the configuration of the design and protection features and elements should address the effects of ageing, corrosion, wear, manufacturing escapes, and likely damage. The possibility of cascading failure effects on redundant features (e.g., fasteners fracturing and compromising sealant directly or over time) should also be considered as part of the assessment when determining what level of fault insertion testing is needed. Guidelines for lightning test methods are provided by EUROCAE ED-105A 'Aircraft Lightning Test Methods', dated July 2013, and the equivalent SAE ARP5416A dated January 2013. Lightning tests are typically needed to demonstrate that fuel tank vent flame arrestors prevent fuel ignition from propagating into the fuel system if the vent outlets are located in lightning direct-attachment zones. The tests and analyses should be documented as part of the substantiating data.

3.3 Demonstrate protection reliability

3.3.1 The applicant should identify the protection features, and qualitatively establish the reliability, using service experience of similar protection features or other means proposed to, and accepted by, EASA. For example, the interference fit of a fastener in a hole may be established as a reliable protection feature based on service experience that interference fit fasteners do not loosen appreciably over the life of the aeroplane. Likewise, dielectric or physical separation of systems from structure may be established as a reliable protection feature, provided that similar dielectric material or support installations have been shown in service or by tests to perform their function adequately for the life of the aeroplane. Where the reliability of a fault-tolerant feature cannot be established to typically exceed the life of the aeroplane, then the appropriate replacement time, inspection interval, and related inspection and test procedure must be included in the Airworthiness Limitations Section of the ICA to ensure the effectiveness of the protection, in accordance with CS 25.954(d). Airworthiness limitation requirements are discussed in Section 5 of this AMC.

3.3.2 The applicant should address failures that can occur in service due to ageing and wear, and failures that can escape the manufacturing processes. For example, the anticipated escapes should include past manufacturing escapes. Any process changes that are implemented to preclude a specific type of escape may be considered if they preclude future escapes. The applicant should consider training to ensure manufacturing process compliance, implement designs that preclude escapes, automate reliable and repeatable drilling and assembly, and monitor process errors.

3.4 Demonstrate compliance with the 'extremely improbable' requirement

3.4.1 The characteristics of lightning, the frequency of aeroplane lightning strikes, and fuel tank flammability exposure are factors that affect the likelihood of lightning causing a catastrophic fuel vapour ignition. CS 25.981(b) limits the fuel tank fleet average flammability exposure to three per cent of the flammability exposure evaluation time, or that of a conventional unheated aluminium wing tank. The worldwide transport aeroplane lightning strike rate is of the order of once in several thousand flight hours.

3.4.2 The standard lightning waveforms in the EUROCAE/SAE standards are based on the combinations of severe lightning characteristics using a current amplitude, energy, rise time, and pulse repetition that conservatively exceed the majority of recorded values. Most aeroplane lightning strikes have significantly lower current values of amplitude, duration, energy transfer, rise time, and pulse repetition than the severe characteristics in EUROCAE ED-84A/SAE ARP5412B. This reduces the likelihood of a lightning-related ignition source even when the fuel system lightning protection effectiveness has degraded from what is demonstrated using the standard lightning waveforms in EUROCAE ED-84A/SAE ARP5412B.

3.4.3 The simultaneous occurrence of a lightning strike attaching to, or conducting currents through, the fuel system during flammable conditions, at a sufficiently severe level represented by the test levels of EUROCAE ED-84A/SAE ARP5412B, is remote by itself. Remote failure conditions are defined in AMC 25.1309 (Qualitative Probability Terms).

3.4.4 If shown to be effective and reliable, fault-tolerant lightning protection complies with CS 25.954(c) without further analysing the probability of the failures, taking into account the remote probability of the environmental conditions discussed above. The applicant should show that the fault-tolerant lightning protection features are designed and installed to be effective over their life or the life of the aeroplane or with appropriate inspections and maintenance. Lightning protection features and elements that have shown their reliability in service by adequate documented service history data on previous similar designs may be incorporated into the fault-tolerant design.

4 ASSESS NON-FAULT-TOLERANT PROTECTION FOR LIGHTNING IGNITION SOURCES

4.1 Overview

4.1.1 Fuel system configurations and failure conditions that result in non-fault-tolerant ignition sources should be minimised and precluded where practical. If the design is identified to be non-fault-tolerant, the design should be re-evaluated to determine whether practical measures could be implemented to make it fault-tolerant. Wherever practical, fault-tolerant design protection features and elements should be implemented and assessed. 'Practicality' is defined as a balance of the available means, economic viability, and proportional benefit to safety. A means to provide fault tolerance that is possible with little economic impact is practical even if an event is not anticipated to occur in the life of an aeroplane without it. If the applicant determines that fault-tolerant ignition source prevention is impractical for a specific design feature or failure, the applicant should review this determination of impracticality for concurrence with EASA.

4.1.2 For design features and elements that have failures where fault-tolerant ignition source prevention is impractical, the applicant should assess these non-fault-tolerant design features and elements to demonstrate that, taken together, the likelihood of a catastrophic fuel vapour ignition resulting from a lightning strike and flammable fuel tank conditions is extremely improbable. To successfully demonstrate this, it will likely be necessary to show that the occurrence of such a fault is extremely remote and limited to a very small number of design features and elements. To support the results of the assessment, maintenance considerations have to be identified in order to maintain the aeroplane in this state during the life of the aeroplane. Analysis and similarity can be used, but similarity should include the similarity of the design, similarity of the current density at the design feature, and similarity of the production and maintenance conditions. Agreement with the authorities on the use of similarity should be achieved before this approach is used. In many instances, a specific manufacturer's limited experience may not be representative of the overall transport fleet experience.

4.1.2.1 See Appendix B, paragraph B.1 of this AMC for examples of design elements or features where providing fault-tolerant lightning ignition source prevention should be practical.

4.1.2.2 See Appendix B, paragraph B.2 of this AMC for examples of design features or failures where providing fault-tolerant lightning ignition source prevention could be impractical.

4.1.2.3 See Appendix B, paragraph B.3 of this AMC for examples of design, manufacturing, and maintenance processes that may be useful in establishing compliance.

4.1.3 Applicants should identify all potential non-fault-tolerant design and protection features early in their design process. All practical measures to provide intrinsically safe protection and fault-tolerant ignition source prevention should be incorporated, which is more easily accomplished early in the design process.

4.1.4 Applicants should establish the probabilities of the flammable conditions within the fuel system where non-fault-tolerant features are present.

4.1.5 Once the probabilities of flammable conditions and the probabilities of critical lightning strikes occurring within the fuel system are defined, an evaluation of the potential for the occurrence of a structural discrepancy within the fuel system can be performed. When the probability of lightning attachment to certain regions of the aeroplane is included in the compliance approach, applicants should use data from similar aeroplane configurations to substantiate any assumed strike attachment rate.

4.1.6 Regardless of whether it is practical to provide fault-tolerant fuel system lightning ignition source prevention, compliance must demonstrate that the combined risk of catastrophic fuel vapour ignition due to lightning is extremely improbable. The assessment can be a qualitative analysis, a quantitative analysis, or a combination of both. The applicant should use the method that is most appropriate for the specific design. Where the protection means are reliable, the potential failure modes are rare, and limited service data is available to accurately determine the failure rates, a qualitative assessment is most appropriate. If the failure rates are available and a numerical assessment could be reasonably accurate, a quantitative assessment may be appropriate. If the potential failures are so common that the rates are well established, it is unlikely that a non-fault-tolerant design could be shown to be compliant without frequent maintenance checks. Combinations of failures where one failure also causes a second failure to occur should be considered as a single failure condition (i.e., a common cause or cascading failure). Combinations of independent failure modes that are expected to occur need to be considered.

4.2 Qualitative assessment of non-fault-tolerant conditions

4.2.1 The qualitative assessment must demonstrate that fuel vapour ignition due to lightning is extremely improbable, including the contribution of non-fault-tolerant features and elements. One means of assessing the risk of a catastrophic event due to failures of non-fault-tolerant features is to demonstrate that potential ignition sources due to failure conditions are also remote (per the AMC 25.1309 definition) for designs where fault-tolerant protection features are impractical.

4.2.2 Remote failure condition is defined in AMC 25.1309.

4.2.3 The qualitative assessment should account for the design features to limit failures, the conditions necessary for a failure to result in an ignition source, and any means used to limit the occurrence or latency of a failure. The applicant should evaluate the design's ability to safely conduct the lightning current densities and to prevent the lightning current flow.

4.2.4 A qualitative non-fault-tolerance assessment should show that combinations of service conditions, such as vibration, humidity, temperature changes, and maintenance activities, cannot produce an ignition source when exposed to voltages or currents resulting from lightning strikes to the aeroplane.

4.2.5 The following paragraphs (4.2.5.1 to 4.2.5.4) identify the areas that should be addressed for structural discrepancies within a fuel system.

4.2.5.1 Evaluation of non-fault tolerance should include consideration of structural discrepancies resulting from overstress, ageing, fatigue, wear, manufacturing defects, and accidental and environmental damage. Damage includes conditions that could be reasonably anticipated to occur in the life of an individual aeroplane due to operation and scheduled and unscheduled maintenance. In addition, probable manufacturing escapes in the production process should be considered as probable failures.

4.2.5.2 The determination of the potential for a non-fault-tolerant condition resulting in a lightning-related ignition source should be based on appropriate assessments. The objective of these assessments is to demonstrate that, for the combination of all the discrepant conditions in a fuel tank vapour zone (i.e. ullage), the exposure time of the non-fault-tolerant feature to a lightning-induced electrical current density of sufficient magnitude to become an ignition source will be minimised to such a degree that a catastrophic failure due to a lightning strike is not anticipated during the entire operational life of all the aeroplanes of that type. In performing the assessments to determine the potential for a non-fault-tolerant condition to result in a lightning-related fuel vapour ignition, the following factors should be collectively considered, addressed, and documented:

4.2.5.2.1 Analysis of the electrical current densities within the fuel tank structure considering its material properties and configuration;

4.2.5.2.2 Analysis and test data necessary to support the likelihood of occurrence of a critical lightning strike at a particular location on the aeroplane where a discrepancy exists;

4.2.5.2.3 Analysis and test data necessary to support any conclusion that the electrical current density generated by a lightning strike in the specific vicinity of a structural crack or broken fastener in the fuel tank will not be of sufficient amplitude to cause sparking;

4.2.5.2.4 Analysis and test data necessary to support the likelihood of the fuel tank being flammable; and

4.2.5.2.5 Evaluation of fuel tank structure in all areas of the fuel tank that may be susceptible to a fuel vapour condition and at electrical current densities that can result in a lightning-related ignition. This should include assessing the structure's:

1. Susceptibility to failure (such as cracking, delamination, fastener failures, failed fastener cap seals, failed sealant, etc.);

2. Inspectability (determining whether discrepant structure could be reliably inspected such that the exposure time of the failure to a critical lightning strike will be reduced to a level that supports the safety objective);

3. Service data (reports of failed structure such as cracks, delamination, failed fasteners, failed fastener cap seals, or sealant that could become an ignition source);

4. Maintenance inspection programs (determining whether inspections will reliably detect failures and discrepancies such that their exposure time will be reduced to a level that supports the safety objective). This includes mandated inspections (e.g., the Airworthiness Limitations Section of the ICA required by Section H25.4 of Appendix H to CS-25 and CS 25.1529); and

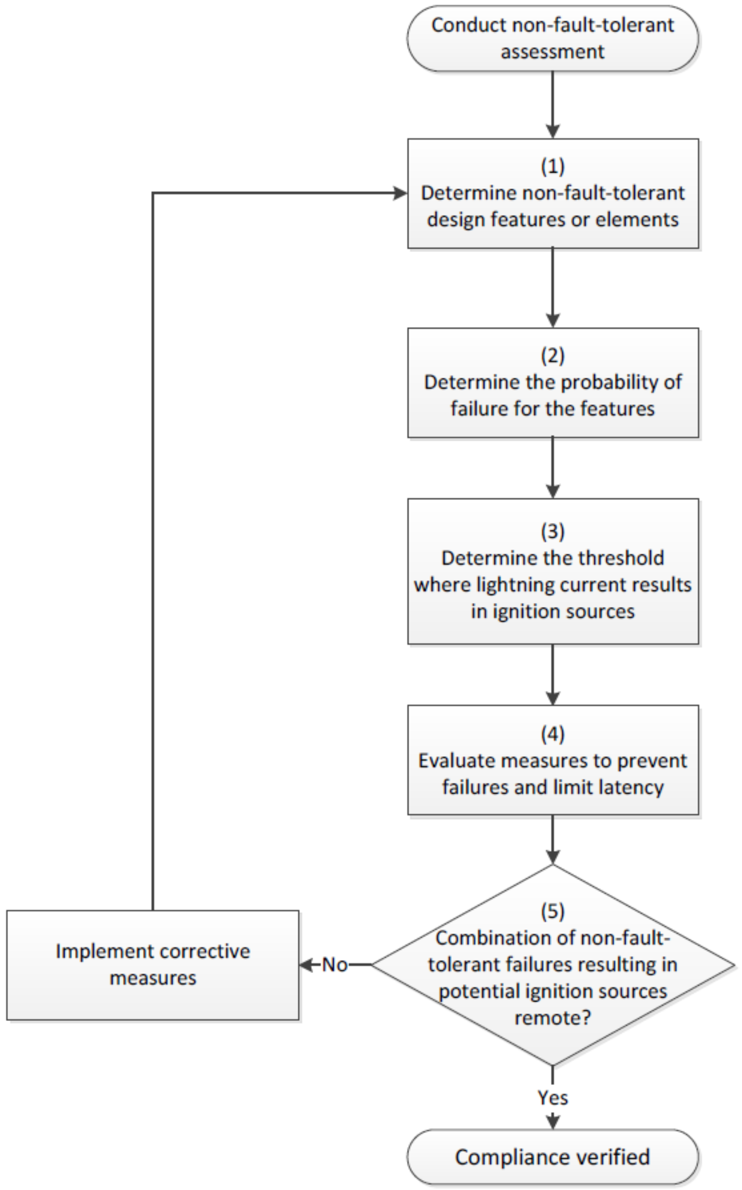
5. Fatigue and damage tolerance evaluation of the crack initiation/propagation rate, crack characteristics (e.g., crack width versus crack length or edge crack versus crack at or near a fastener hole), detectable crack size, probability of detection, inspection threshold, and inspection interval.

4.2.5.3 See Appendix B of this AMC for an example of an assessment process addressing the potential for fuel tank structural cracking.

4.2.5.4 The qualitative assessment should consider any means used to ensure that the combination of faults will be remote. However, it cannot include the likelihood of lightning attaching to the aeroplane, or the flammability of the fuel tanks.

4.2.5.5 Figure 1 of this AMC provides a guide to the qualitative assessment process. Each of the activities in the qualitative assessment process, shown in Figure 1, is discussed in the paragraphs that follow.

Figure 1. Assessing the Combined Risk of All Non-Fault-Tolerant Failures



4.2.5.6 Figure 1, Item (1).

The first step is to determine whether there are design features or elements that do not provide fault-tolerant lightning protection, as described in paragraph 2.9.4.3.

4.2.5.6.1 When a failure is considered possible, qualitatively assess with supporting test data and fleet experience to determine whether the condition is likely to occur in the life of the aeroplane fleet. This supporting data may include:

— Lightning testing relevant to specific or similar design features (see paragraph 2.3 of this AMC);
— Dielectric strength testing of insulating materials and structures such as brackets, clamp cushions, air gaps, and wire harness insulation;
— Field service reports or databases related to the non-fault-tolerant condition being assessed;
— Engineering tests to determine the durability of features, such as fatigue tests, thermal cycling tests, or corrosion tests;

— Fleet experience may also be used to estimate the likelihood of failures. The determinations should be based on conservative assumptions;
— Service experience records of manufacturing or maintenance escapes, if available; and
— Manufacturing records for defects found.

4.2.5.6.2 It may be possible to demonstrate that a design feature or element will perform similarly to a previously certificated design or design feature under foreseeable lightning threats. If applicable, provide a comparative analysis of similar design features and details on a previously certified aeroplane. The comparative analysis would include a detailed assessment of the design features and details that affect susceptibility to failure, exposure time to lightning environment, service experience, and any applicable analyses and test data.

4.2.5.7 Figure 1, Item (2).

Assess the probability of the failure condition occuring. If this failure is latent for a long time, or the failure could occur at many locations that are exposed to conducted lightning currents, the likelihood of that failure resulting in an ignition source could be significant.

4.2.5.8 Figure 1, Item (3).

Evaluate the likelihood of lightning attaching in the vicinity of non-fault-tolerant features and resulting in a current of sufficient amplitude to cause an ignition source at those features. Appropriate factors to consider include:

1. The possibility of lightning attachment to locations on the surface of the aeroplane near the failed non-fault-tolerant features.

2. The lightning-related ignition source threshold current for the failed non-fault-tolerant features. This is the lightning current amplitude that would result in an ignition source at the failed non-fault-tolerant feature.

3. The amplitude of the lightning current that would be necessary to produce a conducted current that would exceed the ignition source threshold.

4.2.5.8.1 Failed features within fuel systems will usually tolerate some lightning current without producing an ignition source. Above this threshold, an ignition source can occur. The lightning current amplitude, charge transfer, and action integral that result in an ignition source can be determined by tests on parts and panels that incorporate the structural features in a defined fault condition.

4.2.5.9 Figure 1, Item (4).

Consider any factors that may be used to ensure the integrity of the installations. A specified inspection interval can be proposed to detect the failure. Additional manufacturing controls may be implemented to minimise the occurrence of defects and escapes during production.

4.2.5.10 Figure 1, Item (5).

The qualitative assessment should consider all the potential non-fault-tolerant features and determine whether the combination of potential for ignition sources due to failures of these features is remote. Broken fasteners and structural cracks are two failures where the applicant may find it impractical to demonstrate fault-tolerant protection. The applicant is responsible for demonstrating that ignition sources created by the combination of a non-fault-tolerant failure, a flammable environment, and a lightning strike of sufficient amplitude to result in an ignition source will be extremely improbable.

4.3 Quantitative assessment of Non-fault-tolerant conditions

4.3.1 Quantitative assessment of non-fault-tolerant features can be used. The quantitative assessment must demonstrate that fuel vapour ignition due to lightning is extremely improbable, including the contribution of non-fault-tolerant features and elements. However, to do this, there must be a reasonable amount of reliable data for the rate of failures.

4.3.2 The following four conditions should be evaluated collectively:

1. The probability of the occurrence of a flammable condition within a fuel tank in the vicinity of an ignition source due to lightning.

2. The probability of the occurrence of a lightning strike of sufficient intensity to produce an ignition source at a failed non-fault-tolerant design feature.

3. The potential for the presence of a failure of a non-fault-tolerant protection feature within a fuel system.

4. The total number of non-fault-tolerant features.

4.3.3 The same factors for a qualitative assessment should be considered for the quantitative assessment approach. The additional step is to quantify each of these factors for use in the numerical assessment. A fault tree analysis (discussed in paragraph 2.9.3 of this AMC) may be used to determine whether the combined risk of the non-fault-tolerant conditions is unlikely to result in a catastrophic event over the life of the fleet. From a numerical perspective, a probability of the order of 10^{-9} per flight hour or less is the accepted standard for demonstrating that the combined risk, including all failures, is extremely improbable.

4.4 Evaluating non-fault-tolerance for systems.

Fuel, mechanical, hydraulic, and electrical components that penetrate, are located within, or are connected to the fuel tanks have typically been able to provide fault-tolerant design capability. These components include the associated clamps, shields, supports, bonding straps, and connectors. It is therefore expected that applicants develop fault-tolerant designs for these components.

5 ESTABLISH AIRWORTHINESS LIMITATIONS

CS-25, Appendix H, Section H25.4, Airworthiness Limitations Section, requires mandatory replacement times, inspection intervals, and related inspection and test procedures for lightning protection features that are approved under CS 25.954. Section H25.4(a)(5) requires CDCCLs, inspections and tests, and mandatory replacement times to be located in a section of the ICA titled 'Airworthiness Limitation.'

5.1 Critical design configuration control limitations

5.1.1 The applicant must establish CDCCLs to protect features that prevent lightning-related ignition sources within the fuel systems. This requires the applicant to identify the lightning protection design features, as well as to prepare instructions on how to protect those features. Identification of a feature refers to listing the feature in the CDCCL. During aeroplane operations, modifications, and unrelated maintenance actions, these features can be unintentionally damaged or inappropriately repaired or altered. Instructions on protection are meant to address this safety concern. An example of a common design feature to prevent ignition sources caused by wiring is wire separation so that wires cannot chafe against one another or against structure or other components. An example of an instruction on how to protect this design feature would be 'When performing maintenance or alterations in the vicinity of these wires, ensure that a minimum wire separation of 15.24 cm (6 inches) is maintained.'

5.1.2 CDCCLs are essential to ensure that maintenance, repairs, or alterations do not unintentionally violate the integrity of the type design of the fuel tank system. The CDCCLs should include information regarding how to prevent compromising the critical design features, or restore them when other maintenance or alterations are being performed. The CDCCLs should be established based on evaluating design-specific critical features that are determined from the safety analysis and a determination of the anticipated maintenance, alteration, or repair errors that could compromise the feature. The following list of examples of CDCCLs is intended to provide examples of lightning protection features that have been identified in certain designs and is not intended to be inclusive of all the features that should be considered for a particular design. It is likely that the safety analysis will identify the need for additional CDCCLs.

5.1.2.1 Fuel tank structural fasteners can be potential lightning ignition sources. Specific fastener design features such as the fastener material, coating, and countersink depth are typically needed to prevent lightning ignition sources at the fasteners. Installation processes such as fastener hole clearances, fastener pull-ups, and hole angularities can be critical. The orientation of the fastener head in the fuel tank structure can be critical. The criticality of fuel tank structural fasteners may be dependent on their location, particularly those located in direct lightning attachment zones. The CDCCLs should identify these critical fastener features and referring 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 current on the fuel tubes, especially on aeroplanes with carbon-fibre composite fuel tank structure. 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, 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 lightning ignition source protection. The limitation may specify that the integrity of the sealant must be verified in areas of the fuel system where maintenance or alterations take place. Cracked, peeling, or missing sealant could indicate that the protection integrity 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 structure. The limitation may specify that the presence and integrity of the bushings or grommets must be verified in areas of the fuel system where maintenance or alterations take place; and 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 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 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 feature identified in the CDCCL. CDCCLs can also include requirements to have placards 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 Although not intended by the introduction of CDCCLs and other fuel system airworthiness limitations in the context of CS 25.981, CDCCLs may include both the critical design feature as well as the tasks associated with maintaining the CDCCLs. Typically, these airworthiness limitations require adherence to a specific CMM at a specific revision level when repairing or overhauling fuel system components. In this case, operators are required to adhere to all the elements of the CMM specified in the CDCCLs. Any deviations from the CMMs specified in the CDCCLs, including using later revisions of those CMMs, must be approved by EASA (in accordance with Part 21). To prevent this situation, it is preferable to identify only those critical features of components in the CMMs as CDCCLs, instead of identifying the entire CMM as CDCCLs (or other types of airworthiness limitations).

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 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 history 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 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 are penetrating, 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 lightning ignition source prevention should be practical include the:

1. Installation of rivets and bolts in aluminium structure 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 structure 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 lightning ignition source prevention 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 to 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.

Amend AMC 25.981(a) by replacing its content with the following text:

AMC 25.981(a)

Fuel Tank Ignition Source Prevention

1 PURPOSE

This AMC describes how to show compliance with CS 25.981, which provides the certification requirements for the prevention of ignition sources, other than lightning, within the fuel tanks of transport category aeroplanes. This AMC includes guidelines for the prevention of failure conditions created from ignition sources other than lightning. It describes a means of compliance, using circuit protective devices such as an arc fault circuit breaker (AFCB) or ground fault interrupter (GFI), to provide fail-safe features that have been accepted as showing compliance with CS 25.981. This AMC does not apply to the flammability requirements in CS 25.981(b).

2 SYSTEM SAFETY ASSESSMENT (SSA)

2.1 Before conducting an SSA of the fuel system, each applicant should assemble and review the relevant lessons learned from the overall transport fleet history, as well as from its previous products and suppliers and any other available sources to assist in identifying any unforeseen failures, wear, or other conditions that could result in an ignition source. The sources of information include aeroplane service records, flight logs, inspection records, and component supplier service and sales records.

2.2 Safety assessments of previously certified fuel systems may require additional considerations. For these safety assessments, component sales records may assist in identifying whether component failures and replacements are occurring. In addition, in some cases, changes to components have been introduced following the original type design certification without consideration of the possible effects of the changes on the system's compliance with the requirements to prevent ignition sources. For example, certain components within fuel pumps (e.g., thrust washers) have been changed to improve the life of the pumps, which defeated the original fail-safe features of the pumps. Therefore, the results of reviewing this service history information, and a review of any changes to components from the original type design, should be documented as part of the safety analysis of the fuel tank system.

2.3 The following lists summarise the design features, malfunctions, failures, and maintenance/operational-related actions that have been identified through service experience as resulting in a degradation of the safety features of aeroplane fuel tank systems. These lists are provided as guidance and are not inclusive of all the failures that need to be considered in the failure assessment. They may assist in evaluating possible failure modes during the evaluation of a fuel tank installation.

2.3.1 Pumps

1. The ingestion of pump inlet components (e.g., inducers, fasteners) into the pump impeller, releasing debris into the fuel tank.

2. Pump inlet case degradation, allowing the pump inlet check valve to contact the impeller.

3. A failure of one phase of the stator winding during operation of the fuel pump motor, together with a subsequent failure of a second phase of the motor windings, resulting in arcing through the fuel pump housing.

4. Arcing due to the exposure of electrical connections within a pump housing that has been designed with inadequate clearance to the pump cover.

5. The omission of cooling port tubes between the pump assembly and the pump motor assembly during a pump overhaul.

6. Extended dry running of fuel pumps in empty fuel tanks (e.g. caused by a failure of the fuel pump relay in the on position).

7. The use of steel impellers that may produce friction sparks if debris enters the pump.

8. Debris lodged inside pumps.

9. Pump power supply connectors that have been damaged, worn, or corroded, resulting in arcing within the connector that damages the hermetic seal, causing fuel leakage.

10. Electrical connections within the pump housing that have been designed with inadequate clearance or insulation from the metallic pump housing, resulting in arcing.

11. Thermal switches ageing over time, resulting in a higher trip temperature.

12. Flame arrestors falling out of their respective mountings.

13. Internal wires coming in contact with the pump rotating group, energising the rotor, and arcing at the impeller/adapter interface.

14. Poor bonding across component interfaces.

15. Insufficient arc-fault or ground-fault current protection capability.

16. Poor bonding of components to the structure.

17. Loads transferred from the aeroplane fuel-feed plumbing into the pump housing, resulting in a failure of the housing mounts and a subsequent failure of the pump case, which defeated the explosion-proof capabilities of the pump.

18. A premature failure of the fuel pump thrust bearings, allowing steel rotating parts to contact the steel pump side plate.

19. Erosion of the fuel pump housing, causing a loss of the fuel pump explosion-proof capability and exposure of the fuel pump wiring to the fuel tank.

2.3.2 Wiring to fuel pumps

1. Wear of Teflon or other insulating sleeving and wiring insulation on wires in metallic conduits located inside fuel tanks, allowing arcing from the wire through the conduits into fuel tank ullages.

2. Damage to the insulation on wiring routed adjacent to the fuel tank exterior surfaces, resulting in arcing to the metallic fuel tank surface.

2.3.3 Fuel pump connectors

1. Electrical arcing at connections within electrical connectors due to bent pins, wear, manufacturing variability (e.g. tolerances), or corrosion.

2. Fuel leakage and a subsequent fuel fire outside the fuel tank caused by corrosion or wear of electrical connectors to the pump motor, leading to electrical arcing through the connector housing (the connector was located outside the fuel tank).

3. Selection of improper insulating materials in the connector design, resulting in degradation of the material because of contact with the fuel that is used to cool and lubricate the pump motor.

2.3.4 Fuel quantity indicating system (FQIS) wiring

1. Degradation of wire insulation material (cracking).

2. Conductive or semi-conductive (silver, copper, or cadmium) deposits on electrical connectors inside fuel tanks.

3. Inadequate wire separation between FQIS wiring and structure, or between other wiring, resulting in contact that causes chafing of the wiring.

4. Unshielded FQIS wires routed in wire bundles together with high voltage wires, creating the possibility of short circuit failures on the FQIS wires in excess of the intrinsically safe levels.

5. FQIS wiring that does not adhere to the aeroplane manufacturer's standard wiring practices (i.e., wires bent back along themselves with a bend radius less than the one defined in the aeroplane manufacturer's standard wiring practices, multiple splices lying next to one another, etc.).

2.3.5 FQIS probe installation

1. Conductive or semi-conductive corrosion (copper or silver sulphur deposits) causing a reduced breakdown voltage in FQIS wiring.

2. Damage to FQIS wire insulation resulting in a reduced breakdown voltage because of wire clamping features at the electrical connections on fuel quantity probes.

3. Contamination in the fuel tanks creating an arc path for low levels of electrical energy between the FQIS probe walls (steel wool, lock wire, nuts, rivets, bolts, and mechanical impact damage to probes).

2.3.6 Valve actuators

A failure of one solenoid in a dual solenoid actuated valve, resulting in overheating of one solenoid to a temperature above the auto-ignition temperature.

2.3.7 Float switch systems

1. Conduits containing float switch wiring failure due to freezing of water that entered the conduit, allowing fuel leakage into the conduit and along the aeroplane front spar, resulting in an engine tailpipe fire.

2. Float switch wire chaffing being observed, which might have provided a potential for a subsequent electrical short to the conduit.

3. A float switch sealing failure that allowed fuel/water to egress into the switch, compromising switch operation in an explosive environment.

2.3.8 Fuel tubes, vent tubes, conduits, and hydraulic lines.

1. Poorly conducting pipe couplings that may become electrical arc sources when exposed to electric currents.

2. Insufficient clearances between tubes and the surrounding structure.

3. Intermittent electrical bonding in flexible couplers.

4. Bonded couplers unable to conduct the expected power fault currents without arcing.

2.3.9 Electrical generator power feeder cables

1. Arcing of electrical power feeder cables to a pressurised fuel line, resulting in a fire adjacent to the fuel tank.

2. Arcing of electrical power feeder cables to an aluminium conduit, resulting in molten metal dropping onto a pressurised fuel line and consequently causing pressurised fuel leakage.

2.3.10 Bonding straps

1. Corrosion of bonding strap wires, resulting in a failure to provide the required current paths.

2. Inappropriately attached connections (loose or improperly grounded attachment points).

3. Worn static bonds on fuel system plumbing connections inside the fuel tank, due to mechanical wear of the plumbing due to wing movement and corrosion.

4. Corrosion of the bonding surfaces near fuel tank access panels that could diminish the effectiveness of the bonding features.

5. Ageing of self-bonding fuel system plumbing connections, resulting in higher resistance bonding.

6. Missing bonds.

7. Loose or intermittent contacts between bond straps and other conductive components.

2.3.11 Pneumatic system failures

Leakage of hot air from ducting located near fuel tanks due to a duct failure, resulting in undetected heating of the tank surfaces to a temperature above the auto-ignition temperature.

2.3.12 Electrostatic Charge

1. The use of a non-conductive type of reticulated polyurethane foam in only a portion of the fuel tank system, which allowed electrostatic charge build-up and arcing in the unprotected portion of the system.

2. Spraying fuel through refuelling nozzles located in the upper portion of the tank.

3 FUEL VAPOR IGNITION SOURCES

3.1 Overview

There are four primary phenomena that can result in the ignition of fuel vapour within aeroplane fuel tanks:

— Electrical sparks and arcs,
— Filament heating,
— Friction sparks, and
— Auto-ignition or hot surface ignition.

3.1.1 The conditions required to ignite fuel vapour from these ignition sources vary with the pressures and temperatures within the fuel tank, and can be affected by sloshing or spraying of fuel in the tank. Due to the difficulty in predicting fuel tank flammability and eliminating flammable vapour from the fuel tank, it should be assumed that a flammable fuel/air mixture may exist in aeroplane fuel tanks, and it is required that no ignition sources be present.

3.1.2 Any components located in or adjacent to a fuel tank must be designed and installed in such a manner that, during both normal and anticipated failure conditions, ignition of flammable fluid vapour will not occur. Compliance with this requirement is typically shown by a combination of component testing and analysis. Testing of components to meet the appropriate level of explosion-proof requirements should be carried out for various single failures, and combinations of failures, to show that arcing, sparking, auto-ignition, hot surface ignition, or flame propagation from the component will not occur. The testing of components may be accomplished using several military standards and component qualification tests. For example, Method 511.6, Procedures I and II, of Military Standard MIL-STD-810H 'Environmental Engineering Considerations and Laboratory Tests' dated January 2019 defines one method that can be used for showing that a component is explosion proof as defined in Appendix C of this AMC. Section 9 of EUROCAE ED-14G Change 1, dated January 2015, 'Environmental Conditions and Test Procedures for Airborne Equipment', and the equivalent RTCA, Inc., Document No DO-160G dated December 2010, can also be used for showing that airborne equipment is explosion proof.

3.2 Electrical sparks and electrical arcs

3.2.1 Laboratory testing has shown that the minimum ignition energy in an electrical spark required to ignite hydrocarbon fuel vapour is 200 microjoules*. Therefore, for electrical or electronic systems that introduce electrical energy into fuel tanks, such as FQIS, the energy of any electrical arcs or sparks that are created into any fuel tank should be less than 200 microjoules during either normal operation or operation with failures.

** The 200-microjoule level comes from various sources. The most quoted is from Lewis and von Elbe's book, Combustion, Flames and Explosions of Gases (Florida: Academic Press, Inc., 1987; (orig. publ.*

1938)). It has a set of curves for minimum ignition energy for the various hydrocarbon compounds in jet fuel, and they all have similar minimum ignition energy levels of greater than 200 microjoules.

Note: Standards that allow 320 microjoules are not acceptable for showing intrinsic safety. ('Intrinsically safe' is defined in Appendix C, paragraph C.20, of this AMC).

3.2.2 To ensure that the design has adequate reliability and acceptable maintenance intervals, a safety factor should be applied to this value when establishing a design limit. Fuel tank systems should be designed to limit the allowable energy level to the lowest practical level. Systems with a maximum energy of 20 microjoules are considered technologically feasible. Normal system operations at minimum ignition energies of up to 50 microjoules would be acceptable. Under failure conditions, the system should have an ignition energy of less than 200 microjoules.

3.3 Filament heating current limit

Analyses and testing indicate that a small piece of steel wool will ignite a flammable mixture when a current of approximately 100 milliamperes (mA) root mean square (RMS) is applied to the steel wool. Therefore, for electrical or electronic systems that introduce electrical energy into fuel tanks, such as FQIS, the electrical current introduced into any fuel tank should be limited. Because there is considerable uncertainty associated with the level of current necessary to produce an ignition source from filament heating, a safety factor should be applied to this value when establishing a design limit. A maximum steady-state current of 25 mA RMS is considered an intrinsically safe design limit for electronic and electrical systems that introduce electrical energy into fuel tanks. For failure conditions, the system should limit the current to 50 mA RMS, and induced transients to 125 mA peak current.

3.4 Friction sparks

Pump inlet check valves, inducers, nuts, bolts, rivets, fasteners, lockwire, roll pins, cotter pins, drill chips, manufacturing debris, and so forth may be drawn into fuel pumps and contact the impeller, resulting in the possibility of metallic deposits on rotating and stationary components within the pump. This condition has resulted in the creation of friction sparks, and this should be an assumed failure condition when conducting the SSA. Fail-safe features as described in paragraph 5.2.19.2.2 of this AMC have been used to mitigate this hazard.

3.5 Maximum allowable surface temperatures

CS 25.981(a)(1) and (2) requires to:

> *(1) Determine the highest temperature allowing a safe margin below the lowest expected auto-ignition temperature of the fuel in the fuel tanks.*
>
> *(2) Demonstrate 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.*

3.5.1 Auto-ignition temperatures of fuels

Fuels approved for use on transport category aeroplanes have differing auto-ignition temperatures. The auto-ignition temperature of JP-4 (wide-cut jet fuel) is approximately 242 °C (468 °F) at one atmosphere of pressure. Under the same atmospheric conditions, the auto-ignition temperature of JET A (kerosene) is approximately 224 °C (435 °F) to 232 °C (450 °F), and gasoline (i.e. petrol) is approximately 427 °C (800 °F). The auto-ignition temperature of these fuels varies inversely with the ambient pressure. Also, as stated in ASTM E659, Standard Test Method for Autoignition Temperature of Chemicals, 'the autoignition temperature by a given method does not necessarily represent the minimum temperature at which a given material will self-ignite in air. The volume of the vessel used is particularly important since lower autoignition temperatures will be achieved in larger vessels.' In view of this, factors affecting the pressure in the fuel tank should be taken into consideration when determining compliance with CS 25.981.

3.5.2 Maximum surface temperature

A surface whose temperature reaches a value 10 °C (50 °F) below the auto-ignition temperature of the fuel air mixture is defined as being at the maximum allowable surface temperature providing a safe margin below the lowest auto-ignition temperature of the fuel. A temperature of 204 °C (400 °F) is accepted as the maximum surface temperature inside fuel tanks for kerosene type fuels without further substantiation. (Maximum surface temperature considerations for areas outside the fuel tank are discussed in paragraph 5.3.6.3 of this AMC.)

3.5.3 Transient higher surface temperature

The conditions (ambient pressure, dwell time, fuel type, etc.) within fuel tanks are such that a higher value may be used as a transient surface temperature limit. For example, a maximum allowable fuel tank surface temperature of 204 °C (400 °F), with a transient excursion that reduces the safe margin below 232 °C (450 °F) (i.e., the lowest expected auto-ignition temperature) for a maximum of two minutes, can be used for kerosene type fuels. The excursion above 204 °C (400 °F) occurs only during failure conditions such as a failure of the engine pneumatic system to regulate the temperature, or a duct rupture. Utilising elevated temperatures has been based on specific design features, such as an overtemperature shutoff of the pneumatic system so that the temperature cannot reach or exceed the accepted auto-ignition temperature of 232 °C (450 °F) for kerosene type fuels. Applicants should submit comprehensive test data and an analytical rationale substantiating any transient excursion in order to show that they are maintaining a safe margin below the lowest expected auto-ignition temperature of the fuel.

3.6 Fuel system electrostatics

3.6.1 Electrostatic charges are generated in liquid hydrocarbons when they are in motion with respect to another surface such as fuelling hoses, filters, nozzles, fuel tank structure, and aeroplane plumbing. The documents referenced in Appendix B, paragraphs B.3 and B.5 of this AMC provide information on this subject. For example, during aeroplane refuelling, jet fuel is loaded either from a tanker truck or from an airport hydrant system. Flowing fuel can generate an electrical charge, especially through fuel filtration. The accumulation of charge in the fuel is a function of many factors. If the fuel conductivity is low, the relaxation time for dissipation of the electrical charge is long. Additionally, if the conductivity of the aeroplane structure is low, as it is commonly in composite wings, the relaxation time of the fuel bulk charge to structure may be longer than it would be for a traditional metallic wing structure. Some composite structures have a lower conductivity than traditional metallic structures. A comparison can be made of the conductivity of the fuel with the conductivity of the aeroplane structure. Jet fuel typically has significantly lower conductivity than composite structures, meaning that the conductivity of the jet fuel dominates the charge relaxation rate and consequently results in similar charge relaxation rates between the different types of aeroplane structures. Regardless, the fuel will accumulate an electrical charge inside an aeroplane fuel tank. This electrical charge may produce a high potential on the fuel surface and an electrical discharge to the structure. This is particularly a concern if large unbonded objects are located inside an aeroplane fuel tank. Smaller components may also become charged, and the applicant should address this in the safety assessment. If the vapour space fuel/air mixture is in the flammable range, ignition of the mixture is possible, resulting in a fuel tank explosion and fire.

3.6.2 Charge accumulation is influenced by many factors. Without an electrical conductivity improver (also referred to as a dissipator/dissipater, static dissipater additive, electrical conductivity additive, or conductivity improver additive), typical Jet A fuel has a low electrical conductivity. An electrical conductivity improver will increase the charging rate of fuel, but at the same time greatly improve the conductivity of the fuel to rapidly dissipate the developed charge. Contaminants, considered as ionic impurities, enhance the charging tendency of the specific fuel. Fuels from different parts of the world and from different refineries will therefore have different charging tendencies based on the types of contaminants present.

3.6.3 Water contamination, however, increases the charging tendency of the fuel without a corresponding increase in conductivity. Water interacts with the additives or the naturally occurring contaminants in the fuel to provide this pro-static effect.

When refuelling, care should be taken to not disturb the interface between the fuel remaining in the tank and the possible layer of water below it. Disruption of this interface up into the tank ullage/vapour space may lead to an electrical discharge capable of igniting a mixture of flammable fuel vapour and air.

3.6.4 Methods for minimising the magnitude of the developed charge have been developed, and are in place on transport category aeroplanes, including the following methods:

3.6.4.1 The refuel plumbing is sized and includes an orifice to maintain maximum flow rates in accordance with the electrostatic guidelines established by the National Fire Protection Association (NFPA) (NFA 77) and the ASTM (D4865).

3.6.4.2 Guidelines have been published (e.g. by ASTM) to limit flow velocities to 6 to 7 meters per second while the discharge port is covered with fuel. These guidelines also indicate that the flow velocity should be held to less than 1 meter per second until the discharge port is covered with fuel. These guidelines were developed with gasoline (i.e. petrol) in mind and are, therefore, conservative when applied to the kerosene type fuels used in commercial aviation. The design guidelines for commercial aircraft in SAE AIR1662 limit velocities to 6 to 9 meters per second in fuel plumbing and 3 meters per second at the exit nozzle. Limiting the flow velocity may be achieved by incorporating multiple refuelling discharge ports, lowering the flow velocity through the use of piccolo tubes that distribute the fuel at low velocities in the tank, and locating them at or near the bottom of the tank. Location of the refuelling discharge at the bottom of the tank minimises fuel spray — a contributor to static charge development — and provides for the ports to be covered by fuel reserves in main tanks and in the early stages of fuel flow as the refuel rate varies from 1 meter per second up to the full flow of 6 to 7 meters per second in normally emptied tanks.

Note: It may not be practical to develop a dual flow rate refuelling system, so one way to address these guidelines may be to limit the refuelling velocities to less than 1 meter per second through the use of multiple discharge points and piccolo tubes.

3.6.5 Methods of relaxing the charge have also been developed. Bonding straps are used on fuel components and plumbing lines to allow the charge to dissipate to the tank structure. During refuelling, the aeroplane is bonded to the refuelling vehicle with a separate bonding wire to provide an electrical path back to the fuel filter, which is the principal electrostatic charge generator. An electrical conductivity improver may also be used to increase fuel conductivity to quickly dissipate the developed charge. However, EASA does not require this type of additive, unless it is specified as part of the type design approval. Any limitations on the use of an electrical conductivity improver would need to meet the requirements of CS 25.1521, Powerplant limitations, and CS 25.1557, Miscellaneous markings and placards.

3.6.6 Applications of the above methods, and adherence to industry practices and guidelines on electrostatics, should be identified for each aeroplane model. Airline operations and practices regarding aeroplane refuelling should also be evaluated to verify that the procedures necessary for the safe operation of the specific aeroplane model are in place and followed. Restrictions, if any, on refuel rates, fuel properties, and the requirement for fuel additives should be identified as CDCCLs.

3.6.7 Polyurethane reticulated foam used for ignition suppression within fuel tanks and other non-conducting objects may accumulate and retain charge. These items may have to be treated with antistatic additives to prevent charge accumulation.

4 DESIGN CONSIDERATIONS

The number of components and systems inside aeroplane fuel tanks whose failure could result in an ignition source within the fuel tank should be minimised. The following design practices are accepted by EASA for minimising ignition sources:

4.1 Fibre optics

Wiring entering the tank for such purposes as temperature monitoring and fuel quantity indication should be minimised. The use of alternate technology, such as fibre optics, may provide a means of reducing or eliminating electrically powered components from inside the fuel tanks.

4.1.1 Fuel pump electrical power supply

4.1.2 Fuel pump power wiring

If practical, fuel pumps should be located such that the electrical power for the pumps is routed outside the fuel tanks in such a manner that failures in the electrical power supply cannot create a hot spot inside the tank, or arc into the fuel tank. While the routing of the fuel pump power supply outside the fuel tank, and away from the fuel tank walls, may eliminate the potential for arcing directly into the fuel tank or heating of tank surfaces, the failure analysis should consider the need for electrical circuit protective devices. If the power supply cannot be routed outside the tank, additional design features should be considered as discussed in paragraph 4.3.2 below.

Note: The applicant should consider, in the design of the pump wiring system and when showing compliance, the electromagnetic effects and electrical transients that may damage the wiring or pump.

4.1.3 Fuel pump electrical connectors

4.1.3.1 Arcing at the pump electrical connector has resulted in uncontrolled fuel leakage, an ignition source, and an uncontrolled fire outside the fuel tank. This can create a fuel tank ignition source due to the external fire heating the fuel tank surfaces. Fuel pumps should include features to isolate the electrical connector from the portion of the fuel pump where fuel is located. Applicants should show that the arcing that occurs in these designs cannot cause a cascading failure from arcing in the electrical connection, resulting in a fuel leak and a fire. One approach includes the incorporation of a dry area between the electrical connector and the fuel pump. Another approach includes extending the fuel pump power wire so the electrical connector is well away from the fuel pump. This approach has included a drip loop on the wire to prevent any fuel leaking onto the wire from being present at the electrical connector.

4.1.3.2 Alternatively, or in addition to isolating electrical connectors from the fuel, limiting the electrical energy into the fuel tank can prevent an ignition source from occurring. The design of traditional fuel pumps has resulted in the need to install AFCB or GFI protection features to limit the energy release during an arcing event to prevent an ignition source from occurring.

4.2 Location of the pump inlet

Debris that may enter a fuel pump inlet can cause sparks inside the fuel tank. One means to address this ignition source has been to locate the pumps such that the pump inlet remains covered with fuel whenever the pump is operating within the aeroplane operating envelope. Another means has been to prevent the propagation of any ignition from the pump into the fuel tank by using flame arrestor technology. (The performance of the flame arrestor should be validated by test to verify its effectiveness at stopping a flame front.) Any protective means, including those shown in paragraphs 4.2.1 and 4.2.2 below, should be demonstrated to be effective under the pitch, roll attitude, and negative G conditions anticipated to occur in service.

4.2.1 Main feed tanks

The installation of baffles in the tank structure, and the use of collector tanks that are continually filled with fuel using ejector pumps, are methods that have proven successful in keeping the pump inlets and pump housings submerged in fuel.

4.2.2 Auxiliary tanks

For auxiliary tanks that use motor-driven fuel pumps and that are routinely emptied, accepted design practices include shutting off the motor-driven pumps before uncovering the fuel pump inlet, and the installation of a flame arrestor in the scavenge pump inlet line, or scavenging the remaining fuel with ejector pumps. (Note that the installation of features such as a flame arrestor in the fuel system would need to meet the fuel system performance requirements in CS 25.951, Fuel System: General.)

4.3 Wiring

The following paragraphs on wiring represent acceptable approaches for dealing with wiring used in and near fuel tanks. For specific requirements and further guidance, the applicant should review the wiring installation and design requirements in the electrical wiring interconnect systems (EWIS) rules of CS-25 Subpart H and the associated AMC.

4.3.1 Intrinsically safe wiring

All the wiring that is intended to conduct intrinsically safe levels of electrical power into or through the fuel tanks should incorporate protective features that prevent an exceedance of the intrinsically safe levels discussed in paragraphs 3.2 and 3.3 of this AMC. This wiring should also be protected from the transients induced by high intensity radiated fields (HIRF). The following protective features could be used to support that objective:

— Separation and shielding of the fuel tank wires from other aeroplane wiring and circuits,
— Shielding against HIRF and other electromagnetic effects, and
— The installation of transient-suppression devices to preclude unwanted electrical energy from entering the tank.

4.3.2 Higher energy wiring

This includes all wiring that is not intrinsically safe.

4.3.2.1 Wiring should not be routed through metallic conduits inside the fuel tank or adjacent to fuel tank surfaces such that damage, inappropriate maintenance, or other failure/wear conditions could result in arcing to the conduit or metallic tank surface and the consequent development of an ignition source in the fuel tank. If metallic or other conductive conduit materials are used, a single failure of electrical arcing of the wiring to the conduit, adjacent tank surfaces, or structure should be assumed to occur. In addition, circuit protective features or other features should be incorporated to preclude the development of an ignition source in the fuel tank. The methods that may be used to address this foreseeable failure condition include the use of circuit-protective features such as dual conduits, thick-walled conduits, and/or fast-acting AFCB or GFI circuit breakers. Providing multiple layers of sleeving alone would not be considered acceptable, since wear could defeat the multiple layer protection.

4.3.2.2 Where electric wires are routed through metallic conduits installed in a fuel tank, high surface temperatures or arcing through the conduit walls can be created by short circuits. All the wiring conducting levels of power that exceed intrinsically safe levels (e.g., the fuel pump power supply) into or through a fuel tank should be evaluated assuming arcing to adjacent surfaces, such as metallic conduits or wing surfaces, unless fail-safe protective features are provided. A critical electrical wiring condition might be one in which the insulation is worn, cracked, broken, or of low dielectric strength, allowing intermittent or constant arcing to occur without consuming enough power to cause the circuit protection device, such as a thermal mechanical circuit breaker, to open. Inspection of wiring from in-service aeroplanes has shown that greater than expected wear may occur on sleeving and wiring insulation due to movement of the wire within the conduit. Roughness of the conduit material and variations in vibration levels for each installation may significantly increase wear. In addition, inspections have shown that some protective sleeving has been missing or improperly installed, or the wrong sleeving material has been used, resulting in damage to the insulation. For these reasons, the use of protective sleeving on wiring would not, by itself, be adequate for showing compliance. The design should be tolerant to these types of foreseeable failure or maintenance errors.

4.3.3 Wire separation

Wiring designs used on transport category aeroplanes vary significantly between manufacturers and models; therefore, it is not possible to define a specific, universal separation distance, or the characteristics of physical barriers between wire bundles, to protect critical wiring from damage. The separation requirements for wiring and other components of EWIS are contained in CS 25.1707, System separation: EWIS. AMC 25.1707 contains guidance on determining an adequate separation distance between EWIS and between EWIS and aeroplane systems and structures. Even if CS 25.1707 is not in the type certification basis of the aeroplane being modified, the guidelines contained in AMC 25.1707 should be applied, along with the guidelines contained in this AMC, when determining the adequate separation distance. Intrinsically safe wiring for fuel tanks needs to be protected from induced currents caused by power system switching transients, or electromagnetic interference due to close proximity to other aeroplane wiring. In addition, damage to wire insulation can result in unwanted electrical energy being transmitted into the fuel tank, if the damaged wire can come into contact with the conductor of another wire that is not intrinsically safe. Of particular concern is the possibility of a wire bundle fire that exposes and breaks wires that are not intrinsically safe, and also damages the insulation of intrinsically safe wiring that is in close physical proximity. The broken wires may still be energised and could contact conductors of the damaged intrinsically safe wire. If physical separation is used to protect intrinsically safe fuel system wiring from other wiring, or to protect fuel tank walls from high-power wiring, the applicant must establish the minimum physical separation. The applicant should conduct an analysis to verify that currents and energies greater than those specified in paragraphs 3.2 and 3.3 of this AMC will not be applied to intrinsically safe wiring, considering the factors listed below. The following factors are based on the guidance contained in paragraphs 3. and 4. of AMC 25.1707:

4.3.3.1 The electrical characteristics, power, and criticality of the signals in the wire bundle and adjacent wire bundles;

4.3.3.2 Installation design features including the number, type, fire resistance, and location of support devices along the wire path of the intrinsically safe wire and adjacent higher power wires;

4.3.3.3 The maximum amount of slack wire resulting from wire bundle build tolerances and other wire bundle manufacturing variations;

4.3.3.4 Probable variations in the installation of the intrinsically safe fuel system wiring and adjacent wiring, including the position or omission of wire support devices and the amount of slack wire that is possible;

4.3.3.5 The expected operating environment, including the amount of deflection or relative movement that can occur and the effect of a failure of a wire support device, or a broken wire, or other methods used to maintain physical separation;

4.3.3.6 The effects of wire bundle fires;

4.3.3.7 Maintenance practices, as defined by the aeroplane manufacturer’s standard wiring practices manual, and the ICA required by CS 25.1529, CS 25.1729; and

4.3.3.8 Localised separation.

Note: Some areas of an aeroplane may have localised areas where maintaining a general physical separation distance is not feasible. This is especially true in smaller transport category aeroplanes or in areas where wiring spans the wing-to-body join of larger transport aeroplanes. In those areas that limit the separation distance, additional means of ensuring physical separation and protection of the wiring may be necessary. Testing and/or analysis used to show that the reduced separation distance is acceptable should be conservative and consider the worst possible failure condition not shown to be extremely improbable. The applicant should substantiate that the means to achieve the reduced separation provides the necessary level of protection for wire-related failures and electromagnetic effects.

4.3.4 Inspection

Means should be provided to allow for the visual inspection of the wiring, physical barriers, and other physical means of protection. Non-destructive inspection aids may be used where it is impracticable to provide for direct visual inspection, if it is shown that the inspection is effective and the inspection procedures are specified in the maintenance manual required by CS 25.1529 and CS 25.1729.

4.3.5 Identification

Means must also be provided to make EWIS wires readily identifiable and visible to maintenance, repair, or alteration personnel. The method of identification must remain legible throughout the aeroplane's operational life. The complete regulatory requirements for EWIS identification are contained in CS 25.1711, Component identification: EWIS.

4.3.6 Circuit breakers

Service experience has indicated that thermal mechanical circuit breakers installed in fuel pump circuits have not been shown, on some aeroplane designs, to preclude arcing of electrical wiring through metallic barriers into the fuel tank, barriers such as conduits, fuel pump housings, electrical connectors, or the tank wall. Evidence suggests that arcing from the wiring to metallic surfaces may not result in a hard short, which would trip the circuit breaker and may result in intermittent low level arcing that gradually arcs through the metallic barrier into the fuel tank. For these failure conditions, circuit protective devices such as an AFCB or GFI may be used to provide the fail-safe features necessary to show compliance. Appendix A of this AMC provides guidance for the certification of an AFCB or GFI.

4.3.7 The use of non-metallic conduits

If a non-metallic conduit is used, its compatibility with fuel should be shown. The non-metallic conduit should be evaluated for the effects of ageing due to heat, corrosion at the connecting fittings, electrostatic charge build-up, and resistance to heat damage from internal shorts of wires routed within the conduit.

4.3.8 Wire splices

Splices in fuel system wiring have been allowed as a standard repair procedure. The acceptability of splices will be based upon the system design and fail-safe features. The safety assessment may show that splices in fuel tank system wiring, such as fuel quantity indicating wiring within the fuel tank and fuel pump windings, are prohibited. This would be defined as a CDCCL.

4.3.9 The use of silver in fuel tanks

Silver can combine with sulphur or water and form silver-sulphide or oxide deposits between exposed conductors (terminal block connections, etc.). The silver-sulphide deposits reduce the resistance between the conductors and can ignite fuel vapour when exposed to very low levels of electrical energy. If the use of silver in electrical components and wiring in the tank is determined to be critical, it should be defined as a CDCCL. The energy levels that have been shown to ignite fuel vapour during laboratory tests approach the levels normally used on FQIS wires and probes (e.g. FAA Report No. DOT/FAA/AR-03/61, Silver-Sulphur Deposits on Fuel Quantity Indication System and Attendant Wiring). This issue should be carefully addressed.

4.3.10 The use of steel wool

Steel wool has been used as a cleaning tool to remove corrosion and to clean parts inside fuel tanks. Steel wool creates small conductive filaments that can cause ignition sources in a fuel tank if the steel wool makes a connection between two conductors in fuel tank quantity gauging system components. For this reason, applicants should not allow the use of steel wool inside fuel tanks, and recommend using other abrasives. (However, as stated in paragraph 5.3.4.1 in this AMC, the applicant should assume the presence of conductive debris, such as steel wool, when performing the fuel tank ignition prevention analysis.)

5 SAFETY ANALYSIS

5.1 Ignition source failure analysis

Compliance with CS 25.981 requires each applicant to develop a failure analysis for the fuel tank installation to substantiate that ignition sources will not be present in the fuel tanks. The requirements of CS 25.981 are in addition to the more general propulsion failure analysis requirements of CS 25.901 and CS 25.1309 that have been applied to propulsion installations.

5.1.1 CS 25.981(a)(3) defines three failure scenarios that must be addressed in order to show compliance with the rule:

5.1.1.1 No single failure, regardless of the probability of occurrence of the failure, may cause an ignition source.

5.1.1.2 No single failure, regardless of the probability of occurrence, in combination with any latent failure condition not shown to be at least extremely remote (i.e., not shown to be extremely remote or extremely improbable), may cause an ignition source.

5.1.1.3 No combinations of failures that are not shown to be extremely improbable may cause an ignition source. That is, each combination of failures that can create an ignition source must be separately shown to be extremely improbable.

5.1.2 SAE ARP4761, 'Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment' dated December 1996, describes methods for completing an SSA. An assessment may range from a simple report, which offers descriptive details associated with a failure condition, interprets test results, compares two similar systems, or offers other qualitative information, to a detailed failure analysis that may include estimated numerical probabilities. The depth and scope of an acceptable SSA depend on the following:

5.1.3.1 The complexity and criticality of the functions performed by the system under consideration,

5.1.3.2 The severity of the related failure conditions,

5.1.3.3 The uniqueness of the design and the extent of the relevant service experience,

5.1.3.4 The number and complexity of the identified causal failure scenarios, and

5.1.3.5 The detectability of contributing failures.

Note: CS 25.981 and CS 25.901 are intended to address system failures or conditions that may result in the presence of an ignition source in the fuel tanks. These specifications are not intended to address failures or conditions that could lead to the ignition of fuel vapour, which are addressed by other specifications, such as:

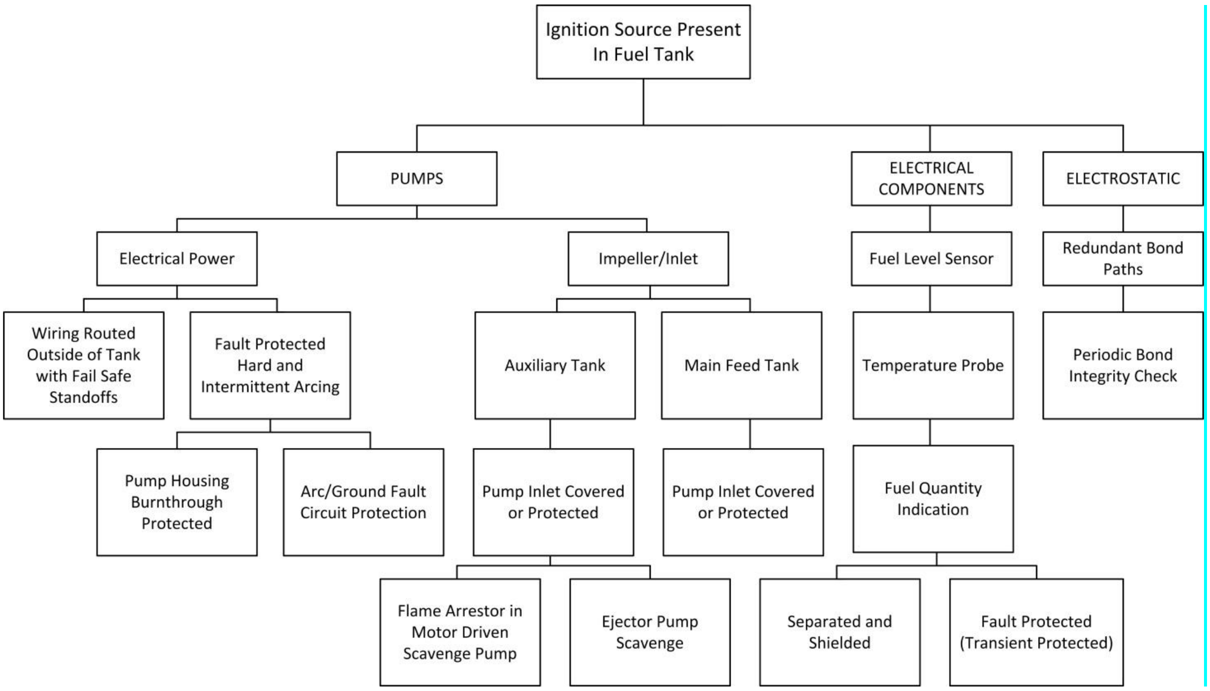
— Uncontained engine debris,
— External engine fires following an engine separation,
— Damage resulting from explosive materials such as bombs,
— Post-crash fire heating of tank surfaces,
— Propagation of fire through the aeroplane vent system into the fuel tanks, or

— A fire originating within the engine that burns through the engine case.

5.2 Qualitative safety assessment

5.2.1 Typical aeroplane fuel tank systems have a limited number of possible ignition sources. Figure 1 below shows some causes of ignition sources and methods that may be used to meet the fail-safe requirements. The level of analysis required to show that ignition sources will not develop will depend on the specific design features of the fuel tank system being evaluated. Detailed quantitative analysis should not be necessary if a qualitative safety assessment shows that features incorporated into the fuel tank system design protect against the development of ignition sources within the fuel tank system. For example, if intrinsically safe FQIS wiring entering the fuel tanks and the associated line replacement unit (LRU) were shown to have protective features such as separation (including circuit separation in the LRU) and shielding and/or transient suppression/energy limiting devices, the portion of the compliance demonstration for the associated wiring would likely be limited to showing the effectiveness of the features and defining any long-term maintenance requirements, including the mandatory replacement times, inspection intervals, related inspection procedures, or CDCCLs so that the protective features are not degraded.

Figure 1. Examples of Fuel Tank Ignition Source Considerations



5.2.2 In the case of the installation of a flame arrestor in the inlet line to a fuel pump, the compliance demonstration for the fuel pump may be limited to showing that the arrestor was effective at precluding propagation of the flame from the pump back down the inlet line into the tank, and showing that any anticipated failures or events could not violate the explosion-proof features of the pump assembly. A CDCCL may be necessary to maintain the flame arrestor design feature. If the flame arrestor cannot be shown to be effective for the life of the installation, an airworthiness limitation limiting the life of the flame arrestor would be necessary. In addition, revalidation of the fuel system with other regulations (e.g. icing and reduced flow due to contamination) would be required if modifications were incorporated into the fuel feed system. The SSA criteria, process, analysis methods, validation, and documentation should be consistent with the guidance material provided in SAE ARP4761, using the unique guidance specific to the fuel tank system as defined in this AMC.

5.3 Assumptions and considerations for fuel tank system analysis

The applicant should conduct the fuel tank system analysis based on the following assumptions:

5.3.1 Fuel tank flammability

The analysis should assume that the environment inside the fuel tank is always flammable. The conditions required to ignite fuel vapour from ignition sources vary with the pressures and temperatures within the fuel tank and can be affected by sloshing or spraying of fuel in the tank. Due to the difficulty in predicting fuel tank flammability, it should be assumed that a flammable fuel/air mixture exists in aeroplane fuel tanks and it is required that no ignition sources be present. The SSA should be prepared considering all the in-flight, ground, service, and maintenance conditions for the aeroplane, assuming that an explosive fuel/air mixture is present in the vapour space of fuel tanks and vent systems at all times, unless the fuel tank has features that mitigate the effects of tank ignition (e.g. polyurethane foam).

5.3.2 Failure condition classification

Unless design features are incorporated that mitigate the hazards resulting from a fuel tank ignition event (e.g. polyurethane foam, an adequate structural margin), the SSA should assume that the presence of an ignition source is a catastrophic failure condition.

5.3.3 Latent failures

5.3.3.1 In order to eliminate any ambiguity as to the restrictions on latent failures, CS 25.981(a)(3) explicitly requires that any anticipated latent failure condition must not leave the aeroplane one failure away from a catastrophic fuel tank ignition. In addition to this limitation on latency, CS 25.1309(c) limits the latent failure conditions to those that do not create an 'unsafe system operating condition.' Consequently, if a latent failure condition is not extremely remote (i.e., it is anticipated to occur) and it creates an 'unsafe system operating condition,' then flight crew alerting must be provided to 'enable them to take appropriate corrective action.' Notwithstanding these restrictions on latency, there are practical limitations on the available means of compliance. For example, detecting a failure condition requires a finite period of time, and there are not always 'appropriate corrective actions' that can be taken during the flight. Consequently, for the purpose of complying with CS 25.981(a)(3), the period of latency for any anticipated significant latent failure condition should be minimised and not allowed to exceed one flight cycle. For the purpose of complying with CS 25.1309(c), whenever the aeroplane is operating one failure away from a catastrophic fuel tank ignition, this should be considered an 'unsafe system operating condition,' recognising that sometimes the only appropriate corrective action when problem detection is available is to continue to the destination but not to initiate another flight without making appropriate repairs.

5.3.3.2 Another practical limitation on the available means of compliance is the technological feasibility of providing inherent failure detection within the design for all significant failures. Sometimes periodic inspection is the only practicable means of reliably detecting a failure condition. Consequently, when such inspections are identified within the analysis as the means of detection, the inspection method and frequency must be sufficient to conclude that the probability of occurrence of the significant latent failure condition is extremely remote.

5.3.3.3 Any mandatory replacement time, inspection interval, related inspection procedure, and all the CDCCLs identified as required to prevent development of ignition sources within the fuel tank system for CS 25.981(a) must be identified in the Airworthiness Limitations Section of the ICA as fuel system Airworthiness Limitations. The Airworthiness Limitations Section should include the following:

5.3.3.3.1 A designation of the maintenance actions and alterations that must be inspected (critical inspections), including at least those that could result in a failure, malfunction, or defect endangering the safe operation of the aircraft, if not performed properly or if improper parts or materials are used.

Note: A validation inspection should be conducted to reaffirm all or a portion of the initial inspection requirements for those critical inspections that, if not performed properly or if improper parts or materials are used, could result in a failure, malfunction, or defect endangering the safe operation of the aeroplane. For those air carriers that use a mechanic for the initial inspection, an inspector should be used to conduct the validation inspection. For those air carriers that use an inspector for the initial inspection, another qualified inspector should be used to conduct the validation inspection.

5.3.3.3.2 The procedures, standards, and limits necessary for critical inspections and acceptance or rejection of the items required to be inspected, and for periodic inspections and calibration of precision tools, measuring devices, and test equipment.

5.3.4 Failure conditions

In accordance with CS 25.981(a)(3), the analysis must consider the effects of manufacturing variability, ageing, wear, corrosion, and likely damage. For the purpose of compliance with CS 5.981, 'extremely remote' failure conditions and 'extremely improbable' failure conditions are defined in AMC 25.1309. Likely damage is damage that, using engineering judgment or past experience, would lead one to conclude that an occurrence is foreseeable. Examples of likely damage are:

— a wire bundle located where a mechanic could use it as a handhold;
— an instrument located where, if someone dropped a wrench, damage would result; or
— a fuel probe located where a mechanic could use it as a step in the tank.

5.3.4.1 The analysis should be conducted considering the deficiencies and anomalies listed in paragraph 2.3 of this AMC, the failure modes identified by the review of service information (including review of supplier service data), and any other failure modes identified by the functional hazard assessment of the fuel tank system. For example, the applicant should assume the presence of conductive debris such as lockwire, steel wool, nuts, bolts, rivets, etc. CS 25.981 requires that the effects of manufacturing variability, ageing, wear, corrosion, and likely damage must be considered when showing compliance, which is needed to show compliance with CS 25.901(c). Credit for fail-safe features must be substantiated.

5.3.4.2 The level of manufacturing variability, ageing, wear, corrosion, and likely damage that must be considered should be determined based upon an evaluation of the detectability of degraded or out-of-specification configurations, and established and documented within the analysis. In-service and production functional tests, component acceptance tests, and maintenance checks may be used to substantiate the degree to which these states must be considered. For example, inspection of fuel tank system bonding on production aeroplanes has shown that some bonds were inadequate. Functional testing of all bonding was incorporated to address this deficiency. In some cases (e.g. component bonding or ground paths), a degraded state will not be detectable without periodic functional tests of the feature. For these features, inspection/test intervals should be established based on previous service experience of equipment installed in the same environment. If previous experience on similar or identical components is not available, conservative initial inspection/test intervals should be established until design maturity can be assured.

5.3.5 External environment

The severity of the external environmental conditions that should be considered when showing compliance with CS 25.981 is that of the conditions established by the certification specifications.

5.3.6 External sources of tank auto-ignition

The possibility of fuel tank ignition due to surface-ignition sources created by external tank heating should be considered. This includes heating of the tank due to the operation or failure of systems outside the tank within both the pressurised and unpressurised areas of the aeroplane, such as overloaded electric motors or transformers, failures in the pneumatic system, and/or ducting that could cause localised heating of tank surfaces. In addition, the possibility of localised heating due to external fires should be considered.

5.3.6.1 CS 25.967(e) requires that, 'Each fuel tank must be isolated from personnel compartments by a fumeproof and fuelproof enclosure.'

5.3.6.1.1 Leakage of fuel or vapour into spaces adjacent to the fuel tank, where a secondary fuelproof and fumeproof barrier is not provided, has typically been assumed for areas such as:

— The wing leading edges (including any adjacent compartment such as the strut) and trailing edges,
— Fairings located below the fuel tanks,
— Fuel pump enclosures, and
— Unpressurised areas of the fuselage surrounding fuel tanks located in the empennage.

5.3.6.1.2 Components located in these areas have been required to meet the explosion-proof requirements. These components or systems should be included in the analysis. Examples of such equipment include, but are not limited to, environmental control system (ECS) air conditioning packs, motors, power assisted valves, fuel pumps, hydraulic pumps/motors, certain flight control actuators, ECS controls, and wiring and valves.

5.3.6.2 A safety review of the flammable fluid leakage zones adjacent to fuel tanks should be conducted to determine whether the design complies with the requirements of CS 25.863(a) and CS 25.981. In general, the fire protection philosophy for any area considered a flammable fluid leakage zone is to assume that flammable vapour may be present in the zone and to minimise the probability of ignition of vapour (CS 25.863(a)). This has typically been accomplished by using combinations of the following design considerations:

— Grounding and bonding of electrical equipment,
— Qualification of electrical equipment as explosion proof,
— Sealing of electrical connectors,
— Proper support, protection, and separation of wiring,
— Drainage provisions in the leakage zone,
— Ventilation of the leakage zone in flight and of areas around the auxiliary tanks, and
— Immediate maintenance action to correct leaks in these areas.

5.3.6.3 Surface temperatures in areas adjacent to fuel tanks

EASA has approved installations where surfaces adjacent to the tank experience temperatures in excess of the internal fuel tank surface temperature limit. Manufacturers have substantiated that the conditions (ambient pressure, dwell time, fuel type, etc.) within these areas are such that a higher value may be used. For example, applicants have successfully substantiated, for certain pneumatic system installations, a maximum allowable surface temperature of 204 °C (400 °F) with a transient excursion up to 260 °C (500 °F) for a maximum duration of two minutes. The excursion above 204 °C (400 °F) occurs only during failure conditions such as a failure of the engine pneumatic system to regulate the temperature, or a duct rupture. Approval of these elevated temperatures has been based on specific design features, such as an over-temperature shutoff of the pneumatic system so that the surface temperatures adjacent to the tank cannot exceed the surface ignition temperature justified for the fluid type, including the effect of local airflow and ventilation conditions within the zone. The internal tank surface temperatures resulting from the failure should not exceed the surface temperature limit for the fuel type used as described in paragraph 3.5 of this AMC.

5.3.7 Electrical ignition sources

The applicant should perform a failure analysis of all the fuel systems and subsystems that have wiring routed into fuel tanks. Systems that should be considered include those for fuel pump power and control and indication, fuel quantity indication, fuel temperature indication, fuel level sensors, and any other wiring routed into or adjacent to fuel tanks. The analysis should consider system level failures, failures within LRUs, and the component level failures discussed below. The analysis should include the existence of latent failures and subsequent failures that may lead to an ignition source within the fuel tank. Examples include undetected failures of tank components or wiring, the undetected presence of conductive debris, damage to FQIS or level sensor probes, or corrosion, in combination with external failures such as hot shorts or electromagnetic effects. In addition, the applicant should provide a description of the protective means employed in the fuel system wiring. This should include a description of features such as separation/segregation, transient suppression devices, shielding of wiring, and methods employed to maintain configuration control of critical wiring throughout the life of the aeroplane.

5.3.8 Electrical short-circuits

5.3.8.1 One method that may provide protection of circuits that enter fuel tanks is the incorporation of a transient suppression device (TSD) in the circuit close to the point where those wires enter the fuel tanks. Consideration should also be given to protection of the wiring between the TSDs and the tank if the protection devices are not located at the tank entrance, and also to the possibility of transients being induced in the wiring between the TSDs and the electrical devices in the fuel tanks. Caution should be exercised when using a TSD to ensure that the TSD addresses both voltage and current suppression in order to limit the energy and current below the limits provided in Section 3.2 of this AMC.

5.3.8.2 Another method of protection that has been used to provide a fail-safe design with respect to electrical shorts is the separation of wiring to electrical devices in the fuel tanks from other electrical power wires and circuits, combined with shielding between the wiring that enters the fuel tanks and any other electrical power-carrying wires in the aircraft installation. The effects of electrical short circuits, including hot shorts, on the equipment and wiring that enters the fuel tanks should be considered, particularly for the FQIS wiring, fuel level sensors, and probes. Latent failures from factors such as contamination, damage/pinching of wires during installation, or corrosion on the probes, connectors, or wiring should be considered when evaluating the effects of short circuits. The wire routing, shielding, and segregation outside the fuel tanks, including within the FQIS components (e.g., gauging units), should also be considered when evaluating the effects of short circuits. The evaluation should consider both electrical arcing and localised heating that may result from short circuits on equipment, FQIS probes, and wiring. The evaluation of electrical short circuits should include consideration of shorts within electrical equipment, and wiring from the equipment into the fuel tank. Prevention of fuel ignition from electrical shorts to wiring that enters the fuel tanks may require specific wire and circuit separation and wire bundle shielding.

5.3.9 LRU design evaluation

The design review should include an evaluation of the separation and protective features incorporated into any fuel system LRU whose failure could result in high-level electrical power (i.e., above the intrinsically safe levels) entering the fuel tank. For example, circuit board failures could cause the LRU power supply circuits for the fuel quantity gauging system to come into contact with the circuits that lead into the fuel tank, resulting in a possible ignition source. Failures that can lead to violating the separation features within the LRU can be external or internal events. External failures include overvoltage or overcurrent, high humidity, temperature, vibration, shock, and contamination. Internal failures include manufacturing defects or flaws in the conductor, substrate, or coating. To address these failures, the design should either provide isolation and physical separation between the critical circuits, such as the circuits that enter a fuel tank, or adequate protective features, such as the transient suppression devices as discussed earlier, to protect the circuits that enter the fuel tank. Any LRU that meets the design requirements identified in Underwriters Laboratories Inc., UL 913, Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, III, Division 1, Hazardous (Classified) Locations, is considered acceptable, provided the following issues are addressed:

— Ideally, higher power circuits within the LRU should not be located on the same circuit board or in a wire harness or electrical connector with intrinsically safe circuits or wiring;
— There should be a physical barrier between circuit boards to isolate the intrinsically safe circuits from the effects of broken components or fire within the LRU; and
— If limiting devices are installed on the same circuit board in series with the system circuitry to limit the amount of power or current transmitted to the fuel tank, there should be 7.62 cm (3 inches) between the traces, unless the manufacturer can justify a smaller separation on the basis that the effects of fire on the circuit board will not compromise the intrinsically safe circuit(s).

5.3.10 Electromagnetic effects including HIRF

See AMC 25.954 for guidelines on establishing compliance with the requirements for fuel system protection from lightning effects.

5.3.10.1 The evaluation should consider the electromagnetic effects due to HIRF, electrical transients, and RF emissions on the fuel system conductors (e.g. fuel tank plumbing, structure, fuel, equipment and wiring) within the fuel tanks, particularly for the FQIS wiring and probes. The applicant should also consider the latent failures from factors such as contamination, damage, or corrosion on the probes or wiring when evaluating the effects of electrical transients. The wire routing, shielding, and segregation of conductors (e.g., plumbing, component casings, wiring, etc.) outside the fuel tanks should also be considered when evaluating the effects of electrical transients because the generation of the transient and the coupling to conductors may occur outside the fuel tanks. The evaluation should consider both electrical sparks and arcs, and localised heating, which may result from electromagnetic effects on the fuel tank system, FQIS probes, and wiring.

5.3.10.2 The evaluation should consider latent failures of electromagnetic protection features, such as shielding termination corrosion, shield damage, and transient limiting device failures, and the applicant should establish appropriate indications or inspection intervals to prevent the existence of latent failure conditions. The failure of other system components may also affect the protection against electromagnetic effects. Consequently, the evaluation should consider the effect of any anticipated failure on the continued environmental protection.

5.3.10.3 The evaluation of electromagnetic effects should be based on the specific electromagnetic environment of a particular aeroplane model. Standardised tests, such as those in EUROCAE ED-14G Change 1 dated January 2015, 'Environmental Conditions and Test Procedures for Airborne Equipment', and the equivalent RTCA, Inc., Document No DO-160G dated December 2010, Sections 19 and 20, are not sufficient alone to show that the appropriate standardised test categories, procedures, and test levels of EUROCAE ED-14G/RTCA DO-160G are selected, without an evaluation of the characteristics of the specific electromagnetic environment and the induced transient levels assigned to systems installed within a particular aeroplane model. Simulation of various latent failures of fuel system components within the tanks may be needed to show the effectiveness of the transient protection. The effectiveness of these features should be verified using the appropriate test procedures and test levels of EUROCAE ED-14G/RTCA DO-160G, determined above.

5.3.10.4 Prevention of fuel ignition due to electromagnetic effects may require specific wire segregation and separation, wire bundle shielding, or transient suppression for wires entering fuel tanks. The effectiveness of the transient protection features should be verified using the appropriate test procedures and test levels of EUROCAE ED-14G/RTCA DO-160G, determined above.

5.3.10.5 Redundancy of bond paths

A failure of bonding jumpers is generally considered a latent failure, since there is no annunciation or indication of the bonding failure. The aeroplane fleet fuel tank inspections that occurred as a result of the TWA 800 investigation (National Transportation Safety Board Aircraft Accident Report NTSB/AAR-00/03, 'In-flight Breakup Over the Atlantic Ocean Trans World Airlines Flight 800, Boeing 747-131, N93119, Near East Moriches, New York,' dated July 17, 1996) showed that failures of bonding jumpers, due to damage, wear, or manufacturing errors, were not unusual. Based on this, it would be difficult to show that the probability of a failure of a single bonding jumper is extremely remote or extremely improbable. Therefore, electrical bonding jumpers or other bonding provisions would need to consider the consequences of these latent failures. This may result in designs that incorporate electrical bonding redundancy, if the failure of a single electrical bonding feature could create a fuel tank ignition source. Additionally, manufacturers would need to consider the use of appropriate maintenance to detect failed bonding jumpers. An example of such maintenance might include periodic inspections to limit latency.

5.3.10.6 Self-bonding couplers

Early generation, self-bonding, flexible fuel couplers did not have multiple bonding paths. Thus, these bonding couplers exhibited single-point failures that caused a loss of function. These self-bonding flexible couplers failed because of missing bonding springs, anodising on bonding surfaces, and incorrect installation. The safety assessment of designs incorporating multiple bonding paths must consider these failure modes, and qualification testing should show that no ignition sources are present in the full-up (non-degraded condition) and possible degraded condition with failure modes present within the couplings. For example, failure assessments of clamshell-type, self-bonding metallic couplings in composite fuel tanks have shown that arcing could occur if a coupling was improperly latched, or became unlatched and fell to the bottom of the fuel tank. The design of the coupling would need to address these failure modes. Improper latching could be addressed through positive latching features with tactile and visual indications that the coupling is properly latched. Redundant fail-safe features, such as redundant hinge and latching features, redundant bonding features, etc., may be needed to address other possible failure modes.

5.3.10.7 Resistance or impedance limits of aeroplane electrical bonding provisions

5.3.10.7.1 There is no specific EASA guidance on the maximum resistance or impedance of aeroplane electrical bonding provisions because electrical bonding within a fuel system should be tailored to the performance requirements of a particular aeroplane design. The electrical bonding should consider the electrical sources, electrical faults, and electrostatic charges. The electrical bonding should also consider the fuel system design of the specific aeroplane, which would include the structure material used (aluminium, carbon-fibre composites, fibreglass composites, etc.), the configuration of the fuel system (routing of fuel tubes, wires, and hydraulic tubes), and the electrical bonding concept (intentional isolation, self-bonding fittings, separate bonding jumpers, etc.). Given the large variation in design approaches and the close relationship between the design approach and the electrical bonding requirements, it is not practical for EASA to provide specific guidance on the maximum bonding resistance or impedance.

5.3.10.7.2 Some type certificate (TC) holders have performed tests on their aeroplanes to determine the specific requirements for electrical bonding. Others, in the absence of specific aeroplane test data, have chosen conservative electrical bonding approaches. The approach is a decision each TC holder should make based on the specific situation for that TC holder’s aeroplane models.

5.3.10.8 Bonding integrity checks

Past experience has shown that measurement of bond resistance is the desired method of ensuring bond path integrity. During bonding resistance measurements, the protective finish of components might be damaged in order to penetrate the insulating anodised surface layer, which may lead to subsequent corrosion damage. This concern has resulted in some TC holders defining non-intrusive inspections for electrical bonding. These inspections may include detailed visual inspections provided that the quality of the electrical bonding feature can be adequately assessed by visual cues, such as visible corrosion, breakage, tightness, or missing bonding provisions. For critical bonds, this method would not by itself be adequate. Other inspection methods include inductively-coupled loop resistance measurements that eliminate the need to disconnect bonding jumpers, or to penetrate corrosion-prevention coatings. The need for bonding inspections, the frequency of the inspections, and the determination as to whether the inspections must be an airworthiness limitation should be established under the fuel tank SSA.

5.3.10.9 Bond corrosion and integrity

5.3.10.9.1 Degradation of electrical bonding provisions, such as bonding jumpers, has occurred on in-service aeroplanes. Results from aeroplane fuel tank inspections conducted on a sample of aeroplanes by manufacturers and operators showed discolouration, corrosion, and damage to bonding jumpers. It is not clear whether the discolouration indicates that corrosion that will become more severe with time, or whether it is simply a surface colour change. The applicant should define the bonding feature characteristics — such as visible corrosion, discolouration, jumper strand separation, and jumper strand breakage — that will be used to distinguish discrepant bonding provisions.

5.3.10.9.2 The level of corrosion observed on bonding features, specifically on bonding jumpers, varies greatly across aeroplane fleets. While some aeroplanes within a fleet and certain locations within the fuel tanks showed no evidence of corrosion, other aeroplanes and locations exhibited higher levels of corrosion. Inspection results indicate that the materials used in certain bonding jumpers (tin-plated copper) may be more prone to corrosion. Nickel-plated copper wire does not experience similar corrosion. Corrosion programs for aeroplane structure have long recognised the variability of corrosion within the fleet. Factors that influence the level of corrosion of bonding jumpers include the fuel type (sulphur content, etc.), the presence of water in the fuel tank, installation effects such as cracking of the tin plating when the jumper is installed, the temperature, humidity, and chemicals used for preparation of the fuel tanks prior to aeroplane storage, etc. While certain levels of corrosion or discolouration may be acceptable between inspection intervals, the showing of compliance should include substantiation that the materials used in the bonding jumpers are appropriate for use in the fuel tanks in consideration of the proposed inspection intervals. This substantiation should consider the variability in corrosive environments and the factors noted above that may exist on in-service and stored aeroplanes in the fleet.

5.3.10.10 CS 25.981 states: ‘(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 vapors.’ Fuel tube flexible couplings and components as small as nuts, bolts, and washers may develop sufficient charge to cause arcing due to electrostatic conditions if not properly accounted for in the design. Electrical bonding would need to be considered if these couplings are identified as ignition sources during the ignition source evaluation and assessment.

5.3.11 Friction sparks

The failure modes and effects analysis (FMEA) should include an evaluation of the effects of debris entering the fuel pumps, including any debris that could be generated internally, such as any components upstream of the pump inlet. Industry practices for fuel tank cleanliness, and design features intended to preclude debris entering the fuel pumps, have not been effective at eliminating debris. Service experience has shown that pump inlet check valves, inducers, nuts, bolts, rivets, fasteners, sealant, lockwire, and so forth have been drawn into fuel pumps and contacted the impeller. This condition could result in the creation of friction sparks, and it should be an assumed failure condition when conducting the SSA. Fail-safe features should be incorporated into the fuel pump design to address this condition. Examples of means that may be incorporated into the fuel pump design to address this concern include:

— the installation of inlet flame arrestors,
— the use of reticulated foam,
— the use/installation of ejector fuel pumps without impellers to scavenge fuel, or
— maintaining fuel over the pump inlet throughout the aeroplane flight attitude envelope.

6 COMPONENT FAILURE MODE CONSIDERATIONS

6.1 Component qualification review

The qualification of components, such as fuel pumps, has not always accounted for unforeseen failures, wear, or inappropriate overhaul or maintenance. Failures to account for these failure modes and testing the pump, using the procedures defined in Military Standard MIL-STD-810H, Method 511.6, Explosive Atmosphere, have led to some fuel pumps entering airline service having never been tested to demonstrate whether they have explosion-proof capabilities. This combined experience suggests that more needs to be done to establish the capabilities of fuel pumps and other fuel system components to operate safely in an explosive environment. Such a capability should be substantiated considering these factors in addition to the conditions noted in paragraph 3.3 of this AMC. The amount of qualification review can be significantly reduced if the fail-safe features noted earlier in this AMC are followed (e.g. not operating pumps in the vapour spaces of the tank, incorporating arc fault or ground fault protection on the electrical circuit, etc.). Therefore, an extensive evaluation of the qualification of components may be required if a qualitative assessment of the component and installation features does not eliminate the component as a potential ignition source.

6.2 Maximum component temperature for qualification of fuel system components

The maximum component temperatures may be determined experimentally. Tests should be conducted that are long enough for the component to reach the maximum temperature. All the foreseeable failures and malfunctions of the fuel tank components (including those failures and malfunctions that could be undetected by the flight crew and maintenance personnel) should be considered when determining the maximum temperatures.

6.2.1 Components mounted adjacent to the exterior surface of the fuel tank can create a high localised temperature on the inner surface of the tank. This can be investigated by laboratory tests that duplicate the installation, or by a validated heat transfer analysis using the maximum potential temperature of the component.

6.2.2 When aeroplane equipment or system components such as engine bleed air ducting or ECS are located near fuel tanks, an FMEA should be performed to determine the failures of adjacent systems or components that could cause elevated surface temperatures. The maximum internal tank temperatures that can occur during normal and failure conditions should be determined. Systems, such as over-temperature protection devices, should be evaluated to determine whether periodic health checks are necessary to ensure that latent failures do not exist.

6.3 Possible failure modes for determination of maximum component temperatures.

The following list identifies some possible failure modes, but not all the conditions, that should be explored in determining the maximum temperature expected for fuel tank components:

6.3.1 Fuel pumps

6.3.1.1 Normal fuel pump operation considering the highest hot day ambient and fuel tank temperatures: in many cases, fuel pump motors are protected by a (single) three-phase thermal circuit breaker. In several instances, the resetting of circuit breakers has resulted in arcing inside the fuel tank and the development of an ignition source from an existing failure. Therefore, the fuel pump circuit should also preclude the development of an ignition source if the breaker is reset or forced in by a mechanic. Methods that may be used to address this foreseeable failure condition include the use of circuit protective features such as non-resettable, fast-acting AFCB or GFI circuit breakers.

6.3.1.2 Two-phase operation of three-phase electrical fuel pumps: a failure of a single phase of a multiple-phase fuel pump will significantly increase the load on the remaining phases of the pump and the generation of heat in the pump. In many cases, thermal protection features within the pump have been incorporated to address this failure condition, but these means have not been effective at preventing continued operation of a pump with a failed electrical phase. Another failure condition that should be considered is the subsequent failure of a second phase of the pump and possible arcing or heat damage. In general, pumps should not be allowed to operate following a failure of a single electrical phase of the pump if such operation could result in the development of an ignition source. Automatic protective means, such as AFCBs or GFIs or other means, should be provided to shut down the pump when a single electrical phase failure occurs. Periodic inspections or maintenance of these features may be required.

6.3.1.3 Dry operation of fuel pumps, including lack of lubrication: service history has shown that flight crews and maintenance personnel have inadvertently operated fuel pumps for long periods of time without fuel in the fuel tank. Fuel pumps are typically qualified for dry run operation for periods of time based upon assumptions made about the possible duration of inadvertent operation, or the failure conditions, which could result in dry running of the pump. For example, some pumps were operated during qualification testing up to a maximum of 8 hours continuously, with total accumulated dry run operation of 24 hours. These qualification tests were accomplished in order to show that the fuel pump performance was still adequate following the dry pump operation. The tests were not conducted in an explosive environment and, hence, were not intended to qualify the pumps for such operation. In other cases, previous approvals were predicated on the assumption that the fuel pump would not be dry run operated because the pump would be turned off by the flight/ground crew following a pump low-pressure indication. Extended dry operation of pumps may result in surface temperatures above the auto-ignition temperature of the fuel, or may expose the pump to dry run operation where debris from the fuel tank could enter the impeller and cause sparks. Manufacturers' recommended procedures have not been shown to be adequate in preventing dry run operation. Therefore, additional fail-safe features are necessary to preclude ignition sources caused by the dry run operation of aeroplane fuel pumps. One or more of the following fail-safe means should be considered for the protection of fuel pumps:

1. Incorporating design features to keep the fuel pump inlet submerged in jet fuel to prevent dry running of the pump under all operating conditions.

2. Incorporating automatic pump shutoff features into the fuel pump or aeroplane to preclude dry run operation.

3. Other means such as the installation of flame arrestors in the fuel pump inlet to preclude flame propagation into the fuel tank.

6.3.1.4 The temperatures associated with the fuel pump following wet operation with wet mechanical components both at zero and reduced fluid flow.

6.3.1.5 The temperatures associated with moving mechanisms that are locked or seized.

6.3.1.6 The temperatures generated as a consequence of pump impeller slippage.

6.3.1.7 High temperatures or high currents due to a broken shaft. The design has to contain the broken shaft, and the pump and its control system must consider the high currents and temperatures that would follow.

6.3.1.8 Failed bearings: the effects of wear on the fuel pump features incorporated into the design to maintain explosion-proof characteristics should be evaluated. For example, the wear of bearings or failures, including spinning of any bushings, and the possible effects on quenching orifices should be evaluated. In many cases, the fuel pump explosion-proof features are not redundant, and the failure or degradation of the features is latent. If single or probable combinations of failures in the fuel pump can cause an ignition source, CS 25.981 requires the incorporation of the fail-safe features noted previously. If wear of the pump can cause the degradation of fail-safe features, appropriate inspections, overhaul, or life limiting of the pump should be included in the airworthiness limitations section of the ICA, per CS 25.981(d) and Appendix H to CS-25, paragraph H25.4.

6.3.2 FQIS

6.3.2.1 FQIS wiring in the tank, with maximum voltage and current applied, considering normal and failure conditions, including the effects of high-voltage systems outside the tank in proximity to the FQIS wires.

6.3.2.2 FQIS components in the normal and failed state with the above associated maximum voltages and fault currents applied.

6.3.3 Float switch system

Float switch system temperatures should be determined considering the maximum environment temperatures and the application of the applicable maximum voltage and fault currents.

6.3.4 Fuel system components

The temperatures of the fuel system components should also be evaluated considering the failure of the bonding straps.

6.3.5 Pneumatic system

Pneumatic system temperatures need to be evaluated for the effects of duct ruptures impinging on the external tank surface. Radiant and conducted heat transfer associated with the tank and components affecting tank wall temperatures should also be considered (see the previous discussion of spaces adjacent to fuel tanks).

6.3.6 Electrical defects and arcing

Electrical defects that generate excessive heat, and arcing at the electrical connections to the pump housing or within the connector.

6.3.7 Submerged heat exchangers

Submerged heat exchangers and supply tubing operating under conditions of maximum heat rejection to the fuel. This should include failures in any systems outside the fuel tank that could result in heat exchanger or supply tubing surface temperatures exceeding 204 °C (400 °F).

6.3.8 Failed or aged seals

6.3.8.1 Spraying of fuel in the tank from any pressurised fuel source may cause electrostatic charging of the components in the fuel tank. In addition, the use of sealant in connectors that is not compatible with the fuel may allow leakage into the connector and the possibility of a fire near the connector.

6.3.8.2 Fuel line couplings

Ageing of seals may result in hardening of the seal material and leakage and spraying of fuel within the fuel tank; therefore, fuel line coupling designs should be evaluated and a design life should be established for all seals that are shown to age and allow leakage that can cause unacceptable electrostatic charging of components.

6.3.9 Fuel pump cooling flow

Fuel used for the cooling of fuel pumps may be sprayed from the fuel pump. Fuel pump cooling flow should not be sprayed into the fuel tank vapour space for the same reason as stated in 6.3.8 for the spraying of fuel. Means should be provided to distribute the discharged cooling fuel into the fuel tank at or near the bottom of the fuel tank.

6.3.10 Explosion-proof electrical connector sealant and seals

Electrical connections to fuel pumps are typically located either inside or outside the fuel tank in areas of the aeroplane where the presence of flammable fuel vapour should be assumed because no secondary sealing of fuel is provided. Fuel leakage and corrosion at electrical connectors located outside the fuel tank has allowed the presence of both flammable vapour and electrical arcing at connectors, resulting in fires. In other applications, arcing has occurred at the pump connections inside the fuel tanks, requiring the installation of appropriately sized steel shields to prevent arcing through the connector or pump housing into the fuel tank or areas where flammable vapour could exist.

6.3.11 Arcing at the pump electrical connections

Wear, corrosion, manufacturing variability (e.g. tolerances), connector distortion and seal damage from ice, and bent pins in the connector are examples of failures that have caused high resistance or shorting and arcing in arcing electrical connectors. Based upon historical data showing that these and other failure modes listed previously in this AMC have occurred in fuel pump connectors, arcing in the connectors is a foreseeable failure. Each of these single or cascading failure modes should be included in the FMEA. High current loads present during pump start-up and operation exacerbate arcing in the connector. The size and duration of the arcing event should be established based upon the fuel pump electrical circuit protection features. Arcing at the pump electrical connections, and the resultant damage to the pump connector, housing, and explosion-proof features due to intermittent, and maximum energy, arcing events should be assumed. If fuel is present on the backside of the connector, failures resulting in fuel leakage in conjunction with arcing in the connector should be assumed if the fuel leak is a latent failure or is the result of a cascading failure. The design of traditional fuel pumps has resulted in the need to install AFCB or GFI protection features to address foreseeable failures and limit the energy release during an arcing event to prevent an ignition source from occurring. The pump connector should be shown to contain any resultant arcing or fire and to maintain all surface temperatures below the auto-ignition temperature of the fuel. Component manufacturer maintenance records and qualification test results should be reviewed as part of the safety analysis process to establish that any sealants and materials in the connector are compatible with the operating environment and to determine whether a design life or periodic inspections for the pump connector are needed.

7 AIRWORTHINESS LIMITATIONS FOR THE FUEL TANK SYSTEM

7.1 CS-25 Appendix H, paragraph H25.4(a)(2) requires that each mandatory replacement time, inspection interval, related inspection procedure, and all the CDCCLs approved under CS 25.981 for the fuel tank system, be included in the airworthiness limitations section of the ICA.

7.2 Critical design configuration control limitations include any information necessary to maintain those design features that were defined in the original type design as being needed to preclude the development of ignition sources. This information is essential to ensure that maintenance, repairs, or alterations do not unintentionally violate the integrity of the original fuel tank system type design. The original design approval holder should define a method to ensure that this essential information will be evident to those that may perform and approve repairs and alterations. Visual means to alert the maintenance crew should be placed in areas of the aeroplane where inappropriate actions may degrade the integrity of the design configuration. In addition, this information should be communicated by statements in the appropriate manuals, such as wiring diagram manuals.

7.2.1 CDCCLs may include any maintenance procedure that could result in a failure, malfunction, or defect endangering the safe operation of the aeroplane, if not performed properly or if improper parts or materials are used. This information is essential to ensure that maintenance, repairs, or alterations do not unintentionally violate the integrity of the original type design of the fuel tank system.

7.2.2 CDCCLs are intended to identify only the critical features of a design that must be maintained. CDCCLs have no intervals; they establish configuration limitations to maintain and to protect the 'critical design feature' identified in the CDCCLs. CDCCLs can also include requirements to install placards on the aeroplane with information about the critical features. For example, certain components of a fuel pump (or all the components) may include critical features that are identified as CDCCLs. These critical features must be identified in the Airworthiness Limitations Section of the ICA and should also be identified in the component maintenance manual (CMM) as CDCCLs to provide awareness to maintenance and repair facilities.

7.2.3 Certain CDCCLs apply to elements of fuel system components. As such, 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. (See the CMM deviation definition in Appendix C of this AMC.)

7.3 Any fuel tank system components that are determined to require periodic maintenance, inspection, or overhaul to maintain the integrity of the system or maintain protective features incorporated to preclude a catastrophic fuel tank ignition event must be defined and included in the airworthiness limitations section of the ICA. An inspection airworthiness limitation has a specific task and interval (such as 10 years). The inspection interval should be established based on the standard practices defined in AMC 25.1309 for the evaluation of component failures. The inspection could also be required following maintenance to verify that a CDCCL feature is maintained. Examples of inspection airworthiness limitations include the following:

7.3.1 Ageing fuel line coupling seals/o-rings

In certain instances, the materials used in fuel line couplings may lose flexibility and harden with age. Under pressurised operation, the seal may allow fuel leakage. This will allow spraying of fuel in the tanks or other areas of the aeroplane where spraying fuel could create a fire hazard. Repetitive inspections, functional checks, or mandatory replacement intervals may be required to prevent leakage.

Note: While not related to compliance with CS 25.981, the hazards associated with the ageing of fuel coupling O-rings, resulting in air entering fuel lines during suction feed operation, should also be addressed when developing the fuel system maintenance program.

7.3.2 Wear of pump bushings, bearings, and seals

Wearing of pump bushings, bearings, and seals may significantly affect the performance of fuel pumps and degrade the features necessary to maintain the explosive-proof qualification. In most cases, these failure conditions are latent; therefore, incorporation of other fail-safe features, as discussed earlier in this AMC, should be considered. If fail-safe features, such as the installation of feeder tanks that are filled using ejector pumps, are incorporated, the functioning of those features would need to be ensured by indications or periodic functional tests. The installation of fuel level sensors in the feeder tanks would provide continuous monitoring of the function. Another means could be the installation of flow indicators in the flow line of the ejector pump that can be viewed by maintenance personnel, and a mandatory periodic inspection of this function is one example of a method of a mandatory maintenance action.

7.3.3 Fuel pump electrical power protective features

If a failure of an AFCB or GFI protective feature and/or a thermal fuse (closed) is latent and this feature is needed to maintain the fail-safe features, periodic checks would likely be needed. The inspection interval, and the need for built-in test features with indications of failures, should be established through the safety analysis process and should consider the factors described in paragraph A.3.4.3 of Appendix A to this AMC.

7.3.4 Transient suppression/energy limiting devices

If a failure of the device is latent and this feature is needed to maintain the fail-safe features, periodic checks will likely be needed.

7.3.5 Wire shield grounding

Component grounds and wires will likely require inspections and measurements to determine whether they are properly grounded.

7.3.6 Fuel tank access panel/door seals

Maintenance tasks should adequately provide procedures for inspections and checks of access panels and door seals.

7.3.7 Corrosion, wear, and damage to fuel pump connectors

Maintenance tasks should provide adequate procedures for inspecting and checking fuel pump connectors for wear, corrosion, and damage.

7.3.8 Integrity of the fuel pump electrical supply conduit

Maintenance tasks should provide adequate procedures for inspecting the integrity of the structure, sealing, drain holes, and bends of the electrical supply conduit to the fuel pump.

7.4 Maintainability of design and procedures

Maintainability, both in the design and procedures (i.e. the master minimum equipment list, aeroplane maintenance manual, etc.), should be verified by the applicant. This should include, as a minimum, verification that the system and procedures support the safety analysis assumptions and are tolerant to the anticipated human errors.

7.5 Incorporation by reference into airworthiness limitations

7.5.1 Where the words 'in accordance with' or 'per' are used in the airworthiness limitations, the procedures in the referenced document must be followed to ensure that the critical design feature is maintained. Any changes to these procedures require approval by EASA before they can be used.

7.5.2 Where the words ‘refer to’ are used in the airworthiness limitation, the procedures in the referenced document represent one method of complying with the airworthiness limitation. An accepted alternative procedure may be developed by the operator in accordance with its procedures in its maintenance program/manual. Prior approval by EASA is not required for this action.

7.6 Visible identification of CDCCLs

7.6.1 CS 25.981(d) establishes a requirement for visibly identifying the critical features of a design that are located in certain areas. The DAH should define a method of ensuring that this essential information will be communicated with statements in the appropriate manuals, such as wiring diagram manuals, it will be evident to those who perform and approve such repairs and alterations, and it will be identified as a CDCCL.

7.6.2 An example of a CDCCL that would result in a requirement for visible means would be maintaining wire separation between the FQIS wiring and other high-power electrical circuits where the separation of the wiring was determined to be a CDCCL. Acceptable methods of providing visible means would include colour coding and labelling the wiring. For retrofits of markings onto existing wiring, the placement of identification tabs at specific intervals along the wiring would be acceptable. Standardisation within the industry of the colour coding of the wiring used for the fuel tank system would assist maintenance personnel in the functional identification of wiring. It is recommended to use pink coloured wiring as a standard for fuel tank system wiring.

Appendix A. Certification of Arc Fault Circuit Breakers (AFCBs) or Ground Fault Interrupters (GFIs)

A.1 PURPOSE

This Appendix provides guidelines for the certification of AFCB or GFI devices that have been shown to be practical means to protect the circuits of electric-motor fuel pumps and other fuel tank components that use higher than intrinsically safe electrical power (for example, motor-operated valves).

A.2 BACKGROUND

A.2.1 Service experience has shown that failures in the power supply circuit of a fuel pump, discussed in the body of this AMC, can result in ignition sources and, therefore, must be assumed as a foreseeable failure condition. Traditional thermal circuit breakers are sized to prevent nuisance trips during fuel pump transient power demands and have not tripped when intermittent electrical arcs occured. Intermittent arcing can erode metallic barriers such as conduits, electrical connectors, and the pump housing, resulting in a loss of the integrity of the explosion-proof features, or creating ignition sources outside in areas adjacent to the fuel tank. Addressing the failure modes discussed in this AMC has resulted in the need to provide fast-acting GFI or AFCBs in traditional fuel pump electrical circuits in order to show compliance with CS 25.981.

A.2.2 AFCBs have been used as a practical means to protect against arcing in the power circuits of fuel pump motors powered by either alternating current or direct current. SAE International has issued two aerospace standards for AFCBs, one for alternating current circuits and one for direct current circuits. (See paragraph B.3 of Appendix B of this AMC).

A.2.3 Fuel pump housings and metallic conduits are grounded to the airframe, and any arcing to the cavity wall or conduit creates a ground fault. Therefore, GFIs have been used in AC pump power circuits as a practical means to ensure that power is quickly disconnected from the fuel pump in the event of a ground fault in the pump or the associated power wiring.

A.3 CERTIFICATION GUIDELINES

One acceptable means for the applicant to show compliance with the applicable regulations is to demonstrate, through design, review, analysis, and test, that the AFCB or GFI performs as intended under any foreseeable operating conditions and addresses the following guidance:

A.3.1 Fault detection trip levels

A.3.1.1 The applicant should show that the AFCB or GFI can distinguish between actual fault events and events characteristic of the normal aeroplane pump start-up operating loads and environmental conditions. Laboratory testing and/or aeroplane ground/flight testing should be performed to show the 'intended function' of the AFCB or GFI. The test methods chosen should reproduce the most common types of arcing in fuel pumps that occur in an aeroplane environment due to ground or arc faults. The AFCB or GFI should be designed to prevent nuisance tripping due to normal aeroplane electrical loads and electrical bus switching, and to operate continuously with the normal and abnormal aeroplane electrical bus switching characteristics associated with the master minimum equipment list dispatch relief configurations.

A.3.1.2 Installation of the AFCB or GFI should not result in an appreciable increase in the loss of the fuel pump function. A reliability requirement of the order of 100 000 hours mean time between failures may be satisfactory, but the applicant should show that a failure of the AFCB or GFI does not result in an appreciable increase in the occurrence of failures that result in the loss of fuel pump function.

A.3.1.3 Sufficient laboratory testing and aeroplane testing should be conducted to show the AFCB or GFI nuisance trip performance, including tests for lightning, HIRF, and electromagnetic compatibility. In addition, sufficient laboratory testing should be conducted to show that the AFCB or GFI trips before arcing in the fuel pump can lead to the ignition of fuel vapour in the fuel tank.

A.3.1.4 A means should be provided to latch the AFCB or GFI in a state that removes power from the fuel pump motor in the event that a ground fault has been detected, until the AFCB or GFI is reset. A trip of a single AFCB or GFI should not be reset until the reason for the trip has been determined and repaired, or until it has been determined that no ground fault exists. Intermittent arcing can cause tripping of circuit protection devices resulting from failures that are difficult to isolate during maintenance actions. Single trip events may be attributed to a nuisance fault. However, maintenance instructions should include notes that state that repeated tripping of devices indicates that an intermittent fault exists, and the circuit should not be energised until the fault is isolated and repaired.

A.3.2 Software

Inadvertent operation of multiple AFCB or GFI devices has the potential to affect the continued operation of more than one engine, a condition that EASA considers to be hazardous. The software used by the AFCB or GFI devices should be developed and verified in accordance with the latest version of AMC 20-115.

A.3.3 Airborne Electronic hardware

Application-specific integrated and complex circuits used by the AFCB or GFI devices should be developed and tested in accordance with the latest version of AMC 20-152.

A.3.4 System safety assessment

A.3.4.1 AFCB or GFI devices may be installed in circuits that perform essential or critical functions, and/or their performance could impact the safety of flight. The applicant should perform an installation SSA in accordance with CS 25.901(c), 25.981(a) and (d), and 25.1309. The SSA should include a functional hazard assessment to determine the effects of failures of the AFCB or GFI devices on the safety of the aeroplane and to verify that the design limits the probability of undesirable failure conditions to acceptable levels. In addition, the applicant should address the potential for possible common cause trips due to hardware/software errors and common cause trips due to environmental conditions such as HIRF (CS 25.1317), lightning (CS 25.954 and 25.1316), and electromagnetic interference (CS 25.1301, and 25.1353(a)).

A.3.4.2 A failure to provide fuel pump power due to the unintended activation of multiple AFCB or GFI devices has the potential to affect the continued operation of more than one engine. A circuit protective device failure, cascading failure, or common cause failure that affects multiple engines would be non-compliant with CS 25.903(b) if it prevents the continued operation of the remaining engines, or requires immediate crew action to prevent a multiple engine power loss.

A.3.4.3 A failure of an AFCB or GFI device to detect an arc or ground fault condition in a fuel pump circuit can contribute to a catastrophic failure condition. Assuming that the loss of the explosion-proof features of the pump (examples discussed in paragraph A.2.1) or arcing at the electrical connector could result from a single failure, EASA considers the undetected failure of an AFCB or GFI alone, which prevents its detection of or response to an arc or ground fault, to be a hazardous failure condition. The probability of a loss of arc or ground fault protection should either be shown to be extremely remote (if latent, consistent with the requirement of CS 25.981(a)(3)) or annunciated to the flight crew prior to flight. If failures of the AFCB or GFI can contribute to hazardous or catastrophic failure conditions, the safety assessment should analyse the common cause failures or design errors that could result in these conditions and verify that appropriate protection to prevent them is provided. Due to the nature of AFCB and GFI devices, special attention should be given to protection from lightning, EMI, and HIRF.

A.3.4.4 As discussed in Section A.3.7 below, means should be provided for the flight crew to reset the AFCB or GFI in the event that more than one fuel pump AFCB or GFI trips simultaneously in flight.

A.3.4.5 Further, the applicant should show by design, analysis, and fault insertion testing, if applicable, the validity of failure analysis assumptions, and show that the probability of the failure of AFCB or GFI to detect the existence of a ground or arc fault condition and remove power from a pump is extremely remote (10^{-7} or less). In order to show this, AFCB and GFI installations have typically required an automatic built-in test feature that verifies the AFCB or GFI is operational before applying power to the fuel pump prior to each flight (see Section 5.3.3 of this AMC).

A.3.5 Power and ground requirements

AFCBs or GFIs are active devices and they require power to function. The applicant should show that the AFCB or GFI power and ground connections are implemented such that all the aeroplane’s load margins are sufficient and that proper circuit protection or other methods are used to protect the AFCB or GFI power and ground wiring. The applicant should also show that there are no hazards to maintenance or flight crews due to possible hot shorts to electrical panels containing AFCBs or GFIs. In addition, if the installation of AFCBs or GFIs involves the direct replacement of devices on a given electrical panel, the applicant should show that there is adequate power/heat dissipation and ensure a safe touch temperature.

A.3.6 Built-in test

AFCB and GFI devices should incorporate the built-in test and annunciation features needed to meet the reliability requirements for showing compliance with CS 25.981(a)(3). For example, if a single or cascading failure in the fuel pump electrical circuit can result in an ignition source, a circuit protection feature failure rate less than extremely remote (1×10^{-7}) would be required in order to comply with CS 25.981. Traditional protective devices without built-in tests and annunciations of failures have not been shown to achieve this level of reliability. Applicants should consider to install multiple protective devices in series or provide built-in tests with annunciation.

A.3.7 Troubleshooting procedures

A.3.7.1 Because AFCBs or GFIs are capable of detecting ground paths on pumps and aeroplane wiring that may not be detected by visual inspection, the applicant should define the operational and maintenance philosophies and the methodology associated with an AFCB or GFI trip that does not rely solely on visual inspections. The applicant should show how the maintenance procedures would be able to safely distinguish and diagnose an AFCB or GFI trip and a nuisance trip without causing a fuel tank explosion. Operational instructions and maintenance procedures should be provided to prevent the resetting of tripped AFCBs or GFIs until it can be assured that resetting an AFCB or GFI will not cause the occurrence of a fuel tank explosion. Human factors should be taken into account to minimise the possibility of human errors during aeroplane operation and maintenance.

A.3.7.2 If multiple boost pumps are protected with AFCB or GFI devices such that the continued operation of multiple engines could be affected, there should be a means for the flight crew to reset tripped AFCB or GFI devices in flight. A loss of fuel pump capability due to inadvertent tripping in some fuel tanks could result in a loss of the fuel reserves needed to complete an extended operations (ETOPS) flight or a safe diversion. To prevent causing an ignition source, the applicable aeroplane flight manual should contain a limitation against the reset of a single AFCB or GFI. However, in order to address common cause inadvertent tripping, procedures should be provided for resetting AFCB or GFI devices when multiple AFCBs or GFIs have tripped simultaneously in flight.

A.3.8 Hardware qualification

Environmental testing — including thermal, shock and vibration, humidity, fluid susceptibility, altitude, decompression, fungus, waterproof, salt spray, and explosion-proof testing — should be performed in accordance with EUROCAE ED-14G/RTCA DO-160G or equivalent standards. The applicant should define an insulation, dielectric, and electrical grounding and bonding standard acceptable to EASA for the AFCBs or GFIs. Appropriate test categories in each section of EUROCAE ED-14G/RTCA DO-160G should be chosen based on the AFCB or GFI installation environment defined for the specific aeroplane. Particular attention should be given to the normal and abnormal power input tests outlined in Section 16 of EUROCAE ED-14G/RTCA DO-160G. A system with AFCBs or GFIs installed must comply with CS 25.954 and CS 25.1316 for lightning protection, CS 25.1301 and CS 25.1353(a) for electromagnetic compatibility, and CS 25.1317 for HIRF.

A.3.9 Aeroplane tests

The applicant should show by ground tests, flight tests, or both that all the AFCBs or GFIs remain armed during both normal and abnormal electrical power bus and load switching as described in paragraph

A.3.1.1 of this AMC, and are not adversely affected by the operation of other aeroplane systems. The aeroplane tests should also show that neither the AFCBs nor the GFIs would produce electromagnetic interference that would affect other aeroplane systems.

A.3.10 Instructions for Continued Airworthiness (ICA)

A.3.10.1 The applicant must submit the ICAs required by CS 25.1529 in order to provide the necessary procedures to service and maintain AFCB or GFI installations. As required by Appendix H to CS-25, H25.4, the Airworthiness Limitations Section of the ICA must include each mandatory replacement time, inspection interval, related inspection procedure, and all the critical design configuration control limitations (CDCCLs) approved under CS 25.981 for the AFCB or GFI installation. Inspection intervals determined from the safety analysis should be included for the detection of latent failures that would prevent the AFCBs or GFIs from tripping during a ground or arc fault event.

A.3.10.2 AFCBs or GFIs used for showing compliance with the CS 25.981 requirements for preventing ignition sources are typically CDCCLs in these installations. As required by CS 25.981(d), the applicant must provide visible means of identifying the AFCB or GFI as a CDCCL and should provide design features to minimise the inadvertent substitution of an AFCB or GFI with a non-AFCB or GFI device.

A.3.11 Aeroplane flight manual limitations

The aeroplane flight manual limitations section should address any limitations related to the intended function of the AFCBs or GFIs and any self-test features of the AFCB or GFI design.

Appendix B: Related Documents

B.1 EUROCAE Documents

— EUROCAE ED-14G Change 1 ‘Environmental Conditions and Test Procedures for Airborne Equipment’, dated January 2015.
— EUROCAE ED-79A ‘Guidelines for development of civil aircraft and systems’, dated December 2010.
— EUROCAE ED-107A ‘Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment’, dated July 2010.

B.2 RTCA Documents

— RTCA DO-160G, ‘Environmental Conditions and Test Procedures for Airborne Equipment’, 6 December 2010.

B.3 SAE International Documents

— AIR1662A, ‘Minimization of Electrostatic Hazards in Aircraft Fuel Systems’, dated August 2013.
— ARP4404C, ‘Aircraft Electrical Installations’ (guidance document for design of aerospace vehicle electrical systems).
— ARP4754A, ‘Certification Considerations for Highly Integrated or Complex Aircraft Systems’, dated December 2010.
— ARP4761, ‘Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment’, dated December 1996.
— ARP5583A, ‘Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment’, dated June 2010.

— AS50881F, 'Wiring Aerospace Vehicle' (procurement document used to specify aerospace wiring; replaces MIL-W-5088), dated May 2015.
— AS5692A, 'ARC Fault Circuit Breaker (AFCB), Aircraft, Trip-Free Single Phase and Three Phase 115 VAC, 400 Hz - Constant Frequency', dated December 2009.
— AS6019, 'ARC Fault Circuit Breaker (AFCB), Aircraft, Trip-Free 28 VDC', dated June 2012.

B.4 Military Specifications

MIL-STD-810H, Environmental Engineering Considerations and Laboratory Tests, dated January 2019.

B.5 Other Industry Documents

— Air Force Aero Propulsion Laboratory Technical Report AFAPL-TR-75-70, Summary of Ignition Properties of Jet Fuels and Other Aircraft Combustible Fluids, dated September 1975, http://www.dtic.mil/get-tr-doc/pdf?AD=ADA021320.
— ASTM D2155-12, Standard Test Method for Determination of Fire Resistance of Aircraft Hydraulic Fluids by Autoignition Temperature.
— ASTM D4865, Standard Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems, August 2009.
— ASTM E659-15, Standard Test Method for Autoignition Temperature of Chemicals, ASTM International.
— NASA Report NASA/TM-2000-210077, Some Notes on Sparks and Ignition of Fuels, dated March 2000, https://ntrs.nasa.gov/search.jsp?R=20000053468.
— National Fire Protection Association NFPA 77, Recommended Practice on Static Electricity, latest edition, http://www.nfpa.org.
— Underwriters Laboratories Inc., UL 913, Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, III, Division 1, Hazardous (Classified) Locations, dated 31 July 2006, https://standardscatalog.ul.com/standards/en/standard_913_8.

Appendix C Definitions

C.1 ARC FAULT CIRCUIT BREAKER (AFCB)

A device that provides thermal circuit breaker protection, detects electrical arcing faults, and interrupts electrical power to the fault. (See paragraph B.3 of this AMC for the SAE standards for alternating current and direct current AFCBs.)

C.2 AUTO-IGNITION TEMPERATURE

The minimum temperature at which an optimised flammable vapour 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.

C.3 AUXILIARY TANKS

Fuel tanks installed that make additional fuel available for increasing the flight range of the aeroplane. The term 'auxiliary' means that the tank is secondary to the aeroplane's main fuel tanks; i.e., the functions of the main tanks are immediately available and operate without immediate supervision by the flight crew in the event of a failure or the inadvertent depletion of fuel in an auxiliary tank. Auxiliary tanks are usually intended to be emptied of usable fuel during flight and have been installed in various locations including centre wing structures, horizontal stabilisers, wings, and cargo compartments.

C.4 BARRIER

A physical partition attached to the aeroplane structure that separates one wire or group of wires from another wire or group of wires in order to prevent arcing, fire, and other physical damage between wires or groups of wires.

C.5 COMPONENT MAINTENANCE MANUAL (CMM) DEVIATION

1. A term used for the approval of changes to CMMs that are the subject of CDCCLs or other types of airworthiness limitations adopted by a type design change.

2. A term used for the approval of changes to CMMs referenced in CDCCLs or other types of airworthiness limitations that are mandated by airworthiness directives (ADs), provided the CDCCL or airworthiness limitation includes wording that allows the use of 'later approved' CMMs. Otherwise, approval must first be granted as an alternative method of compliance (AMOC) with the AD. As with AMOC approvals, a CMM deviation approval must be granted by EASA.

C.6 CRITICAL DESIGN CONFIGURATION CONTROL LIMITATIONS (CDCCLS)

Airworthiness limitations that define those critical design features of the design that must be maintained to ensure that ignition sources will not develop within the fuel tank system.

C.7 ELECTRICAL SPARKS

A spark that is initiated by a potential difference, which causes an electrical breakdown of a dielectric such as a fuel/air mixture, produced between electrodes that are initially separated, with the circuit initially carrying no current. The term voltage sparks is sometimes used interchangeably with the term electrical sparks.

C.8 ELECTRICAL ARCS

Electrical arcs occur between electrodes that are in contact with each other and carry excessive current, which results in melting at the contact points. This may result in electric arc plasma and/or the ejection of molten or burning material. The term thermal sparks is used interchangeably with the term electrical arcs.

C.9 EXPLOSION PROOF

Components designed and constructed so they will not ignite any flammable vapour or liquid surrounding the component under any normal operating condition or any failure condition. Further information on the possible failure conditions that should be considered is specified in CS 25.981(a)(3).

C.10 FAIL-SAFE

Applicants should assume the presence of foreseeable latent (undetected) failure conditions when demonstrating that subsequent single failures will not jeopardise the safe operation of the aeroplane.

C.11 FILAMENT HEATING

The heating of a small diameter piece of conductive material when exposed to electrical current.

C.12 FLAMMABLE

Flammable, with respect to a fluid or gas, means susceptible to igniting readily or to exploding.

C.13 FLASHPOINT

The flashpoint of a flammable fluid is defined as the lowest temperature at which the application of a flame to a heated sample causes the vapour to ignite momentarily, or 'flash.' The test standard for jet fuel is defined in the fuel specification.

C.14 FRICTION SPARK

A heat source in the form of a spark that is created by mechanical contact, such as debris contacting a rotating fuel pump impeller.

C.15 FUEL SYSTEM AIRWORTHINESS LIMITATION

Any mandatory replacement time, inspection interval, related inspection procedure, and all the critical design CDCCLs approved under CS 25.981 for the fuel tank system identified in the airworthiness limitations section of the ICA (as required by CS 25.981(d) and Section H25.4 of Appendix H to CS-25).

C.16 GROUND FAULT INTERRUPTER (GFI)

A device that provides thermal circuit breaker protection, detects an electrical power short circuit-to-ground condition, and interrupts electrical power to the ground fault.

C.17 HOT SHORT

Electrical energy introduced into equipment or systems as a result of unintended contact with a power source, such as bent pins in a connector or damaged insulation on adjacent wires.

C.18 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 vapour 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.

C.19 INSTALLATION APPRAISAL

A qualitative appraisal of the integrity and safety of the installation.

C.20 INTRINSICALLY SAFE

Any instrument, equipment, or wiring that is incapable of releasing sufficient electrical or thermal energy to cause an ignition source within the fuel tank under normal operating conditions, or the anticipated failure conditions (see CS 25.981(a)(3)) and environmental conditions.

C.21 LATENT FAILURE

Please refer to the definition provided in AMC 25.1309.

C.22 LINE REPLACEMENT UNIT (LRU)

Any components that can be replaced while the aeroplane remains in operational service. Examples of fuel system LRUs include components such as flight deck and refuelling panel fuel quantity indicators, fuel quantity system processors, and fuel system management control units.

C.23 MAXIMUM ALLOWABLE SURFACE TEMPERATURES

As defined in CS 25.981(a)(1) and (2), the surface temperature within the fuel tank (the tank walls, baffles, or any components) that provides a safe margin under all normal or failure conditions, which is at least 27.8 °C (50 °F) below the lowest expected auto-ignition temperature of the approved fuels.

The auto-ignition temperatures of fuels will vary because of a variety of factors (ambient pressure, dwell time, fuel type, etc.). The value accepted by EASA without further substantiation for kerosene fuels, such as Jet A, under static sea level conditions, is 232.2 °C (450 °F). This results in a maximum allowable surface temperature of 204.4 °C (400 °F) for an affected component surface.

C.24 QUALITATIVE

Those analytical processes that assess system and aeroplane safety in an objective, non-numerical manner.

C.25 QUANTITATIVE

Those analytical processes that apply mathematical methods to assess system and aeroplane safety.

C.26 TRANSIENT SUPPRESSION DEVICE (TSD)

A device that limits transient voltages or currents on wiring to systems such as the fuel tank quantity, fuel temperature sensors, and fuel level switches, etc., to a predetermined level.

Item 4: Cabin safety items

Item 4.1: Emergency demonstration

It is proposed to amend CS-25 Appendix J, paragraph (a) to harmonise it with the corresponding FAA Part 25 Appendix J paragraph (a). This will provide a value for the minimum exterior ambient light level that is consistent with the value EASA has already accepted.

Amend Appendix J by replacing paragraph (a) by the following text:

Appendix J

Emergency Demonstration

(…)

(a) The emergency evacuation must be conducted with exterior ambient light levels of no greater than 3.2 lux (0.3 foot-candle) prior to the activation of the aeroplane emergency lighting system. The source(s) of the initial exterior ambient light level may remain active or illuminated during the actual demonstration. There must, however, be no increase in the exterior ambient light level except for that due to activation of the aeroplane emergency lighting system.

(…)

Item 4.2: References to FAA AC 25-17A

It is proposed to amend all AMCs referring to FAA Advisory Circular (AC) 25-17A in order to include Change 1 of this AC.

Amend AMC 25.785 as follows:

AMC 25.785

Seats, Berths, Safety Belts, and Harnesses

~~The~~ FAA Advisory Circular (AC) 25.785-1B, *Flight Attendant Seat and Torso Restraint System Installations*, dated 11.5.2010, and the relevant parts of ~~the~~ FAA AC 25-17A Change 1, *Transport*

Airplane Cabin Interiors Crashworthiness Handbook, dated 24.5.2016 ~~18.5.2009~~, are accepted by the Agency as providing an ~~A~~acceptable ~~M~~means of ~~C~~compliance ~~to~~ with CS 25.785.

Note: 'The relevant parts' means 'the parts of ~~the~~ AC 25-17A Change 1 that address the applicable FAR/CS-25 paragraph'.

(…)

Amend AMC 25.791 as follows:

AMC 25.791

Passenger information signs and placards

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~05/18/09~~, are accepted by the Agency as providing acceptable means of compliance with CS 25.791.

Note: 'The relevant parts' means 'the parts of the AC 25 -17A Change 1 that address~~es~~ the applicable FAR/CS-25 paragraph'.

Amend AMC 25.803 as follows:

AMC 25.803

Emergency evacuation

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~05/18/09~~ and AC 25.803-1A *Emergency Evacuation Demonstrations*, dated 03/12/12 are accepted by the Agency as providing acceptable means of compliance with CS 25.803.

Note: 'The relevant parts' means 'the parts of AC 25 -17A Change 1 that address~~es~~ the applicable FAR/CS-25 paragraph'.

Amend AMC 25.807 as follows:

AMC 25.807

Emergency Exits

The term 'unobstructed' should be interpreted as referring to the space between the adjacent wall(s) and/or seat(s), the seatback(s) being in the most adverse position, in vertical projection from floor - level to at least the prescribed minimum height of the exit.

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~05/18/09~~ are accepted by the Agency as providing acceptable means of compliance with CS 25.807.

Note: 'The relevant parts' means 'the parts of the AC 25-17A that address~~es~~ the applicable FAR/CS-25 paragraph'.

Amend AMC 25.809 as follows:

AMC 25.809

Emergency exit arrangement

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18.5.2009~~, are accepted by the Agency as providing an acceptable means of compliance with CS 25.809.

Note: 'The relevant parts' means 'the parts of AC 25-17A Change 1 that address the applicable FAR/CS-25 paragraph'.

Amend AMC 25.810 as follows:

AMC 25.810

Emergency egress assisting means and escape routes

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18.5.2009~~, are accepted by the Agency as providing an acceptable means of compliance with CS 25.810.

Note: 'The relevant parts' means 'the parts of AC 25 -17A Change 1 that address the applicable FAR/CS-25 paragraph'.

Amend AMC 25.811 as follows:

AMC 25.811

Emergency exit marking

The relevant parts of FAA Advisory Circular (AC) AC 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18.5.2009~~, are accepted by the Agency as providing an acceptable means of compliance with CS 25.811.

Note: 'The relevant parts' means 'the parts of AC 25-17A Change 1 that address the applicable FAR/CS-25 paragraph'.

Amend AMC 25.811(d) as follows:

AMC 25.811(d)

Sign Combination

The signs required by CS 25.811(d)(1), (d)(2) and (d)(3) may be combined according to the applicable parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18 May 2009~~.

Amend AMC 25.812 as follows:

AMC 25.812

Emergency lighting

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~05/18/09~~ and AC 25.812-2 *Floor Proximity Emergency Escape Path Marking Systems Incorporating Photoluminescent Elements*, dated 24/7/97 are accepted by the Agency as providing acceptable means of compliance with CS 25.812.

Note: 'The relevant parts' means 'the parts of AC 25-17A Change 1 that address~~es~~ the applicable FAR/CS-25 paragraph'.

Amend AMC 25.813 as follows:

AMC 25.813

Emergency exit access

The term 'unobstructed' should be interpreted as referring to the space between the adjacent wall(s) and/or seat(s), the seatback(s) being in the most adverse position, in vertical projection from floor - level to at least the prescribed minimum height of the exit.

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18.5.2009~~, are accepted by the Agency as providing an acceptable means of compliance with CS 25.813.

Note: 'The relevant parts' means 'the parts of AC 25-17A Change 1 that address~~es~~ the applicable FAR/CS-25 paragraph'.

Amend AMC 25.815 as follows:

AMC 25.815

Width of aisle

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~05/18/09~~, are accepted by the Agency as providing acceptable means of compliance with CS 25.815.

Note: 'The relevant parts' means 'the parts of AC 25 -17A Change 1 that address~~es~~ the applicable FAR/CS-25 paragraph'.

Amend AMC 25.819 as follows:

AMC 25.819

Lower deck service compartments (including galleys)

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18.5.2009~~, are accepted by the Agency as providing an acceptable means of compliance with CS 25.819.

Amend AMC 25.853 as follows:

AMC 25.853

Compartment interiors

The relevant parts of FAA Advisory Circular (AC) 25-17A Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~18.5.2009~~, AC 25.853-1 *Flammability Requirements for Aircraft Seat Cushions*, dated 17.9.1986, and AC 25-18, *Transport Category Airplanes Modified for Cargo Service*, dated 6.1.1994, and AC 20-178, *Flammability Testing of Aircraft Cabin Interior Panels After Alterations*, dated 4.6.2012, are accepted by the Agency as providing the acceptable means of compliance with CS 25.853.

Note: 'The relevant parts' means 'the parts of AC 25-17A Change 1 that address the applicable FAR/CS-25 paragraph'.

Amend AMC to CS 25.855 and 25.857 as follows:

AMC to CS 25.855 and 25.857

Cargo or baggage compartments

(…)

2. RELATED DOCUMENTS

(…)

b. FAA Advisory Circulars (AC).

The following FAA Advisory Circulars are accepted by the Agency as providing acceptable means of compliance with CS 25.857:

AC 25-17A Change 1, Transport Airplane Cabin Interiors Crashworthiness Handbook (the relevant parts addressing the applicable FAR Part 25/CS-25 paragraphs)

(…)

Amend AMC to Appendix S, S25.20(b)(2) as follows:

AMC to Appendix S, S25.20(b)(2)

Comparative assessment of evacuation capability

Use of the Latin square method as detailed in Appendix 4 to FAA Advisory Circular (AC) 25-17A Change 1 *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 24.5.2016 ~~05/18/09~~ is accepted by EASA as providing acceptable means of compliance with S25.20(b)(2).

Item 4.3: References to FAA AC 25-562-1B and AC 20-146

It is proposed to amend AMC 25.562 to include Change 1 of FAA Advisory Circular (AC) 25.562-1B.

Amend AMC 25.562 as follows:

AMC 25.562

Emergency landing dynamic conditions

FAA Advisory Circular (AC) 25.562-1B Change 1, *Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes*, dated 30.9.2015 ~~10.1.2006~~, ~~except paragraph 5.e.(5)(d),~~ and FAA AC 20-146A, *Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft*, dated 29/6/2018 ~~19.5.2003~~, are accepted by the Agency as providing acceptable means of compliance with CS 25.562.

Item 4.4: Floor surfaces – standards for friction measurement

It is proposed to amend AMC to CS 25.793 and CS 25.810(c) to introduce a list of standards for friction measurement accepted by EASA in recent certification projects.

Amend AMC to CS 25.793 and CS 25.810(c) by replacing it with the following text:

AMC to CS 25.793 and CS 25.810(c)

Floor surfaces

The slip-resistant properties of floor surface material should be tested wet with the type of slippery liquid expected during operation. In addition, dry testing should also be conducted to provide reference friction values. In all the test conditions, the dynamic coefficient of friction (DCOF) should be at least 0.45.

The following standard methods, using rubber and leather test devices, are acceptable (within their limitations) to conduct the testing:

— Military Specifications MIL-W-5044B (dated 24 February 1964) and MIL-W-5044C (dated 25 August 1970), titled 'Walkway Compound, Nonslip and Walkway Matting, Nonslip',
— DIN 51131:2014-02, titled 'Testing of floor coverings - Determination of the anti-slip property - Method for measurement of the sliding friction coefficient',
— ISO 8295:1995, titled 'Plastics - Film and sheeting - Determination of coefficients of friction',
— EN 13893:2002, titled 'Resilient, laminate and textile floor coverings - Measurement of dynamic coefficient of friction on dry floor surfaces',
— ANSI/NFSI B101.3-2012, titled 'Test Method for Measuring Wet DCOF of Common Hard-Surface Floor Materials'.

<u>Item 4.5: Emergency exit arrangement - naïve subject testing for the opening of passenger-operated exits</u>

It is proposed to create AMC to 25.809(c) and (e) to address naïve subject testing for the opening of passenger-operated exits, reflecting the current and past practice for certification of this type of exit.

Create AMC to CS 25.809(c) and (e) as follows:

AMC to CS 25.809(c) and (e)

Testing of the opening of passenger-operated exits

For emergency exits intended to be operated by passengers, such as non-floor level overwing exits (e.g. Type III and IV exits), testing with naïve subjects should be performed in order to demonstrate that opening the emergency exits is simple and obvious and does not require exceptional effort.

The demonstration may be conducted either on the aeroplane or on a representative mock-up, and it should include all the relevant safety markings and exit opening instructions.

The opening of the emergency exit should be demonstrated by a sufficient number of naïve test subjects selected to be representative of the passenger population with respect to gender, age, size and handedness. Meeting the criteria of paragraph (h) of Appendix J to CS-25 is an acceptable means to achieve a representative age and gender distribution of the participants in the test.

Item 4.6: Emergency egress assisting means and escape routes - deployment and inflation tests

It is proposed to create AMC 25.810(a)(1)(v) to indicate that at least one deployment and inflation test should be conducted on the aeroplane, consistent with previous EASA certification projects.

Create AMC 25.810(a)(1)(v) as follows:

AMC 25.810(a)(1)(v)

Deployment and inflation tests

For each exit, at least one of the (minimum) five consecutive deployment and inflation tests should be performed with an assisting means installed on the aeroplane.

Item 4.7: Life-preserver stowage provisions

A new AMC 25.1411(f) is proposed. Its content is harmonised with ETSO-C127b, Appendix 1, Table 2, Section 3. This AMC aims to ensure that life preserver stowages, that are not part of a seating system complying with ETSO-C127b, will be certified to the same standard regarding the reach and the retrieval of the life preserver.

Create AMC 25.1411(f) as follows:

AMC 25.1411(f)

Life preserver stowage provisions

The applicant should demonstrate that the life preserver is within easy reach of, and can be readily removed by, a seated and belted occupant (shoulder strap(s) may be removed prior to demonstration), for all seat orientations and installations that are intended for use during taxi, take-off and landing. In lieu of an actual life preserver, a representative object (e.g. of the same size and weight) may be utilised for testing. The evaluation to quickly retrieve the preserver is to begin with the occupant moving their hand(s) from the seated position to reach for the preserver and to end with the occupant having the preserver in their hand(s) and fully removed from the stowage container. It does not include the time for the occupant to return to the upright position, to remove a pull strap from the preserver (if used) or to open the preserver package provided by the preserver manufacturer.

The applicant should test the critical configuration(s) to demonstrate retrieval of the life preserver in less than 10 seconds by a minimum of 5 test subjects with a success rate of no less than 75 %. The test should evaluate three anticipated occupant test subject size categories: the 5th, 50th and 95th percentile. At least one occupant from each size category should demonstrate successful retrieval within 10 seconds. No more than 40 % of the overall test subject population should be in the 5th or 95th percentile occupant categories.

1) For passenger seats, the test subjects should be naïve. For the purpose of this test, naïve test subjects should be defined as follows: they should have had no experience within the prior 24 months in retrieving a life preserver. The subjects should receive no retrieval information other than a typical preflight briefing. The occupant size categories to be evaluated should be defined as:

a. A 5th percentile occupant is no taller than 1.5 m (60 in).

b. A 50th percentile occupant is at least 1.6 m (63 in) tall but no taller than 1.8 m (70 in).

c. A 95th percentile occupant weighs at least 110.7 kg (244 lb).

2) For flight attendant and observer seats, the test subjects do not need to be naïve. The occupant size categories to be evaluated should be defined as:

a. A 5th percentile occupant is no taller than 1.5 m (60 in).

b. A 50th percentile occupant is at least 1.6 m (63 in) tall but no taller than 1.8 m (70 in.).

c. A 95th percentile occupant weighs at least 110.7 kg (244 lb).

3) For pilot/co-pilot seats, the test subjects do not need to be naïve. The occupant size categories to be evaluated should be defined as:

a. A 5th percentile occupant is no taller than 1.57 m (62 in).

b. A 50th percentile occupant is at least 1.6m (63 in) tall but no taller than 1.8 m (70 in.).

c. A 95th percentile occupant weighs at least 110.7 kg (244 lb).

Item 4.8: Escape systems installed in non-pressurised compartments

Amend AMC 25.810 as follows:

AMC 25.810

Emergency egress assisting means and escape routes

(…)

For emergency assisting means that are installed in non-pressurised compartments, the applicant should take into account the effects of exposure to very low temperature conditions during flight on the performance of the assisting means. The applicant should demonstrate that the assisting means functions properly when the cold soak effects associated with the expected flight durations and altitudes are combined with a 46 km/h (25 kt) wind directed from the most critical angle.

Item 4.9: Emergency evacuation

Amend AMC 25.810(c)(2) as follows:

AMC 25.810(c)(2)

Emergency Evacuation

Acceptable methods of measurement of reflectance are given in ~~AC20-38A and~~ AC20-47, published by the Federal Aviation Administration.

Item 5: Electronic AFM – computation of misleading primary information

It is proposed to amend AMC 25.1581 Appendix 1, paragraph 6.a(1) to reflect the need to assess the potential safety effect at aeroplane level, and use this assessment as a basis when determining the AFM software architecture and level of integrity.

Amend AMC 25.1581 as follows:

AMC 25.1581

Aeroplane Flight Manual

(…)

APPENDIX 1 COMPUTERISED AEROPLANE FLIGHT MANUAL

(…)

6 SOFTWARE INTEGRITY, DEVELOPMENT AND DOCUMENTATION REQUIREMENTS

(…)

a. Software Integrity

(1) The potential safety effect at the aeroplane level of the computation of hazardously misleading primary information such as take-off speeds, landing approach speeds, engine thrust or power, engine limit data or other related aeroplane performance data, should be assessed ~~improbable (as defined in~~

~~CS 25.1309)~~. This assessment should be the basis for determining the software architecture and the level of integrity of the AFM software application. The AFM software application should, as far as practicable, be protected from inadvertent, deliberate, or unauthorised alterations. For example, self-check features could be used to provide software verification and protection against deliberate or inadvertent alteration.

(…)

Item 6: On-board weight and balance systems

It is proposed to create a new AMC 25-1 under General Acceptable Means of Compliance in order to recognise EUROCAE Document ED-263 as an acceptable standard to be used when demonstrating compliance of an OBWBS with the applicable certification specifications.

Create AMC 25-1 as follows:

AMC 25-1

On-board weight and balance systems

Applicants for the certification of an on-board weight and balance system should take account of EUROCAE Document ED-263, 'Minimum Operational Performance Standard for Onboard Weight and Balance Systems', dated June 2019.

ED-263 defines standards for an advisory OBWBS (i.e. class II) that displays the measured gross weight and calculated centre of gravity for use by the flight crew as an independent means of verifying the conventional weight and balance information provided for the preparation of the dispatch of the aeroplane (e.g. the load sheet). These standards are intended to ensure that the system satisfactorily performs its intended function(s) under all the conditions normally encountered during routine operation of the aeroplane.

Item 7: Air conditioning system

It is proposed to amend AMC 25.831(a) to clarify that an alert should be triggered if the air conditioning system is still 'off' after the allowed limited time period of operation with air conditioning selected 'off'.

Amend AMC 25.831(a) as follows:

AMC 25.831(a)

Ventilation

(…)

3. Operations with the air conditioning system 'off'

The following provisions should be considered for the limited time periods, such as during take-off, during which the air conditioning system is 'off':

a. There should be a means to annunciate to the flight crew that the air conditioning system is selected to 'off'. If, after the end of the maximum allowed time period (e.g. typically after the take-off), the air conditioning system is still in the 'off' position, an alert should be triggered to inform the flight crew of the status of the air conditioning system.

(…)

Item 8: Flight Guidance system

It is proposed to amend AMC N°1 to CS 25.1329 to:

– provide clarification on the autopilot disengagement aural alert, and

– to provide clarification with regard to potential hazards for systems without automatic disengagement to address the automatic trim response to an override of the autopilot.

Amend AMC N°1 to CS 25.1329 as follows:

AMC N°1 to CS 25.1329

Flight Guidance System

(…)

8.1.2.1 Autopilot Disengagement Alerts (see CS 25.1329(j))

Since it is necessary for a pilot to immediately assume manual control following disengagement of the autopilot (whether manual or automatic) a visual and aural warning must be given (CS 25.1329(j)).

~~This warning must be given without delay, and must be distinct from all other cockpit warnings (CS 25.1329(j)). The warning should continue until silenced by one of the pilots using:~~

Visual warning: a timely visual warning, distinct from all other cockpit warnings, must be provided and must be located in the primary field of view for both pilots. See CS 25.1329(j).

Aural warning: a timely aural warning must be provided and must be distinct from all other cockpit warnings. See CS 25.1329(j). Even when the autopilot is disengaged by a pilot, it should sound for long enough to ensure that it is heard and recognised by the pilot and other flight crew members (at least a single cycle), but not for so long that it adversely affects communication between crew members or that it is a distraction. The aural warning should continue until silenced by one of the following means:

— Activation of an autopilot quick disengagement control;
— Re-engagement of the autopilot; or
— Another acceptable means.

~~It should sound for a minimum period, long enough to ensure that it is heard and recognized by that pilot and by other flight crew members, but not so persistent that it adversely affects communication between crew members or is a distraction.~~

Multiple-autopilot system: Disengagement of an autopilot within a multiple-autopilot system (e.g., downgraded capability), requiring immediate flight crew awareness and possible timely action, should cause a Caution level alert to be issued to the flight crew.

Disengagement of an autopilot within a multiple-autopilot system, requiring only flight crew awareness, should cause a suitable advisory to be issued to the flight crew.

(…)

8.4 Flight Crew Override of the FGS

(…)

8.4.1 Autopilot

(…)

2) If the autopilot is not designed to disengage in response to any override force, then the response shall be shown to be safe (CS 25.1329 (l)).

a) Sustained application of an override force should not result in a potential hazard, such as when the flight crew abruptly releases the force on the controls. During sustained application of an override force, the automatic trim should not run to oppose the flight crew commands in any manner that would result in unacceptable aeroplane motion. Mitigation may be accomplished through provision of an appropriate alert and flight crew procedure.

> NOTE: The term 'sustained application of override force' is intended to describe a force that is applied to the controls, which may be small, slow, and sustained for some period of time. This may be due to an inadvertent crew action or may be an intentional crew action meant to 'assist' the autopilot in a particular manoeuvre. (See Chapter 14, Compliance Demonstration Using Flight Test and Simulation, paragraph 14.1.5, Flight Crew Override of the Flight Guidance System, of this AMC for more information.)

b) Transients resulting from an override force: Under normal conditions, a significant transient should not result from manual autopilot disengagement after the flight crew has applied an override force to the controls (CS 25.1239(d)).

> NOTE 1: The term 'override force' is intended to describe a pilot action that is intended to prevent, oppose or alter an operation being conducted by a flight guidance function, without first disengaging that function. One possible reason for this action could be an avoidance manoeuvre (such as responding to a ACAS/TCAS Resolution Advisory) that requires immediate action by the flight crew and would typically involve a rapid and forceful input from the flight crew.

> NOTE 2: For control wheel steering considerations, refer to Section 11.6.

~~Sustained application of an override force should not result in a hazardous condition.~~

~~Mitigation may be accomplished through provision of an appropriate Alert and flight crew procedure.~~

> ~~**NOTE:** The term "sustained application of override force" is intended to describe a force that is applied to the controls that may be small, slow, and sustained for some period of time. This may be due to an inadvertent crew action, or may be an intentional crew action meant to "assist" the autopilot in a particular manoeuvre. See Section 14.1.5.~~

> ~~**NOTE:** For CWS – refer to Section 11.6~~

(…)

Item 9: Primary flight displays during unusual attitude and declutter modes

Amend AMC 25-11 as follows:

AMC 25-11

Electronic Flight Deck Displays

(…)

CHAPTER 5

ELECTRONIC DISPLAY INFORMATION ELEMENTS AND FEATURES

31. Display Information Elements and Features. (…)

e. Sharing Information on a Display. (…)

(4) Clutter and deClutter

(a) A cluttered display presents an excessive number or variety of symbols, colours, and/or other unnecessary information and, depending on the situation, may interfere with the flight task or operation. A cluttered display causes increased flight crew processing time for display interpretation, and may detract from the interpretation of information necessary to navigate and fly the aeroplane. Information should be displayed so that clutter is minimised.

(b) To enhance pilot performance a means should be considered to declutter the display. For example, an attitude indicator may automatically declutter when the aeroplane is at an unusual attitude to aid the pilot in recovery from the unusual attitude by removing unnecessary information and retaining information required for the flight crew to recover the aeroplane. Failure messages, flags, or comparative monitoring alerts related to the information required by CS 25.1303 should not be removed by decluttering the display.

Item 10: Lightning protection and electrical bonding and protection against static electricity

Amend AMC 25.581 as follows:

AMC 25.581

Lightning Protection

1. INDUSTRY STANDARDS

The following documents may be used when showing compliance with CS 25.581 :

- EUROCAE document ED-84A dated July 2013 (Aircraft Lightning Environment and Related Test Waveforms) or the equivalent SAE ARP5412B.
- EUROCAE document ED-91A (Aircraft Lightning Zoning) or the equivalent SAE ARP5414B.
- EUROCAE document ED-105A (Aircraft Lightning Test Methods) or the equivalent SAE ARP 5416A.
- EUROCAE document ED-113 (Aircraft Lightning Direct Effects Certification) or the equivalent SAE ARP 5577.

~~1~~2 EXTERNAL METAL PARTS

~~1~~2.1 External metal parts should either be –

a. Electrically bonded to the main earth system by primary bonding paths, or

b. So designed and/or protected that a lightning discharge to the part (e.g. a radio aerial) will

cause only local damage which will not endanger the aeroplane or its occupants.

~~1~~2.2 In addition, where internal linkages are connected to external parts (e.g. control surfaces), the linkages should be bonded to main earth or airframe by primary bonding paths as close to the external part as possible.

~~1~~2.3 Where a primary conductor provides or supplements the primary bonding path across an operating jack (e.g. on control surfaces or nose droop) it should be of such an impedance and so designed as to limit to a safe value the passage of current through the jack.

~~1~~2.4 In considering external metal parts, consideration should be given to all flight configurations (e.g. lowering of landing gear and wing-flaps) and also the possibility of damage to the aeroplane electrical system due to surges caused by strikes to protuberances (such as pitot heads) which have connections into the electrical system.

~~2~~3 EXTERNAL NON-METALLIC PARTS

~~2~~3.1 External non-metallic parts should be so designed and installed that –

a. They are provided with effective lightning diverters which will safely carry the lightning discharges described in EUROCAE document ED-84A ~~(including Amendment N°1 dated 06/09/99)~~ dated July 2013 titled : Aircraft Lightning Environment and Related Test Waveforms, or the equivalent SAE ARP5412B document.

b. Damage to them by lightning discharges will not endanger the aeroplane or its occupants, or

c. A lightning strike on the insulated portion is improbable because of the shielding afforded by other portions of the aeroplane.

Where lightning diverters are used the surge carrying capacity and mechanical robustness of associated conductors should be at least equal to that required for primary conductors.

~~2~~3.2 Where unprotected non-metallic parts are fitted externally to the aeroplane in situations where they may be exposed to lightning discharges (e.g. radomes) the risks include the following:

a. The disruption of the materials because of rapid expansion of gases within them (e.g. water vapour),

b. The rapid build-up of pressure in the enclosures provided by the parts, resulting in mechanical disruption of the parts themselves or of the structure enclosed by them,

c. Fire caused by the ignition of the materials themselves or of the materials contained within the enclosures, and

d. Holes in the non-metallic part which may present a hazard at high speeds.

~~2~~3.3 The materials used should not absorb water and should be of high dielectric strength in order to encourage surface flash-over rather than puncture. Laminates made entirely from solid material are preferable to those incorporating laminations of cellular material.

~~2~~3.4 Those external non-metallic part which is not classified as primary structure should be protected by primary conductors.

~~2~~3.5 Where damage to an external non-metallic part which is not classified as primary structure may endanger the aeroplane, the part should be protected by adequate lightning diverters.

~~2~~3.6 Confirmatory tests may be required to check the adequacy of the lightning protection provided (e.g. to confirm the adequacy of the location and size of bonding strips on a large radome.)

Amend AMC 25.899 as follows:

AMC 25.899

Electrical Bonding and Protection Against Static Electricity

(…)

2 Characteristics of Lightning Discharges

Industry standards.

Refer to EUROCAE document ED-84 (including Amendment N°1 dated 06/09/99) titled: Aircraft Lightning Environment and Related Test Waveforms; or the equivalent SAE ARP5412 document.

The following documents may be used when showing compliance with CS 25.581:

— EUROCAE document ED-84A dated July 2013 (Aircraft Lightning Environment and Related Test Waveforms) or the equivalent SAE ARP5412B.
— EUROCAE document ED-91A (Aircraft Lightning Zoning) or the equivalent SAE ARP5414B.
— EUROCAE document ED-105A (Aircraft Lightning Test Methods) or the equivalent SAE ARP 5416A.
— EUROCAE document ED-113 (Aircraft Lightning Direct Effects Certification) or the equivalent SAE ARP 5577.

(…)

Item 11: Operation without Normal Electrical Power

Amend AMC 25.1351(d) as follows:

AMC 25.1351(d)

Operation without Normal Electrical Power

(…)

6 Alternate Power Source Duration and Integrity

(…)

e. Usage of a battery system to ensure continuity of electrical power. This sub-paragraph applies if a battery system is used to ensure the continuity of electrical power when the non-time-limited power source(s) is(are) not providing electrical power. When establishing the minimum battery endurance requirements, the following conditions should be considered:

— It must be shown that following the loss of normal electrical power, the batteries provide an adequate power supply to those services which are necessary to make a controlled descent and landing, stop and complete a safe evacuation of the aeroplane (CS 25.1351(d) and 25.1362).
— The applicant should take into account the transient time period between the loss of normal electrical power and the alternate electrical power source being operational, as well as other

time period(s) when the alternate electrical power source is not available. For example, the time period between when the RAT electrical generator goes off-line and when the aeroplane is stopped on ground and a safe evacuation of the aeroplane is performed.

— The most critical configuration, from a battery point of view, should be considered. Loss of normal electrical power is usually associated with one of the following conditions: either the all-engine out case or the loss of power coming from the primary power centre. In the second case, the proximity of the batteries to the power centre should be taken into account. Any battery located near this power centre will have to be considered as part of the normal electrical power generating system (ref. CS 25.1351(d)(1).

— The time periods corresponding to the intended usage of the batteries in the emergency scenario will need to be substantiated, with a due margin taken for any uncertainty. Any permanent load on the batteries (i.e. a hot bus) will also have to be accounted for.

— For determining the capacity of the batteries, Section 6.1(b) of this AMC, on time-limited power sources, applies.

— The capability of the backup battery to provide adequate power for the required minimum duration should be demonstrated by actual testing.

— Instructions for continued airworthiness for the batteries should be provided. These instructions should ensure that adequate battery power is available between maintenance cycles. There should be a means for the flight crew or maintenance personnel to determine the actual battery charge state prior to take-off.

4. Impact assessment (IA)

The proposed amendments are expected to contribute to updating CS-25 to reflect the state of the art of large aeroplane certification and improve the harmonisation of CS-25 with the FAA regulations. Overall, this would provide a moderate safety benefit, would have no social or environmental impacts, and would provide some economic benefits by streamlining the certification process. There is no need to develop a regulatory impact assessment (RIA).

5. Proposed actions to support implementation

N/A

6. References

6.1. Related regulations

N/A

6.2. Affected decisions

Decision No. 2003/2/RM of the Executive Director of the Agency of 17 October 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes («CS-25»)

6.3. Other reference documents

— Aviation Rulemaking Advisory Committee-Transport Airplane Performance and Handling Characteristics-Continuing a Task. Notice of phase 2 task assignment for the Aviation Rulemaking Advisory Committee (ARAC). Federal Register Volume 79, Number 70 (Friday 11 April 2014).

— FAA final rule [Docket No. FAA-2014-1027; Amendment No. 25-146], 'Transport Airplane Fuel Tank and System Lightning Protection', Federal Register / Vol. 83, No. 183 / Thursday 20 September 2018,

— FAA Advisory Circulars (AC):

  — AC 25.981-1D 'Fuel Tank Ignition Source Prevention Guidelines' dated 24 September 2018, and

  — AC 25.954-1 'Transport Airplane Fuel System Lightning Protection' dated 24 September 2018.

7. Appendix

N/A

8. Quality of the document

If you are not satisfied with the quality of this document, please indicate the areas which you believe could be improved and provide a short justification/explanation:

— technical quality of the draft proposed rules and/or regulations and/or the draft proposed amendments to them

— text clarity and readability

— quality of the impact assessment (IA)

— others (please specify)

Note: Your replies and/or comments to this section shall be considered for internal quality assurance and management purposes only and will not be published in the related CRD.