EASA European Union Aviation Safety Agency	**Special Condition**	Doc. No. : SC-E25.963-01 Issue : 1 Date : 6 December 2022 Proposed ☐ Final ☒ Deadline for comments: 27 JAN 2023

SUBJECT	:	Installation of Conformal Rear Centre Tank – Crashworthiness Conditions
REQUIREMENTS incl. Amdt.	:	CS 25.561, CS 25.562, CS 25.721, CS 25.963, CS 25.994 at Amdt. 22
ASSOCIATED IM/MoC[1]	:	Yes☒ / No ☐
ADVISORY MATERIAL	:	FAA AC 25-8

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[1] Associated Interpretative Material and/or Means of Compliance may be published for awareness only and they are not subject to public consultation.

INTRODUCTORY NOTE:

The following Special Condition (SC) has been classified as important and as such shall be subject to public consultation in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) which states:

"*2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency.*"

ABBREVIATIONS:

RCT	Rear centre tank

IDENTIFICATION OF ISSUE:

EASA received an application for a major change to type design on a large aeroplane.

1) The design change introduces a conformal fuselage structural fuel tank[2] to the aeroplane, also called rear centre tank (RCT) located behind the main landing gear wheel bay, in the lower section of the fuselage, partially replacing the aft cargo compartment.

   The experience gathered with large aeroplanes carrying more than 19 passengers, equipped with classical wing fuel tanks (including centre wing fuel tanks) and auxiliary tanks located in cargo compartments, is generally considered satisfactory in terms of protection of the cabin occupants against crash events. However, the integration of an RCT located below the cabin floor, because of its design and location, is considered as an unusual design feature relative to design practices on which CS-25 certification specifications are based. Therefore, in application of point 21.B.75 of Part 21, EASA identified the need to prescribe special detailed technical specifications (named Special Conditions) to ensure adequate occupants protection against the risks of external fire and burnthrough, fuel vapour ignition and fuel tank explosion as well to ensure crashworthiness of this fuel tank so that no fuel is released in sufficient quantities so to start a serious fire in an otherwise survivable crash event.

   The protection against external fire burnthrough was addressed through a dedicated Special Condition that was published by EASA in February 2021:

   https://www.easa.europa.eu/document-library/product-certification-consultations/final-special-condition-ref-sc-d25856-01

   The protection against the fuel vapour ignition and fuel tank explosion was addressed through a dedicated Special Condition that was published by EASA in June 2022:

[2] A conformal fuselage structural fuel tank is a fuel tank, that carries aircraft loads and shares some boundaries with the fuselage skin.

https://www.easa.europa.eu/en/document-library/product-certification-consultations/proposed-special-condition-ref-sc-d25863-01

The present Special Condition addresses the RCT crashworthiness.

2) CS 25 at amendment 22, that is applicable to the RCT major change to type design project, includes specifications that address the risk of fuel spillage due to crash event. However, those specifications limit the risk to crash conditions specified in CS 25.721(b):

- *CS 25.963(d)(4) : Fuel tanks must, so far as it is practicable, be designed, located and installed so that no fuel is released in or near the fuselage or near the engines in quantities sufficient to start a serious fire in otherwise survivable emergency landing conditions. For each fuel tank and surrounding airframe structure, the effects of crushing and scraping actions with the ground should not cause the spillage of enough fuel, or generate temperatures that would constitute a fire hazard under the conditions specified in CS 25.721(b).*
- *CS 25.994: Fuel system components in an engine nacelle or in the fuselage must be protected from damage which could result in spillage of enough fuel to constitute a fire hazard as a result of a wheels-up landing on a paved runway under each of the conditions prescribed in CS 25.721(b).*
- *CS 25.721(b): The aeroplane must be designed to avoid any rupture leading to the spillage of enough fuel to constitute a fire hazard as a result of a wheels-up landing on a paved runway, under the following minor crash landing conditions:*
  - *(1) Impact at 1.52 m/s (5 fps) vertical velocity, with the aeroplane under control, at Maximum Design Landing Weight,*
    - *(i) with the landing gear fully retracted and, as separate conditions,*
    - *(ii) with any other combination of landing gear legs not extended.*
  - *(2) Sliding on the ground, with -*
    - *(i) the landing gear fully retracted and with up to a 20° yaw angle and, as separate conditions,*
    - *(ii) any other combination of landing gear legs not extended and with 0° yaw angle.*

The existing CS-25 emergency landing conditions need to be complemented, considering the unusual design, location and installation aspects of the RCT.
The sole existing guidance addressing the protection of fuel tank in fuselage is the FAA AC 25-8. It provides design considerations and precautions in fuel tank installation, but it is mainly focussing upon auxiliary fuel tanks located within the fuselage pressure shell, that do not share any boundary with the fuselage skin. It also points out that survivable crashes have occurred beyond the existing defined emergency landing conditions.

There is a need to define a Special Condition to specify under which crash conditions, in addition to the conditions defined by CS-25 Amdt. 22, the unusual design of the RCT should prevent fuel spillage in sufficient quantities to start a serious fire in an otherwise survivable crash event. There is also the need to define the means of how to demonstrate compliance with this Special Condition.

Considering all the above, the following Special Condition is proposed to complement CS-25 Amdt. 22 certification specifications:

SC-E25.963-01

Special Condition

Installation of Conformal Rear Centre Tank – Crashworthiness Conditions

1. APPLICABILITY

This Special Condition is applicable to large aeroplanes with a conformal fuselage structural fuel tank[3] installed.

1.1 RELATED CS

CS 25.561, CS 25.562, CS 25.721, CS 25.963, CS 25.994 at Amendment 22

2. SPECIAL CONDITION

In amendment of demonstrating compliance with the current related CS identified in chapter 1.1 above, the actual design shall comply with the following special detailed technical specifications:

The conformal fuselage structural fuel tank must, so far as it is practicable, be designed, located and installed so that no fuel is released in or near the fuselage or near the engines in quantities sufficient to start a serious fire in otherwise survivable crash conditions beyond the emergency landing conditions specified in CS 25.963(d)(4) (that cross-refers to CS 25.721). These extended crash conditions must include the consideration of off runway events and loss of landing gears and engines due to contact with obstacles.

[3] A conformal fuselage structural fuel tank is a fuel tank, that carries aircraft loads and shares some boundaries with the fuselage skin.

INTERPRETATIVE MATERIAL TO SPECIAL CONDITION SC-E25.963-01

The associated Interpretative Material is published for awareness only and is not subject to public consultation.

1. Guidance on what constitutes an otherwise survivable crash condition.

EASA's review of accidents and the ARAC Transport Aircraft Crashworthiness and Ditching Working Group (TACDWG) (Report Rev B, September 20th, 2018) report leads to the following guidance on otherwise survivable crash conditions in the context of this special condition only. The focus of the guidance is on vertical descent rates to be associated with aeroplane impact conditions that are considered survivable from an occupant perspective assuming there is no fire in support of the evaluation of the RCT design. These conditions should be consistent with the level of occupant protection afforded by the type design from which the aeroplane is derived. The guidance is not intended to represent or help define an envelope of all previous accidents in which some occupants have survived as this would result in an impractical design objective.
The majority of crashes considered as survivable in the ARAC report include flight into terrain before the runway or on the runway without the aeroplane descent rate being reduced.
Note: Landing approaches are considered stabilized at descent rates of 1000ft/min or less (i.e. below 17ft/sec), but may be more with special procedures when permitted for specific operations that demand higher descent rates. In several accidents, external influences such as wind shear may have caused an increase in descent velocity.

Survivability of occupants:
According to the finding in the ARAC report, several accidents at aeroplane descent rates up to 25ft/sec (for the limit of a survivable accident of an aeroplane at MTOW) have resulted in fuselage fracture but remained survivable for many of the occupants. In such events, local fuselage section crushing and occupant fatalities often also occur in other areas of the fuselage. This local fuselage section impact damage as a result of the aeroplane impact at 25ft/sec may often exceed the level of damage that would result from impact of that section when freely dropped at more than 25ft/sec Vz and up to 30ft/sec; in particular for those sections further away from the aeroplane c.g.. A value of up to 30ft/sec for a typical section impact has been used by aviation authorities as a starting point for special conditions related to occupant survivability with respect to new aeroplane designs.

Consideration of the aeroplane and RCT location:
Conversely, the aeroplane is a derivative of an existing design and for the typical fuselage sections of a narrow body aeroplane, existing data shows that the occupant survivability is highly probable up to 23ft/sec (ref ARAC). In other sections survivability may be lower, but evidence from accidents shows that there remains some potential for survivability beyond these levels. As such, in an aeroplane impact condition with Vz of 25ft/sec, where some sections may sustain impacts equivalent to up to 30ft/sec, the demonstrated level of occupant survivability may be substantially exceeded in many sections of the fuselage, but not necessarily all, which would be consistent with the objective for setting otherwise survivable crash conditions.

In addition, the applicant has already performed aeroplane level analysis that show the RCT is well located and better protected from impact scenarios than the other sections of the fuselage.

Conclusion:
EASA considers that the conditions defining an otherwise survivable impact for the aeroplane RCT crashworthiness should therefore include aeroplane vertical descent velocities of up to 25ft/sec.
Further aspects of these impact conditions would need to be defined and agreed should the applicant chose to pursue the aeroplane level analysis.
Considering aeroplane levels scenarios with vertical descent velocities of up to 25ft/sec, a reduction of Vz at section level may be justified for the RCT section, due to the location of the RCT and the protection offered by the engines, landing gear and areas of the fuselage that would impact the ground before the RCT.
At RCT section level in conditions representing a free drop on to a hard surface, a Vz of 23ft/sec can also be considered appropriate.
Other survivable crash scenarios such as events when the fuselage breaks or sliding on the ground following loss of landing gear and engines also need to be considered in determining suitable means of compliance for evaluation of the RCT crashworthiness.

2. **Guidance on what ‘constitutes a fire hazard’ and ‘fuel quantities sufficient to start a serious fire’ in the context of fuel tank crashworthiness**.

CS-25 considers fuel or other flammable fluids quantities that could be considered as hazardous with regards to fire or explosion risk (i.e. without being exhaustive, some examples are included in AMC 25.963(d) and (e), CS 25.994, CS 25.1189, …). Most of the time, those considerations are high level within individual requirements and in some instances more detailed consideration are given within the AMC specifically associated to the rule intent (e.g. AMC 25.1189). Whereas in others, they are more related to practices resulting from validations (e.g. FAA IP for Drainage/Ventilation or Flammable Fluid Fire Protection) or use of standards (e.g. ISO 2685 test criteria for fire resistance/fire proofness of fluid contained in components…).
Therefore, it appears that there is no unified definition.
Criteria for defining fuel quantities sufficient to start a serious fire or a fuel leak that constitutes a fire hazard reflect various considerations, such as:

a) The intent of the specific rule to which it is associated,
b) Consideration of past practices,
c) Consideration of design capability (state-of-the-art and practicality).

CS-25 is not very descriptive on the fuel quantity or the amount of fuel liberated that could be considered acceptable for fuel tank crashworthiness. Even if there could be some benefit in examining CS-27/CS-29 based criteria, that have been in place since 1994 (i.e. NIL fuel leak) and for which fuel tank designs have been demonstrated to be capable of, the use of those criteria would possibly need considerable adapation that could require rulemaking activities.
EASA acknowledges that both CS 25.963 and CS 25.994 are allowing a certain amount/quantity of fuel to leak from a fuel tank in a survivable crash condition. Even if the wording is not identical, CS 25.963 states ‘*… in quantities sufficient to start a serious fire…*’ and deals with fuel tanks whereas CS 25.994 deals more with systems and states ‘*… spillage of enough fuel to constitute a fire hazard…*’ there is a degree of consistency.

The most recent attempt to characterize fuel tank structural leak came with AMC 25.963(e) Amdt. 14, with the following definition being adopted:
A running leak, a dripping leak, or a leak that 15 minutes after wiping dry, results in a wetted surface exceeding 6 inches in length or diameter is considered to constitute '*a hazardous fuel leak*'.
Therefore, when a single leak that does not fulfill the proposed definition would result from the crash condition (or multiple leaks that are assessed to be more significant), an aeroplane level assessment should be completed to demonstrate that quantity of released fuel will not start a serious fire.
A fire would be considered '*serious*' in the context of fuel tank crashworthiness, when the fire effects (heat, explosion, flame, toxicity, fumes, smoke, …) would prevent the safe evacuation of cabin occupants within 5 minutes after the start of the fire.

3. Guidance for systems and equipment interfacing with the RCT and that could cause RCT hazardous external leakage in case of emergency landing conditions.

The CS 25.561(c)(1)(ii) states:

> *'(c) For equipment, cargo in the passenger compartments and any other large masses, the following apply:*
> *(1) These items must be positioned so that if they break loose, they will be unlikely to: […]*
> *(ii) Penetrate fuel tanks or lines or cause fire or explosion hazard by damage to adjacent systems; or […].'*

The CS 25.994 states:

> *'Fuel system components in an engine nacelle or in the fuselage must be protected from damage which could result in spillage of enough fuel to constitute a fire hazard as a result of a wheels-up landing on a paved runway under each of the conditions prescribed in CS 25.721(b).'*

To remain consistent with the intent of the Special Condition SC-E25.963-01, EASA reminds that the survivable crash conditions to be applied to fuel system components should go beyond the conditions prescribed by CS25.721.

The Means of Compliance to Special Condition SC-E25.963-01 do apply to systems and equipment interfacing with the RCT structure and RCT fuel leakage retention means.
When, based on demonstration by test or analysis supported by test, systems or equipment located in or connected to the RCT or the remaining fuselage cannot create hazardous fuel spillage, it is accepted that these systems or equipment, could be excluded from the applicability of this Special Condition SC-E25.963-01.

MEANS OF COMPLIANCE TO SPECIAL CONDITION SC-E25.963-01

The associated Means of Compliance is published for awareness only and is not subject to public consultation.

1. Additional design precautions

The applicant should consider incorporation of additional global design features, so far as is practicable, such as a bladder and crushable structure to mitigate the effects of impact and scraping on the ground, including contact with obstacles. The design should be evaluated considering the points 2., 3., 4. and, if applicable, 5. below.

2. Fuselage break points

To prevent a fuel leak that could constitute a fire hazard, the RCT should be installed in an area of the fuselage that is not likely to fail or rupture in a survivable crash condition exceeding the applicable existing emergency landing conditions.
Different impact conditions at aeroplane level should be investigated, at different weights (i.e. MLW, MTOW) and different configurations (i.e. all landing gears extended or retracted), to demonstrate that when fuselage failure or rupture happens, this does not occur in the area where the RCT is installed.

3. Crushing of lower fuselage under vertical descent impact velocities

When the fuselage section that contains the RCT is subjected to an impact condition with a vertical descent velocity, the RCT should not liberate enough fuel as to constitute a serious fire hazard. This should be demonstrated via a fuel tank integrity drop test or analysis supported by test evidence, using the following parameters:

a) The vertical descent velocity to be achieved by the fuselage/RCT section should be no less than 7 m/s (23 fps), unless a lower velocity is substantiated by an aeroplane level analysis that addresses the conditions defined below.
b) Various fuel states should be investigated from unusable up to full.
c) Various payload states should also be investigated from 0 to maximum capacity of the section.
d) The drop surface should be non-deforming.
e) In case of a physical test, the RCT fuselage section should be dropped freely and impact the horizontal position within +/- 10 degrees and most critical fuel state should be considered.
f) The definition of RCT fuselage section should consider all design features as present in the aeroplane type design configuration.
g) Pass/failure criteria is the demonstration of no fuel leak that could constitute a fire hazard.
h) All parameters used in the compliance demonstration should be agreed with the Agency.

<u>Aeroplane level analysis:</u>
Aeroplane level crash conditions (scenarios) for substantiation of vertical descent velocity Vz for RCT section compliance demonstration:

1. a) Vz up to 25ft/s with landing gear down on a hard surface considering aeroplane weights up to MLW and passenger occupancy and cabin distribution, with aeroplane pitch attitudes sufficiently above and below normal attitudes to account for variations due to atmospheric

conditions and other probable causes. Consideration should be given to the range of pitch attitudes encountered in the numerous past accidents that have occurred in gear down configuration at up to MLW.

1. b) Vz up to 25ft/s[4] with landing gear down on a hard surface considering aeroplane weights up to MTOW and passenger occupancy and cabin distribution, with aeroplane attitudes sufficiently above and below normal attitudes[5] to account for probable variations in pitch attitudes in emergency landing conditions.

2. Vz up to 25ft/s[4] with landing gear up on a hard surface considering aeroplane weights up to MTOW and passenger occupancy and cabin distribution, with aeroplane attitudes[5] sufficiently above and below normal attitudes to account for probable variations in pitch attitudes in emergency landing conditions.

3. a) Sliding on the engine nacelles at MTOW then encountering an obstacle that separates the engines.

3. b) Aeroplane rolling on surface at MTOW and hitting an obstacle, which leads to separation of NLG and both MLGs

4. Direct impact of the fuselage at 12ft/sec Vz on a hard surface assuming prior loss of engines and landing gear at MLW at a range of aeroplane attitudes sufficiently above and below normal attitudes to account for upsets due to atmospheric conditions and other causes including aeroplane response due to the initial impacts of engines and landing gear. In lieu of specific supporting data the same pitch attitudes as agreed for scenario 1a may be used.

Other parameters such as fwd speed to be agreed with the Agency for each condition.

4. Sliding on the ground

With the aeroplane sliding on the ground with damage to the RCT section following the aeroplane impacts assessed under all conditions defined under point 3., this condition should not result in increased temperatures inside the RCT that may lead to subsequent ignition of fuel or fuel vapours. In addition, sliding on the ground should not lead to damage that would liberate enough fuel to constitute a fire hazard.

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[4] For Scenarios 1b and 2, a lower value of Vz might be used for which it is demonstrated that an agreed measure for cabin occupant survivability is exceeded at the majority of frame positions in both the forward and rear fuselages). Exceedance of occupant survivability for the aeroplane level model analysis is defined by either exceeding a criterion that is based on tests or analysis supported by test of representative fuselage sections subject to vertical impact conditions or by exceeding the global fuselage strength by a significant margin.

[5] The aeroplane attitudes below normal attitudes for scenarios 1b and 2 are to be determined taking into consideration a stable Total Engine Flame Out (TEFO) descent and an All Engine Operative (AEO) approach when a specific TEFO situation is shown not to be survivable. When the AEO approach is applied and the impact resulting from the initially determined pitch attitude, forward speed and Vz combination does not exceed the agreed measure for occupant survivability, then the final Vz should be determined by increasing Vz for the initially determined pitch attitudes until the agreed survivability criteria* is exceeded. Variations in impact attitude due to pilot input, including failure to flare, atmospheric conditions and a range of impact slopes including ICAO Annex 14 recommended slope limits for runway end safety areas, should be taken into account.

Therefore, for the fuselage section encompassing the lower RCT structure, the following conditions should be investigated to determine the resulting temperatures due to sliding and evaluate any damage to the RCT external fuel boundary due to scraping on the ground:

a) The aeroplane should be assumed to slide on the ground with a forward speed of VL1 and with up to a 20° yaw angle.
b) All parameters used in the thermal analysis should be agreed with the Agency.
c) Appropriate aeroplane mass and RCT fuel states used for the analysis needs to be agreed with Agency.
d) If design features such as skids or other structure extending from the outer boundary of the fuselage/RCT line are used, aeroplane attitudes beyond the wings level in the horizontal plane should be investigated unless stability due to the design configuration is substantiated.

Prior to initiating the sliding condition, the RCT section including any elements beneath it required to protect the RCT during sliding, need to be demonstrated to be able to withstand the impact conditions defined under point 3.

5. Internal Protection

When an internal non-fuel tight protection feature is installed to address cases where the structure could be ruptured in scenarios other than those described above in points 2., 3. and 4. (e.g. off runway contact with obstacles impacting the RCT), leakage in excess of that prescribed in the Interpretative Material to Special Condition SC-E25.963-01 are acceptable, but should be minimised. Minimisation shall be assessed in terms of fuel quantity delivered to the ground and the effects on the emergency evacuation capability should a fire occur. In any case, a sufficient number of emergency exits must remain available to permit the evacuation within a period of time of 5 minutes.