EASA European Union Aviation Safety Agency	**Special Condition** Aeroplane Ice Protection System operation above the maximum altitudes of CS-25 Appendix C icing envelopes	Doc. No.: SC-F25.1419-01 Issue : 1 Date : 02.07.2019 Proposed ☒ Final ☐ Deadline for comments: 30.08.2019

SUBJECT	:	Aeroplane Ice Protection System operation above the maximum altitudes of CS-25 Appendix C icing envelopes
REQUIREMENTS incl. Amdt.	:	CS 25.1419, CS 25.1093(b), CS 25 Appendix C
ASSOCIATED IM/AMC[1]	:	Yes☒ / No ☐
ADVISORY MATERIAL	:	

INTRODUCTORY NOTE:

The following Special Condition 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.*"

IDENTIFICATION OF ISSUE:

Considering all the above, the following Special Condition is proposed:

CS 25.1419 requires applicants seeking certification for flight in icing conditions to demonstrate that the aeroplane is able to safely operate within the CS-25 Appendix C Continuous Maximum (CM) and Intermittent Maximum (IM) icing environment. CS 25.1093(b) requires the power-plant installation being able to properly function in icing conditions of Appendix C as well.

Although the intent of CS 25.1419 and CS 25.1093(b) is for the aeroplane to safely operate in icing conditions, the specifications limit the icing conditions to CM and IM icing conditions as specified in CS-25 Appendix C. CM and IM icing conditions are currently limited to a maximum of 22000 feet, with a possible extension to 30000 feet for IM icing conditions. Icing conditions may exist above current Appendix C icing envelopes, albeit they are currently not precisely characterised. Although one can postulate that they are less severe in nature compared to Appendix C conditions owing to the Liquid Water Content (LWC) general trend with temperature, it cannot be completely ruled out that icing conditions above Appendix C may definitely exist.

Indeed, the Appendix C of CS-25 constitutes an engineering standard to characterise the icing atmosphere. Such envelope has been in use since 1964 to select values of icing-related cloud variables for the design of aeroplane in-flight ice protection systems. As a matter of fact, it was developed based on data from the continental US atmospheric conditions and the available knowledge on aviation environment that existed at that time. Secondly, there is no available data on icing conditions that may exist over tropic and equatorial warm oceanic waters. Finally, hot-day conditions are not addressed in the current CS 25 Appendix C. Indeed, according to the flight test data showed in FAA technical report ADS-4, Figure 1-21, there are significant number of icing encounters at altitude between 16000 and 20000 ft. occurring at temperature warmer than

[1] In case of SC, the associated Interpretative Material and/or Acceptable Means of Compliance may be published for awareness only and they are not subject to public consultation.

the current Appendix C (Source Boeing flights). Furthermore, the same picture (figure 1-21) also includes two reported icing encounters above 30000 feet (supposed to be the higher altitude for the IM icing envelope), at 37000 and 39000 feet, respectively; the occurrence at 37000 feet was reported as "severe". (Letter No. 6-7731-69, dated April 29, 1963, from E. A. Rock, Staff Engineer, the Boeing Company, Renton Washington). The report also states (§ 1.3.3) that "…an Ice Protection System designed to meet Appendix C icing environment will probably have no difficulties when icing is encountered at high altitude."

It is acknowledged that current Appendix C icing envelope maximum altitude only goes up to 30,000 feet for the IM icing conditions, but it is mainly attributed to the "limited" altitude capability of the aeroplanes used during research projects to determine the icing envelope at that time. Nevertheless, it is commonly agreed that below -40°C, air cannot hold any more moisture.

Although CS 25.1419 and CS 25.1093(b) have been often interpreted in the way that the ice protection system (IPS) effectiveness would not be assessed above the Appendix C altitude, an IPS designed to meet Appendix C icing environment is expected to provide adequate protection for any icing encounter at altitudes above the Appendix C envelope.

Decades of safe in-service history of in-flight icing operation with aeroplane whose IPS thermal power was only naturally reduced (phased out) by engine bleed flow availability with altitude (i.e., due to natural reduction of global engine inlet mass flow with altitude) prove the robustness of such IPS design. It will be referred hereafter as "traditional On/Off IPS". In such a case, and on the basis of the past good in-service experience, it is assumed that an aeroplane equipped with "traditional On/Off IPS" operated in the full flight aeroplane envelope can be certified using the Appendix C envelope, and that no further assessment is required for the part of the flight envelope which is beyond the Appendix C.

On the other hand, some aeroplane may incorporate IPS design features able to implement a "per-design" reduction/cut-off of the engine bleed usage for anti-icing above the current Appendix C altitude limits in order to optimise engine performance, to reduce the fuel consumption and the impact on the environment. The bleed 'optimisation' logic could be implemented at engine or aeroplane level.

This has led to IPS design with an active "optimisation" (or modulation) of anti-icing bleed flow schedule with altitude; this feature eventually results into a more or less rapid phasing out of anti-icing thermal power (generally outside Appendix C altitude limits) particularly between the Appendix C altitude thresholds and the maximum aeroplane operational ceiling. In some aeroplane, in some extreme operational conditions, bleed air usage for anti-icing purpose is even inhibited beyond a certain altitude since it can lead to serious engine operability issues (such as engine surge, roll-back...).

Compared with the here-above referred "traditional On/Off" IPS design where the limitation of thermal power is only (mainly) driven by the air bleed availability from the engine with altitude without performing any further air bleed optimisation, these latter designs represent globally a novel or unusual design when compared to the existing flying fleet.

This Special Condition primarily addresses aeroplane thermal IPS supplied by engine bleed air flow. Nevertheless, it can potentially apply to any other IPS concept, when such IPS envisages similar design features aimed at optimising the anti-icing function.

Such modulated IPS may be unable to maintain the protected surface temperatures above zero at altitudes above the Appendix C envelope limits, and, particularly, at low temperatures, ice could accrete on the protected surface.

In order to address such unusual IPS design and to ensure that the aeroplane is able to safely operate in icing conditions in the entire aeroplane flight envelope, according to the Annex I of Commission Regulation (EU) No 748/2012 , also known as “Part-21”, Subpart A, 21.A.16B(a)(1), there is a need to raise a Special Condition (SC): “The product has novel or unusual design features relative to the design practices on which the applicable airworthiness code is based”.

The SC text is complemented by acceptable means of compliance (AMC) in order to indicate how to demonstrate compliance with the SC.

The SC text as well as the AMC are provided below.

Special Condition on Aeroplane Ice Protection System operation above the maximum altitudes of CS-25 Appendix C icing envelopes

If an ice protection system (IPS) is optimised/modulated, or even inhibited, above the maximum altitude of Appendix C icing envelopes, the applicant shall demonstrate that the aeroplane can safely operate in icing conditions encountered at any altitudes of the operational flight envelope, or an AFM limitation shall be introduced to prohibit operations in icing conditions at altitudes beyond a certified icing envelope.

Acceptable Means of Compliance to SC to demonstrate safe operation above the maximum altitudes of the Appendix C icing envelopes with an optimised/modulated IPS.

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

An aeroplane IPS is considered optimised/modulated wherever a bleed 'optimization' logic is implemented at engine or aeroplane level. When an aeroplane is operated with such IPS logic, it could not be able to demonstrate safe operation in icing conditions within its entire flight envelope. In such a case the applicant should define the certified icing envelope where the aircraft operation in icing condition is unrestricted.

The applicant should follow one of the following 3 options:

1. The applicant demonstrates safe operation in icing conditions at all altitudes up to its operational ceiling; then the certified icing envelope is the aeroplane flight envelope, and no AFM limitation is required.
2. The applicant does not demonstrate safe operation in icing conditions at altitudes above the maximum altitude of the Appendix C icing envelopes; then the certified icing envelopes are those indicated in the CS-25 Appendix C only; and an AFM limitation is introduced to prevent aeroplane operation in icing conditions above the maximum altitude of Appendix C icing envelopes.
3. The applicant demonstrates safe operation in icing conditions up to a certain altitude between the maximum altitude of Appendix C icing envelopes and its operational ceiling; then the certified icing envelope is the Appendix C icing envelopes extended up to the demonstrated altitude; and an AFM limitation is introduced to prevent aeroplane operation in icing conditions at altitudes above the demonstrated altitude and up to its ceiling.

With regard to the Case 2 – limitation to Appendix C icing envelopes -, considering the difference in term of maximum altitude in the CM and IM icing envelopes, 2 ways forward are envisaged:

- If a limitation is proposed at 22000 feet, no further demonstration is required from the applicant;
- If a limitation is proposed between 22000 and 30000 feet, the capability to safely operate in CM icing conditions has to be demonstrated up to the proposed altitude limit accordingly.

With regard to the case 3, CM and IM icing conditions should be assessed above their respective maximum altitude envelopes and up to the altitude limit for flight in icing conditions selected by the applicant.

An applicant may demonstrate safe flight operation of an aeroplane with an optimised IPS design above the altitude of Appendix C icing envelopes through two compliance strategies, i.e.:

a) based on comparative analysis with previously certified IPS designs with safe flight-in-icing in-service experience, or

b) based on direct demonstration.

Below some guidance material for options a) and b)

Compliance Strategy/Option a): Comparative Analysis

For new aeroplane design having comparable handling qualities and performance in both dry air and Appendix C icing conditions to previous certified product, the applicant may demonstrate compliance with the Special Condition by means of a comparative analysis between the proposed "optimised" IPS above the altitude of Appendix C icing envelopes and a previously approved design, supported by safe flight-in-icing in-service history in the entire certified aeroplane operating envelope.

The analysis should demonstrate that the new IPS provides comparable performance as the reference one within the respective aeroplane operational envelopes. The applicant might claim that although the IPS thermal flow is optimised above Appendix C altitudes, it still provides sufficient ice protection and remains comparable to former IPS design in a reference fleet.

Both aeroplane operational envelopes and the kind of operation of the IPS should be comparable.

Compliance Strategy/Option a): Direct Demonstration

Applicants may seek for direct demonstration to validate that the aeroplane, while operated with an optimised/modulated or even inhibited IPS above the Appendix C icing envelopes altitude, is still safe. For the evaluation of safe operation, the applicant should assess the degradation of aeroplane performance and handling qualities created by the potential ice accretion on aeroplane unprotected and protected parts. Furthermore, the applicant should assess the effect of sudden release of the ice accretions on the engines and essential equipment.

The applicant should propose and substantiate the icing conditions and scenarios that should be considered. In the absence of any proposal, the following icing conditions and operational scenarios may be considered.

Atmospheric icing Conditions**.**

In the lack of empirical data to precisely characterise the icing atmosphere standard over 22,000 feet for CM conditions and over 30,000 feet for IM conditions, the following conservative assumptions are taken:

- The CM icing conditions at 22,000 feet are extended up to the maximum operating aeroplane altitude, by assuming the liquid water content for the coldest temperature shown in CS-25 Appendix C, Figure 1 reducing linearly to 0 g/m^3 at -40 °C and the absence of liquid phase below that temperature.

- The IM icing conditions at 30,000 feet are extended up to the maximum operating aeroplane altitude, by assuming the liquid water content for the coldest temperature shown in CS 25 Appendix C, Figure 4 and the absence of liquid phase below -40°C.

Operational scenario to compute the relevant airframe ice accretion.

The basic assumption is that the aeroplane may be flying within the Appendix C conditions and may already have some ice accretion on unprotected areas and/or runback ice beyond protected areas.

To show that the aeroplane can safely operate in CM icing conditions at altitudes above 22,000 feet and in IM icing conditions at altitudes above 30,000 feet, the applicant should consider the following operational scenarios to define the appropriate "en-route" ice shapes accordingly:

1. Operations in icing conditions above 22,000 feet in CM icing conditions

a) The critical ice accretion that would be already on the aeroplane after a climb through a single 17.4 nm CM cloud within the Appendix C, i.e., below 22,000 ft.

b) The critical ice accretion from step a) plus an exposure to one CM cloud in cruise at altitudes between 22,000 feet and the maximum aeroplane cruise operating altitude. The applicant will define the cloud distance as per figure 3 of Appendix C and leading to the maximum runback ice accretion behind the ice protected area(s) (if any). 310 nm should be selected if the IPS is inhibited on purpose without any aeroplane operational restriction, in order to maximise the ice accretion mass.

2. Operations in icing conditions above 30,000 feet in IM icing conditions

a) The critical ice accretion that would be already on the aeroplane after a climb through a single 2.6 nm IM cloud within the Appendix C, i.e., below 30,000 ft.

b) The critical ice accretion from step a) plus an exposure to one IM cloud in cruise at altitudes between 30,000 feet and the maximum cruise operating altitude. The applicant will define the cloud distance as per figure 6 of Appendix C and leading to the maximum runback ice accretion behind the ice protected area(s) (if any). 5.21 nm should be selected if the IPS is inhibited on purpose without any aeroplane operational restriction.