European Union Aviation Safety Agency

Notice of Proposed Amendment 2022-08

in accordance with Article 6(1) of MB Decision No 01-2022

Analysis of on-ground wing contamination effect on take-off performance degradation

RMT.0118

EXECUTIVE SUMMARY

The objectives of this Notice of Proposed Amendment (NPA) are to:

— mitigate the risks of incidents and accidents caused by airframe ground icing contamination or inadequate de-acing/anti-icing operations; and

— align the requirements of CS-25 with the existing EASA AIR OPS regulations regarding allowed take-off with a determined level of contamination.

This NPA proposes to amend the certification specifications for large aeroplanes on the following areas:

1) design requirements for take-off with a determined level of contamination of the aerodynamic surfaces; and

2) criteria for the testing and selection of de-icing/anti-icing fluids for a large aeroplane type design.

This NPA does not propose the mandate of on-board systems to alert the crew of potential contamination of the wing. Within the NPA it is proposed instead to continue and reinforce safety promotions actions to raise awareness of the community on this issue.

The NPA does not propose changes to CS-23.

The proposed amendments and safety promotion actions are expected to increase safety.

This NPA takes into consideration the recommendations from rulemaking group report RMT.0118, dated 15 September 2021 (please refer to the annex to this NPA).

Domain:	Safety		
Related rules:	CS-25		
Affected stakeholders:	Large aeroplane TC Holders and applicants		
Driver:	Safety	**Rulemaking group:**	Yes
Impact assessment:	Yes		

EASA rulemaking procedure milestones

Start Terms of Reference	**Public consultation** NPA 2022-08	**Proposal to the Commission** EASA Opinion	Adoption by the Commission Implementing/Delegated act	**Decision** Certification Specifications, Detailed Specifications, Acceptable Means of Compliance, Guidance Material
21.3.2017	25.7.2022	n/a	n/a	2023/Q4

Disclaimer

This document has not been subjected to linguistic review.

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1. About this NPA

1.1. How this NPA was developed

- The European Union Aviation Safety Agency (EASA) developed this Notice of Proposed Amendment (NPA) in line with Regulation (EU) 2018/1139[1] (the 'Basic Regulation') and the Rulemaking Procedure[2]. This Rulemaking Task (RMT).0118 is included in Volume II of the European Plan for Aviation Safety (EPAS) for 2022-2026. The scope and timescales of the task were defined in the related Terms of Reference (ToR)[3].

- EASA developed this NPA, based on the input of Rulemaking Group (RMG) RMT.0118. The NPA is hereby submitted for consultation in accordance with Article 115 of the Basic Regulation, and Article 6(1) of the Rulemaking Procedure.

- The major milestones of this RMT are presented on the cover page.

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/**[4].

The deadline for the submission of comments is **25 October 2022**.

1.3. The next steps

- Following the public consultation, EASA will review all the comments received.

- Based on the comments received, EASA may publish a decision to amend the related certification specifications (CSs) and acceptable means of compliance (AMC) / guidance material (GM), and initiate safety promotion actions.

- The individual comments received on this NPA and the EASA responses to them will be reflected in a comment-response document (CRD), which will be published on the EASA website[5].

[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 01-2022 of 2 May 2022 on the procedure to be applied by EASA for the issuing of opinions, certification specifications and other detailed specifications, acceptable means of compliance and guidance material ('Rulemaking Procedure'), and repealing Management Board Decision No 18-2015 (https://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-01-2022-rulemaking-procedure-repealing-mb).

[3] ToR RMT.0118 - Analysis of on-ground wing contamination effect on take-off performance degradation | EASA (europa.eu)

[4] In case of technical problems, please send an email to crt@easa.europa.eu with a short description.

[5] https://www.easa.europa.eu/document-library/comment-response-documents

2. In summary — why and what

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

A number of incidents and accidents have been caused by the degradation of aircraft aerodynamic performance, reduction of safety margins and reduction of manoeuvrability/controllability due to airframe ground icing contamination or inadequate de-/anti-icing operations. EASA has received a number of safety recommendations related to this subject.

Analysing the incidents and accidents, two categories of issues/risks have been identified:

1. Take-off with in-icing condition with unnoticed contaminated wing; and
2. De-icing/anti-icing fluid effects on the aerodynamic performances, safety margins, manoeuvrability, and controllability of the aeroplane at take-off.

In parallel, a disconnection was noted between Commission Regulation (EU) No 965/2012 (where take-off with contamination may be possible if permitted in the aircraft flight manual), and CS-25 (where performance demonstrations are conducted on a clean aircraft). Today, there is no provision in CS-25 to certify the aircraft in respect of cold-soak effect. EASA has issued a certification review item (CRI) on certain certification projects, containing provisions that an applicant should consider when evaluating the performances of its design with wing surface contaminated because of cold-soaked effects.

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 NPA will contribute to achieving the overall objectives by addressing the issues described in Section 2.1.

— The specific objective(s) of this NPA is (are) to:

o mitigate the risk of loss of control of an aeroplane (in particular during, but not limited to, the take-off phase), and the risk of runway excursion after an aborted take-off at high speed, caused by an aerodynamic performance or controllability degradation, as a result of aerodynamic surfaces contamination by ice or de/anti-icing fluids; and

o align the requirements of CS-25 with the existing EASA OPS regulations regarding allowed take-off with a determined level of contamination.

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

It is proposed to amend CS-25 by:

- creating a new paragraph CS 25.1595 and related AMC – AFM pre-defined take-off contamination with certification specifications to provide for safe take-off of a large aeroplane with a determined level of frozen contaminant on its critical surfaces;
- creating a new paragraph CS 25.1597 and related AMC – Ground de-icing/anti-icing fluids, which would require that operating limitations, operating procedures and performance information associated with the use of de-icing and anti-icing fluids be established and provided in the AFM;
- amending existing CS 25.1583 – Operating limitations with the introduction of:

    - a subparagraph (l) that would require that, when pre-take-off contamination established under CS 25.1595 is allowed, its possible location, type and extend are clearly identified in the AFM.
    - a subparagraph (m) that would require that information is provided in the AFM that explicitly state whether the use of de-icing and anti-icing fluids is permitted and if so, which fluid types are approved for use.
  - amending Appendix C – Part II Airframe Ice Accretions and Appendix O – Supercooled large drops icing conditions, to refer to the proposed CS 25.1595;
  - amending AMC 25.21(g) – Performances and handling characteristics in icing conditions, to refer to the proposed CS 25.1597.
- The proposed amendments to CS-25 would tackle the issue of performance degradation because of de/anti-icing fluid effects, as well as the disconnection between CS-25 and Commission Regulation (EU) No 965/2012.
- It is not proposed to amend CS-25 with a requirement to install an on-board system to alert the crew of potential contamination of the aircraft wing.
- Instead it is proposed to continue and re-enforce safety promotion actions to raise awareness of the community on procedures related to winter operations.
- The safety promotion action would tackle the issue of take-off with unnoticed wing contamination.

2.4. What are the expected benefits and drawbacks of the proposed amendments

The expected benefits and drawbacks of the proposed amendments are summarised below. For the full impact assessment, please refer to Chapter 0.

The envisioned safety promotion actions are expected to enhance safety by further raising awareness of the community on the procedures related to winter operations, thus mitigating the risk of take-off with unnoticed contaminated wing by icing conditions

The proposed changes are expected to enhance safety by ensuring a consistent approach with regards to:

i) the certification of large aeroplanes and their approval for take-off with a certain level of allowed pre-defined frozen contamination, thus addressing the disconnection between Commission Regulation (EU) No 965/2012 and CS-25 and contamination by cold-soak effect

ii) approving the use of type I, II, III, and IV deicing/anti-icing fluids on aeroplanes, thus mitigating the risk of possible adverse effect ofde-icing/anti-icing fluids on the aerodynamic performances, safety margins, maneuverability, and controllability of the aeroplane at take-off.

3. Proposed amendments and rationale

— The amendment is arranged to show deleted, new or amended, and unchanged text as follows:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in blue;

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

Where necessary, the rationale is provided in *blue italics.*

3.1. Draft certification specifications

CS 25.1583 Operating limitation

[…]

(l) The following information must be furnished if the applicant is seeking certification for take-off with AFM defined pre-take-off frozen contamination:

(1) The operating limitations shall identify the specified location, type, and extent of AFM defined pre-take-off frozen contamination established under CS 25.1595.

(2) The operating limitations shall prohibit the combination of AFM defined pre-take-off frozen contamination with icing conditions, if not approved under the Type Certificate.

Rationale

Subparagraph (l) is added to make the link with the proposed paragraph CS 25.1595 and is to ensure that necessary information regarding take-off with defined pre-take-off contamination are included in the AFM.
For more details, refer to the Annex to this NPA.

(m) The following information must be furnished:

(1) The operating limitations shall identify the specification and type of de-icing/anti-icing fluid approved under the Type Certificate

(2) The operating limitations shall prohibit the use of the de-icing/anti-icing fluid, if not approved under the Type Certificate.

Rationale

Subparagraph (m) is linked to proposed paragraph CS 25.1597 and is to ensure that necessary limitations with respect to use of deicing and anti-icing fluids are included in the AFM. For more details, refer to the Annex to this NPA.

CS 25.1595 AFM defined pre-take-off contamination

[…]

If the applicant is seeking certification for take-off with AFM defined pre-take-off frozen contamination, any operating procedures, and associated limitations necessary for safe aeroplane operations with defined pre-take-off contamination must be established and included in the approved part of the aeroplane flight manual in accordance with CS 25.1581, 25.1583, 25.1585 and 25.1587.

The applicant seeking certification for take-off with AFM defined pre-take-off frozen contamination must also consider the following certification specifications (See AMC 25.1595):

(CS 25.21(g); CS 25.101; CS 25.103; CS 25.105; CS 25.107; CS 25.109; CS 25.111; CS 25.113; CS 25.115; CS 25.117; CS 25.121(a), (b), (c); CS 25.143(a)(1)(2), (b)(3), (c)(1), (d), (e), (f), (g), (h), (k); CS 25.147(c), (d), (e), (f); CS 25.161(a), (b), (c)(1), (c)(3), (d), (e); CS 25.171; CS 25.173; CS 25.177; CS 25.181; CS 25.201; CS 25.203; CS 25.207; CS 25.251(a); CS 25.629; CS 25.1091(d)(2); CS 25.1093(b); CS 25.J1093; CS 25.1309(b)(c); CS 25.1419; CS 25.1420; CS 25.1501(a); CS 25.1501(a); CS 25.1533; CS 25.1581(a), (h); CS 25.1583; CS 25.1587(b); Appendix C; Appendix O.

In the context of CS 25.1595, when the above-mentioned certification specifications refer to “icing conditions”, it should be understood as “AFM defined pre-take-off contamination condition” or the combination of both “icing conditions” and “AFM defined pre-take-off contamination condition”, as applicable.

Rationale

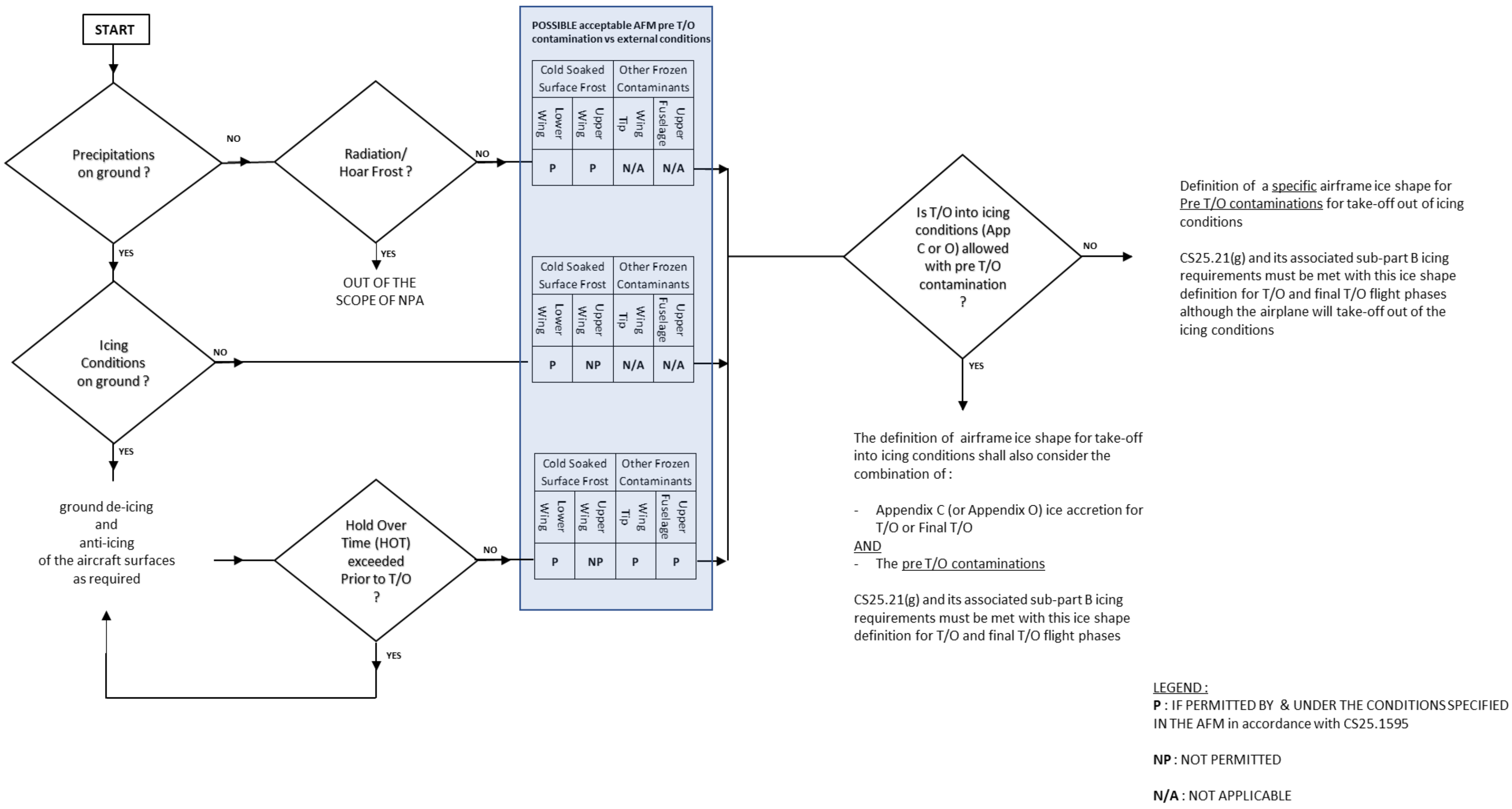
A review of the possible impacted requirements in the existing certification specifications was conducted, while considering current design practices and available technologies.

It was concluded that it would be most efficient to create a new paragraph and its corresponding AMC, gathering material to be established and made available in the AFM, to ensure safe operation with a defined pre-take-off contamination

Where deemed necessary, existing paragraphs are proposed to be updated to refer to the new paragraph, i.e., AMC 25.21(g); CS-1583, Appendix C and Appendix O

The following flow chart summarises for information, the possible pre-take-off contamination/external conditions which could be permitted under the conditions specified in the AFM, in accordance with proposed CS 25.1595.

For more details, please refer to the Annex to this NPA.


START
Precipitations on ground ?
NO
YES
Radiation/ Hoar Frost ?
NO
YES
OUT OF THE SCOPE OF NPA
Icing Conditions on ground ?
NO
YES
ground de-icing and anti-icing of the aircraft surfaces as required
Hold Over Time (HOT) exceeded Prior to T/O ?
NO
YES
POSSIBLE acceptable AFM pre T/O contamination vs external conditions
Cold Soaked Surface Frost
Other Frozen Contaminants
Lower Wing
Upper Wing
Wing Tip
Upper Fuselage
P P N/A N/A
Cold Soaked Surface Frost
Other Frozen Contaminants
Lower Wing
Upper Wing
Wing Tip
Upper Fuselage
P NP N/A N/A
Cold Soaked Surface Frost
Other Frozen Contaminants
Lower Wing
Upper Wing
Wing Tip
Upper Fuselage
P NP P P
Is T/O into icing conditions (App C or O) allowed with pre T/O contamination ?
NO
YES
Definition of a specific airframe ice shape for Pre T/O contaminations for take-off out of icing conditions
CS25.21(g) and its associated sub-part B icing requirements must be met with this ice shape definition for T/O and final T/O flight phases although the airplane will take-off out of the icing conditions
The definition of airframe ice shape for take-off into icing conditions shall also consider the combination of :
- Appendix C (or Appendix O) ice accretion for T/O or Final T/O
AND
- The pre T/O contaminations
CS25.21(g) and its associated sub-part B icing requirements must be met with this ice shape definition for T/O and final T/O flight phases
LEGEND :
P : IF PERMITTED BY & UNDER THE CONDITIONS SPECIFIED IN THE AFM in accordance with CS25.1595
NP : NOT PERMITTED
N/A : NOT APPLICABLE

AMC1 25.1595 AFM defined pre-take-off frozen contamination

1 Purpose

When requested by the applicant, take-off with AFM defined pre-take-off frozen contamination may be certified. If the certification includes possible combination with take-off into icing conditions, the defined pre-take-off frozen contamination should be considered in combination with the ice accretion resulting from the icing conditions and compliance must be shown using the ice accretions defined in part II of Appendix C and part II of Appendix O, assuming normal operation of the aeroplane and its ice protection system. If the certification precludes take-off into icing conditions (e.g., cold-soaked fuel frost (CSFF) in non-icing conditions), the AFM defined pre-take-off frozen contamination may be considered on its own.

The following AFM defined pre-take-off frozen contamination scenarios should be considered:

- Cold soaked surface frost on a prescribed area of the upper surface of the wing
- Cold soaked surface frost on the lower surface of the wing in the vicinity of the fuel tank
- Frozen contamination adhering to wingtip devices
- Frozen contamination adhering to the upper fuselage

The applicable flight phase is take-off, including ground roll, take-off, and final take-off segments. The AFM defined pre-take-off frozen contamination does not need to be considered for flight phases subsequent to final take-off.

The guidance for AFM defined pre-take-off frozen contamination is not applicable to wing leading edges, control surfaces, engine intakes or propellers or in any area where it could affect flight instrument external probe accuracy. The guidance for AFM defined pre-take-off frozen contamination under precipitation conditions which results in contamination on the wings (excluding wingtips) is not applicable. Frozen precipitation on the horizontal and vertical tail planes, and non-localized contamination (for example, from radiation frost from an aircraft parked overnight with a clear sky), is considered out of the scope of this AMC.

In establishing the limitations for AFM defined pre-take-off frozen contamination scenarios that would be allowed, required procedures for ensuring compliance with the AFM scenarios should be technically valid and operationally practical, and consistent with AMC 25.1581(6)(c)(3) Procedures Development.

Aspects of AMC 25.21(g) are directly applicable for showing compliance with AFM defined pre-take-off frozen contamination scenarios. For example, the AFM defined pre-take-off frozen contamination must be considered in combination with take-off or final take-off ice in icing environments such as wingtip device ground contamination in active precipitation and possible failed holdover times. Alternatively, AFM defined pre-take-off frozen contamination may be considered independently from take-off ice or final take-off ice if the AFM prohibits the combination or if the aeroplane is not certified for flying in icing condition. For example, conditions such as with cold-soak fuel frost that naturally forming in warmer environments where take-off or final take-off ice would not be present.

2 Related requirements

The following requirements shall be considered by the applicant for the purpose of showing compliance to CS 25.1595:

CS 25.21(g)	Proof of Compliance
CS 25.101	Performance - General
CS 25.103	Stall Speed
CS 25.105	Take-off
CS 25.107	Take-off speeds
CS 25.109	Accelerate-stop Distance
CS 25.111	Take-off Path
CS 25.113	Take-off distance and take-off run
CS 25.115	Take-off flight path
CS 25.117	Climb: general
CS 25.121(a), (b), (c)	Climb: one-engine inoperative
CS 25.143(a)(1)(2), (b)(3), (c)(1), (d), (e), (f), (g), (h), (k)	Controllability and Manoeuvrability – General
CS 25.147(c), (d), (e), (f)	Directional and Lateral Control
CS 25.161(a), (b), (c)(1), (c)(3), (d), (e)	Trim
CS 25.171	Stability - General
CS 25.173	Static longitudinal stability
CS 25.177	Static Directional and Lateral Stability
CS 25.181	Dynamic Stability
CS 25.201	Stall Demonstration
CS 25.203	Stall characteristics
CS 25.207	Stall Warning
CS 25.251(a)	Vibration and Buffeting
CS 25.629	Aeroelastic stability requirements
CS 25.1091(d)(2)	Air intake
CS 25.1093(b)	Powerplant Ice Protection
CS 25.J1093	Air intake system icing protection
CS 25.1309(b)(c)	Equipment, Systems and Installations
CS 25.1419	Ice Protection
CS 25.1420	Supercooled large drop icing conditions
CS 25.1501(a)	General
CS 25.1533	Additional operating limitations
CS 25.1581(a), (h)	Aeroplane Flight Manual
CS 25.1583	Operating Limitations
CS 25.1587(b)	Performance information
Appendix C	Icing Conditions
Appendix O	SLD Icing Conditions

Proof of Compliance

CS 25.21(g) should be considered relevant as the CS 25.1595 AFM defined pre-take-off frozen contamination should be considered in combination with CS 25.21(g) take-off ice, as applicable.

Aircraft Performance (CS 25.101, 25.103, 25.105, 25.107, 25.109, 25.111, 25.113, 25.115, 25.117, 25.121(a)(b)(c))

The principle for the assessment of the following performance requirements is to address AFM defined pre-take-off frozen contamination effects on performance in the same way as take-off ice is addressed. If take-off in icing is permitted with the AFM predefined frozen contamination, then it must be added to the take-off ice shape for the aircraft take-off performance assessments.

As specified in CS 25.105, the take-off speeds prescribed by CS 25.107, the accelerate-stop distance prescribed by CS 25.109, the take-off path prescribed by CS 25.111, the take-off distance and take-off run prescribed by CS 25.113, and the net take-off flight path prescribed by CS 25.115, must be determined in the selected configuration for take-off at each weight, altitude, and ambient temperature within the operational limits selected by the applicant.

The climb gradient requirements defined by CS 25.121(a)(b)(c) must be met for the purpose of showing compliance to CS 25.1595 under the following conditions:

(a) Take-off; landing gear extended with AFM defined pre-take-off frozen contamination, as applicable. In the critical take-off configuration existing along the flight path (between the points at which the airplane reaches VLOF and at which the landing gear is fully retracted) and in the configuration used in CS 25.111 but without ground effect, the steady gradient of climb must be positive for two-engine airplanes, and not less than 0.3 percent for three-engine airplanes or 0.5 percent for four-engine airplanes, at VLOF and with

(i) The critical engine inoperative and the remaining engines at the power or thrust available when retraction of the landing gear is begun in accordance with CS 25.111 unless there is a more critical power operating condition existing later along the flight path but before the point at which the landing gear is fully retracted; and

(ii) The weight equal to the weight existing when retraction of the landing gear is begun, determined under CS 25.111.

(b) Take-off; landing gear retracted. In the take-off configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in CS 25.111 but without ground effect:

(i) The steady gradient of climb may not be less than 2.4 percent for two-engine airplanes, 2.7 percent for three-engine airplanes, and 3.0 percent for four-engine airplanes, at V2 with:

(A) The critical engine inoperative, the remaining engines at the take-off power or thrust available at the time the landing gear is fully retracted, determined under CS 25.111, unless there is a more critical power operating condition existing later along the flight path but before the point where the airplane reaches a height of 400 feet above the take-off surface; and

(B) The weight equal to the weight existing when the airplane's landing gear is fully retracted, determined under CS 25.111.

(ii) The requirements of paragraph (b)(1) of this section must be met:

(A) In non-icing conditions in combination with AFM defined pre-take-off frozen contamination as applicable, if in the configuration used to show compliance with CS 25.121(b):

(a) The stall speed at maximum take-off weight exceeds that in non-icing conditions without AFM defined pre-take-off frozen contamination by more than the greater of 5.6 km/h (3 knots) CAS or 3 % of VSR; or

(b) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b); and

(B) In icing condition in combination with AFM defined pre-take-off frozen contamination as applicable, with the most critical of the take-off ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with CS 25.21(g), if in the configuration used to show compliance with CS 25.121(b) with this take-off ice accretion:

(a) The stall speed at maximum take-off weight exceeds that in non-icing conditions without AFM defined pre-take-off frozen contamination by more than the greater of 3 knots CAS or 3 percent of VSR; or

(b) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b).

(c) Final take-off. In the en-route configuration at the end of the take-off path determined in accordance with CS 25.111:

(i) The steady gradient of climb may not be less than 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes, and 1.7 percent for four-engine airplanes, at VFTO with

(A) The critical engine inoperative and the remaining engines at the available maximum continuous power or thrust; and

(B) The weight equal to the weight existing at the end of the take-off path, determined under CS 25.111.

(ii) The requirements of paragraph (c)(1) of this section must be met:

(A) In non-icing conditions and in combination, as applicable, with AFM defined pre-take-off frozen contamination

(a) The stall speed at maximum take-off weight exceeds that in non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3 % of VSR; or

(b) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b); and

(B) *In icing conditions and in combination, as applicable, with AFM defined pre-take-off frozen contamination, with the most critical of the final take-off ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with CS 25.21(g), if in the configuration used to show compliance with CS 25.121(b) with the take-off ice accretion used to show compliance with CS 25.111(c)(5)(i):*

(a) The stall speed at maximum take-off weight exceeds that in non- icing conditions by more than the greater of 3 knots CAS or 3 % of VSR; or

(b) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b).

Aircraft Handling Characteristics

This section addresses the requirements related to controllability and maneuverability, stability, trim, stall, and miscellaneous flight requirements of CS 25 subpart B

The applicant should assess if the AFM defined pre-take-off frozen contamination could impact the controllability and maneuverability of the aircraft and identify the impacted applicable requirements. Compliance should be shown by analysis, test, or a combination thereof. Qualitative evaluations in combination with other testing are normally adequate to demonstrate compliance with the handling requirements of subpart B with AFM defined pre-take-off frozen contamination.

Controllability and Manoeuvrability (CS 25.143, 25.147)

If compliance is demonstrated by flight test, usually a qualitative evaluation is sufficient to assess the aeroplane's controllability and manoeuvrability. Limited quantitative data may be used to augment the demonstration such as control forces and control surface deflections. In the case of marginal compliance, or the stick-force or stick-force-per-g limits being approached, additional substantiation may be necessary to establish compliance.

Typically, the following paragraphs are applicable:

- 25.143(a)(1)(2),
- 25.143(b)(3),
- 25.143(c)(1),
- 25.143 (d),
- 25.143(e),
- 25.143(f),
- 25.143(g),
- 25.143(h) (for TAKE-OFF and EN-ROUTE CONFIGURATIONS)
- 25.143(k)
- 25.147 (except 25.147(a) and (b)
- 25.161 (except 25.161(c)(2))

Trim (CS 25.161)

The effects of AFM defined pre-take-off frozen contamination on trim should be evaluated by the applicant.

Stability (CS 25.171, 25.173, 25.177, 25.181)

The effects of AFM defined pre-take-off frozen contamination on stability should be evaluated by the applicant.

Stall (CS 25.201, CS 25.203, CS 25.207)

A stall characteristics evaluation program should be conducted, mainly if the AFM defined pre-take-off frozen contamination includes parts of wings such as cold soak fuel frost or wing tip device contamination.

CS 25.201(c)(2) is not required to be demonstrated for Appendix C ice shapes under the specification, so similarly it is not required for AFM defined pre-take-off frozen contamination scenarios.

Vibration and Buffeting (CS 25.251(a))

CS 25.251(a) should be considered by the applicant when accumulation of AFM defined pre-take-off frozen contamination may be present on surfaces that may introduce buffet difference compared to the baseline, clean airplane. CS 25.251(b) through(e) are not required to be demonstrated for Appendix C and O ice shapes so similarly are not required for AFM allowed defined pre-take-off frozen contamination scenarios.

Design and Construction – Aeroelastic Stability Requirements (CS 25.629)
This requirement should be considered by the applicant for AFM defined pre-take-off frozen contamination in the cases that a mass accumulation may occur in and around control surfaces or balance bays.

Powerplant (CS 25.1091(d)(2), CS 25.1093(b))
These requirements should be considered by the applicant for AFM defined pre-take-off frozen contamination. This may be a concern for contamination scenarios that may shed from surfaces upstream of a rear mounted engine inlet.

Ice Protection (CS 25.1419, CS 25.1420)
This requirement should be considered in combination with Appendix C and Appendix O, as applicable.

Operating Procedures, Limitations, Information and Aeroplane Flight Manual (CS 25.1501(a), 25.1533, 25.1581(a)(h), 25.1583, 25.1585, 25.1587(b))
Any unique operating procedures, information, including performance information, limitations or other information related to AFM frozen contamination necessary for safe operation of the aeroplane must be established and furnished in the AFM.

Appendix C Icing Conditions
This requirement should be considered by the applicant for consideration of AFM defined pre-take-off frozen contamination, as applicable.

Appendix O SLD Icing Conditions
This requirement should be considered by the applicant for consideration of AFM defined pre-take-off frozen contamination, as applicable.

3 General methodology

Analysis/similarity, wind tunnel and flight testing as described below are acceptable means of compliance for AFM defined pre-take-off frozen contamination. Additional guidance for specific forms of contamination is contained in separate subparagraphs.

3.1 Analysis

Such analysis when used should address the scope (affected areas, location, and definition of the frozen contamination) of AFM defined pre-take-off frozen contamination and provide all supporting data and rationale showing that:

- the defined pre-take-off frozen contamination does not adversely affect the handling characteristics and the performance of the aeroplane, as required by -CS 25.1595,
- the defined pre-take-off frozen contamination does not adversely affect the functioning of surrounding systems and equipment (i.e., the flight instrument external probes systems, ventilation port/scoop, etc.),
- the shedding of defined pre-take-off frozen contamination will not create unacceptable damages to the engines or the surrounding components which would prevent continued safe flight and landing.

All analysis tools and methods should be validated by tests or should have been validated by the applicant on a previous certification program. The applicant who uses a previously validated method or tool should substantiate why this approach is still applicable to the new program.

Where the assumptions of the analysis are dependent on an aircraft system (such as fuel tank temperature), then system reliability shall be considered consistent with CS 25.1309(b) and 1309(c).

The definition, characteristics (in term of ice thickness, roughness) and location of the permitted frozen deposit adhering to the surface must be proposed and substantiated by the applicant and agreed with the Authority.

3.1.1 Analysis to determine scope of contamination

The applicant should assess the scope of contamination which it is proposed to permit. It should be shown that the scope considered is conservative with respect to that which may occur in practice.

The applicant should define the type of frozen contaminant (e.g., cold soaked frost or frozen precipitation) and the affected surfaces, establish the corresponding extent/thickness of ice accretion and identify all the limiting factors necessary to bound that definition (such as time exposure, precipitation conditions, ambient moisture & temperature, fuel, and structure temperature, etc.)

Restrictions should be included on the conditions permitted where necessary to achieve this definition. For instance, it may be required to clean the relevant surfaces of the airframe when deicing other surfaces, to bound the time exposure for accumulation of contaminant to that provided by hold-over times on other surfaces, or the environmental conditions where contaminant is permitted may be restricted to eliminate combinations of contaminant from different sources. For an aircraft parked in active precipitation, the maximum amount of precipitation which could accumulate on an untreated surface is the amount which would cause expiry of the applicable hold-over time for the treated surfaces. By assuming a maximum precipitation rate within the defined levels, and assuming a maximum HOT for the available fluids, a total precipitation amount can be conservatively defined. This may be used to define the maximum amount of contaminant to be considered. The nature of the precipitation considered should be consistent with the critical case; for example, when considering ice slab shedding, freezing rain or drizzle would provide the most likely scenario to form ice slabs.

If found desirable to restrict the conservative assumptions in the method above, a more detailed ice catch analysis could be performed to provide a more precise estimate of the thickness of ice on the surface. Alternatively, it may be appropriate to not attempt to define the actual nature of the contaminant, but to define the effects of any contaminant conservatively.

3.1.2 Analysis for aerodynamic impacts

Analysis may be used to determine the aerodynamic impacts of the defined contamination scenario and the applicant should follow the prescribed guidance of AMC 25.21(g) appropriately.

In lieu of performing a detailed analysis of the nature of the contaminant to be addressed, a sufficiently conservative assumption for the aerodynamic impact of the contaminant may be substituted. For example, when addressing contamination of a wing tip device, if full airflow separation at the device is assumed for the purpose of analysis, then it is not necessary to define the precise shape of the contaminant.

3.1.3 Shedding analysis

Analysis may be performed to show that ice shed from the surfaces with AFM defined pre-take-off frozen contamination will not create unacceptable damages which would prevent continued safe flight and landing. Guidance material from AMC 25.1093(b) (§1.3), AMC 25J1093(b) (paragraph 1) and AMC 25.1419 (a) (paragraph 4) should be considered.

3.1.4 Similarity analysis

For certification based on similarity to other type-certificated aeroplanes previously approved with pre-take-off frozen contamination, the applicant should specify the aeroplane model and the affected surfaces to which the reference of similarity applies. The applicant should show specific similarities in the areas of physical, thermodynamic, and aerodynamic characteristics as well as in environmental exposure.

The applicant should conduct analysis to show that the permitted pre-take-off contamination, and effect on the aeroplane’s performance and handling as well surrounding environment/systems are equivalent to that of pre-take-off frozen contamination in the previously approved configuration.

3.1.5 Comparative analysis

If the compliance to appendix O with pre-take-off frozen contamination is sought, use of comparative analysis as defined in AMC 25.1420(d) may be allowed. If additional allowed AFM defined pre-take-off frozen contamination surfaces are added compared to the reference fleet then it should be demonstrated that the same margins for ice accretion and shedding sources as well as for aeroplane performance and handling characteristics are retained with reference to the appendix C icing.

3.2 Analysis for effect of additional weight

The applicant also needs to consider the effects of additional weight regarding loads/flutter per AMC 25.21(g) paragraph 4.2, Proof of Compliance.

3.3 Wind tunnel test

Wind tunnel tests may be used to determine the aerodynamic impacts of the AFM defined pre-take-off frozen contamination. This can be considered in combination with take-off ice or final take-off ice, as applicable, in the determination of the lift, drag and moment impacts of the contamination represented with scale roughness on the model airfoil.

The surface roughness of the artificial ice AFM defined pre-take-off frozen contamination shape to be tested should be agreed with the Agency as being representative of the AFM defined pre-take-off frozen contamination.

Wind tunnel tests are often used to obtain aerodynamic data for ice contaminated lifting surfaces. The data is used to compare the aerodynamic impacts of the ice contamination, such as drag or stall speed increases, to acceptable thresholds or to compare the relative impacts of different ice shapes. In this latter case the test results are often used to identify the critical ice shape that will be flight tested to show that the ice contaminated aircraft meets the handling qualities and performance certification requirements.

3.4 Flight test to determine scope of contamination

It is recognized it may be logistically difficult to cold soak a large fuel loading in the wings in the appropriate high humidity environments commensurate with cold soaked surface frost.

Prolonged flight in cold conditions followed by humid environment may be used to determine the scope of the defined frost scenario. This can include consideration of a conservative in-service observations through tankering fuel and cold soaking procedures at high altitude followed by landing and frost accretion measurements.

3.5 Flight test to determine aerodynamic impacts

Flight testing may be used to demonstrate the aerodynamic impacts of the AFM defined pre-take-off frozen contamination. This may be performed either with the actual accretion of cold surface frost in natural conditions followed by flight testing as soon as practical, or with an applied surface grit commensurate with a determined frost thickness, height, and defined area. Current practice has shown that environmental testing may not be practical for assessing aerodynamic impacts but would be useful for model validation.

The surface roughness of the artificial AFM defined pre-take-off frozen contamination shape used should be agreed with the Agency as being representative of the AFM defined pre-take-off frozen contamination.

AMC 25.21(g) may be used as a guidance to develop an appropriate flight test programme to address AFM defined pre-take-off frozen contamination effect.

In addition to 25.21(g) prescribed guidance, the take-off testing prescribed in AMC 25.1597 may be used to determine lift impacts in ground effect.

(4) Requirements & guidance – upper wing surface cold soaked surface frost

4.1 General

Cold soaked surface frost is a result of environmental frost occurring on a surface when moist air is in contact with the surface, primarily from cold soaked fuel or other massive cold soaked structure. The common occurrence of cold soaked frost can be attributed to the cold soaking of fuel at high altitudes which remains in a tank after landing, common in situations where an airline has tankered extra fuel to destination airports. The cold fuel in contact with the wing skins results in frost forming on the surface.

Upper surface wing cold soaked surface frost can cause a reduction in lift and an increase in drag during the climb. These effects are considered similar to those for take-off ice and final take-off ice. Effects of upper surface wing cold soaked surface frost shall be considered in combination with the effects of lower surface cold soaked surface frost. These effects may be considered on their own, or in combination with take-off ice or final take-off ice, as appropriate.

Aspects affecting continued take-off should be considered, such as margin to stall.

Comparable to requirements for CS 25.1419 for in-flight ice shedding, CS 25.1093(b) for clear ice shedding, engine ingestion considerations or damages to surrounding components or structure parts should be considered.

The aerodynamic impacts from cold soaked frost can generally be attributed to the frost thickness, roughness, and location on the airfoil; with the primary contributor being the roughness. Applicable means for characterizing cold soaked surface frost may include ancestor aeroplane analysis and similarity, analysis, simulation, wind tunnel or flight test. An applicant should validate a chosen method for cold soaked surface frost characterization as equivalent or conservative to real-world operations.

There are many sources available related to the formation for frost as well as its effects on aircraft. Several key resources related to frost formation and characterization include [3] [4] [5]. The effects of frost on aircraft is further detailed in [6] [7] [8] [9].

It is recognized that the refrigeration industry has more robust frost accretion models regarding characterization of thickness. However, a common industry accepted model for thickness and roughness accretion on an airfoil does not currently exist at the time of this report publication. Thermodynamic models may also be used by the applicant to represent frost thickness and roughness determinations. The selected thickness or roughness should be validated or proven to be conservative considering the parameters selected for the AFM defined pre-take-off frozen contamination. Industry research projects are also in-work to better quantify frost accretion in terms of roughness and thickness and to validate with frost wind tunnel and thermodynamic simulation models. Inspection or survey of the aircraft exposed to the conditions conducive to cold soak fuel frost may also be considered to validate aspects of the analysis.

Procedures and operational considerations, such as potential growth of the contamination between detection/assessment and take-off, should also be considered during definition of the permitted frost.

An applicant may choose to limit frost accretion dimensions in their AFM definition in combination with appropriately simplified and operationally practicable means for the crew to determine acceptability of the prevailing airplane condition.

4.2 Impact

The applicant should consider an appropriate combination of analysis, wind tunnel, or flight testing to substantiate aerodynamic performance impacts on flight or ground handling characteristics.

This type of contamination consists of either a layer of roughness or a substrate with a top layer of roughness. Theory, supported by research, including the Journal of Aircraft report on Aerodynamic Effects of Anti-Icing Fluids on a Thin High-Performance Wing Section [10], indicates that it is the height of the roughness that is the dominant feature that impacts the aerodynamic penalty associated with the frost. The thickness of the substrate of ice upon which the roughness sits has little impact upon the performance of the lifting surface.

The applicant should consider the most critical, operationally practicable scenario of frost accretion for the or aeroplane type design being certified. This can either be assessed conservatively (e.g., by considering a peak frost accretion for all scenarios independent of mission), or through a more detailed analysis agreed to with the Agency, accounting for practicable mission profiles driving aircraft surface temperatures (as a result of remaining fuel tank quantities, flight duration, and temperatures aloft for a given mission), in combination with the possible ambient temperatures and humidity on the ground, and as defined in the AFM. The effect of frost upon a lifting surface can be assessed in a suitable wind tunnel. Aerodynamic effects of such shapes could be evaluated with wind tunnel testing.

Roughness affects the aerodynamic performance of a lifting surface due to its impact upon the boundary layer. Reynolds number effects are important and should be considered by the applicant when defining the wind tunnel test programme and interpreting the results of the tests.

When comparing the aerodynamic characteristics of the contaminated lifting surface to that of the uncontaminated surface determined in the wind tunnel the applicant should consider whether it is necessary to scale the performance increments to compensate for the difference in Reynolds Number between WTT and flight.

At the option of the applicant, the effect of frost upon a lifting surface can be assessed directly in-flight testing. Testing of naturally occurring cold soaked surface frost has been seen to be difficult due to the limitations of the geographical test location and environmental conditions. The critical mission and ground environments may not be reproducible in the type certification environment. Therefore, flight testing with a static roughness (grit) artificial frost shape should be considered to adequately model the most critical scenario of frost from expected mission profiles for that type model.

(5) Requirements & guidance – lower wing surface cold soaked surface frost

Similar to upper surface cold soak fuel frost of Section 4.1, the lower surface may also exhibit frost accretions. Lower surface wing cold soaked surface frost can cause a reduction in climb gradient. However, take-offs with 3 mm (1/8 inch) or less frost on the lower surface of the wing due to cold soaked fuel has been a longstanding accepted practice in the industry, dating as far back as 1972 on the DC-8, -9 and -10. Research by the FAA Tech Center at the NASA LaRC LTPT in of 1992 [8] similarly concluded that 3 mm (1/8 inch) or less frost on the lower surface of the wing due to cold soaked fuel has negligible performance or handling qualities impacts. This was then codified in an amendment to CFR 121.629(b) after this research concluded in 1992. This common practice is further substantiated by the substantial fleet history across each of the OEM's fleets since its more widespread implementation in 1992. With these considerations, take-off with such frost on the lower surface of the wings may be allowed without consideration of a cumulative effect with Appendix C/O take-off ice or final take-off ice. A statement of similarity to applicant data or supporting industry data in [8], [6] and consistent with FAA CFR 121.629(b) and 91.527(a) could be an acceptable means of compliance.

(6) Requirements & guidance – wing tip device frozen contamination

6.1 General

It is recognized that some wingtip devices may not be visible from the cockpit to appropriately complete a pre-take-off contamination check during the holdover times of the aircraft critical surfaces (i.e., large span aircraft, or freighter aircraft). It is also recognized that some wingtip devices are in an orientation that is not commensurate with the holdover times determined for horizontal surfaces and may result in localized fluid failures due to fluid flow off from gravity. This approach may be considered as a path for the applicant to show that this possible contamination adhesion of the wingtip device does not present an appreciable impact to performance or controllability of the aircraft.

For the purpose of this AMC, a wing tip device should be defined by the manufacturer that can be clearly delineated and follow AMC 25.1581(6)(c)(3) when considering a procedure that can be clearly defined and operationally practicable. In general, this would be a clearly delineated portion of the wing that departs the orientation of the main wing plane (such as winglets, strakes, sharklets, raked wingtips, or folding wing tips, etc.)

Possible adhesion of frost, ice, snow, or other freezing precipitation on the surfaces of the aircraft may occur in the following scenarios with varying levels of impacts:

- Wingtip device is not cleaned, and contamination can adhere in an unbounded exposure time and conditions

- Wingtip device is de-iced only, and subsequently may collect frozen contamination during the holdover time determined from other critical surfaces of the airplane
- Wingtip device is de-iced and anti-iced and fluid fails locally on the device.

This guidance assumes that the wingtip device is initially clean. Therefore, an untreated wingtip device with adhering contamination is not considered within this guidance due to the relatively unbounded contamination definition. De-icing or de/anti-icing methods provide the acceptable operational relief while still limiting the exposure in active precipitation to the holdover times of the other critical surfaces of the airplane.

In order to provide reasonable operational alleviations, the wingtip device shall be initially cleaned/de-iced before the permitted contamination is accounted for.

Allowances for wingtip device contamination should still be bounded by the HOT determination for the airplane, and if HOT is exceeded the airplane will be treated again, including deicing of the wingtip devices.

6.2 Impacts

Wingtip devices are generally included in an aircraft design as a drag-reduction device. They generally do not carry significant lifting loads and may demonstrate separated airflow characteristics at higher aircraft angles of attack. Frozen contamination on wingtip devices may also, reduce margins to flutter.

An applicant may take this into consideration to model a conservative scenario of full airflow separation in combination with the associated profile drag from the contamination adhered to the surface. In these cases, the addition of de/anti-icing treatment may be considered as an additional mitigating factor.

A definitive characterization of the frozen contamination may not always be possible. However, industry research is available that helps to understand the critical scenarios that may be observed in operation. A TCCA/FAA report "2003-04 TP 14377E Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces" [11] supports the conclusion that a surface treated with anti-icing fluid will retain some inherent benefits from the fluid residues that further prevent adhesion beyond visually failed fluids. This report investigated contaminant adhesion characteristics with a calibrated shearing tool after fluid failure. This report concluded that snow does not adhere with Type II/IV fluids, at any snowfall rate or ambient temperature, well beyond the identified fluid failure time. However, for freezing precipitation (freezing drizzle, light freezing rain, rain on cold-soaked wing), it was found that adhesion after fluid failure could occur in short order. This contamination was described as “…a crust of solidified contamination at the air-fluid interface, while still preserving a very thin film of fluid underneath.” It was also noted that although the adhesion shear tool could not remove the crust, slightly more shear forces (i.e., by using a scraper) allowed the contamination to fall off relatively easily and all at once. Therefore, consideration of the crusted freezing rain scenario may be considered as an alternative scenario for ground precipitation conditions that require anti-icing and are still limited to the determined holdover times for other critical surfaces.

An applicant may also decide to limit the exposure in active precipitation and therefore limit the resulting contamination to a minimal level. This can be accomplished by initially requiring the wing tip device surfaces be initially cleaned/de-iced and limiting the time in active precipitation (e.g., the established holdover times for other critical surfaces of the aircraft). The procedure to follow if a time limit is exceeded should also be taken into consideration (e.g., if bounded by the holdover times of other critical surfaces of the aircraft, and that time is exceeded, then the wingtip devices must be retreated).

The contamination might not be perfectly symmetric due to various factors (e.g., wind, treatment, taxi considerations, etc.). This is not expected to be significant effect for control and maneuverability but should be considered.

The contamination caused by prematurely failed fluids on winglets is not exactly known or defined, but full chord roughness is a likely surrogate. The applicant may wish to conservatively apply full span roughness, holding ice shapes, or even assume full airflow separation of the device. For such shapes the increments between contaminated and uncontaminated may be impacted by Reynolds Number, the applicant should take care to appropriately account for this.

(7) Requirements & guidance – upper fuselage frozen contamination

7.1 General

Frozen contamination on the upper fuselage can cause an increase in drag during the climb or engine ingestion in the event of shedding. In some jurisdictions, and for certain engine mounting configurations, the upper fuselage is defined as a "critical surface" due to the shedding concern. AMC25.1093(b) paragraph 1.3 addresses engine ingestion aspects.

Comparable to requirements for 25.1419 for in-flight ice shedding, and 25.1093(b) and 25.J1093 for clear ice shedding, engine ingestion considerations and damage to surrounding components or structure parts should be considered.

7.2 Impacts

(a) In order to bound the amount of ice which could be shed from the fuselage, some measure must be applied to restrict the thickness of ice. One acceptable approach is to require that the upper fuselage be de-iced whenever the "other" critical surfaces are de-iced. Consequently, for an aircraft parked in active precipitation, the maximum amount of precipitation which could accumulated on the upper fuselage is the amount corresponding to the applicable hold-over time for the (presumably anti-iced) wing etc. By assuming a maximum precipitation rate within the defined levels, and assuming a maximum HOT for the available fluids, a total precipitation amount can be conservatively defined. Since the concern is frozen contaminant ingestion by engine/APU and the most unfavorable permitted precipitation, including freezing & snow conditions, should be considered. The precipitation rate and the associated exposure time should be agreed to with the Agency.

A simplistic analysis of this nature yields consists in evaluating the AFM defined pre-take-off frozen contamination thickness/mass on the fuselage taking no credit for fuselage heating or any residual protection of de-icing fluids. If found desirable, a more detailed ice catch analysis could be performed to provide a more precise estimate of the thickness of the ice on the fuselage.

(b) Regarding the engine solid ice ingestion risk, the thickness of the ice sheet may then be compared to the certified capability of the engine to absorb shed ice, to evaluate how large a slab would be required to be ingested in one piece to exceed the engine capability. Engineering judgement may then be used as part of a rationale argument as to whether such an extent of ice would remain in one piece following shedding from the fuselage.

(c) Although the definition of the fuselage as a critical surface depends solely on engine location, some guidance material indicates that there may be other considerations which lead to treatment of the fuselage, such as operability of exits or clearing of vents. A similar analysis for ice thickness, combined with an analysis of the effect of such an ice thickness on the required function being considered, could be used to evaluate de-icing/anti-icing guidance and procedures for any aircraft where this was an issue.

(d) A thin upper fuselage frost was tolerated in the past such that the marking could be seen through the frost. The increase of roughness and thickness is not expected to cause a significant increase of aircraft drag compared to already tolerated frost. This should be confirmed by the applicant.

(e) The applicant should show that the take-off weight increase resulting from the upper fuselage frozen contamination will have insignificant effect on climb capability or otherwise be accounted for in the performance data. Past certification experience has determined that less than 5% reduction in climb gradient has been considered insignificant.

(8) Documentation

8.1 Aircraft Flight Manual (AFM)

The results of the test program should be used to establish any required limitations, procedures, and performance to be provided in the AFM.

Any required changes in operating procedures should be identified. If take-off procedures or speeds are modified, suitable performance adjustments (e.g., to take-off run, take-off distance and/or accelerate stop distance) should be provided.

Address the following items in the AFM, if applicable:

- The AFM should identify the type(s) of AFM defined pre-take-off frozen contamination that are allowed. Any airplane-specific restrictive information considered necessary for safe airplane operations with AFM defined pre-take-off frozen contamination should be furnished in the AFM Limitations section. An example is restrictions on the use of flaps.
- Where found necessary to limit the AFM defined pre-take-off frozen contamination level assumed for certification, the AFM should contain detailed description and unequivocal steps allowing the crew to determine if existing contamination are within the AFM-defined frozen contamination limits. This should include consideration of the effect that environmental and aircraft conditions may have on the contamination changes from time of assessment by the crew to the moment when take-off run starts.
- Any increases in take-off speeds should be specified in the AFM Performance section.
- Any increases in take-off distance due to take-off speeds increased above the established threshold should be presented in the Performance section.

8.2 Advisory material

The manufacturer may provide information on relevant procedures for the crew related to items such as de/anti-icing treatment, holdover times, and pre-take-off contamination check in an advisory document, such as a Flight-Crew Operating Manual (FCOM).

(9) References

[1] A. Brown, "Inflight Cold-Soaked Fuel Frost Observations and Analysis," AIAA, 2012.

[2] C. Tanner, "The Effect of Wing Leading Edge Contamination on the Stall Characteristics of Aircraft," SAE, 2007.

[3] M. Dietenberger, "A frost formation model and its validation under various experimental conditions," NASA, 1982.

[4] C. Hermes, "An analytical solution to the problem of frost growth and densification on flat surfaces," *International Journal of Mass and Heat Transfer,* 2012.

[5] R. Yun and M. Yongchan, "Modeling of frost growth and frost properties with airflow over a flat plate," *International Journal of Regrigeration,* 2002.

[6] M. Bragg, "Effect of Underwing Frost on a Transport Aircraft Airfoil at Flight Reynolds Number," *Journal of Aircraft,* vol. 31, 1994.

[7] T. Cebeci, "Effects of Environmentally Imposed Roughness on Airfoil Performance," NASA, 1987.

[8] E. Hill, "Airplane Performance and Other Considerations Related to Airplane Icing While on the Ground," in *Airplane Deicing Seminar Aircraft Technology Division, Danish Engineering Society*, Copenhagen, Denmark, 1993.

[9] E. Hill and T. Zierten, "Influence of Environmental Factors on Aircraft Wing Performance Effects of Wing Simulated Ground Frost on Airplane Performance," a, 1987.

[10] A. Broeren and C. Clark, "Aerodynamic Effects of Anti-Icing Fluids on a Thin High-Performance Wing Section," *Journal of Aircraft,* vol. 53, 2016.

[11] TP 14377E, "Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces," TC/FAA, 2004.

CS 25.1597 Ground de-icing/anti-icing fluids

Any operating limitations, operating procedures, and performance information necessary for safe aeroplane operations with de-icing/anti-icing fluids applied must be established and included in the aeroplane flight manual in accordance with CS 25.1581.

To establish the operating limitations, operating procedures, and performance information necessary for safe aeroplane operations with de-icing/anti-icing fluids applied, the applicant must consider the following certification specifications (See AMC 25.1597): (CS 25.101; CS 25.105; CS 25.107; CS 25.109; CS 25.111; CS 25.113; CS 25.115; CS 25.143; CS 25.251; CS 25.603; CS 25.629; CS 25.1301; CS 25.1309; CS 25.1529; CS 25.1581

Rationale

A review of the possible impacted requirements in the existing certification specifications was conducted, while considering current design practices. It was concluded that it would be most efficient to create:

- *paragraph CS 25.1597 and AMC 25.1597, Deicing and Anti-icing Fluids, to require that operating limitations, operating procedures, and performance information associated with the use of deicing and anti-icing fluids be established and provided in the AFM*

- *subparagraph (m) of CS 25.1583, to require that limitations be provided in the AFM that explicitly state whether use of deicing and anti-icing fluids is permitted and if so, which types are approved.*

For more details, refer to the Annex to this NPA.

AMC1 25.1597 Ground de-icing/anti-icing fluids

1 Purpose

This AMC establishes methods to comply with CS 25.1597 which requires that operating limitations, operating procedures, and performance information related to deicing/anti-icing fluids be established and included in the AFM. Additionally, several other specifications are identified as applicable for the approval of the application of deicing/anti-icing fluids on an aircraft, as listed in paragraph 2.

2 Related requirements

The following requirements shall be considered by the applicant for the purpose of showing compliance to CS 25.1597:

CS 25.101	Performance - general
CS 25.105	Take-off
CS 25.107	Take-off speeds
CS 25.109	Accelerate-stop distance
CS 25.111	Take-off path
CS 25.113	Take-off distance and take-off run
CS 25.115	Take-off path
CS 25.143	Controllability and Maneuverability – General
CS 25.251	Vibration and buffeting
CS 25.603	Suitability of materials
CS 25.629	Aeroelastic stability requirements
CS 25.1301	Function and installation
CS 25.1309	Equipment, systems, and installations
CS 25.1529	Instructions for Continued Airworthiness
CS 25.1581	AFM: General

3 Background

Typically, deicing fluids are used before take-off to remove frost or ice contamination, while anti-icing fluids are used before take-off to prevent frost or ice contamination from occurring for a period of time (commonly referred to as “holdover time”) after application. Anti-icing fluids can be characterized as non-Newtonian, pseudo-plastic fluids, also known as “thickened” fluids.

Deicing/anti-icing fluids are formulated to prevent freezing precipitation adhering to aerodynamic surfaces during ground operations and to shear away from these surfaces during take-off and flight. Fluid can often be observed in the form of waves towards the trailing edge of wing surfaces prior to rotation and during initial climb. This residual fluid has the potential of affecting take-off performance and handling characteristics. Additionally, if some fluid does not flow off the aeroplane and accumulates in aerodynamically quiet areas or on internal flight control components a potential exists for stiff or frozen flight controls.

Wind tunnel tests have been established to help ensure minimal effect of fluids on take-off aerodynamics. SAE AS5900 “Standard Method for Aerodynamic Acceptance of SAE AMS1424 and SAE AMS1428 Aircraft Deicing/Anti-icing Fluids” establishes a standard Aerodynamic Acceptance Test (AAT) to ensure acceptable aerodynamic characteristics of deicing/anti-icing fluids as they flow off aeroplane lifting and control surfaces during the take-off ground acceleration and initial climb. SAE AMS 1424 is the specification for Type I fluids and SAE AMS 1428 is applicable to Type II, III, and IV fluids.

The SAE AS5900 AAT uses a measurement of the fluid’s boundary layer displacement thickness (BLDT) on a flat plate during a simulated take-off in a wind tunnel. Fluid acceptability depends on the fluid’s boundary layer displacement thickness after a representative take-off acceleration profile, the boundary layer displacement thickness of a reference fluid, and the temperature range at which the fluid is to be used in service. SAE AS5900 identifies a high-speed ramp, a middle-speed ramp, and a low-speed ramp test. Before introduction of the middle-speed ramp test, Type II and Type IV fluids were typically qualified to the high-speed ramp test and Type III fluids were qualified to the low-speed ramp test. However, fluids may also be qualified to different speed ramps, at the discretion of the fluid manufacturer. In this respect, for fluids qualified to multiple ramp tests, the aeroplane is assumed to be operated in respect of the related ramp test.

For aeroplanes with take-off acceleration profiles such that time-to-liftoff or rotation speeds are less than the low-speed ramp test for Type III approvals or high-speed ramp test for Type II/IV approvals, the fluid flow-off characteristics of the fluid on the SAE AS5900 test may not adequately represent the flow-off on the aircraft and a specific demonstration is required to assess the effect at aircraft level. A lift loss decrement of up to 6% at take-off (CLLOF) measured at lift off before adjustment of take-off speed schedule has been accepted. This decrement has been accepted on the basis that with the airplane at the same rotation pitch attitude and AOA, it will take a speed about 3% higher to generate the same lifting force. The CS-25 standards for icing certification allow up to a 3% increase in stall speeds before the effects of icing must be considered. This level of lift loss also corresponds to some of the results of fluid testing on a Boeing Model 737-200ADV that was part of the research effort to develop the aerodynamic acceptance test for fluids.

The SAE AS5900 is designed primarily to ensure acceptable lift loss characteristics and does not necessarily indicate insensitivity to adverse effects from thickened fluids on either airplane control surface effectiveness or control forces.

Operational and certification experience with aeroplanes with unpowered (reversible) longitudinal control surfaces shows that thickened fluids may require the pilot to apply additional longitudinal control forces during take-off rotation and climb, regardless of take-off rotation speed. No known events related to adverse controllability have been reported in-service which have involved powered (irreversible) flight controls. The principal mechanism for these events is thought to have been fluid flow through the tailplane/elevator gap to the suction side of the elevator which could adversely affect the elevator hinge moment and surface effectiveness. Consequently, it is considered that for aeroplanes with irreversible longitudinal controls, and where there is no significant fluid path for accumulation on the lower (suction during rotation) surface, there is no risk of handling degradation during rotation. Therefore, consideration of the effects of thickened fluids does not require a handling assessment during the rotation for such aeroplanes. Although aeroplanes with powered elevators are considered to be insensitive to the effects of increased hinge moments during rotation, due to potential degradation of elevator effectiveness, assessments of rotation characteristics are required for aeroplanes with powered longitudinal controls if there is a path leading to significant fluid accumulation on the lower surface (suction during rotation). Controllability assessments during rotation and after take-off are specified for aeroplanes with unpowered (reversible) controls.

4 Scope and applicability

Approval for use of Type I, II, III, or IV fluids on a specific aeroplane model should address the following items, as applicable:

— Take-off Performance (CS 25.101, CS 25.105, CS 25.107, CS 25.109, CS 25.111, CS 25.113, CS 25.115)

— Controllability (CS 25.143)

— Vibration and Buffeting (CS 25.251)

— Suitability of materials (CS 25.603)

— Aeroelastic stability requirements (CS 25.629)

— Effects of fluid ingress on aeroplane systems (CS 25.1301 and CS 25.1309)

— Fluid Considerations for ICA (CS 25.1529)

— Fluid Considerations for aeroplane systems

The applicant must take into consideration that the horizontal stabilizer underside surface could in some circumstances be treated with thickened fluid and shall confirm that such treatment has no adverse repercussion on the airplane. Particular concerns are the potential rotation force increase for airplanes with unpowered longitudinal flight controls or the potential reduction of horizontal tail effectiveness for aircraft with lower rotation speeds.

The considerations outlined in 4.1 and 4.2 for evaluating the aerodynamic effects of thickened fluids (Types II, III and IV) apply only to aeroplanes with the specific attributes noted. Additional details regarding industry experience with analysis, similarity, and flight test methodologies for evaluating the aerodynamic effects of thickened fluids meeting the SAE AS5900 AAT standards are described in SAE ARP6852.

All other items listed above are applicable to all aeroplanes for which approval of Type I, II, III, or IV deicing/anti-icing fluids is sought.

4.1 Take-off performance

The scope of take-off the performance evaluation depends on several factors. Flight tests, analysis or similarity to a previously tested model may be used to show compliance as guided by the following considerations.

4.1.1 Assessment of lift loss based on fluid-off characteristics

Due to assumptions inherent in the SAE AS5900 test procedures, the required tests on the fluids do not adequately model the fluid flow-off characteristics for aeroplanes with rotation speeds or times to rotation less than the tested values: low speed ramp (60 knots, 15s), high speed ramp (100 knots, 20s). A review of the aeroplane' s take-off acceleration profile compared with the SAE AS5900 low speed acceleration profile for Type III approvals or high-speed acceleration profile for Type II/IV approvals should be used to determine if flight tests are necessary to validate acceptable lift loss characteristics. Lift loss characteristics for aeroplanes with rotation speeds or time to rotation less than SAE AS5900 AAT high or low speed ramp criteria (as applicable to the fluid type approvals requested) or relevant aerodynamic configuration differences to the reference aircraft (737-200ADV for highspeed ramp and DHC-8 for the low-speed ramp) should be based on flight tests or similarity to a previously tested model.

4.1.2 Fluids effects on rotation characteristics

As discussed in section 3, some aeroplane types with unpowered longitudinal controls require increased longitudinal control force to rotate the aeroplane for take-off and there is potential for thickened fluids to adversely impact control surface effectiveness on any aeroplane with a path for fluid to flow to the lower surface of the elevator. Should such characteristics be present, the applicant should determine any effects of late or slow rotation on take-off distance.

Additionally, compliance with CS 25.107(e)(4), which addresses the effects of "reasonably expected variations in service from the established take-off procedures", should be considered for aeroplanes with increased rotation control forces. Specifically, in a nose down out-of-trim condition as described in AMC No 1 to CS 25.107(e)(4), the combination of control force required to counter the mistrim combined with an incremented rotation force requirement due to fluids may affect the associated take-off distance.

CS 25.107(e)(4) also addresses potential over-rotation. Although tendency for over-rotation due to effects of fluids has not been reported, should the applicant observe susceptibility to that characteristic during tests with fluids using normal rotation techniques additional evaluations may be required.

4.2 Controllability

As discussed in section 3, due to potential for changes to required control forces attributable to the presence of thickened fluids, controllability considerations after take-off apply to aeroplanes with unpowered (reversible) flight controls. The need for longitudinal and lateral control evaluations may be considered separately as appropriate to the associated control surface configurations.

To determine if using thickened fluids results in degraded or unusual flight or ground handling characteristics, applicants should conduct flight tests, complete analysis, or show similarity to a previously tested model.

4.3 Controllability

Type II and IV fluids are considered to have a similar effect on airplane aerodynamics and controllability, and both have a greater effect than Type III fluids. Results of an assessment of the aerodynamic and controllability effects of Type II or IV fluid as described in this AMC may be used to support approval of Type II, Type III, and Type IV fluids if any mitigations identified during the assessment are applied to use of all of fluid types for which approval is requested. Alternatively, if the mitigations resulting from Type II or IV evaluation are considered too penalizing for use of Type III, a dedicated Type III assessment can be performed to establish any appropriate mitigations unique to operations with Type III.

5 Means of compliance

5.1 Analysis, similarity, review

Analysis or similarity may be used to determine the aerodynamic impacts of deicing/anti-icing fluids on take-off performance, controllability, vibration/buffet, and flutter.

Industry experience with several similarity and analysis methodologies can be found in SAE ARP6852 [5].

A lift loss decrement of up to 6% at take-off (CLLOF) measured at lift off before adjusting take-off speed schedule has been accepted as not significant. For decrements greater than 6%, minimum take-off speeds should be increased by at least one-half of the percentage decrement in CLLOF. (For example, for an 8% decrement in CLLOF take-off speeds VR and V2 should be increased by at least 4%). Take-off distances specified in the AFM should be increased accordingly.

Similarity for performance aspects (lift loss) may be considered compared to the SAE AS5900 AAT and its reference aircraft (737-200ADV for high-speed ramp and DHC-8 for the low-speed ramp), or to another previously tested model. Similarity to the SAE AS5900 AAT should include a review of the aeroplane's acceleration profile compared with the relevant rotation speeds and times to rotation defined in the SAE AS5900 high, mid, or low speed ramp criteria, as well as aerodynamic configuration differences to the reference aircraft (737-200ADV for high-speed ramp and DHC-8 for the low-speed ramp).

Alternatively, in case the acceleration profiles do not meet those prescribed the AAT, further considerations, and similarity to another previously tested model may be necessary. Take-off performance can also be established by similarity to previously tested models, as it can be expected that the fluid impact results determined by flight test of aeroplanes sharing key configuration and performance characteristics such as wing and tail geometry, flight controls, leading and trailing edge devices, rotation speeds and times to rotation, or other key parameters can be correlated (Ref. SAE ARP6852 Rev C Section 4.2). A flight test-based correlation demonstrates that the SAE AS5900 AAT is directly applicable to qualify fluids for use on similarly designed aeroplanes. In addition, in-service history of similarly designed and previously approved models should be considered.

Effects on take-off rotation characteristics and controllability can also be established by similarity to previously tested models, as it can be expected that the fluid impact results determined by flight test of aeroplanes sharing key configuration and performance characteristics such as wing and tail geometry, flight controls, leading and trailing edge devices, rotation speeds and times to rotation, or other key parameters can be correlated (Ref. SAE ARP6852 Rev C Section 4.2). In addition, in-service history of similarly designed and previously tested models should be considered.

Similarity analyses can comprise of comparisons of aeroplane features, characteristics and take-off performance, in-service history and flight test based analytical comparisons using CFD, wind tunnel testing and/or additional flight testing. Similarity analysis may result in a reduced scope of required testing, as well as possibly entirely replacing the need for testing, depending on the completeness of the analysis.

Similarity to existing safe designs can also be used to show compliance to fluid effects on vibration/buffet and flutter, in combination with a design review, to identify where accumulation of fluids may introduce adverse effects on flight control components. The review may include the aeroplane's design and maintenance practices to previously tested models with exemplary fleet history, calculated design philosophies, and thorough operational procedures documented in ICA documents. Drain paths should be provided anywhere liquids or fluids can accumulate and detailed inspection and cleaning procedures related to fluid residue effects on flight controls and systems should be included in ICA documentation.

5.2 Flight test

5.2.1 General

Flight testing with deicing/anti-icing fluids may be used to assess each aeroplane type for any adverse performance or handling effects and to establish appropriate information to be furnished in the Aircraft Flight Manual (AFM) in the form of additional limitations, normal and non-normal operating procedures, and performance adjustments.

A test program can also be used to validate any AFM or Flight Crew Operating Manual (FCOM) procedures for ground deicing/anti-icing operation as well as maintenance inspection and cleaning procedures for fluid or gelled fluid retention in "aerodynamic quiet areas".

It is not practicable to conduct a complete evaluation of aerodynamic characteristics due to the transient nature of the most critical fluid accumulation during take-off. In particular maximum lift coefficient, stall AOA and drag increment cannot be determined using traditional flight test methods and constraints. Hence the test guidelines are oriented towards demonstration of no adverse characteristics when using the recommended procedures and performance data rather than determining compliance with minimum prescribed margins.

5.2.2 Test considerations

If flight testing is used to determine fluid impacts, the applicant should make the best attempt to adhere to the following guidelines:

5.2.2.1 Fluid selection

BLDT Limit
To ensure the testing is accomplished close to the fluid's critical temperature, the planned target test day temperature should result in a neat fluid boundary layer displacement thickness (BLDT) within 1 mm of the maximum allowable BLDT per the results of SAE AS5900 testing for that fluid.

Fluid Dilution
The fluid should be used undiluted (neat).

Viscosity
Conduct a viscosity check of an on-wing fluid sample to confirm it is at least the minimum viscosity published in the official holdover timetables.

5.2.2.2 Weather

Ambient Temperature
There is considerable evidence to suggest that adverse aerodynamic effects increase at lower temperature and ideally it is preferable to target tests at the coldest temperature at which the fluid can be used and which meets the criterion for BLDT.

If there is the practical difficulty with obtaining low temperatures meeting the BLDT criterion "on schedule" a representative cold temperature may be acceptable provided no significant adverse characteristics are observed.

If conditions do not result in meeting the BLDT criterion then additional activity may be required to ensure that compliance is adequately shown, particularly if adverse characteristics are observed. This activity may include tests at additional temperatures, dilution of the fluid to increase the test day BLDT, or additional tests with other fluids. Any of these alternatives should be agreed with by the Agency.

Precipitation
Conduct tests in non-precipitation conditions so the applied fluid is not diluted by precipitation.

5.2.2.3 De-icing and anti-icing procedures

Follow the fluid application procedures that will be recommended for the airplane. Treat all applicable surfaces (including the horizontal stabilizer and vertical stabilizer). Slats/flaps should be in the recommended position for fluid application.

5.2.2.4 Time from fluid application to take-off

Conduct take-off tests as soon as possible following fluid application.

5.2.2.5 Configuration

Systems Operation

Take-off test procedures should include expected systems operation for take-off with fluids applied and into icing conditions (e.g., ice protection system operation, permissible configurations of air systems, flight control system pre-flight procedures). This permits the determination of any adverse interaction between system operation and the fluid (e.g., "baking" and hardening of the fluid on critical surfaces, air data probes, fumes or odors, etc.).

Elevator/horizontal stabilizer gap

For airplanes with reversible longitudinal controls and a gapped elevator configuration, the elevator/horizontal stabilizer gap should be measured and documented for future reference.

5.2.3 Take-off performance

Typically, high thrust, the lowest take-off gross weight and maximum flap position approved for take-off is considered critical for this evaluation because of the lower scheduled take-off rotation speed and the shorter time it takes to reach that speed. A mid-to-forward centre-of-gravity position should be used. When practical, heavy weight take-off tests shall also be conducted to evaluate the angle-of-attack (AOA) margin, the pitch authority at take-off rotation, and any effects on take-off performance.

5.2.3.1 Lift loss determination

Perform take-offs with and without thickened fluid applied to determine the percentage of lift loss due to the presence of the thickened fluid. A 6% decrement in lift coefficient at liftoff (CLLOF) measured at lift off should be considered significant. For decrements greater than 6%, minimum take-off speeds should be increased by at least one-half of the percentage decrement in CLLOF. (For example, for an 8% decrement in CLLOF take-off speeds VR and V2 should be increased by at least 4%). Take-off distances specified in the AFM should be increased accordingly.

Several test techniques for determining lift loss have been found to be acceptable.

One acceptable means is to target fixed pitch angles for liftoff, either by a pre-rotation or normal rotation at scheduled VR across to a range of liftoff pitch attitudes. Take-offs with rotation to a targeted fixed pitch angle provide a measure of the lift loss at the liftoff pitch attitude (AOA). Several pitch angles should be targeted representing the range of normal pitch angles at liftoff. The upper boundary of the suggested range is the scheduled initial target pitch attitude. Tests at maximum pitch attitude achievable on ground are not required. The CLLOF versus pitch attitude at liftoff relationship should be compared with the aeroplane without fluid contamination and the difference in CLLOF for a typical take-off pitch angle (AOA) can be determined.

An alternative procedure is to use data from normal take-offs with and without fluid contamination to develop lift curves (CL-AOA) for the take-off phase. The take-offs should utilize the normal scheduled VR and pitch attitude. Data should be collected from liftoff until established at an appropriate stabilized climb speed. Using the lift curves, determine the CLLOF decrement by comparing CL with and without contamination at a reference AOA corresponding to a representative clean wing CLLOF.

The critical take-off configuration for testing would be the configuration that results in the largest lift loss with fluids. Normally the minimum and maximum take-off flap positions should be considered, at low take-off weight. The cg position should be mid to forward.

Regardless of technique, CLLOF values should be measured using accurate instrumentation, good testing conditions and precise test execution.

There should not be any adverse handling characteristics experienced during these tests.

5.2.3.2 Take-off angle-off-attack (AOA) margin test

The aerodynamic acceptance test for the fluid is based on a loss of CLMAX (or increase in stall speed) due to the presence of the thickened fluid. Since the minimum values of V2 and VFTO are factors of stall speed, an increase in stall speed without a corresponding increase in take-off speeds would result in a lower AOA margin to stall during take-off. In addition, the effect of the thickened fluid may also decrease the stall AOA, leading to a further reduction in the AOA margin during take-off.

It would be impractical to conduct airplane stall tests with a representative take-off thickened fluid configuration since most of the thickened fluid would be expected to have sheared off prior to reaching a safe altitude for performance stall testing. However, representative take-offs should be conducted to show that there are no noticeable adverse effects on AOA margin due to the thickened fluid.

Conduct all-engines-operating high thrust take-offs with rotation at:

(1) VR and

(2) at a speed equal to the scheduled VR minus 7% or the scheduled VR minus 10 knots, whichever results in the higher rotation speed.

Conduct this testing after the lift loss determination testing in paragraph 5.2.3.1. If VR was increased because of those tests, use the increased VR speed minus 7% or the increased VR speed minus 10 knots, whichever results in the higher rotation speed, for these tests. Consider the minimum and maximum take-off flap positions at low take-off weight and mid-to-forward center-of-gravity position. If limited by the minimum control speed in the air (VMCA), use a higher weight resulting in the lowest VR value without being limited by VMCA.

Also conduct simulated one-engine-inoperative take-offs, with the maximum take-off flap setting for which approval of take-off with a thickened fluid is sought, and rotation at VR according to procedures for take-off with a thickened fluid applied. (Note: The one-engine-inoperative condition can be simulated by conducting the test with all engines operating, but with the engines at reduced power or thrust.)

There should not be any adverse handling characteristics experienced during these tests. In particular, there should be no evidence of excessive reduction in AOA margin, such as buffet or instability in either pitch or roll.

5.2.3.3 Other take-off performance considerations

The take-off AOA margin tests may also be used to verify take-off performance. Review the time from rotation to liftoff, from liftoff to V2, and the rotation/liftoff airspeeds. Also consider any results of “variations from established take-off procedures” controllability evaluations described in section 5.2.4.3. Use engineering judgment to determine if there are any significant differences from the clean aeroplane that would warrant changing the AFM performance data for use after a thickened fluid has been applied.

‘Question 1 to stakeholders:

Stakeholders are invited to provide their views on the need to establish a pass/fail criteria (threshold) in this section, instead of using engineering judgement, for the determination of what is a "significant difference".'

5.2.4 Controllability

For airplanes with unpowered (reversible) controls, the control forces during take-off and climb should be shown to comply with CS 25.143. If rotation control forces are increased over the non-treated airplane, the Operational Suitability Data (OSD) should identify if the increased force is a training emphasis item. There should be no "snatching" or discontinuities in control force in any axis. This evaluation should also include whether the use of thickened fluids may affect the airplane's responsiveness to the pitch control input for rotation.

5.2.4.1 All-engines operative

The following evaluations should be conducted with all engines operating in the most critical configuration (e.g., thrust, weight, cg, flap position, speed):

(1) For airplanes with unpowered (reversible) longitudinal controls:

a. Control power and control force during rotation at the scheduled VR.

b. Controllability during take-off with rotation at a speed equal to the scheduled VR minus 7% or the scheduled VR minus 10 knots, whichever results in the higher rotation speed.

c. controllability evaluations after take-off (± 0.5g, or stall warning) with take-off flaps, as soon as practical after liftoff, at V2 +10 knots.

(2) For airplanes with unpowered (reversible) lateral controls:

a. Controllability evaluations after take-off (± 40º bank angle changes) with take-off flaps, as soon as practical after liftoff, at V2 +10 knots.

5.2.4.2 One-engine inoperative

The following evaluations should be conducted at the minimum practical gross weight, with the maximum approved take-off flap position and simulated one engine inoperative:

(1) For airplanes with unpowered (reversible) longitudinal controls:

a. Control power and control force during rotation at VR.

b. Controllability evaluations after take-off (+1.3/+0.8g, or stall warning) with take-off flaps, as soon as practical after liftoff, at V2.

c. Controllability evaluations immediately after flap retraction at VFTO.

(2) For airplanes with unpowered (reversible) lateral controls:

a. Controllability evaluations after take-off (± 30º bank angle changes) with take-off flaps, as soon as practical after liftoff, at V2.

5.2.4.3 Variation from established take-off procedures

If flight test evaluations per 5.2.4.1 and 5.2.4.2 demonstrate increased rotation forces relative to the aeroplane without fluids, an assessment of continued compliance with CS 25.107(e)(4) should be conducted. The assessment should consider the rotation characteristics of the out-of-trim take-off evaluations per CS 25.107(e)(4) and AMC No 1 to CS 25.107(e)(4) demonstrated on the clean aeroplane in combination with increased rotation forces experienced with fluids applied. If indicated by the combined effects assessment, conduct a flight test demonstration or analysis and, if necessary, adjust take-off distances to ensure continued compliance with CS 25.107(e)(4).

Although tendency for over-rotation due to effects of fluids has not been reported, should the applicant observe susceptibility to that characteristic during tests with fluids using normal rotation techniques additional evaluations may be required.

5.2.5 Vibration and buffeting

Assess vibration and buffet characteristics during the take-off testing being performed.

If there is evidence of fluid retention in areas that could affect control hinge moments or on control surfaces that could affect control balance, or if unusual vibration or buffeting is noted during other flight tests, consideration should be given to assessing vibration and buffet characteristics in other flight conditions.

The evaluation must meet the vibration and buffeting requirements of CS 25.251(a).

(6) Fluid considerations for ICA

The applicant should provide guidance on how to de-ice the aircraft that may be used by ground de-icing crews. This may supplement the general guidance and training requirements already defined in AS6285. AS6285 provides guidance on the types of considerations to be addressed. AS6286 provides the basis of minimum training and qualification requirements for ground-based aircraft deicing/anti-icing.

The applicant shall provide guidance in the maintenance instructions specified in ICA regarding fluid accumulation in aerodynamically quiet areas or on internal flight control components that could be cause for special periodic inspections.

To provide the guidance mentioned above, the applicant should determine areas of the airplane susceptible to fluid ingress and flight control components whose operation could be affected due to fluids contamination. This may be addressed through test and inspection or through a combination of design review, similarity, or fleet service history.

If test and inspection is performed, a thickened fluid should be applied, however, the fluid test requirements (e.g., BLDT limits) specified in Section 5.2.2.1 would not be applicable to this inspection.

Fluid application(s) shall be conducted, following the procedures consistent with SAE AS6285 and any prescribed manufacturers recommended procedures. The number of fluid applications may be determined by design review or inspection. The effects of flight as well as the fluid application should be considered. An inspection of internal areas and volumes shall be conducted after having performed a representative flight, and any fluid ingress shall be documented. The areas for detailed inspection may be determined by design review or evidence during a post-flight visual inspection.

Use the results of this inspection to guide the development of the maintenance instructions specified in paragraph 8.3 "Instructions for Continued Airworthiness" of this AMC. Any fluid accumulation in a flight critical area or component should lead to dedicated periodic inspections of that aera.

(7) Fluid considerations for aeroplane materials and systems

7.1 Effects of fluid on materials

The applicant shall identify any area where the de-icing/anti-icing fluid could be encountered after spraying and after possible fluid migration.

The applicant shall demonstrate that the aeroplane, systems, equipment and/or materials are compatible with the types of aircraft de/anti-icing fluids defined in the AFM. This can be achieved for equipment/system by the tests specified in the section 11.0 of EUROCAE ED-12/RTCA DO 160 through careful selection of the agents to be tested. The applicant is not required to test every de/anti-icing fluid.

SAE AMS1424 and AMS1428 include requirements for effects of de-icing/anti-icing fluids on common aircraft materials.

Most of the aircraft de-icing fluids use conventional or non-conventional glycol (or a glycol/water dilution) as freezing point depressant and comply with SAE AMS1424/1. It is, therefore, normally acceptable to test one of the glycols based anti-de/anti-icing fluids specified in AMS 1424/1 to confirm the compatibility of the aircraft materials and equipment with de/anti-icing fluids. Some fluid manufactures have started to develop new fluids based on alkali organic salt dilutions, i.e., non-glycol-based fluids which comply with SAE AMS1424/2. These alkali-based fluids may present two adverse effects on the aeroplane and its operation: 1) interacting with thickening agents used in de/anti-icing fluids thereby reducing their viscosity and consequently reducing the holdover time and 2) causing galvanic corrosion on metallic parts. Some aircraft manufacturers have introduced recommendations in their manuals against use of alkali organic salt-based fluids. If SAE AMS 1424/2 fluids are approved for use, then the applicant should perform further testing of the types of non-glycol fluids approved for use on the aeroplane.

7.2 Effects of fluid ingress on aeroplane systems

Consistent with existing requirements of CS 25.1301 and CS 25.1309, there should be validation that there would be no unexpected fluid ingress into flight critical areas that may affect internal systems or components.

The applicant should determine areas of the airplane that are susceptible to fluid ingress and specify any procedures necessary to limit it (e.g., flight control positions at the time of fluid application, system mode selections, etc.). This may be addressed through test and inspection or through a combination of design review, similarity, or fleet service history.

Any aeroplane system element exposed to deicing/anti icing fluid should be demonstrated not be susceptible to degradation in accordance with EUROCAE ED-14 / RTCA Document DO160 section 11 or any other equivalent accepted industry standard.

7.3 Fluid effects on system operating procedures

Any potential adverse effect of deicing/anti-icing fluid on airplane systems should be assessed and the recommended procedures for system operation or spraying area restriction modified accordingly to minimize these effects (e.g., airframe and engine anti-ice system operation, ECS operation, APU operation, engine operation, etc.).

Potential adverse effects include, but may not be limited to, the following:

- Ingestion into engines or APU leading to engine damage or possible environmental control system and cabin air contamination.
- Blockage or fluid ingress paths through fuel vents, system/compartment ventilation inlets and outlets.
- “Baking” of fluids on heated surfaces (for example heated probes, heated intake lips or wing surfaces) affecting system operation or heated surface roughness.
- Effects on external probes: potential disruption of air data indications (airspeed, altitude, temperature, AOA) due to fluid interaction with sensors or ports, and the possible drying of fluid on heated sensors causing sensing anomalies.

- Windshield damage due to high pressure deicing jet impact or the degradation of pilots' view during take-off due to fluid streaming over the windshield or enhanced vision system.
- Impacts on externally mounted system components. For example, procedures may recommend against spraying wheels, brakes and thrust reversers.

The recommended systems operation procedures following ground deicing/anti-icing procedures and spraying area restrictions should also be evaluated through test or combination of design review, similarity, or fleet service history.

(8) Documentation

8.1 Aeroplane flight manual (AFM)

The results of the test program should be used to establish any required limitations, procedures, and performance information to be provided in the AFM per CS 25.1583(m) and CS 25.1597

Any required changes in system operating procedures should be identified. If take-off procedures or speeds are modified, suitable performance adjustments (e.g., to take-off run, take-off distance and/or accelerate stop distance) should be provided.

Address the following items in the AFM as applicable:

- The critical surfaces and equipment that must be free of frozen contamination (ice, frost, snow, slush).
- The AFM should identify the type(s) of fluid approved for use on the aircraft. The AFM Limitations section should also state, "Use of the approved fluid types is prohibited at ambient temperatures below the Lowest Operational Use Temperature specified for the fluid."
- For any of the fluid types (I, II, III, or IV) that have not been approved in accordance with this AMC, the AFM should state the use of that fluid type(s) is prohibited.
- Any airplane-specific restrictive information considered necessary for safe airplane operations with deicing or anti-icing fluids applied should be furnished in the AFM Limitations section. Examples include restrictions in the use of flaps.
- Take-off procedures should include normal system operation (including ice protection system) for take-off in icing conditions including any procedures for ice protection system operation to avoid fluid "baking" and hardening on critical surfaces.
- Pre-flight or post-flight inspection and cleaning of areas in which fluid residue is shown to occur.
- Any effects on aircraft controllability, for example, appreciable increases in control forces for rotation should be described.
- Suitable performance adjustments (e.g., to take-off run, take-off distance and/or accelerate stop distance) should be provided in the AFM Performance section.
- Configuration Deviation List (CDL) items should be re-evaluated for deicing/anti-icing operations and prohibited as appropriate. It should be evaluated how missing items may affect fluid migration patterns and susceptibility to fluid ingress. An example would be prohibiting dispatch with any missing seals from the horizontal stabilizer, in the case of operations requiring de-icing or anti-icing.

8.2 Unapproved operational information

It is recommended that the manufacturer provides adequate information on ground deicing/anti-icing procedures and aircraft operating procedures following deicing/anti-icing in the FCOM, AOM (or equivalent manufacturer's unapproved operational manual or document). Acceptable (small) changes in aeroplane handling characteristics should be described.

Items to consider include, but are not limited to:

- Guidance on external walk around inspection to assess presence of ice and need for aircraft de-icing
- Engine operation. Typically, it is preferable for the engines to be off during de-icing procedures. If this is not possible then engines should be at idle
- Bleed air system selected Off during de-icing procedures
- APU not operating whenever possible during de-icing procedures
- Flap position, elevator and/or stabilizer position during de-icing procedures
- Cabin pressure control system outlets and equipment and ECS ram intakes: consider selection of configurations that close the ram intakes e.g., ditching mode and/or ECS packs OFF (note maximum allowable time with packs off or ditching mode selected on ground during de-icing procedures.
- Supplemental cooling systems OFF whenever possible during de-icing procedures
- Ensure ditching mode is deselected prior to take-off
- Pre- take-off visual check of wings to assess need for repeat of de-icing
- Flight control check to be performed only after ground de-icing
- Note that windshields should not be de-iced with de-icing/anti-icing fluid. The windshields shall only be de/anti-iced with the windshield ice protection system
- Specific procedures during de-icing process such as delaying arming the spoilers and not moving the flaps or the rudder trim and other flight control surfaces until de-icing is completed

The applicant should consider the need to provide additional guidance for ground de-icing crews, emphasizing items or deviations from the standard training received and standard de-icing practices applied, such as those defined in AS6286 and AS6285. These might include:

- Any specific spray techniques required for the aircraft
- No spray zones

8.3 Instructions for continued airworthiness

In accordance with CS 25.1529, it is expected that any specific inspection and cleaning procedures for fluid accumulation will be contained in the appropriate manual(s). Address the following items in the maintenance instructions, if applicable:

- Inspection
    - Drain holes
    - Control balance bays
    - Identified aerodynamically quiet areas
    - Internal control system components
- Cleaning and Lubrication

  - o Establish deicing procedures to ensure residue from thickened fluids is removed from the airplane. An example would be high-pressure washing with a hot Type I fluid/water mix in areas where fluid could accumulate
  - o Cleaned surfaces may require subsequent re-lubrication

- ➢ Guidance and procedures. Provide guidance and procedures for the following items:
  - o What to look for, for example, re-hydrated gel and/or dried fluid residues and what these looks like
  - o Where to look for such gel/residues on the airplane structure and control systems
  - o How to effectively remove these gel/residues.
  - o Guidelines on how to determine the frequency of such checks and corrective actions. (It is not intended that type certificate holders define the frequency of tasks, as this is not practicable given the large variation in the operational use of airplanes. Type certificate holders should provide best practice information on the methods, techniques, and tools that may be employed by operators to monitor the use of such fluids and adjust their maintenance programs accordingly.)

(9) Reference documents

1- EASA Terms of Reference for rulemaking task RMT.0118 (25.704), "Analysis of on-ground wing contamination effect on take-off performance degradation"
2- SAE Aerospace Standard AS5900, "Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 Aircraft Deicing/Anti-Icing Fluids"
3- SAE Aerospace Material Specification AMS1428, "Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III and IV"
4- SAE Aerospace Material Specification AMS1424, "Fluid, Aircraft Deicing/Anti-Icing, SAE Type I"
5- SAE Aerospace Recommended Practice ARP6852, "Methods and Processes for Evaluation of Aerodynamic Effects of SAE-Qualified Aircraft Ground Deicing/Anti-Icing Fluids"
6- SAE Aerospace Standard AS6285, "Aircraft Ground Deicing/Anti-Icing Processes"
7- SAE Aerospace Standard AS6286, "Aircraft Ground Deicing/Anti-Icing Training and Qualification

'Question 2 to stakeholders:

Stakeholders are invited to provide their views on the following item of discussion raised during the development of this proposal:'

Discussion on number of fluids to be tested:

Based on the fact that the fluid's physical properties that causes the following effects are not known:

a) effect 1: a transient reduced effectiveness of the elevator (described by pilots as *aircraft not rotating* or *sluggish aircraft*), and/or

b) effect 2: a high torque opposing to the elevator rotation (handling characteristics),

some group members are of the opinion that testing only one fluid is insufficient in order to state that the effect of any fluid[1] on the airplane[2] has conservatively been accounted for.

This opinion is maintained even if the fluid chosen for the testing has been selected based on the fact that the fluid is 'closely compliant' with the aerodynamic acceptance test (AAT) as per SAE AS5900, i.e. the fluid BLDT is close and below the permitted BLDT limit in the AAT.

While the adverse effect of lift degradation on an aircraft flight-tested is correlated to the BLDT of the fluid on a flat plate, this is not the case to the other above mentioned effects at aircraft level. Therefore a fluid with the highest permitted BLDT cannot be considered as a conservative parameter when assessing these other effects.

Other group members are of the opinion that engineering judgment and limited available experience indicate that if a fluid chosen based on the BLDT criteria has a very limited effect on the performance and handling characteristics of the aircraft to the point that no corrections are required when compared to the normal behavior of the dry elevator/aircraft, other fluids would have also a very limited effect, and no further evaluation would be needed after having assessed the first fluid on the aircraft.

It is also acknowledged by the members supporting this position that it is impractical and too onerous to certify the aircraft for each fluid.

Therefore, while there is no better understanding on how the fluid properties/parameters impact on the phenomena above, the proposal of the members supporting this position for the getting approval for the application on the aircraft of all fluids compliant with SAE standards, is as follows:

All applicants need to consider these effects on their airplane. However, the Agency would accept declaration by applicants stating that its airplane with powered elevators is not affected by the 'effect 2'.

Also, instead of flight testing, an applicant can claim that its airplane is not affected by the 'effect 1' if it can justify that there is no contamination of the underside of the horizontal tailplane. This justification can take credit of similarity analysis with an airplane with same architecture, geometry, performance parameters and evidence of good record history.

With regards to the fluid selection for flight-test demonstrations, if an applicant can justify the selection of a conservative fluid[3], the applicant needs only to flight test the aircraft with this fluid applied and adjust AFM parameters based on the test results (Case 0).

If the applicant cannot provide a rationale for the selection of a conservative fluid, the applicant needs to test the aircraft with fluid A to assess <u>for effects of the phenomena described above</u> (fluid A is chosen in agreement with the Agency and based on BLDT criteria[4]):

- If there is no appreciable effect (*) when testing Fluid A, testing is finished and any fluid[5] is considered adequate for the aircraft. (Case I-END)
- If there is an appreciable effect when testing Fluid A, further tests with other fluid(s) are necessary. (Case II)

The appreciable effect of the airplane de-icing and/or anti-icing treatment is established by comparing the aircraft handling characteristics or performance in dry configuration. Appreciable effects compared to dry configuration are not necessarily associated with a non-compliance with the certification requirements in CS-25, but they are significant enough to the point that they would be noticeable by an aircraft pilot under typical conditions.

The following list is non-exhaustive and is provided as an example of appreciable effects

- An increase of control force (>10%) (*)
- A rotation delay or a decrease of the pitch rate
- An increase of take-off distance (>5%) (*)

- Vibrations

(*) Note - It is understood that there is no appreciable effect with regards to quantifiable parameters, when the measured force/distance are below the limits above.

When further tests with other fluid(s) are necessary (Case II), the applicant shall repeat the flight tests with a commercial thickened fluid chosen by the applicant B (fluid B) applied neat.

If tests with fluid B do not reveal any effect greater that the previously identified with fluid A or any new appreciable effect specific to fluid B (Case II-A END), then the testing is finished, subject to agreed correction (i.e. additional margin) on the aircraft performance values and record the appreciable effects in the AFM for pilot awareness.

The correction will be based on fluid A testing results plus consideration of unknown behavior of the aircraft when treated with other non-tested fluids and non-tested conditions (different dilutions, OAT, aircraft configurations). In particular, corrections will be larger when actual test conditions were not those on the agreed test plan and when test results for fluid B were not reasonably foreseen by the applicant or difficult to justify based on own experience and results with the first fluid. Corrections will have to be reviewed by the Agency for apporiateness, introducing higher corrections when the test conditions substantially differ from those on the agreed test plan.

If tests with Fluid B reveal any amplification of the appreciable effect previously identified with fluid A or any new appreciable effect specific to Fluid B (Case II-B END), corrected AFM parameters will be determined assuming that one of the other commercial fluids that were not tested has the effect of fluid A plus twice the difference between fluid B and fluid A effects. Alternatively to these AFM corrections, the applicant may decide to test a third fluid agreed with the Agency and propose lower corrections on AFM parameters.

In all tested cases, handling characteristics would need to be CS-25 compliant and the applicant will develop in the AFM a description of the effects of the fluids, compared to the clean aircraft and, if decided by the Agency, capture these effects as an item of special emphasis for pilot training, including FSTD data.

The flow chart below summarises the different cases.

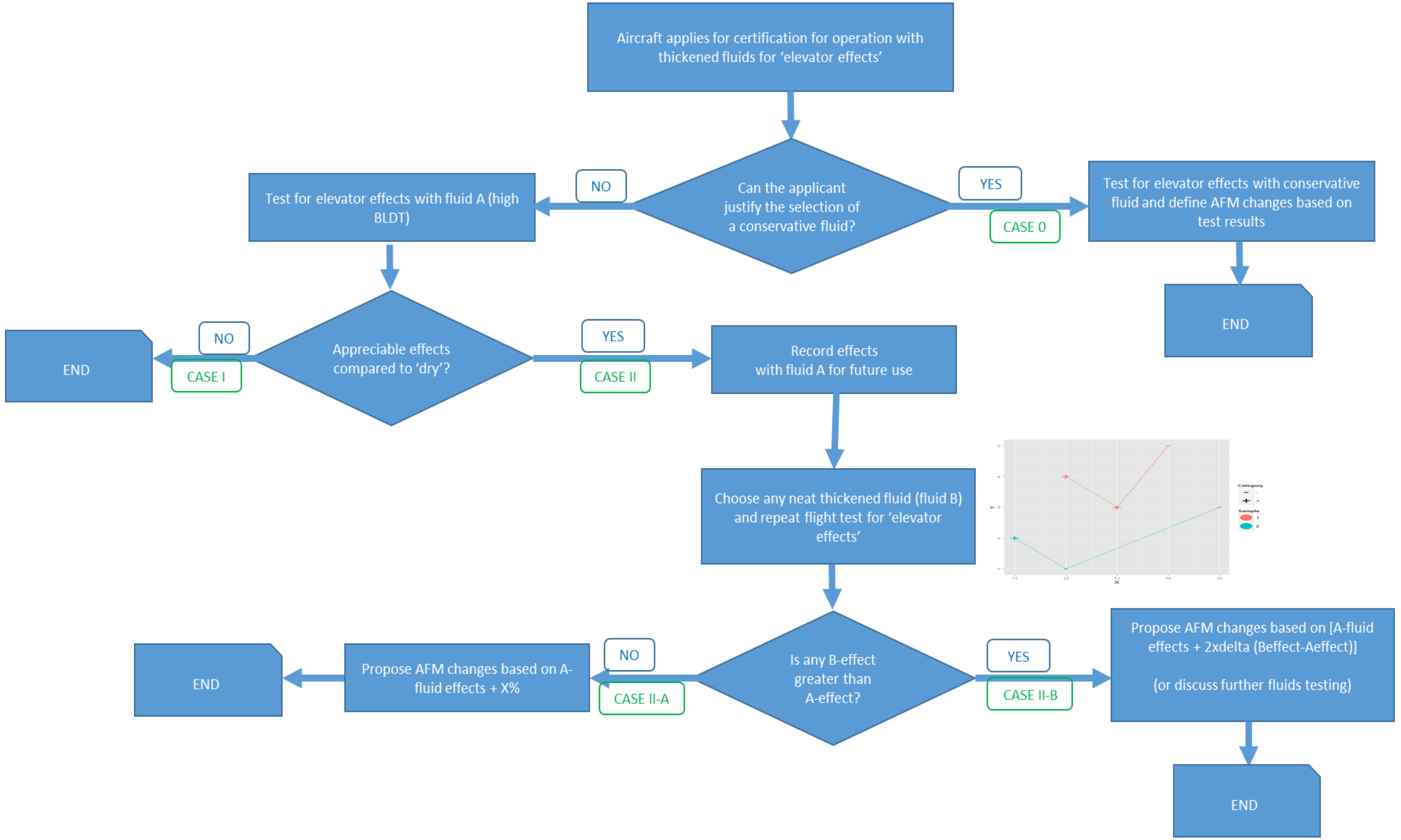
[1] SAE AMS 1428 compliant.

[2] The group also discussed about which were the potential airplanes affected by the two effects.

[3] Compared to all existing commercial fluids, the conservative fluid generates higher penalties on the aircraft performance/controllability for the two phenomena described in this document.

[4]Fluid, test location and expected weather conditions should be chosen aiming to test a neat fluid with an ‘adequate BLDT for testing’ (i.e., BLDT not lower than BLDT AAT limit minus one mm). Diluting the fluid on the day of the test is permitted to achieve an ‘adequate BLDT for testing’ if the OAT on the testing day is not cold enough.

[5]When referring to the fluids, it has to be considered the correspondence between the aircraft acceleration profile and the adequate ramp of the AAT passed by the fluid. Airplane accelerating faster than the equivalent ramp used for the fluid qualification, need to develop a test plan with different acceleration profiles that allow extrapolate fluid validity results for the airplane’s shortest acceleration distance/quickest acceleration profile.


Aircraft applies for certification for operation with thickened fluids for 'elevator effects'
Can the applicant justify the selection of a conservative fluid?
NO
YES
CASE 0
Test for elevator effects with conservative fluid and define AFM changes based on test results
END
Test for elevator effects with fluid A (high BLDT)
Appreciable effects compared to 'dry'?
NO
CASE I
END
YES
CASE II
Record effects with fluid A for future use
Choose any neat thickened fluid (fluid B) and repeat flight test for 'elevator effects'
Is any B-effect greater than A-effect?
NO
CASE II-A
Propose AFM changes based on A-fluid effects + X%
END
YES
CASE II-B
Propose AFM changes based on [A-fluid effects + 2xdelta (Beffect-Aeffect)]
(or discuss further fluids testing)
END

It is acknowledged by the group that all of the fluid properties affecting handling characteristics, including rotation characteristics and elevator hinge moments, are not well understood, despite research intended to specifically address this knowledge gap. Indeed, results of flight test investigation into rotation forces by one OEM have not established a clear pattern between multiple fluids or even with a single fluid.

It is however the position of the majority of the group that in the absence of a definitive identified issue, weight should be given to the service experience and established practice with regard to the assessment of thickened fluids on handling characteristics. In this regard it is felt that that the practice laid out in FAA and TCCA documents, of testing a single fluid for the purpose of assessing handling effects, has been generally successful in identifying issues.

Therefore, and in the interest of harmonization, it is the position of the balance of the group that testing with a single thickened fluid – typically that selected for performance/lift-loss testing on the basis of BLDT – is an appropriate requirement.

Specific

Two specific points of divergence in the two positions occur during the proposed sequence of tests identified in the dissenting position:

1. That a second fluid should be tested if specific results are obtained following the initial fluid test and,
2. That the adjustments to be applied to the aircraft performance (AFM) following the second fluid test are a combination of the effects of both fluids, with added empirical (arbitrary) factors applied

While the first point is quite straightforward, the group position is that no second test is required regardless of initial results since variability of results cannot be confidently attributed to differences between fluids.

With regard to the second point, members of the group have expressed concerns over the details of the proposal with regard to the choice of the second fluid, the justification for the factors applied, the dependency of the final AFM penalty on the order of fluid testing and a number of other factors; these concerns indicate that further work would be require to define an acceptable proposal for the requirement to test more than one fluid, were such a position to be adopted.

CS 25 Appendix C

Part II Airframe Ice Accretions

(a) Ice accretions - General. The most critical ice accretion in terms of aeroplane performance and handling qualities for each flight phase must be used to show compliance with the applicable aeroplane performance and handling requirements in icing conditions of subpart B of this part. Applicants must demonstrate that the full range of atmospheric icing conditions specified in part I of this appendix have been considered, including the mean effective drop diameter, liquid water content, and temperature appropriate to the flight conditions (for example, configuration, speed, angle-of-attack, and altitude). The ice accretions for each flight phase are defined as follows:

(1) Take-off Ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, occurring between the end of the take-off distance and 122 m (400 ft) above the take-off surface, assuming accretion starts at the end of the take-off distance in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix, and in combination, as applicable, with AFM defined pre-take-off frozen contamination per CS25.1595 if approval of AFM defined pre-take-off frozen contamination is sought.

(2) Final Take-off Ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 122 m (400 ft) and either 457 m (1500 ft) above the take-off surface, or the height at which the transition from the take-off to the en-route configuration is completed and VFTO is reached, whichever is higher. Ice accretion is assumed to start at the end of the take-off distance in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix, and in combination, as applicable, with AFM defined pre-take-off frozen contamination per CS 25.1595 if approval of AFM defined pre-take-off frozen contamination is sought.

…

(d) For both unprotected and protected parts, the ice accretion for the take-off phase may be determined by calculation, assuming the take-off maximum icing conditions defined in appendix C, and assuming that:

(1) Airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice, except, as applicable, the AFM defined pre-take-off frozen contamination per CS 25.1595, at the start of the take-off;

Rationale

Appendix C, Part II is amended to include the consideration of an AFM defined pre-take-off contamination scenario in combination with Appendix C take-off ice as applicable.

CS 25 Appendix O Supercooled Large Drop icing conditions

Part II Airframe Ice Accretion

…

(c) Ice accretions for airplanes certified in accordance with §§ 25.1420(a)(2) or (3). For an airplane certified in accordance with § 25.1420(a)(2), only the portion of the icing conditions of part I of this Appendix in which the airplane is capable of operating safely must be considered.

(1) Take-off ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces, occurring between the end of the take-off distance and 400 feet above the take-off surface, assuming accretion starts at the end of the take-off distance in the icing conditions defined in part I of this Appendix, and in combination, as applicable, with AFM defined pre-take-off frozen contamination per CS25.1595 if approval of AFM defined pre-take-off frozen contamination is sought.

(2) Final take-off ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 122

m (400 feet) and either 457 m (1 500 feet) above the take-off surface, or the height at which the transition from the take-off to the en-route configuration is completed and VFTO is reached, whichever is higher. Ice accretion is assumed to start at lift-off the end of the take-off distance in the icing conditions defined in part I of this appendix, and in combination, as applicable, with AFM defined pre-take-off frozen contamination per CS25.1595 if approval of AFM defined pre-take-off frozen contamination is sought.

…

(7) For both unprotected and protected parts, the ice accretion for the take-off phase must be determined for the icing conditions defined in part I of this appendix, using the 15:

(i) The aerofoils, control surfaces, and, if applicable, propellers are free from frost, snow, or ice, except, as applicable, the AFM defined pre-take-off frozen contamination per CS 25.1595,at the start of take-off;

Rationale

Appendix O, Part II is amended to include the consideration of an AFM defined pre-take-off contamination scenario in combination with Appendix O pre-detection ice for 1420(a) and 1420(b) applications, and to Appendix O take-off ice as applicable for 1420(c) applications.

4. Impact assessment (IA)

4.1. Take-off with wing contaminated by icing conditions

4.1.1. What is the issue

4.1.1.1 Safety risk assessment

Accidents/serious incidents in commercial or non-commercial operations where the cause/contributing factor was the degradation of aircraft aerodynamic performances, reduction of safety margins and reduction of manoeuvrability/controllability due to unnoticed airframe ground icing contamination (17 accidents involving EU-MS operators or EU-product designs and 200 fatalities in the period 1989-2019).

On 27 December 2019, a Fokker 100 aircraft impacted the ground shortly after having departed from Almaty (Kazakhstan). Twelve occupants of the aeroplane were fatally injured. The investigation is still on-going, but first indications show that the wings were intentionally not de-iced.

On 13 December 2017, an ATR 42 aircraft (C-GWEA) impacted the ground shortly after having departed from Fond-du-Lac (Canada). One passenger died from the consequences of the injuries received during the accident. The investigation concluded that the crew started the take-off with known ice contamination on the aircraft's critical surfaces.

On 4 March 2013, a Beechcraft Premier 1A (VP-CAZ) lost control during take-off from Annemasse, France. Two occupants of the aeroplane were fatally injured, while the third one was seriously injured. The BEA investigation concluded that the accident was caused by the pilot's insufficient appreciation of the risks associated with ground-ice, which led him to take off with contamination of the critical airframe surfaces. This contaminant deposit then caused the aerodynamic stall of the aeroplane and the loss of control shortly after lift-off. Several safety recommendations were issued, including the following one (ref. FRAN-2014-006): *'EASA, in coordination with the FAA and the other non-European civil aviation authorities, **study the technical and regulatory means to put in place in order to install systems for the detection of frozen contaminants on the critical surfaces of aircraft**'.*

On 02 April 2012, an ATR 72 aircraft (VP-BYZ) was destroyed in an accident shortly after take-off from Tyumen (Russia). Thirty-three occupants of the aeroplane were fatally injured. The investigation concluded that the cause of the accident was the pilot's decision to take-off without de/anti-icing treatment despite the known presence of snow and ice deposits on aircraft. As a result, the investigation board (MAK) issued a recommendation to the State of Design ***"(…) to consider the introduction of a requirements to mandatory equip at least those A/C types whose aerodynamic performance is very sensitive to ground icing with an on-board system for automatic detection of ground icing conditions and notifying flight crews."***

On 25 January 2007, a Fokker F28 (F-GMPG) lost control during take-off from Pau-Pyrénées airport, France and performed an emergency landing in a field in front of the runway. One person on the ground was fatally injured. The investigation

concluded that a contributing factor to the loss of control was the presence of ice contaminants on the wing surfaces. The deposit on the wings changed the aeroplane's performance and handling qualities. As a result, the BEA issued the following safety recommendation (ref. FRAN-2009-001):
'The BEA recommends that while being watchful to keep the operational requirements relating to the ground de-icing pre-flight check, ***EASA sets out to improve the certification specifications to require the analysis of aircraft behaviour when, the wings surfaces are contaminated on ground and to guarantee the maintaining of acceptable safety margins, in case of slight contamination****.'*

Note: this recommendation can also be linked to the issue developed in Subtask B.

On 4 January 2002, another accident, caused by non-de-icing of the aircraft, involved a Bombardier CL600-2B16 aircraft (N90AG) during take-off at Birmingham International Airport. All five occupants of the aeroplane were fatally injured. After investigation, the following safety recommendation (ref. UNKG-2003-060) was issued:
'*It is recommended that the FAA and JAA* ***review the current procedural approach to the pre-take-off detection and elimination of airframe ice contamination and consider requiring a system that would directly monitor aircraft aerodynamic surfaces for ice contamination and warn the crew of a potentially hazardous condition****.'*

Note: some of the recommendations refer to both on-board and on-ground systems to detect the contamination of the aircraft aerodynamic surfaces. Those remote on ground ice detections systems are considered out of the scope of this rulemaking task.

4.1.1.2 Who is affected

Aircraft designers and operators

4.1.1.3 How could the issue evolve

Over the period 1989-2013, several accidents where a take-off was commenced with (suspected) contamination on the wings have been reported. 14 of those accidents took place in Europe in commercial air transport (4 events), or involved a product designed in Europe (10 events). They resulted in a total of 187 fatalities: 11 with EASA-MS operators and 176 with non-EASA-MS operators. This corresponds per 100 million flight cycles to an estimated accident rate of 0.15 and a fatality rate of 2.04.
The common factor in such events was a failure to ensure that the aircraft's critical surfaces (in particular the wings) were free from contamination, which is a non-compliance to the applicable operational regulations.
Measures in responses to such events have mostly been enhanced training and awareness activities undertaken by airworthiness authorities, manufacturers, and operators to ensure that winter operations standards and best practices are widespread among the community. In particular, EASA issued Safety Information Bulletin No 2011-22 in July 2011, with the reminder to "Ensure that the aircraft is properly de/anti-iced prior to departure and that the flight crew has determined immediately prior to take-off, or in accordance with an approved ground-ice program, that contamination is not adhering to the critical surfaces".
Following that period and the issuance of the EASA SIB, in the period between 2014 and 2019, 3 accidents took place in Europe in commercial air transport or involved a product designed in Europe, resulting in 13 fatalities (all fatalities were with non-EASA-MS operators).

These accidents seem to be still the consequence of non-application of the de-icing/anti-icing procedures or even take-off with known contamination of the critical surfaces.
They correspond per 100 million flight cycles an estimated accident rate of 0.11 and a fatality rate of 0.46.
One could see this reduction in the accident and fatality rates as an effect of the measures and safety promotion taken in the past.

4.1.2. What we want to achieve — objectives

— The operational objectives of this proposal are to reduce the risk of accident and serious incident during take-off, due to unexpected presence of frozen contaminants on the critical surfaces.

— The question is whether additional actions are necessary in an attempt to further decrease the accident rate, e.g., by requiring the installation of on-board systems to detect and alert the crew on the presence of ice on the aircraft critical surfaces prior to take-off.

4.1.3. How we want to achieve it — options

Table 1: Selected policy options

Option No	***Short title***	***Description***
0	No action	No policy change (rules remain unchanged and risks as outlined in the issue analysis).
1	Amend CS-25	Require in CS-25 an on-board system able to detect and alert the pilots in case of presence of frozen contaminants on the critical surfaces
2	Option 1 + Part-26	Retroactive requirement to install a system also on already certified types
3	Safety promotion and standardisation	Continue to raise awareness on peculiarities of winter operations and associated procedures Standardise the information to appear in the AFM in relation with winter operations.

4.1.4. What are the impacts

4.1.4.1 Safety impact

On-board systems to detect and alert the crew on the presence of ice on certain aircraft critical surfaces exist today, but in their current design, they are able to detect only a known contamination scenario on a specific part of an aircraft. In particular, an ice detection system was developed and mandated in 2001 (FAA AD 2001-06-16) to detect ice accretion in one area of the upper wing surface of the Boeing DC-9 and MD-88 aircraft type. This mandate was prompted by incidents in which ice accumulation (mainly caused by cold soak fuel frost phenomena) on the wing upper surfaces shed

into the engines during take-off, possibly leading to ingestion of ice into one or both engines and consequent loss of thrust from one or both engines.
It cannot be certain today that the system can be adapted with the same reliability to other aircraft types without affecting efficiency of operations (risk of false alerts), in addition of being able to detect ice contamination only on a specific area.

4.1.4.2 Environmental impact

No impact on aircraft noise and emission is expected.

4.1.4.3 Social impact

— No social impact is expected.

4.1.4.4 Economic impact

The FAA estimated in 2001 the cost of installation of such primary upper wing ice detector system. Adjusted for inflation, this cost would range from € 62 985 to € 116 138 per DC-9/MD-88 aeroplane. There is, however no information on the cost of customisation of such system to other aircraft types.

'Question 3 to stakeholders on the economic impacts:

Stakeholders are invited to provide quantified elements to justify the possible economic impacts of the options proposed, or alternatively propose other justified solutions to the issue.'

4.1.4.5 General Aviation and proportionality issues

— The proposal does not mandate the installation of the system. The safety promotion actions envisioned are expected to also benefit to the GA community.

4.1.5. Conclusion

4.1.5.1 Comparison of the options

It is considered that the mandate of an on-board system on new designs or already certified types would not guarantee a significant safety benefit, also taking into consideration that in some cases the crew attempted the take-off, while being aware of the contamination.
Continuation of safety promotion and standardisation actions is therefore the prefered option (**Option 3**), in comparison to the other options. However, the technology for on-board system should continue to be monitored for possible future applications.

Note: this is in line with action n°3[6] of the EASA safety assessment on Ice On-Ground Scenario.

[6] Description of action 3: Review EASA publications (SIBs) on ground icing to consolidate a single reference document containing all updated safety information on threats and mitigating measures. This safety promotion document aims to assisting flight crews and operators in the planning and execution of operations in icing conditions during the ground phases, notably in preparation of their winter operations.

'Question 4 to stakeholders

Stakeholders are invited to provide any other quantitative information they find necessary to bring to the attention of EASA.'

As a result, the relevant parts of the IA may be adjusted on a case-by-case basis.'

4.1.6. Monitoring and evaluation

— The monitoring of the effects created by the safety promotion action will consist of, in the long term, the direction of the trend of the numbers of accident and serious incidents associated with take-off with unnoticed/not allowed contamination on the aircraft wings. This would be available after the aeroplanes have experience sufficient time in operation with the additional safety promotion actions in place. In order to obtain relevant statistical information, this may be performed at least 5 years after the publication or completion of the safety promotion action.

— In addition, such actions may be subject to interim/ongoing/ex post evaluation that will show the outcome that is obtained after the application of the safety promotion actions, taking into account the earlier predictions made in this impact assessment. The evaluation would provide evidence-based judgement of the extent to which the action has been relevant (given the needs and its objectives), effective and efficient, coherent, and has achieved added value for the EU. The decision as to whether an evaluation will be necessary should also be taken based on the monitoring results.

4.2. Take-off with wing contaminated by icing conditions

4.2.1. What is the issue

There is currently a disconnection between Commission Regulation (EU) No 965/2012 and CS-25, as follows:

CAT.OP.MPA.250 Ice and other contaminants — ground procedures

(a) The operator shall establish procedures to be followed when ground de-icing and anti-icing and related inspections of the aircraft are necessary to allow the safe operation of the aircraft.

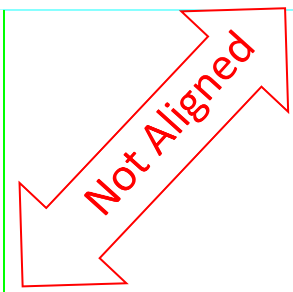
(b) The commander shall only commence take-off if the aircraft is clear of any deposit that might adversely affect the performance or controllability of the aircraft, except as permitted under (a) and in accordance with the AFM.

CS 25 BOOK 1 Appendix C part II (d)

(d) For both unprotected and protected parts, the ice accretion for the take-off phase may be determined by calculation, assuming the take-off maximum icing conditions defined in appendix C, and assuming that:

(1) Airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off;

(2) The ice accretion starts at the end of the take-off distance;



The deposit mentioned in CAT.OP.MAP.250 above could be caused by cold-soak effect.

The wings of aircraft are said to be "cold-soaked" when they contain very cold fuel because of having just landed after a flight at high altitude or from having been re-fuelled with very cold fuel. Ice can form on the external surfaces of cold-soaked aircraft, even when the outside temperature is above 0°C, in presence of visible moisture, high humidity, or water precipitation, provided that the airframe surface remains at 0°C or below. Two typical cold-soak effect sources exist:

— Cold fuel present in fuel cells; and

— Cold massive airframe structural parts.

Cold-soak ice contamination can appear on the ground, but also in flight when the aircraft descends and encounters warmer air altitudes. The phenomenon is well known for potentially appearing on wings or horizontal stabiliser surfaces, but it can also appear on other airframe surfaces.
FAA operational rules (e.g., Part-121) differ from the EU, since they do not allow take-off with frost on critical surfaces. There is also no related provision in FAA specifications for initial airworthiness.
However, FAA has granted exemptions to Part-121 airlines to operate some products with the capability of take-off with frost on the upper wing after having investigated compliance with certification requirements of the aircraft with AFM-declared permitted contamination.

TCCA already proposed a change to their operational regulation (CARs 602.11 and 701.25) to permit take-off frost on some critical surfaces (TCCA NPA 2020-006 Aircraft icing – released in March 2020).

4.2.1.1 Safety risk assessment

Today, there is no provision in CS-25 to certify the aircraft in view of this cold-soak effect, but EASA issued a certification review item (CRI) on certain certification projects. It contains provisions that an applicant should consider when evaluating the performances of its design with wing surface contaminated because of cold-soaked effects.
There are no SRs pertinent to the scope of this RMT.

4.2.1.2 Who is affected

— Aircraft designers and operators

4.2.1.3 How could the issue evolve

The disconnection between EU operational regulation and CS-25 would continue, creating some confusion among the stakeholders (operators and aircraft manufacturers).

4.2.2. What we want to achieve — objectives

— The operational objectives of this proposal is to bridge the disconnection between EU-OPS and CS-25, while ensuring that maintained performances of the aeroplane with a certain level of frozen contaminants on the critical surfaces can be demonstrated.

4.2.3. How we want to achieve it — options

Table 2: Selected policy options

Option No	*Short title*	*Description*
0	No action	No policy changes. EASA would continue to issue a CRI when necessary
1	Amend CS-25	Create specifications to provide for demonstration of acceptable performance with a certain level of frozen contaminants on the critical surfaces.

4.2.4. What are the impacts

4.2.4.1 Safety impact

In case of Option 0, EASA would continue to issue a CRI when a TC holder or applicant for new TC would request to have its design certified with the capability to take-off with a certain level of contamination on the upper surface of the wings. Such CRI has however not been applied in a consistent manner and in some cases, it did not consider the combined effect of contamination of both the upper and lower surfaces of the wings. One could see there a certain uncertainty about the achieved level of safety.

With Option 1, on the contrary, those provisions would be directly in the certification specifications. And it would be required to always consider the combined effect of contamination of both the upper and lower surfaces of the wings. The potential safety concern raised by Option 0 would then be mitigated.

4.2.4.2 Environmental impact

— No impact on aircraft noise and engine emission is expected.

4.2.4.3 Social impact

— No social impact is expected.

4.2.4.4 Economic impact

Option 1 would align the EU operational regulation and CS-25 and would also bring an economic benefit as it would save some workload (on EASA and applicants) caused by the management of CRIs. It would also provide certainty to applicants on the certification requirements to be expected for future projects, when wishing to demonstrate that the aerodynamic performance of their aeroplane is maintained despite a certain level of contaminant on its critical surfaces. For products for which the exercise is not yet done, the demonstration of such capability would have a development cost (tests, simulations, …). This cost, estimated to be around EUR 300 000, may be reflected on the operator. But it would be mitigated by the economic benefit for both the aircraft manufacturer and for the operator when an aeroplane is able to operate under certain weather conditions.

‘Question 5 to stakeholders on the economic impacts:

Stakeholders are invited to provide quantified elements to justify the possible economic impacts of the options proposed, or alternatively propose other justified solutions to the issue.'

4.2.4.5 General Aviation and proportionality issues

— This proposal concerns only large aeroplane products. It is not considered at this stage to allow the possibility to take-off with contaminant to CS-23/General Aviation aeroplanes.

4.2.5. Conclusion

4.2.5.1 Comparison of the options

With option 0, CRI would continue to be used on a case by case basis. With Option 1, on the contrary, those provisions would be directly avaialable in the certification specifications and would allow to align the requirements of CS-25 with the existing EASA OPS regulations regarding allowed take-off with a determined level of contamination.

Option 1 (CS-25) is the preferred option.

Note 1: No retroactive requirement is considered here since, developing such capability is voluntarily. Without explicit information in the AFM, an aircraft will not be entitled to be operated with contamination.

'**Question 6 to stakeholders**

Stakeholders are invited to provide any other quantitative information they find necessary to bring to the attention of EASA.

As a result, the relevant parts of the IA may be adjusted on a case-by-case basis.'

4.2.6. Monitoring and evaluation

The monitoring of the effects created by the proposed amendment of CS-25 will consist of experience gathered with EASA and the competent authorities regarding the certification and operation of aircraft with allowed contamination at take-off. It will depend on the applications received by EASA and the competent authorities of Member States after the amendment of CS-25. A review may be made at the earliest five years after the amendment of CS-25.

In addition, the changes made to CS-25 be subject to interim/ongoing/ex post evaluation that will show the outcome that is obtained after the application of the new rules, taking into account the earlier predictions made in this impact assessment. The evaluation would provide evidence-based judgement of the extent to which the proposal has been relevant (given the needs and its objectives), effective and efficient, coherent, and has achieved added value for the EU. The decision as to whether an evaluation will be necessary should also be taken based on the monitoring results.

4.3. De-icing/anti-icing fluid effects on the aerodynamic performances, safety margins, manoeuvrability, and controllability of the aeroplane at take-off

4.3.1. What is the issue

— In order to remove ice contamination from their surfaces on the ground, aeroplanes are treated before take-off with low freezing point fluids (de-/anti-icing fluids). They are a necessary element to operate the aeroplanes in ‘ground icing conditions’, providing protection against ice contamination up to the moment of rotation for lift-off. Nevertheless, the presence of the fluids also affects the aerodynamic characteristics of the aeroplanes. De-/anti-icing fluids are developed in compliance with international industry standards which intend to ensure that the fluids will leave the aeroplane surfaces during the take-off roll, before lift-off. However, there is no regulation mandating the evaluation of the effects of these fluids by the aeroplane manufacturers.

— Note: most relevant effects of fluids on aircraft are:

- lift loss (during take-off).
- Cl MAX/Stall speeds (during take-off).
- vibration/buffeting.
- rotation difficulties.
- ingestion of fluids in cavities (fluid residues rehydrated and frozen).

4.3.1.1 Safety risk assessment

Accidents and incidents have been caused by the degradation of aircraft aerodynamic performance, reduction of safety margins and reduction of maneuverability/controllability due to inadequate deicing/anti-icing operations.
On 11 January 2010, a serious incident with a British Aerospace ATP aeroplane (SE-MAP) occurred at Vantaa airport, Helsinki, Finland. The event did not cause any injury. The investigation by the Swedish accident investigation body (SHK) showed that several similar incidents involving the same type of aeroplane and similar conditions had occurred before. The incidents involving elevator restrictions were caused by a phenomenon which, for unknown reasons, occurs following the use of anti-icing fluids containing thickening agents on individual aeroplanes where the stabiliser and elevator are too close together. In addition to recommend an extension of the EASA’s remit to include certification of fluids used for ground de-/anti-icing of aircraft, SHK also recommended that EASA ‘**should investigate the possibility of tightening requirements on aircraft design organizations in terms of demonstrating that the aircraft has full manoeuvrability during all phases of the take-off procedure after the application of de- and anti-icing fluids**.’

4.3.1.2 Who is affected

Aircraft designers and operators.

4.3.1.3 How could the issue evolve

EASA issued Safety Information Bulletin (SIB) No.: 2015-18 on the potential adverse effect of anti-icing fluids during take-off. TCHs have reported incidents linked to the operation with anti-icing fluids. ATR, Boeing, Pilatus, Embraer, Bombardier, Textron, Bae have tested their aircraft with fluids and introduced some operational limitations or instructions, when necessary.

The risk on existing designs is therefore considered mitigated. However, applicants for new designs will still face the need to select the adequate anti icing/de-icing fluid for their product and will need guidance.

4.3.2. What we want to achieve — objectives

— The operational objectives of this proposal are to mitigate the risk of accident and serious incident due to adverse effect of de-icing/anti-icing fluid on the aerodynamic performances, safety margins, manoeuvrability, and controllability of the aeroplane at take-off.

4.3.3. How we want to achieve it — options

Table 3: Selected policy options

Option No	*Short title*	*Description*
0	No action	No policy change (rules remain unchanged and risks as outlined in the issue analysis).
1	Amend CS-25 (+AMC/GM)	Create specifications in relation with de-icing and anti-icing fluids (techniques and limitations for safe operations to be included in AFM)
2	Option 1 + Part-26	Retroactive requirement on already certified types

4.3.4. What are the impacts

4.3.4.1 Safety impact

Option 0 would not address the issue for future designs,

Option 1 would increase safety by ensuring a consistent approach with regards approving the use of Type I, II, III, and IV deicing/anti-icing fluids on aeroplanes. It would also ensure the AFM identifies the specific fluid types that have been approved and that use of other fluid types is prohibited.

Option 2 would not bring additional benefit compared to Option 1, because the TCH of existing designs have already introduced limitations and instructions for the operations of their products with certain fluids when necessary.

4.3.4.2 Environmental impact

— No environment impact is expected.

4.3.4.3 Social impact

— No social impact is expected.

4.3.4.4 Economic impact

Testing one fluid represent an average cost of EUR 350 000. Testing one additional fluid may add up to 50% increase of this cost.

However, the global cost would be balanced by the avoided costs of aircraft damage and traffic disturbance following a runway excursion (the average value of the aircraft damage caused by a runway excursion is estimated to amount to EUR 11 million per accident. The costs for the airport delays, cancellations and diversions that follow a runway excursion are estimated to be EUR 2.6 million per accident).

'Question 7 to stakeholders on the economic impacts:

Stakeholders are invited to provide quantified elements to justify the possible economic impacts of the options proposed, or alternatively propose other justified solutions to the issue.'

4.3.4.5 General Aviation and proportionality issues

— The proposal concern only CS-25 products, therefore no proportionality issue is expected.

— For CS-23 products, no change is proposed but industry standards could be developed, reflecting the proposed new AMC 25.1597.

4.3.5. Conclusion

4.3.5.1 Comparison of the options

Option 0 would not address the issue for future designs. Option 1 would improve safety and ensure that applicants for certification of new designs are aware in advance of the need to identify which fluids can be used on their aircraft type, demonstrate that the fluids have a acceptable impact on the aircraft performance and to provide the related operating procedures. A retroactive requirement through Option 2 would not bring additional benefit compared to Option 1.
Option 1 (amend CS-25) is therefore the preferred option.

'**Question 8 to stakeholders**

Stakeholders are invited to provide any other quantitative information they find necessary to bring to the attention of EASA.

As a result, the relevant parts of the IA may be adjusted on a case-by-case basis.'

4.3.6. Monitoring and evaluation

— The monitoring of the effects created by the proposed amendment of CS-25 will consist of, in the long term, the direction of the trend of the number of accidents and serious incident associated with degradation of performance because of anti/de-icing fluids on the aircraft wings.

It will depend on the applications received by EASA after the amendment of CS-25. A review may be made at the earliest five years after the amendment of CS-25.

— In addition, the changes made to CS-25 be subject to interim/ongoing/ex post evaluation that will show the outcome that is obtained after the application of the new rules or safety promotion actions, taking into account the earlier predictions made in this impact assessment. The evaluation would provide evidence-based judgement of the extent to which the proposal has been relevant (given the needs and its objectives), effective and efficient, coherent, and has achieved added value for the EU. The decision as to whether an evaluation will be necessary should also be taken based on the monitoring results.

5. Proposed actions to support implementation

- Focused communication for Advisory Body meeting(s) (MAB/SAB/TeB/TEC/COM)
- Clarifications via electronic communication tools between EASA and NCAs (EUSurvey or other)
- EASA Circular
- Detailed explanations/clarifications on the EASA website
- Dedicated thematic workshop/session
- Series of thematic events organised on the regional principle
- Combination of the above-mentioned means

6. References

6.1. Related EU regulations

n/a

6.2. Related EASA 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 references

Regulations/proposed regulation

- Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council

- TCCA NPA 2020-006 Aircraft icing – released in March 2020

Accidents reports:

- Air Transportation Safety Investigation Report A17C0146, ATR42, C-GWEA on 13 December 2017.
- Accident on 4 March 2013 just after take-off from Annemasse (France) to the Beechcraft Premier 1A registered VP-CAZ, published May 2014.
- Final report on results of investigation of accident of ATR72-201 aeroplane VP-BYZ on 02 April 2012.
- Report on the accident to Bombardier CL600-2B16 Series 604, N90AG at Birmingham International Airport on 04 January 2002.

Safety Information Bulletins/Airworthiness Directive

- EASA issued Safety Information Bulletin (SIB) No.: 2015-18, Potential Adverse Effect of Anti-Icing Fluids during Take-off, 08 October 2015
- EASA issued Safety Information Bulletin (SIB) No 2011-22, Ground and Airborne Icing, 28 July 2011
- FAA AD US-2001-06-16 (superseded by FAA AD 2002-21-06), on prevention off ice accumulation ofon the wing upper surface, dated April 2001.

Others reports and studies

- A. Brown, “Inflight Cold-Soaked Fuel Frost Observations and Analysis,” AIAA, 2012
- C. Tanner, “The Effect of Wing Leading Edge Contamination on the Stall Characteristics of Aircraft,” SAE, 2007.
- M. Dietenberger, “A frost formation model and its validation under various experimental
- conditions,” NASA, 1982
- C. Hermes, “An analytical solution to the problem of frost growth and densification on flat surfaces,” International Journal of Mass and Heat Transfer, 2012.
- R. Yun and M. Yongchan, “Modeling of frost growth and frost properties with airflow over a flat plate,” International Journal of Regrigeration, 2002.

- M. Bragg, “Effect of Underwing Frost on a Transport Aircraft Airfoil at Flight Reynolds Number,” Journal of Aircraft, vol. 31, 1994.
- T. Cebeci, “Effects of Environmentally Imposed Roughness on Airfoil Performance,” NASA, 1987.
- E. Hill, “Airplane Performance and Other Considerations Related to Airplane Icing While on the Ground,” in Airplane Deicing Seminar Aircraft Technology Division, Danish Engineering Society, Copenhagen, Denmark, 1993.
- E. Hill and T. Zierten, “Influence of Environmental Factors on Aircraft Wing Performance Effects of Wing Simulated Ground Frost on Airplane Performance”, 1987.
- A. Broeren and C. Clark, “Aerodynamic Effects of Anti-Icing Fluids on a Thin High-Performance Wing Section,” Journal of Aircraft, vol. 53, 2016.
- TP 14377E, “Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces,”, December 2004.

Technical standards

- SAE Aerospace Standard AS5900, “Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 Aircraft Deicing/Anti-Icing Fluids”.
- SAE Aerospace Material Specification AMS1428, “Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III and IV”.
- SAE Aerospace Material Specification AMS1424, “Fluid, Aircraft Deicing/Anti-Icing, SAE Type I”.
- SAE Aerospace Recommended Practice ARP6852, “Methods and Processes for Evaluation of Aerodynamic Effects of SAE-Qualified Aircraft Ground Deicing/Anti-Icing Fluids”.
- SAE Aerospace Standard AS6285, “Aircraft Ground Deicing/Anti-Icing Processes”.
- SAE Aerospace Standard AS6286, “Aircraft Ground Deicing/Anti-Icing Training and Qualification.

7. Annex

Rulemaking group report on RMT.0118: *Analysis of on-ground wing contamination effect on take-off performance degradation* — 15 September 2021[7]

7 https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2022-08

8. Quality of the NPA

To continuously improve the quality of its documents, EASA welcomes your feedback on the quality of this NPA with regard to the following aspects:

8.1. The regulatory proposal is of technically good/high quality

Please choose one of the options below and place it as a comment in CRT; if you disagree or strongly disagree, please provide a brief justification.
Fully agree / Agree / Neutral / Disagree / Strongly disagree

8.2. The text is clear, readable and understandable

Please choose one of the options below and place it as a comment in CRT; if you disagree or strongly disagree, please provide a brief justification.
Fully agree / Agree / Neutral / Disagree / Strongly disagree

8.3. The regulatory proposal is well substantiated

Please choose one of the options below and place it as a comment in CRT; if you disagree or strongly disagree, please provide a brief justification.
Fully agree / Agree / Neutral / Disagree / Strongly disagree

8.4. The regulatory proposal is fit for purpose (capable of achieving the objectives set)

Please choose one of the options below and place it as a comment in CRT; if you disagree or strongly disagree, please provide a brief justification.
Fully agree / Agree / Neutral / Disagree / Strongly disagree

8.5. The impact assessment (IA), as well as its qualitative and quantitative data, is of high quality

Please choose one of the options below and place it as a comment in CRT; if you disagree or strongly disagree, please provide a brief justification.
Fully agree / Agree / Neutral / Disagree / Strongly disagree

8.6. The regulatory proposal applies the 'better regulation' principles[1]

Please choose one of the options below and place it as a comment in CRT; if you disagree or strongly disagree, please provide a brief justification.
Fully agree / Agree / Neutral / Disagree / Strongly disagree

8.7. Any other comments on the quality of this NPA (please specify)

Note: Your comments on Chapter 8 will be considered for internal quality assurance and management purposes only and will not be published in the related CRD.

[1] For information and guidance, see:
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox/better-regulation-toolbox_en