Rulemaking group report on RMT.0118

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

15 September 2021

1 EXECUTIVE SUMMARY

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 maneuverability/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); or
- inadequate de-/anti-icing operations (1 serious incident in 2010 and several suspected).

EASA received 4 related safety recommendations. The below categories of issues were identified:

- take-off in icing condition with unnoticed contaminated wing.
- de-/anti-icing fluid effects on the aerodynamic performances, safety margins, maneuverability, and controllability of the aeroplane at take-off.

In parallel, a disconnection was noted between Commission Regulation (EU) No 965/2012 (take-off with contamination possible if permitted in the AFM), and CS-25 (performance demonstrations are conducted on a clean aircraft).

EASA launched rulemaking task RMT.0118 in March 2017, through the published terms of reference (toR) to:

- 1) mitigate the risk of degradation of aeroplanes' performances/controllability consecutive to aerodynamic surfaces contamination by ice or de-/anti-icing fluid;
- 2) address SRs;
- 3) ensure consistency between EU Air-OPS and provisions in CS-25[1].

This exercise should consider changes to CS-25 and CS-23, as well as potential retroactive requirements.

A rulemaking group (RMG) was created to support EASA in preparation of an NPA.
The RMG was composed of industry associations represented by aircraft manufacturers (Airbus, ATR, Boeing, Bombardier (Chair), Dassault, Embraer, Pilatus and Textron) and aviation authorities (EASA, the CAA of Finland (TRAFI), the FAA, and Transport Canada).

The RMG addressed these issues by structuring them into 3 subtasks to be looked at:

- Subtask A: possible means to alert the pilots about aircraft potential unnoticed contamination: prevent take-off in icing condition with unnoticed contaminated wing
- Subtask C: demonstration of adequate aerodynamic performance of the aircraft treated with de-icing/anti-icing fluids
- Subtask B: Address the disconnection between Ops regulation and CS-25, with demonstration of adequate aircraft performance when the AFM would allow contamination at take-off (e.g. take-off with pre-defined contamination).

The group met regularly between 2017 and 2021 to review those issues, while adapting to the schedule of the rulemaking task. This report contains the outcome of the group discussions and its proposals for EASA with respect to each one of the subtasks.

EASA has considered this report in drafting NPA 2022-XX .

[1] This RMT reflects certain conclusions/recommendations of BIS ice on ground.

Most of the group recommendation have been reflected in the NPA published on EASA's website. This report provides additional information on the backgroundµ/rationale of EASA's proposal.

SUB GROUP (A): TAKEOFF WITH UNNOTICED AIRFRAME GROUND ICING CONTAMINATION

EXECUTIVE SUMMARY

The objective of this task is to mitigate the risk that **a take-off in icing condition with unnoticed contaminated wings** is initiated.

This report proposes to:

- not introduce the mandate of an on-board system to detect and alert the crew on the presence of ice on certain aircraft critical surfaces on new designs or already certified types
- continue to insist on training and raising awareness of affected stakeholder;
- ensure standardization of the information provided in the AFM.

In reviewing the circumstances of the three accidents and associated Safety Recommendations identified in the ToR, in addition to information on other accidents and incidents of a similar nature, past and current certification standards and the state of development of relevant technologies, it is the considered position of the group that no new regulations are warranted in respect of this risk. This is based on the impracticality of adding "robustness" with regard to inadvertent on-ground contamination to existing or future designs (per SR FRAN-2009-001), the immaturity and other issues associated with introduction of detection technologies (per SRs UNKG-2003-060 and FRAN-2014-006) and the perceived effectiveness of improved training and awareness exercises in reducing the incidence of such accidents and incidents. The following sections develop each of these cases in detail.

It should be noted that task (a) is concerned with "inadvertent" contamination, that is, undetected or unaddressed contamination which represents a non-compliance to the applicable operational rules and/or aircraft limitations.

1.1. Review of History of Accidents and Incidents, and Actions Taken, Regarding this Task

There is unfortunately a long history of accidents and incidents where a take-off was (suspected to have been) commenced with contamination on the wings (Appendix 2 of BEA report lists 44 such accidents between 1989 and 2013); in addition, incidents have occurred where other critical surfaces have been (or are believed to have been) similarly contaminated. The overwhelming common factor in these accidents and incidents were failure to ensure that the aircraft critical surfaces, and especially the wing, were free from contamination, which was noncompliant to the applicable AFM limitations and operational regulations.

Responses to address such accidents have generally been targeted towards improving the operational compliance, largely through training and awareness activities. Where design changes have been introduced these have been as mitigating factors for the operational non-compliance rather than to address design non-compliance; for example, EASA AD #2009-0008 for F28 Mark 0070 and Mark 0100 aircraft includes the following statement:

> *If these events would have been directly attributable to design-related causes, this occurrence rate would be beyond the acceptable limit for continuing airworthiness. However, these events are established to have been caused by operational (human) factors instead.*

As examples of mitigating actions taken for some specific aircraft types:

- For the Fokker types, a range of training and awareness activities were conducted by the OEM, in addition to limitation changes, procedure changes and design changes both optional and mandated by regulatory action.
- For the Challenger/CRJ types, a range of training and awareness activities were conducted by the OEM, as well as being mandated through regulatory action, in addition to limitation changes, procedure changes and design changes.
- For the Caravan, a range of training and awareness activities were conducted by the OEM. Training was mandated through regulatory action.

All three of the above types saw a significant reduction in the accident and incident rate following the implementation of the above mitigating actions.

As a more general action, regulatory changes, including such things as emphasis for awareness actions, has also significantly impacted the more general accident rate. For example, following increased FAA emphasis on the hazard of takeoff with a contaminated wing (such as eliminating the allowance for "polished frost") the accident rate for part 23 aircraft has reduced

1.2. Robustness to On-Ground Contamination

The safety recommendation relating to this aspect of the group's work is SR FRAN-2009-001 which recommends "…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." It should be noted that this is interpreted as inadvertent contamination, as would occur due to a deviation from expected procedures and operational requirements. Intentional, allowable forms of contamination already exist (e.g. under wing cold-soak fuel frost), and these, plus any proposals for additional "allowable contamination", are considered as part of the activities of Task (b). While "allowable contamination" can be bounded by various means, inadvertent contamination is harder, and perhaps impossible, to practically bound.

Impracticality of defining a reference ground icing environment - For in-flight icing contamination well defined atmospheric icing conditions, flight conditions and associated methodologies are used to define the contamination(s) to be tested and for which compliance is shown (CS-25, Appendices C and O). No analogous set of standards exist for the ground icing environment. The degree of inadvertent contamination to be considered is not – and cannot reasonably be – quantified without development of similar definitions of reference ground icing environments taking also into consideration the fact that the applicable ground icing conditions would need to be considered for the undetermined period of time during which the airplane is on ground. Such an effort would be of a much larger scope than envisioned by RMT.0118.

A definition of reference ground icing conditions would need to consider the basic operational requirement that the critical surfaces must be clean and consequently any amount of contamination represents an operational error. There appears to be no reasonable basis on which to define the magnitude of such contamination. Instances of contamination ranging from “traces” of frost, not even equivalent to contamination levels typically used to represent pre-activation ice in-flight, to “severe” levels of ice and snow have been reported. There appears to be no direct correlation between the level of contamination and the resulting consequences; this may be in part due to differing sensitivity of different designs, but is also likely associated with the precise nature, position, etc. of the contamination. Due to the open-ended nature of the operational error assumption, the number of conditions and types of contamination that would need to be defined is much larger than for in-flight icing and would likely result in an unwieldly number of variables to reflect in a standard.

Fundamental sensitivity to wing contamination during takeoff - The group has identified a number of aircraft models which have suffered accidents or incidents related to contamination on takeoff, but where the design has been shown to possess a measure of robustness to in-flight wing contamination, either by actually complying to various regulations regarding such, or during development testing which was not subsequently used for the purpose of showing compliance. It is therefore evident that some measure of robustness to contamination would not be enough, without bounding conditions, to provide immunity to such inadvertent on-ground icing scenarios. These examples also highlight that robustness to in-flight wing contamination does not necessarily imply robustness to contamination due to ground icing conditions. Although existing standards for takeoff speed safety margins have been proven over many decades to be safe for a wide variety of conditions and operations as approved via airplane flight manuals, the stall and lift generating characteristics of airplanes are fundamentally sensitive to contamination. The way to maintain those margins is to assure that the airplane critical surfaces are free of contamination prior to takeoff.

Unintended consequences of mitigating “slight contamination” – If contamination were to be assumed present regardless of other actions and procedures, the result would be increased takeoff speeds. While that would indeed create increased margin to stall, it would come at a considerable penalty. The effect of the contamination would need to be taken into account for all conditions and therefore all takeoffs. If the aircraft were to routinely operate at, for instance, 5-10 knots faster, then the consequences of a given runway excursion would be correspondingly worsened as runway incidents are much more common than incidents associated with contamination. The net effect on safety due to increased takeoff speeds for every takeoff would almost certainly be adverse. Additionally, the economic impact would be significant as increased takeoff speeds would result in degraded performance, thereby reducing utility of the aircraft.

In summary, the group does not believe that a change in certification specifications to include inadvertent ground icing contamination is practical nor would lead to improved safety.

1.3. Introduction of On-Ground Detection Technologies

Two of the Safety Recommendations highlighted in the ToR address the question of improved detection of contamination. SRs UNKG-2003-060 recommended that authorities “… consider requiring a system that would directly monitor aircraft aerodynamic surfaces for ice contamination and warn the crew of a potentially hazardous condition” and FRAN-2014-006 recommended that 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”.

The idea of some form of automated or semi-automated means of detecting ice contamination on-ground using technical means, as opposed to the current standard of observation/inspection by humans, has been studied for many years, including through the SAE G-12 committees. These devices have been termed GIDS or ROGIDS – (Remote On) Ground Ice Detection Systems – and have generally been considered as off-aircraft systems, employed to enhance or replace present on-ground inspection processes.

While there remain some technical issues to be resolved for ROGIDS devices, the group acknowledges that there is potential for improving the existing inspection processes by using such means to supplement existing processes. However, it must be also noted that there would remain weaknesses in the inspection scheme regardless.

Firstly, unless the system were applied immediately before brake release, there would remain an opportunity to (re-)contaminate an aircraft prior to takeoff; if the ROGIDS were applied following a de-icing/anti-icing treatment, fluid failure would still be unaddressed. If it were applied at the gate, or prior to fluids application, then improper application would be undetected. Essentially, the elapsed time between “ROGIDS inspection” and takeoff would remain to be covered by existing, mainly procedural, means. (It should be noted that exposure to events subsequent to an inspection applies to any inspection means, not just ROGIDS; it is specifically applicable here as it impacts the scale of deployment of the system which is required)

1.4. Secondly, to deploy a system-wide ROGIDS infrastructure would come at significant expense; restricting deployment to, say, airports with (significant) scheduled services would alleviate some of that cost, but at the penalty of concentrating resources on the least-at-risk sector, scheduled airline service, where the winter ground operations are already well regulated and developed. Providing ROGIDS coverage to a wider network would likely be prohibitively expensive. Introduction of On-Aircraft Detection Systems

Onboard ice detection systems would not be technically feasible nor operationally reliable to detect the many forms of precipitation and environments worldwide which may occur at varying criticality at any location on a given airframe. It is recognized that onboard ice detection systems exist today, but only in a targeted design to detect a specific and known contamination scenario on a specific part of an aircraft.

1.5. Training and Awareness Recommendations

As described in section 2.1, training and awareness activities have played an important, if not key, part in improving the safety of certain aircraft types which had higher than nominal incident rates. Additionally, manufacturers of other types and regulators and industry associations have undertaken both targeted and general campaigns for improved winter operations procedures, which have also reduced the frequency of events generally.

Bearing in mind the proven potential for training and awareness improvements to address the risk, the group recommends that organizations continue to take steps to expand on knowledge and transfer lessons learned and best practices for winter operations, without introducing any additional training requirements. It should be recognized that the regulatory regime for winter operations does vary between types of operations; it is not the intent of this recommendation that such differences be eliminated.

1.6. AFM Limitations with regard to On-Ground Contamination

A review of a number of EASA-approved Flight Manuals for various aircraft indicates that there can be inconsistency in the manner in which critical surfaces (which must be free from contamination) are identified, and what (if any) inspection criteria are specified for these surfaces. FAA-approved manuals for the same types were found to be similar to the EASA manuals.

The group believes that, in line with the recommendation in section 2.3 to disseminate best practices, standardization and consistency in such limitations is strongly recommended:

> For CS23 aircraft, it is recommended that a standardized form of wording be used, such as is recommended in ASTM xyz. It is also recommended that tactile and visual check wording in the ASTM be applicable to level 3, as well as high speed and level 4 aircraft
>
> For all aircraft, but with especial applicability to CS25 types, that existing alleviations with regard to such items as lower surface fuel frost be explicitly stated in the AFM to align with EASA operational regulation wording

In general, CS25 aircraft do not contain limitations or procedures associated with cold weather operations in the AFM, but rather in other crew manuals. It is recommended that OEMs (Both CS23 and CS25) work together to determine and share best practices with regard to such material. It is considered this could also possible be done under the auspices of SAE G-12, and include both regulator and airline participation.

1.7. Recommendations

With respect to subtask (a), inadvertent on-ground contamination, the group recommends that

- (i) Globally recognized deicing standards and recommended practices be adopted and utilized by manufacturers and industry groups. (For example, International Civil Aviation Organization (ICAO) Doc 9640-AN/940 Manual of Aircraft Ground De-icing/Anti-icing Operations, Society of Automotive Engineers (SAE) Aerospace Standards (AS) AS6285 - Aircraft Ground Deicing/Anti-Icing Processes, AS6286 - Training and Qualification Program for Deicing/Anti-icing of Aircraft on the Ground and AS6332 - Quality Assurance Program for Deicing/Anti-icing of Aircraft on the Ground).
- (ii) Training and awareness activities undertaken by regulators, manufacturers and industry groups be continued with the goal of ensuring that winter operations standards and best practices are disseminated throughout the industry. (For example, issuance, as necessary, of SIB, SAFO, etc.)
- (iii) That no new regulation with respect to “robustness” is warranted.
- (iv) That no new regulation with respect to mandating the use of “means of detection” for contamination be adopted, but that the technology continue to be studied for possible future applications (e.g. through SAE G-12)
- (v) That with respect to aircraft manuals

a. For CS23 aircraft, that standardization be applied to the form of AFM limitations with regard to contamination with critical surfaces, including where necessary amendment to guidance material (ASTM) to achieve such standardization.
b. For all aircraft, but with especial applicability to CS25 types, that existing alleviations with regard to such items as lower surface fuel frost be explicitly stated in the AFM to align with EASA operational regulation wording
c. That OEMs work together to determine and share best practices with regard to FCOM/FCTM material. It is considered this could also possible be done under the auspices of SAE G-12, and include both regulator and airline participation.

SUB GROUP (B) PERFORMANCE AND HANDLING QUALITIES IMPACTS WITH AFM DEFINED PRE-TAKEOFF FROZEN CONTAMINATION

EXECUTIVE SUMMARY

The objective of this task is to mitigate the potential risk that **AFM defined pre-takeoff frozen contamination** may have on the aerodynamic performance, safety margins and maneuverability and controllability of the aeroplane at take-off.

This report proposes to:

- Make no changes to CS 23 Amendment 5
- Update CS 25 Amendment 25 to include a new requirement CS 25.1595, for dispatch with **AFM defined pre-takeoff frozen contamination** and Amend CS 25 Amendment CS 25.1583, to require the furnishing of performance information via the AFM
- Create a new AMC, linked to the amended CS 25.1595 requirement.

The following proposed changes should be considered by other regulatory agencies or specification control organizations:

- Recommend harmonization by FAA and TCCA

The proposed changes are based on lessons learned and proposals submitted by affected stakeholders.

The proposed changes are expected to ensure a consistent approach with regard to approving take-off with frozen contamination.

The proposed changes are intended to align EASA CS25 with existing CAT-OPS and NCC-OPS regulations regarding permissible pre-takeoff contamination as defined in the AFM.

In the interest of harmonization, the FAA may consider implementing only combinations of Part 25 and Part 121 via 121.629. TCCA may consider implementation only with combinations of AWM 525 and CARS Subparts 604, 704 and 705. Additionally, it is recognized that in order to implement the technical recommendations of this report for other regulatory frameworks or legal perspectives, it may be necessary to make updates to those individually impacted regulations.

1 EXPLANATORY NOTE FOR SUBTASK (B)

1.1 BACKGROUND

The EASA OPS regulations allow the commander of an aeroplane to takeoff an aircraft with ice accretion if the AFM allows. Currently there are no related CS-23 or CS-25 certification specifications or acceptable means of compliance to provide a compliance vehicle for an aircraft manufacturer to furnish such compliance information in the Airplane Flight Manual consistent with the provisions of the air operations regulations. This NPA is to address the existing gap between operational and type certification regulations.

Refer to TOR RMT.0118 (25.074) [REF §4.1.1].

1.1.1 RELEVANT INDUSTRY PRACTICE

The industry has additionally conveyed several operational scenarios which should be considered as part of this NPA as certain forms of frozen contamination have been shown to have negligible impact on the performance and controllability of the aircraft.

These currently include:

- Upper wing cold soaked surface frost, forming away from aerodynamically critical areas like the leading edge and control surfaces in non-icing conditions, and at facilities that may not have de/anti-icing equipment
- Under wing cold soaked surface frost in areas of the fuel tanks are currently accepted as an industry practice without clear operational implementation or approvals
- Inability to properly complete pre-takeoff contamination checks of wingtip devices not visible from the cockpit or cabin (i.e. scimitar lower blades, freighter aircraft, or larger span swept wings)
- Regulatory inconsistencies related to upper fuselage frost

The direction of the industry toward standardized guidance related to ground icing procedures has improved some of these operational scenarios. FAA-Approved Deicing Program Updates, Winter 2020-2021 (FAA N8900.557) addresses procedures for de/anti-icing treatment of wingtip devices and upper surface frost on specified models to address those operational realities. However, these scenarios that have been shown to have insignificant airplane level performance or handling impacts, face complex implementations for the industry through less preferred workarounds to address a recognized gap in the current certification specifications or guidance.

This NPA acknowledges these operational realities and proposes to provide a certification path to address them without any impact to safety. It lays out a clear compliance path for manufacturers to furnish the necessary knowledge to the operators (via a manual) while seeking approval of winter operational procedures.

1.1.2 RELATED ISSUES

In addition to issues relating to accretion of Cold Soaked Surface Frost (CSSF) on-ground, and the procedures to be followed to permit this contamination to be present for take-off, a related phenomenon is the in-flight formation of Cold Soak Surface Frost on the upper wing. This has been considered as possible in the vicinity of either massive structural elements or of cold-soaked fuel in contact with the wing skin. Such frost has been reported in the literature (e.g. AIAA-2012-3323) [1] and has been observed during certification flight testing by some OEMs. Firstly, it should be noted that although this phenomenon has been widely reported, and the mechanism for the formation of such frost is relatively straightforward such that it would not be considered exceptional, no service difficulty has ever been reported, either to any aircraft manufacturer or to any authority, in connection with such frost formation. The only consequence reported has been the requirement to address the presence of such frost prior to the subsequent take-off.

Secondly, based on a comparison of the reported areas of frost coverage, and the expected nature of such frost, and considering both existing research into the effect of contamination coverage on wings [2] and company-proprietary information, the group has concluded the presence of roughness due to CSSF on the upper surface of the wing not forward of the front spar has negligible impact on lift or drag, and much less than that of ice shapes considered for certification in flight.

Based on the above considerations, it is considered that the presence of in-flight CSSF on the upper wing in the areas expected presents no safety or certification concerns, and no action (e.g. additional rulemaking) should be undertaken in this regard. This conclusion should be revisited when considering new, novel wing designs, which may include changes to materials or relocation of sources for CSFF.

It should be noted that this position is relevant only to in-flight CSSF on the upper wing. Limited service experience with permitting such contamination for take-off gives no corresponding operational record upon which to rely, and the certification assumptions of a clean wing for take-off are very different to the assumption of ice shapes for in-flight icing. For the allowance of CSSF on the upper wing for take-off, reference should be made to the discussion and guidance provided below.

1.2 WHAT WE WANT TO ACHIEVE?

The key objectives to address these in-service issues therefore identify the following AFM defined pre-takeoff frozen contamination scenarios:

- 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 that may develop on wingtip devices during determined holdover time
- Frozen contamination on the upper fuselage

The discussion on the objectives of this RMT also considered notable ongoing research related to these in-service scenarios presented by the ground de/anti-icing operational realities. Some of these ongoing research topics include:

- FAA/TCCA Vertical Tail Contamination Research
- AALTO University Environmental Frost Accretion and Fluid Flow-Off
- FAA & Baylor University Cold-Soak Fuel Frost Accretion
- FAA/TCCA Artificial Snow

Although research such as the CSFF accretion projects may contribute additional knowledge to these already identified in-service issues, other research such as the FAA/TCCA/SAE Vertical Tail Contamination project may present future Policy or Rulemaking considerations related to possible contamination and the vertical tail and rudder control surfaces. The current activity should not prohibit future considerations that possible contamination on the vertical tail may present, but the vertical tail is also considered outside of the scope of this current rulemaking activity.

It may also be considered appropriate to contain the scope of this particular rulemaking activity to have an achievable recommendation within the timeline of this commissioned project. This will also provide the appropriate bounds to prevent the applications from being applied to unintended circumstances. Therefore, it is recommended that frozen contamination on wing leading edges and control surfaces, which are known to have been a contributor to accidents and incidents in the past, should be considered to be out of scope. Frozen contamination on engine intakes, propellers, or in any area where it could affect flight instrument external probe accuracy should be considered to be out of scope. Frozen precipitation conditions resulting in contamination on the wings (excluding wingtips), which are expected to be free of contamination during take-off as a result of current de/anti-icing practices, should be considered to be out of scope. Frozen precipitation on the vertical tail plane, due to possible impacts to directional control (i.e. considerations such as VMCA/VMCG impacts) which current standards with or without icing do not have inherent margin, should be considered to be out of scope. Frozen precipitation on the horizontal tail plane, which are expected to be to be free of contamination during take-off as a result of current de/anti-icing practices, should be considered to be out of scope. Non-localized contamination, such as radiation frost from an aircraft parked overnight with a clear sky, should also considered out of the scope of this rulemaking task. These considerations for scope reduce the subset of impacted regulations to better achieve consensus on the proposed changes.

The out-of-scope concepts discussed may be more associated with the identified known in-service issues, and although they may be applicable to future areas coming out of these research projects, there would need to be more consideration for any new areas for a given future application.

It has been determined that the focus of this RMT activity for specified frozen contamination scenarios will be on CS25 type certified aircraft for the following reasons:

- With recent changes to CS23 and its transition to international standards, detailed prescriptive rules are no longer appropriate in CS23
- The environment for commercial air transport (typically aircraft certified per CS 25) more often face operational constraints (e.g. quick turn aircraft with CSFF and no deicing equipment)
- It is recognized that CS25 certified aircraft operating under CAT.OP.MPA.250, SPO.OP.175 or NCC.OP.185 typically operate with more constraints related to winter procedures and training programs
- Best potential alignment for future harmonization with the FAA and TCCA.

This further recognizes the fact that any rule change allowing an **AFM defined pre-takeoff frozen contamination** shall be commensurate with operators' winter operations and training procedures to ensure the long-standing safety record of the "keep it clean" philosophy are not sacrificed. It is understood that various category aircraft under EASA operational rules CAT.OP.MPA.250(a), SPO.OP.175(b) and NCC.OP.185(a) are required to have an approved winter operations manuals. However, limiting this activity to CS25 aircraft further supports eventual harmonization of intent by FAA in which Part 121 aircraft operation requires an approved winter procedures manual per CFR 121.629(a), but not explicitly required for Part 91 or 135 aircraft per CFR 91.527 or 135.227. Therefore, FAA CFR 91.527 and 135.227 are considered outside of the scope of this task to best encourage eventual harmonization.

Cold soaked surface frost accreting in flight was also discussed as part of this rulemaking task. It is recognized that cold soaked surface frost may occur under certain atmospheric conditions with higher quantity fuel loadings remaining, but that the occurrence of frost on the upper surface of the wing box, away from the leading edges and control surfaces, further substantiated by industry research including AIAA 2012-3323 Inflight Cold-Soaked Fuel Frost Observations and Analysis would have benign effects on performance or handling qualities [2]. Further, the consideration of hold ice or failed ice in showing compliance to Appendix C ice shapes may envelope the scenario of frost on the wing upper surfaces. Further, the group is not aware of any in service occurrence suggesting that in-flight frost accumulation on cold soaked surfaces (adjacent to the fuel tanks or massive structural parts) resulted in any adverse effects on controllability or performance at the aircraft level. This included an exhaustive search of all regulatory accident/incident/event databases tools (e.g. EASA ECCAIRS, TCCA CADORS, as well as all involved manufacturers event history and customer inquiries).

The rulemaking group has taken into account current design practices and technology in developing the guidance within this report.

1.3 REVIEW OF THE EXISTING CERTIFICATION SPECIFICATION

A review of the impacted requirements in the existing certification specification was conducted and is summarised below. Discussion to existing regulations in this section shall be used to determine affected regulations, and not necessarily to identify required changes to include in the NPA. This review was made considering the proposed recommendation for CS 25.1595, AFM Defined Pre-takeoff Contamination, which would address affected regulations as part of the corresponding AMC.

It should also be recognized that the Flight Test Harmonization Working Group (FTHWG) has completed a report related to High Angle-of-Attack Limiting Function (HALF) (REF: https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/09%20-%20FTHWG_Final_Report_Phase_2_RevA__Apr_2017.pdf) that are expected to be released in NPA form in similar timing to this rulemaking effort. This report focuses on the existing EASA CS25 at Amendment 25, however, pending the timing of the FTHWG HALF NPA, should be considered by EASA in parallel. This has been discussed by this group and the proposed changes are not expected to conflict with the proposed changes for HALF updates. There are instances where these recommendations may impact the same regulations.

1.3.1 EASA CERTIFICATION SPECIFICATION – CS 25 AMENDMENT 25

CS 25.21(g) Proof of Compliance

This requirement is considered relevant as the 25.1595 **AFM defined pre-takeoff frozen contamination** shall be considered in combination with 25.21(g) take-off ice or final take-off ice, if approval of **AFM defined pre-takeoff frozen contamination** is sought. . No text updates are necessary to 25.21(g) directly, however, changes are needed in Appendix C and Appendix O aspects related to 25.21(g).

Consistent with Appendix C and Appendix O flight phase definitions for take-off and final take-off ice, **AFM defined pre-takeoff frozen contamination** is assumed not to exist to subsequent phases of flight. It is recognized that some larger **AFM defined pre-takeoff frozen contamination** scenarios may physically persist on the aircraft into subsequent flight phases, but current standards for subsequent flight phases have been considered, and it is understood that the critical ice shapes for those subsequent phases that exists today would envelope any safety concern of the possible combination. It has been operationally accepted that limited lower wing contamination would have no adverse effect on performance or controllability. However, from a Type Certification perspective, this has not been directly assessed, nor has not been considered in combination with take-off ice or final take-off ice. Winglet contamination may be considered in combination with take-off ice or final take-off ice, whereas, cold soaked surface frost is generally a phenomenon that occurs in warmer and more humid environments not generally commensurate with icing conditions.

CS 25.33 Propeller Speed and Pitch Limits

This requirement was considered in the review and determined not applicable, as the propeller will not be an allowed **AFM defined pre-takeoff frozen contamination** and will be required to be de-iced.

CS 25.101 Performance – General

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant in the cases where recalculation of the take-off performance is warranted by changes identified due to **AFM defined pre-takeoff frozen contamination**. As a general principle, the aircraft performance determined in the following regulations should be determined in a consistent fashion should any change be found necessary in addressing **AFM defined pre-takeoff frozen contamination**.

CS 25.103 Stall Speed

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** with respect to the requirement of 25.103(b)(3) that the aircraft be in the appropriate condition or configuration.

CS 25.105 Take-off

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** in the cases where speeds are impacted if there is any appreciable impact to lift-off speeds or climb gradient for the given **AFM defined pre-takeoff frozen contamination**.

CS 25.107 Take-off speeds

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** in the cases where speeds are impacted if there is any appreciable impact to lift-off speeds for the given **AFM defined pre-takeoff frozen contamination**.

CS 25.109 Accelerate-stop Distance

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant if the effects of the **AFM defined pre-takeoff frozen contamination** require a change in take-off speeds.

CS 25.111 Take-off Path

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant if the effect on stall speed or climb gradient of the **AFM defined pre-takeoff frozen contamination** is appreciable.

CS 25.113 Take-off distance and take-off run

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant if the effects of the **AFM defined pre-takeoff frozen contamination** require a change in take-off distance.

CS 25.115 Take-off flight path

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant if the effect on stall speed or climb gradient of the **AFM defined pre-takeoff frozen contamination** is appreciable.

CS 25.117 Climb: general

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant if the effect on stall speed or climb gradient of the **AFM defined pre-takeoff frozen contamination** is appreciable.

CS 25.119 Landing Climb: All-engines-operating

This requirement was considered in the review and determined not applicable, as the **AFM defined pre-takeoff frozen contamination** not need to be considered for flight phases subsequent to final take-off.

CS 25.121 Climb: One-engine-inoperative

It is not proposed to amend this regulation. However, requirements (a), (b) and (c) shall be considered by the applicant if the effect on stall speed or climb gradient of the **AFM defined pre-takeoff frozen contamination** is appreciable. Requirement (d) was considered in the review and determined not applicable, as the **AFM defined pre-takeoff frozen contamination** does not need to be considered for flight phases subsequent to final take-off.

CS 25.143 Controllability and Manoeuvrability – General

It is not proposed to amend this regulation. However, portions of this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. CS 25.143(a)(1) and (2), 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 for take-off and final take-off flight phases, respectively) and 25.143(k) should be addressed. 25.143(b)(1) & (b)(2) are not applicable as this would be in icing conditions which are addressed by 25.143(c). 25.143(i) would not apply as the horizontal tail plane would not be a surface with **AFM defined pre-takeoff frozen contamination**. 25.143(j) is not applicable as this is associated with pre-activation ice, and procedural aspects and system efficiency should be accounted for in the definition of take-off ice. 25.143(l) are not applicable as compliance demonstrations with this requirement may be performed without ice accretion.

Usually a qualitative evaluation is enough to evaluate the aeroplane's controllability and manoeuvrability, added by a limited amount of quantitative data, e.g. control forces and deflections. In the case of marginal compliance, or the force or stick force per g limits being approached, additional substantiation may be necessary to establish compliance.

Currently, manoeuvres used by industry for these evaluations, at the scenario of **AFM defined pre-takeoff frozen contamination**, might include manoeuvre capability, pull-ups, AEO and OEI lateral control characteristics evaluation.

CS 25.145 Longitudinal Control

This requirement is not applicable for consideration of **AFM defined pre-takeoff frozen contamination**, as the considerations included are flight phases or configurations not associated with takeoff.

CS 25.147 Directional and Lateral Control

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant (except for CS 25.147(a) as that addresses the approach phase of flight) for consideration of **AFM defined pre-takeoff frozen contamination**.

Qualitative evaluations in combination with other testing are enough for lateral control evaluation.

Currently manoeuvres used by industry for these evaluations, at the scenario of **AFM defined pre-takeoff frozen contamination**, such as CSFF, might include 30 degree banked turns.

CS 25.149 VMCG & VMCA

In-scope areas of **AFM defined pre-takeoff frozen contamination** were considered to have negligible impacts to VMCA and VMCG. This requirement is not applicable, as contamination of the vertical tail plane is not considered in the scope of this task.

CS 25.161 Trim

It is not proposed to amend this regulation. Portions of this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. CS 25.161(c)(2) landing requirements (glide) are not applicable.

Qualitative evaluations in combination with other testing are enough for trim evaluation.

No dedicated manoeuvre is used by the industry to evaluate trim characteristics.

CS 25.171 Stability - General

It is not proposed to amend this regulation. This requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**.

Qualitative evaluations in combination with other testing are enough for stability evaluation.

No dedicated manoeuvre is used by the industry to evaluate stability characteristics.

CS 25.173 Static longitudinal stability

This requirement is not applicable, since the conditions specified in CS 25.175 are considered not applicable.

CS 25.175 Demonstration of Static Longitudinal Stability

These requirements are not applicable, since the conditions specified in CS 25.175(a), (b), (c) and (d) represent climb, cruise, approach and landing flight phases.

CS 25.177 Static Directional and Lateral Stability
It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**.

Qualitative evaluations in combination with other testing are enough for static directional and lateral stability.

CS 25.181 Dynamic Stability
It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**.

Qualitative evaluations in combination with other testing are enough for dynamic stability evaluation.

CS 25.201 Stall Demonstration
Portions of this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. 25.201(c)(2) is not required to be demonstrated for Appendix C and Appendix O ice shapes under the current rule, so similarly is not required for **AFM defined pre-takeoff frozen contamination** scenarios.

CS 25.203 Stall characteristics
It is not proposed to amend these requirements. Portions of this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**.

A stall characteristics evaluation program shall be conducted, mainly if the **AFM defined pre-takeoff frozen contamination** includes part of wings like upper surface CSFF or wing tip devices contamination. This is one of the options already used currently by the industry in this type of contamination.

CS 25.207 Stall Warning
It is not proposed to amend this regulation. Portions of this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. 25.207(h) and 25.207(i) are not applicable as these are associated with pre-activation ice, and procedural aspects and system efficiency should be accounted for in the definition of take-off ice.

Usually this requirement is evaluated in conjunction with CS 25.201 and CS 25.203 using the same evaluation program.

25.231 Ground Handling Longitudinal
This requirement was considered in the review and determined not applicable, as the **AFM defined pre-takeoff frozen contamination** would have no effect on longitudinal control related to nose over situations more prevalent on tail wheel aircraft, or braking actions during the taxi.

25.233 Ground Handling Directional
The considered **AFM defined pre-takeoff frozen contamination** on other areas of the aircraft were considered to have negligible impacts to lateral ground handling. This requirement is not applicable, as contamination of the control surfaces is not considered in the scope of this task.

CS 25.237 Wind Velocities

Portions of this requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. 25.237(a)(3) is not applicable as **AFM defined pre-takeoff frozen contamination** ice not considered during the landing phase.

CS 25.251 Vibration and Buffeting

It is not proposed to amend this regulation. However, portions of this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** in the cases that accumulation may be present on aerodynamic surfaces that may introduce buffet differences to the baseline, clean airplane. CS 25.251(b)(c)(d)(e) are not required to be demonstrated for Appendix C and O ice shapes under the current rule, so similarly is not required for AFM allowed defined pre-takeoff frozen contamination scenarios.

CS 25.629 Aeroelastic stability requirements

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** in the cases that a significant mass accumulation may occur.

CS 25.1091(d)(2) Precipitation Covered Runways

This requirement was considered in the review and determined not applicable, as this is mostly relevant to surface or airport contamination. Contamination ingestion of this subparagraph is considered to be addressed through 25.1093(b) related to possible aircraft surface contamination shedding.

C25.1091(e) Air Intake System

This requirement was considered in the review, on the basis it had previously existing in EASA CRIs, and determined not applicable, as this is mostly relevant to ingestion of Rain and hail (CS-E 790) and bird strike (CS-E 800).

CS 25.1093(b) Powerplant Ice Protection

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** consistent with AMC 25.1093(b). This may be a concern for contamination scenarios that may shed from surfaces upstream of a rear mounted engine inlet.

CS 25.J1093 Air Intake System Icing Protection

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for AFM defined pre-takeoff frozen contamination consistent with AMC 25.J1093. This may be a concern for contamination scenarios that may shed from surfaces upstream of an APU inlet.

CS 25.1309(b)(c) Equipment, Systems and Installation

It is not proposed to amend this regulation. However, this requirement shall be considered by the applicant for **AFM defined pre-takeoff frozen contamination** where this is dependent on a system behavior.

CS 25.1323, 25.1324, 25,1325 External Air Data Probes

This requirement was considered in the review and determined not applicable, as the surfaces in the proximity will not be an allowed **AFM defined pre-takeoff frozen contamination** scenario and will be required to be de-iced.

CS 25.1419 Ice Protection and CS 25.1420 Supercooled large drop icing conditions

This requirement is considered relevant as the **AFM defined pre-takeoff frozen contamination** shall be considered in combination with Appendix C or O take-off ice or final take-off ice, if approval of **AFM defined pre-takeoff frozen contamination** is sought in icing conditions. No text updates are necessary to 25.1419 and 25.1420 directly, but will be needed in Appendix C and O aspects.

CS 25.1501 Operating Limitations and Information: General

It is not proposed to amend this regulation. However, per requirement (a), any limitation or other information related to **AFM defined pre-takeoff frozen contamination** necessary for safe operation of the aeroplane must be established.

CS 25.1533 Additional Operating Limitations

This requirement is considered relevant to establish an operating limitation to define any **AFM defined pre-takeoff frozen contamination** allowed for take-off.

CS 25.1581 Aeroplane Flight Manual: General

It is not proposed to amend this regulation. However, requirement (a) shall be considered by the applicant should unique information related to **AFM defined pre-takeoff frozen contamination** be necessary for safe operation of the aeroplane.

CS 25.1583 Aeroplane Flight Manual: Operating limitations

It is proposed to amend this regulation to add a new subparagraph 25.1583(l) to address any limitations related to **AFM defined pre-takeoff frozen contamination** established under CS 25.1533 be furnished in the AFM.

CS 25.1585 Aeroplane Flight Manual: Operating procedures

It is not proposed to amend this regulation. However, requirement (a) shall be considered by the applicant should there be any unique operating procedures related to operations with **AFM defined pre-takeoff frozen contamination**.

CS 25.1587 Aeroplane Flight Manual: Performance information

It is not proposed to amend this regulation. However, requirement (b) shall be considered by the applicant should established performance information be affected by operations with **AFM defined pre-takeoff frozen contamination**.

Appendix C Icing Conditions

This requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. Updates in Appendix C are proposed to remove the assumption that the airplane is clean at the start of the take-off roll, and to consider any **AFM defined pre-takeoff frozen contamination** in combination with take-off ice or final take-off ice, as applicable.

Appendix O SLD Icing Conditions

This requirement shall be considered by the applicant for consideration of **AFM defined pre-takeoff frozen contamination**. Updates in Appendix O are proposed to remove the assumption that the airplane is clean at the start of the take-off roll, and to consider any **AFM defined pre-takeoff frozen contamination** in combination with take-off ice or final take-off ice, as applicable.

1.3.2 REVIEW OF OPERATIONAL RULES

A review of EASA, FAA, and TCCA operational regulations with respect to the clean airplane concept was completed. There is an existing lack of harmonization related to aircraft type categories as well as requirements for a regulator approved procedure manual or program. Further, as a direct impact to this exercise is the lack of harmonization related to a link between operational and initial type certification rules. EASA provides this direct link with the qualifier "…in accordance with the AFM". FAA currently does not have a similar link to initial type certification. TCCA recently revised their codified an NPA to include a tie to the AFM as "...and any other critical surface identified in the Aircraft Flight Manual'.

The relevant EASA rules for commercial air transport operations (Part-CAT), for the operation of complex aircraft in the non-commercial operations (Part-NCC) and for 'specialised operations' (Part—SPO) **require an approved winter operational program (*operational* regulatory approval highlighted in green in each example below)** and **include a direct link between operational regulations and initial type certification regulations (*aircraft certification* regulatory approval path highlighted in blue below)** via a performance based requirement per the AFM. This gives the regulatory body on each side of the authority (operational and aircraft certification sides of the house) a path to approve via a deliverable a path to operate under the clean aircraft concept.

EASA 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**.*

EASA NCC.OP.185 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 pilot-in-command 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 the procedures referred to in (a)** and **in accordance with the AFM.***

EASA SPO.OP.175 Ice and other contaminants – ground procedures

*(a) The pilot-in-command 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 in the AFM**.*

*(b) In the case of operations with complex motor-powered aircraft, 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.*

The relevant EASA rules for the operation of non-complex aircraft (Part-NCO and Part-SPO) do not require an approved winter operational program, but still **include a direct link between operational regulations and initial type certification regulations** via a performance based requirement per the AFM.

EASA NCO.OP.165 ICE AND OTHER CONTAMINANTS — GROUND PROCEDURES

*The pilot-in-command 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 in the AFM.***

EASA SPO.OP.175 Ice and other contaminants – ground procedures

*(a) The pilot-in-command 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 in the AFM**.*

On the contrary, the analogous FAA rule applicable to commercial air carriers **requires an approved winter operational program**, but does not include a direct link between operational regulations and initial type certification regulations (e.g. via the AFM).

§ 121.629 Operation in icing conditions.

(a) No person may dispatch or release an aircraft, continue to operate an aircraft en route, or land an aircraft when in the opinion of the pilot in command or aircraft dispatcher (domestic and flag operations only), icing conditions are expected or met that might adversely affect the safety of the flight.

*(b) No person may take off an aircraft when frost, ice, or snow is adhering to the wings, control surfaces, propellers, engine inlets, or other critical surfaces of the aircraft or when the takeoff would not be in compliance with **paragraph (c)** of this section. Takeoffs with frost under the wing in the area of the fuel tanks may be authorized by the Administrator.*

*(c) Except as provided in paragraph (d) of this section, no person may dispatch, release, or take off an aircraft any time conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, **unless the certificate holder has an approved ground deicing/anti-icing program in its operations specifications** and unless the dispatch, release, and takeoff comply with that program. The approved ground deicing/anti-icing program must include at least the following items:*

… [(c)(1) through (c)(4) sub-list and [d] omitted for purpose of this illustration] ...

The analogous FAA operational rules applicable to non-commercial, on demand, and commuter operations (CFR 91.527 and CFR135.227) do not require an approved winter operational program, and do not include a direct link between operational regulations and initial type certification regulations (e.g. via the AFM).

§ 91.527 – Operating in icing conditions.

(a) No pilot may take off an airplane that has frost, ice, or snow adhering to any propeller, windshield, stabilizing or control surface; to a powerplant installation; or to an airspeed, altimeter, rate of climb, or flight attitude instrument system or wing, except that takeoffs may be made with frost under the wing in the area of the fuel tanks if authorized by the FAA.

§ 135.227 – Icing conditions: Operating limitations.

(a) No pilot may take off an aircraft that has frost, ice, or snow adhering to any rotor blade, propeller, windshield, stabilizing or control surface; to a powerplant installation; or to an airspeed, altimeter, rate of climb, flight attitude instrument system, or wing, except that takeoffs may be made with frost under the wing in the area of the fuel tanks if authorized by the FAA.

A revision in January of 2021 brings the TCCA operational rules closer to the EASA implementation, which **require an approved winter operational program** and **includes a direct link between operational regulations and initial type certification regulations (e.g. via the AFM)**. Section 602 includes the overarching rule for each category, while 604 Private Operators, 703 Air Taxi, and 704 Commuter, and 705 Airline Operations rules then tie in the core 602.11 operational rule.

602.11 (1) *In this section, critical surfaces means the wings, control surfaces, rotors, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surfaces of an aircraft**, as well as any other surfaces identified as critical surfaces in the aircraft flight manual.***

(2) No person shall conduct or attempt to conduct a take-off in an aircraft that has frost, ice or snow adhering to any of its critical surfaces.

*(3) Despite subsection (2), a person may conduct a take-off in an aircraft that has frost caused by cold-soaked fuel adhering to the underside or upper side, or both, of its wings if the take-off **is conducted in accordance with the aircraft manufacturer's instructions for take-off under those conditions**.*

(4) Where conditions are such that frost, ice or snow may reasonably be expected to adhere to the aircraft, no person shall conduct or attempt to conduct a take-off in an aircraft unless

(a) for aircraft that are not operated under Subpart 5 of Part VII,

(i)…

(ii) ***the operator has established an aircraft inspection program*** *in accordance with the Operating and Flight Rules Standards, and the dispatch and take-off of the aircraft are in accordance with that program; and*

(b) for aircraft that are operated under Subpart 5 of Part VII, ***the operator has established an aircraft inspection program*** *in accordance with the Operating and Flight Rules Standards, and the dispatch and take-off of the aircraft are in accordance with that program.*

This demonstrates that the current EASA operational rules are sufficient to support an **AFM defined pre-takeoff frozen contamination** condition as written.

In the interest of future harmonization, the FAA should consider an operational rule change in addition to the initial type certification proposed rule changes in order to enable the appropriate links between operational regulations and initial type certification regulations (e.g. via the AFM) similar to EASA and recent updates to TCCA operational regulations.

Further harmonization may also be considered related to more consistent definitions of ***critical surfaces*** in the relevant regulations and guidance material. The FAA operational regulations (14 CFR 91.529 and 14 CFR 121.629) provide for restrictions on the contamination of the airframe for takeoff. CFR 91.527 lists a series of prohibited areas of the aircraft for contamination, and does not specifically address the fuselage. CFR 121.629 adds the condition "or other critical surfaces of the aircraft" to the statement prohibiting contamination. AC120-60 provides a definition of "critical surfaces", and includes "fuselage upper surfaces for aircraft with center mounted engines". In contrast, TCCA operational regulations (CAR 622.11 and CAR 602.11) explicitly identify the upper fuselage as a critical surface for aircraft with rear mounted engines. TCCA guidance material (TP14052 and TP10643) offer a similar definition for "critical surfaces" as the FAA guidance; TP14052 in addition discussed cleaning of "other than critical surfaces" and includes the fuselage as a potential inspection item subsequent to de-/anti-icing.

It should also be noted that there are existing allowances for **AFM defined pre-takeoff frozen contamination**. These include under wing cold soak surface frost allowances in the proximity of the fuel tanks, upper fuselage contamination on rear engine airplanes, upper wing cold soaked surface frost, and wingtip device ground contamination on various type models. TCCA and FAA have implemented regulatory exemptions to the relevant operational rules, either generically or as a recurring individual operator exemption. Harmonization between EASA, FAA, and TCCA in regards to inclusion of the appropriate links between operational regulations and type certification regulations (e.g. via the AFM) would additionally alleviate the need for these existing exemptions. Further, TCCA has codified a recent NPA to incorporate existing regulatory exemptions it currently holds against their CAR OPS rules.

2 PROPOSED CHANGES - EASA CS 25 AMENDMENT 25

2.1 REQUIREMENTS

2.1.1 NEW REQUIREMENTS

It is proposed to add the following new requirement in CS 25 SUBPART G – OPERATING LIMITATIONS AND INFORMATION – Supplementary information".

CS 25.1595 AFM defined pre-takeoff frozen contamination
If the applicant is seeking certification for take-off with **AFM defined pre-takeoff frozen contamination**, any techniques and associated limitations necessary for safe aeroplane operations with defined pre-takeoff 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. (See AMC 25.1595.)

2.1.2 PROPOSED UPDATES TO EXISTING REQUIREMENTS

It is proposed that CS 25.1583 Operating limitations, is amended to include an additional subparagraph for **AFM defined pre-takeoff frozen contamination** in the AFM. Additional text is identified in **blue text**.

CS 25.1583 (l) AFM defined pre-takeoff frozen contamination
The following information must be furnished if the applicant is seeking certification for takeoff with AFM defined pre-takeoff frozen contamination.

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

(2) The operating limitations shall prohibit the combination of AFM defined pre-takeoff frozen contamination with icing environments as applicable, if not approved under the Type Certificate.

It is proposed that CS 25 Appendix C, Part II is amended to include the consideration of an **AFM defined pre-takeoff frozen contamination** scenario in combination with Appendix C take-off ice or final take-off ice, as applicable.

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-takeoff frozen contamination per CS25.1595 if approval of AFM defined pre-takeoff 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-takeoff frozen contamination per CS25.1595 if approval of AFM defined pre-takeoff frozen contamination is sought.**

CS 25 Appendix C, Part II Airframe Ice Accretions

…

(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) Aerofoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice**, unless in combination with AFM defined pre-takeoff frozen contamination per CS 25.1595,** at the start of the take-off;

It is proposed that CS 25 Appendix O, Part II is amended to include the consideration of an **AFM defined pre-takeoff frozen contamination** scenario in combination with Appendix O take-off ice or final take-off ice, as applicable for 1420(c) applications.

CS 25 Appendix O, Part II Airframe ice accretions

…

(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-takeoff frozen contamination per CS25.1595 if approval of AFM defined pre-takeoff 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-takeoff frozen contamination per CS25.1595 if approval of AFM defined pre-takeoff 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 following assumptions:

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

AMC 25.21(g) Performance and Handling Characteristics in Icing Conditions Contained in Appendix C, of CS-25

...

6.4 Take-off Path (CS 25.111). If VSR in the configuration defined by CS 25.121(b) with the “Takeoff Ice" accretion defined in Appendix C and Appendix O to CS-25 and in combination, as applicable, with the **AFM defined pre-takeoff frozen contamination per CS25.1595,** exceeds VSR for the same configuration without ice accretions by more than the greater of 5.6 km/h (3 knots) or 3%, the take-off demonstrations should be repeated to substantiate the speed schedule and distances for take-off in icing conditions. The effect of the take-off speed increase, thrust loss, and drag increase on the take-off path may be determined by a suitable analysis.

Appendix 1 – Airframe Ice Accretion

A1.2.2.1 For both unprotected and protected parts, the ice accretion identified in Appendix C and Appendix O to CS-25 for the take-off phase may be determined by calculation, assuming the following:

- aerofoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice**, unless in combination, as applicable, with AFM defined pre-takeoff frozen contamination per CS 25.1595,** at the start of the take-off;

A.1.2.2.2 The ice accretions identified in Appendix C and Appendix O to CS-25 for the take-off phase are:

- “Take-off ice”: The most critical ice accretion 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 icing environment**, and in combination, as applicable, with AFM defined pre-takeoff frozen contamination per CS25.1595 if approval of AFM defined pre-takeoff frozen contamination is sought.**
- “Final Take-off ice”: The most critical ice accretion between 122 m (400 ft) and the height at which the transition to the en route configuration and speed is completed, or 457 m (1500 ft) above the take-off surface, whichever is higher, assuming accretion starts at the end of the take-off distance in the icing environment**, and in combination, as applicable, with AFM defined pre-takeoff frozen contamination per CS25.1595 if approval of AFM defined pre-takeoff frozen contamination is sought.**

2.2 AMC

A new AMC shall be added for the **AFM defined pre-takeoff frozen contamination** requirements. The team suggest the following text for the AMC implementation:

AMC 25.1595 AFM defined pre-takeoff frozen contamination

1 PURPOSE

When requested by the applicant, take-off with **AFM defined pre-takeoff frozen contamination** may be certified. If the certification includes possible combination with take-off into icing conditions, the defined pre-takeoff 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. CSFF in non-icing conditions), the AFM defined pre-takeoff frozen contamination may be considered on its own.

The following **AFM defined pre-takeoff 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-takeoff frozen contamination** does not need to be considered for flight phases subsequent to final take-off.

The guidance for **AFM defined pre-takeoff frozen contamination** is not applicable on 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-takeoff frozen contamination** resulting 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-takeoff frozen contamination** scenarios that would be allowed, procedural aspects should be technically valid and operationally practical, consistent with AMC 1581(6)(c)(3) Procedures Development.

Aspects of AMC 25.21(g) are directly applicable for showing compliance with **AFM defined pre-takeoff frozen contamination** scenarios. For example, the **AFM defined pre-takeoff 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-takeoff frozen contamination** may be considered independently from take-off ice or final take-off ice if the AFM prohibits the combination. 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 regulations shall be considered by the applicant for the purpose of showing compliance to CS25.1595:

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-takeoff 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-takeoff frozen contamination** effects on performance in the same way as take-off ice is currently 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.

The take-off speeds prescribed by CS 25.107, the accelerate-stop distance prescribed by CS 25.109, the takeoff 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 CS25.1595 under the following conditions:

*(a) Takeoff; landing gear extended with **AFM defined pre-takeoff frozen contamination**, as applicable. In the critical takeoff 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*

(1) 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

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

(b) Takeoff; landing gear retracted. In the takeoff 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:

(1) 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:

(i) The critical engine inoperative, the remaining engines at the takeoff 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 takeoff surface; and

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

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

*(i) In non-icing conditions in combination with **AFM defined pre-takeoff 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 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

*(ii) In icing condition in combination with **AFM defined pre-takeoff frozen contamination** as applicable, with the most critical of the takeoff 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 takeoff ice accretion:*

(A) The stall speed at maximum takeoff weight exceeds that in non-icing conditions 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 takeoff flight path gradient reduction defined in CS 25.115(b).

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

(1) 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

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

(ii) The weight equal to the weight existing at the end of the takeoff path, determined under CS 25.111.

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

*(i) In non-icing conditions and in combination, as applicable, with **AFM defined pre-takeoff 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

*(ii) In icing conditions and in combination, as applicable, with **AFM defined pre-takeoff frozen contamination**, with the most critical of the final takeoff 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 takeoff ice accretion used to show compliance with CS 25.111(c)(5)(i):*

(A) The stall speed at maximum takeoff weight exceeds that in non- icing conditions 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 takeoff flight path gradient reduction defined in CS 25.115(b)

Aircraft Characteristics

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

The applicant should assess if the **AFM defined pre-takeoff frozen contamination** could impact the control and manoeuvrability 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-takeoff 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-takeoff 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-takeoff 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-takeoff frozen contamination** includes parts of wings such as CSFF or wing tip device contamination.

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

Vibration and Buffeting (CS 25.251(a))

CS 25.251(a) should be considered by the applicant for **AFM defined pre-takeoff frozen contamination** in the cases that accumulation may be present on critical aerodynamic 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-takeoff frozen contamination scenarios.

Design and Construction – Aeroelastic Stability Requirements (CS 25.629)

This requirement should be considered by the applicant for **AFM defined pre-takeoff 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-takeoff 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-takeoff frozen contamination**, as applicable.

Appendix O SLD Icing Conditions

This requirement should be considered by the applicant for consideration of **AFM defined pre-takeoff 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-takeoff frozen contamination**. Additional guidance for specific forms of contamination are 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-takeoff frozen contamination and provide all supporting data and rationale showing that:

- the defined pre-takeoff frozen contamination does not have an unacceptable affect on handling characteristics and does not have an appreciable affect on performance of the aeroplane, as required by -CS 25.1595,
- the defined pre-takeoff 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-takeoff 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 (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, in order 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 separation of 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-takeoff 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) (§1) and §AMC 25.1419 (a) (§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 AMC25.1420 (f) to comply with CS 25.1420(d) may be allowed. If additional allowed **AFM defined pre-takeoff 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-takeoff 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-takeoff frozen contamination**shape to be tested should be agreed with agency as being representative of the **AFM defined pre-takeoff 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 TESTING TO DETERMINE SCOPE OF CONTAMINATION

Flight in cold soaked environments 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. 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.

3.5 FLIGHT TESTING TO DETERMINE AERODYNAMIC IMPACTS

Flight testing may be used to demonstrate the aerodynamic impacts of the **AFM defined pre-takeoff 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-takeoff frozen contamination** shape used should be agreed with the agency as being representative of the **AFM defined pre-takeoff frozen contamination**.

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

In addition to 25.21(g) prescribed guidance, the takeoff testing prescribed in AMC 25.1597 [Note: AMC 25.1597 references EASA RMT .0118 Subgroup C Report] 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 takeoff should be considered, such as margin to stall.

Comparable to requirements for 25.1419 for in-flight ice shedding, 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 airplane 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-takeoff 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 taxi and time elapsed between the frozen contaminant detection and take-off, should also be considered during definition of the frost growth.

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.

4.2 IMPACTS

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 type model 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.

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 taken into account 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, takeoffs 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 OEMs fleets since its more widespread implementation in 1992. With these considerations, takeoff with such frost on the lower surface of the wings may be allowed without consideration of a cumulative effect with take-off ice or final take-off ice. The applicant may provide 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).

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-takeoff 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 a wingtip device does not present an appreciable impact to performance or controllability of the aircraft with possible contamination adhesion to alleviate these overly constrained operational scenarios.

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 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 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 scenario with adhering frozen contamination will be prohibited, and the wingtip device shall be initially cleaned/de-iced before the permitted contamination is accounted for.

Allowances for winglet 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 wingtips.

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 flow 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 separation in combination with the associated profile drag from the contamination adhered to the surface. In these cases, the addition of 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 manoeuvrability 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 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

(1) 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. As a consequence, for an aircraft parked in active precipitation, the maximum amount of precipitation which could accumulated on the upper fuselage is the amount which would cause expiry of 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 the most unfavorable permitted precipitation, including freezing & snow conditions, should be taken into account. 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-takeoff 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.

(2) Regarding the engine solid ice ingestion, 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.

(3) 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.

(4) 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.

(5) The applicant shall 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 system operating procedures should be identified. If takeoff procedures or speeds are modified, suitable performance adjustments (e.g. to takeoff run, takeoff 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-takeoff frozen contamination** that are allowed. Any airplane-specific restrictive information considered necessary for safe airplane operations with **AFM defined pre-takeoff 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-takeoff 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 takeoff 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 Operator's Manual (FCOM).

3 References

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SUB GROUP (C) PERFORMANCE AND HANDLING QUALITIES IMPACTS WITH USE OF DE/ANTI-ICING FLUIDS

EXECUTIVE SUMMARY

The objective of this task is to mitigate the risk that deicing/anti-icing fluids potentially have on the aerodynamic performance, safety margins and manoeuvrability and controllability of the aeroplane at take-off.

This report proposes to:

- Make no changes to CS 23
- Update CS 25 to include a new requirement CS 25.1597 for dispatch with a deicng/anti-icing fluids
- Amend CS 25 Amendment CS 25.1583 to require the furnishing of performance information via the AFM
- Create a new AMC linked to the amended CS 25.1597 requirement

The following proposed changes should be considered by other regulatory agencies or specification control organizations:

- Recommend ASTM International create a specification reflecting the new AMC 25.1597 as appropriate to CS-23 aeroplanes
- Recommend harmonization by FAA and TCCA, including FAA Policy PS-ANM-25-10
- Recommend SAE International update ARP6852 with respect to rotation speeds applicable to AOA Margin flight tests as indicated in section 1.4 of this document.

The proposed changes are based on lessons learned and proposals submitted by affected stakeholders.

The proposed changes are expected to ensure a consistent approach with regards approving the use of Type I, II, III, and IV deicing/anti-icing fluids on airplanes, and ensure the AFM identifies the specific fluid types that have been approved and that use of other fluid types is prohibited.

1 EXPLANATORY NOTE FOR SUBTASK (C)

1.1 BACKGROUND

Accidents and incidents 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 deicing/anti-icing operations. EASA has received a number of safety recommendations in this respect. It is therefore proposed to review the existing certification specifications and acceptable means of compliance and propose changes if applicable.

Refer to TOR RMT.0118 (25.074) [REF §4.1.1] [1].

1.2 RELEVANT PAST PRACTICE

Flight tests to evaluate the effect of "thickened" deicing/anti-icing fluids have sometimes resulted in operating limitations and procedures considered necessary by the type certificate holder for safe airplane operation. Thickened fluids are characterized as non-Newtonian (pseudoplastic) fluids and are specified as SAE Types II, III, and IV. Examples of such operating limitations include increased take-off rotation speeds, increased take-off distances and limitations on the use of certain take-off flap settings. Examples of operating procedures include procedures the flightcrew may need to use to rotate the airplane for take-off if use of the fluids results in requiring the pilot to exert more force on the controls to initiate airplane rotation. Type I fluids have not been associated with changes to performance or controllability but their impacts on systems operation and ICA need to be considered.

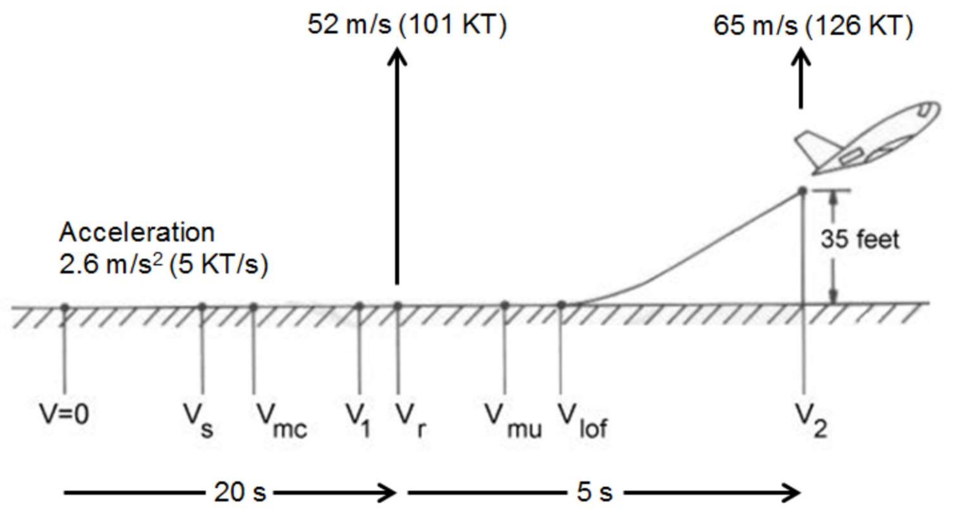
1.3 SAE STANDARDS AND GUIDANCE

The aviation industry and regulatory authorities, working through the SAE International, have established standards for ground deicing/anti-icing fluid specification, qualification of these thickened fluids so that the aerodynamic effect of deicing and anti-icing fluids is constrained, as well as recommended practices for an OEM to test for effects on a specific type model.

Ground deicing/anti-icing fluid specifications are contained in SAE AMS1424 [4] (Type I) and SAE AMS1428 [3] (Types II, III, and IV).

The objective of SAE Aerospace Standard AS5900 [2] is to ensure acceptable aerodynamic characteristics of deicing/anti-icing fluids as they flow off aeroplane lifting and control surfaces during take-off ground acceleration and initial climb. Aerodynamic acceptance of an aircraft ground deicing/anti-icing fluid is based upon the fluid's boundary layer displacement thickness (BLDT) on a flat plate, measured after experiencing the free stream velocity time history of a representative aircraft takeoff.

SAE AS5900 uses a measurement of the BLDT by the presence of a thickened fluid on a flat plate during a simulated take-off in a wind tunnel. Fluid acceptability depends on the fluid's BLDT after a representative take-off acceleration profile, the BLDT of a reference fluid, and the temperature range in which the fluid is to be used in service. The standard identifies a high-speed ramp test, used to simulate large jet aircraft, and a low-speed ramp test, used to simulate commuter turbo-prop aircraft. Take-off acceleration profiles for each of these ramp tests are shown in Figure 1 and Figure 2.



- V_S : Startup Velocity
- V_{mc} : Minimum control speed.
- V_1 : Takeoff decision speed. The speed beyond which the takeoff should no longer be aborted.
- V_r : Rotation speed. The speed at which the pilot begins to apply control inputs to cause the aircraft nose to pitch up, after which it will leave the ground.
- V_{mu} : Minimum unstick speed.
- V_{lof} : Lift-off speed.
- V_2 : The speed of an aircraft at 35 ft. altitude when climbing with one engine inoperative.

Figure 1 High Speed Ramp Acceleration Profile (ref. SAE AS5900)

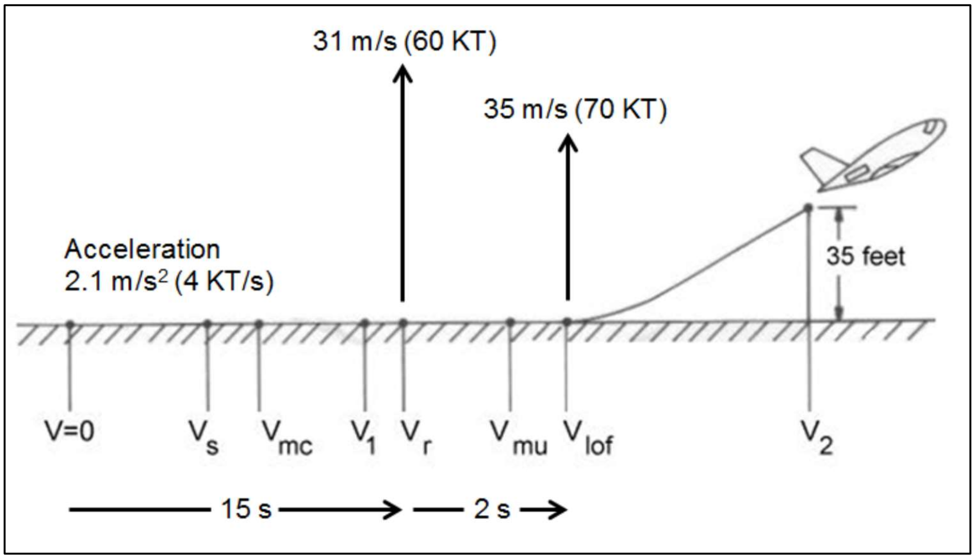


Figure 2 Low Speed Ramp Acceleration Profile (ref. SAE AS5900)

It should be recognized that BLDT is measured at the end of the acceleration profile, at a speed representative of V_2 (high speed ramp) or V_{lof} (low speed ramp) and not the rotation speeds. A table is provided to summarize the acceleration profile and points of interest for each test.

	Acceleration	Rotation event		Liftoff event		End of take-off distance	
		Speed	Time	Speed	Time	Speed	Time
High Speed Ramp Test	2.6 m/s2 (5 knots/s)	52 m/s (101 kt)	20 s	N/A	N/A	65 m/s (126 kt)	25 s
Low Speed Ramp Test	2.1 m/s2 (4 kts/s)	31 m/s (60 kt)	15 s	35 m/s (70 kts)	17 s	N/A	N/A

Table 1 Summary of AS5900 high and low speed ramp test representative events

Typically, Type II and Type IV fluids are qualified to the high speed ramp test and Type III fluids are qualified to the low speed ramp test. However, Type III fluids may also be qualified to the high speed ramp at the discretion of the fluid manufacturer.

The aerodynamic effects may not be adequately evaluated under the AS5900 [2] standard for airplanes take-off rotation speed or time to rotation less than those prescribed in Table 1 for the applicable ramp for the aircraft.

Aircraft with lower rotation speeds or time to rotation than the AS 5900 [2] high 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), will require additional considerations for performance impacts (e.g. take-off testing per proposed AMC, Section

5.2.3 Take-off Performance 0).

It should also be noted that the SAE standards do not address any potential effects on either airplane control surface effectiveness or control forces.

SAE ARP6852 [5] provides industry experience with using similarity analyses, wind tunnels tests, flight tests, and computational fluid dynamics to evaluate aerodynamic effects of thickened fluids on aircraft.

1.4 ISSUES AND PAST IN-SERVICE EVENTS

Effects on Aeroplane Rotation During Takeoff
Authorities have received reports of safety concerns regarding certain airplanes with unpowered longitudinal flight controls when treated with thickened anti-icing fluids. Typically, those reports filed through official means with regulatory authorities came from flight crews that conducted rejected take-offs after their airplanes were treated with thickened anti-icing fluids. The flightcrews reported that the airplanes did not respond to normal, and in some cases, higher-than-normal control column force for rotation to the take-off attitude. They elected to reject the take-off at speeds in excess of V1. Fortunately, these rejected take-offs did not occur during take-offs that were limited by runway length; if runway limited, these rejected take-offs could have resulted in runway overruns with potentially catastrophic outcomes.

The use of thickened fluids has also resulted in delayed response from the airplane to the pilot's pitch control input to rotate the airplane. The lack of expected airplane response to normal control forces to rotate the airplane could lead a pilot to reject a take-off from speeds above take-off rotation speed (VR) and possibly exceed the available runway length during the rejected take-off.

A common factor in these incidents is unpowered longitudinal flight controls. In most of the reported cases, thickened anti-icing fluids had been approved for use on the airplane.

For at least two airplane model/series, regulatory authorities have issued associated airworthiness directives to require changes in take-off procedures, or to apply take-off performance penalties to address potential unsafe conditions resulting from use of Type II or IV fluids (e.g. EASA AD 2010-0263, DGAC AD F-2000-448-053R2). Changes to operating limitations include increased take-off rotation speeds and limitations on the use of certain take-off flap settings.

Fluid residues/Freezing of Controls
European operators reported a large number of stiff or frozen flight control system events. These events have mainly occurred with unpowered flight control systems but have been observed on powered flight control systems if occurring upstream of control units or affected balance bays. The events were attributed to re-hydration and subsequent freezing of residue from thickened deicing/anti-icing fluids. Thickened fluid may collect and evaporate leaving a residue in aerodynamically quiet cove areas, like those along control surface hinge lines. When the residue of the evaporated thickened fluid is re-hydrated by humidity, rain, or washing the airplane, it may freeze and restrict movement of the control surface when the airplane climbs to altitudes where temperatures are below freezing.

Re- hydrated fluid has been found in and around gaps between stabilizers, elevators, tabs, and hinge areas. Residues have also been found on flight control actuators, cables, and pulleys, and in control surface balance bays. This issue has been prevalent in Europe, where operators often repeatedly deice and anti-ice with thickened fluids in a one-step application process. It has not often been reported by North American operators since they mainly use a two-step process where before application of anti-icing fluid, deicing with heated mixtures of Type I fluid and water helps to remove residues, thereby preventing accumulation of the re-hydrated gel residue.

There has been one 14 CFR 25 turbojet airplane found to be aerodynamically sensitive to accumulation of foreign materials, in or around the elevator tab. In this case, ground anti-icing fluid that had accumulated and rehydrated over multiple cycles, caused severe vibration and limit cycle oscillations of the elevator tab.

Adverse Effects in combination with aircraft systems

The combination of deicing/anti-icing fluid treatment with airplane systems such as the wing thermal anti-icing systems have also been noted. One effect observed is the fluid “baking” on hot leading edges when the system is operated on the ground, leaving a rough sticky hard residue on the critical leading edge surface. Another effect observed is smoke-like aerosol in the cabin as a result of ingestion in the APU.

1.5 WHAT WE WANT TO ACHIEVE?

The impact of Type I, Type II, III, or IV deicing/anti-icing fluids on performance, controllability, information necessary for safe operation and instructions for continued airworthiness shall be addressed before operational use of such fluids is authorized.

Approved types of ground deicing/anti-icing fluids must be identified in the AFM.

If using thickened deicing/anti-icing fluids results in significant or unusual flight or ground handling characteristics, this information must be provided in the AFM. 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.

It is expected that the manufacturer will provide information on ground deicing/anti-icing procedures and aircraft operating procedures following deicing/anti-icing deemed relevant to the crew in the FCOM (or equivalent manufacturer’s document).

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).

The task will accomplished by:

Review of existing Certification Specifications and policies to determine the regulations that might be impacted by the use of ground deicing/anti-icing fluids;

Propose means and methods of compliance for impacted requirements where necessary;

Revise existing requirements where necessary; and

Establish new requirements where necessary

1.6 REVIEW OF THE EXISTING CERTIFICATION SPECIFICATION

A review of the potentially impacted paragraphs in the existing certification specification was conducted and is summarized below. This review encompasses the applicable requirements in EASA Certification Specification – CS 25.

CS 25.101 Performance – General
This requirement shall be considered by the applicant in the cases where recalculation of the take-off speeds is necessary due to thickened fluids. Guidance for when recalculation of takeoff speeds is necessary is provided in the proposed AMC.

As a general principle, any change to aeroplane performance or take-off procedures found necessary in addressing thickened fluids should be determined in a manner consistent with the existing performance requirements.

CS 25.103 Stall Speed
Although it is impractical to determine stall speeds with thickened fluids applied, the safety of take-off speeds that are referenced to stall speeds is ensured via lift loss determination and AOA margin tests (early rotation take-offs) defined in the proposed AMC.

CS 25.105 Take-off
This requirement shall be considered by the applicant when the effects of thickened fluids impact take-off speeds or distances. As described in the CS 25.111 discussion, drag effects on climb performance resulting from fluids need not be considered.

CS 25.107 Take-off speeds
This requirement shall be considered by the applicant when the effects of thickened fluids impact take-off speeds.

Requirements for take-off speeds include minimum allowable stall speed multiples to ensure an acceptable safety margin to aerodynamic stall. In recognition that some lift loss due to the effects of icing is inherent to operations in icing conditions, the CS-25 standards for icing certification allow up to a 3% increase in stall speeds before the effects of icing must be taken into account. 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 during prior approvals from several authorities. 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. 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 effects of thickened fluids on early rotation characteristics are evaluated during proposed “AOA Margin” evaluations.

If an applicant were to present an aeroplane with scheduled take-off speeds that are greater than the regulatory minima (e.g. speed adders), then a greater lift loss may be acceptable. In this case, the applicant would need to show that using the scheduled take-off speeds, the resulting margins to take-off speed regulatory limits with thickened fluids applied are not less than those resulting from application of a 6% lift decrement to scheduled take-off speeds that are based on the regulatory minima.

As noted in section 1, certification and service experience with the use of thickened fluids has shown that some aeroplane types with unpowered longitudinal controls exhibit the need for increased longitudinal control force to rotate the aeroplane for take-off. Should such an effect be present, the applicant should consider whether compliance with CS 25.107(e)(4), which addresses the effects of "reasonably expected variations in service from the established take-off procedures", is affected when operating with fluids applied. Specifically, in a nose down out-of-trim condition, the combination of control force required to counter the mistrim combined with an incremented rotation force requirement due to thickened fluids could affect the associated take-off distance. CS 25.107(e)(4) also addresses potential over-rotation. Although, tendency for over-rotation with thickened fluids applied has not been reported, should the applicant observe susceptibility to that characteristic during tests with normal rotation technique, additional evaluations may be required.

CS 25.109 Accelerate-stop Distance
This requirement shall be considered by the applicant when the effects of thickened fluids impact take-off speeds.

CS 25.111 Take-off Path
This requirement shall be considered by the applicant when the effects of thickened fluids impact take-off speeds or distances.

Any drag increment due to fluids is transient and dissipates quickly as the aeroplane accelerates and climbs through the take-off phase. Industry experience with conventionally configured aeroplanes is that drag effects due to thickened fluids on take-off performance are insignificant and do not need to be considered (ref. SAE ARP6852 [5]).

CS 25.113 Take-off distance and take-off run.
This requirement shall be considered by the applicant when the effects of thickened fluids impact take-off speeds or distances.

A simplified, time-based check of rotation and acceleration to V_2 is included in the proposed AMC (5.2.3.3) and would indicate any effect on published take-off speed schedule while significant fluid remains on the aeroplane.

CS 25.115 Take-off flight path
This requirement shall be considered by the applicant when the effects of thickened fluids impact take-off speeds or distances. As described in the CS 25.111 discussion, drag effects on climb performance resulting from fluids need not be considered.

CS 25.117 Climb: general
As described in the CS 25.111 discussion, drag effects on climb performance resulting from fluids need not be considered.

CS 25.119 Landing Climb: All-engines-operating

Since this paragraph applies only to the landing phase it is not applicable to the consideration of thickened fluids.

CS 25.121 Climb: One-engine inoperative
As described in the CS 25.111 discussion, drag effects on climb performance resulting from fluids need not be considered.

CS 25.143 Controllability and Manoeuvrability – General
This requirement is considered relevant as an aircraft treated with thickened fluids may have increased longitudinal control forces compared to a clean airplane at rotation. Reported occurrences have been tied to aeroplanes with unpowered flight controls. These instances have typically been mitigated through specific procedures, such as an increase in rotation speed (and commensurate increase in runway length). It was identified that consideration of 25.143(a)(1), 25.143(b)(1), 25.143(d) and 25.143 (e) would be enough to address these concerns, due to the transient nature of fluids effects. Usually back-to-back takeoffs with and without fluids applied is used to detect any impact of fluids on compliance with those requirements.

All known adverse controllability events in service have involved unpowered (reversible) 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/rotation events. Therefore, consideration of the effects of thickened fluids does not require a handling/rotation assessment 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 significant fluid path for accumulation on the lower (suction during rotation) surface. Controllability assessments during rotation and after take-off are specified for aeroplanes with unpowered (reversible) controls.

Although difficulties with lateral control resulting from thickened fluids have not been reported, susceptibility to effects on lateral controllability is such that assessments after take-off are applicable to aeroplanes unpowered lateral controls.

Unless prohibited in the AFM, 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.

CS 25.145 Longitudinal Control
The controllability and manoeuvrability evaluations proposed to address CS 25.143 are considered to sufficiently demonstrate acceptable longitudinal control characteristics with thickened fluids applied.

CS 25.147 Directional and Lateral Control

The controllability and manoeuvrability evaluations proposed to address CS 25.143 are considered to sufficiently demonstrate acceptable directional and lateral control characteristics with thickened fluids applied.

CS 25.149 VMCG & VMCA

After review of several factors, mainly that CS 25.149 is not applicable in icing conditions per CS 25.21(g), it was concluded that this requirement is not applicable. An absence of in-service events linked to treatment with thickened fluids and loss of one engine during take-off was also noted. The general controllability and manoeuvrability of the aircraft with one engine inoperative is evaluated as part of the evaluations proposed to address CS 25.143.

CS 25.161 Trim

This requirement is not applicable since the effects of applied thickened fluids application is transitory in nature, while trim demands are long term characteristics.

CS 25.171 – CS 25.181 Stability

Stability requirements are not generally relevant since the effects of applied thickened fluids are transitory in nature and dedicated stability evaluations require steady conditions. The controllability and manoeuvrability evaluations proposed to address CS 25.143 sufficiently demonstrate acceptable stability characteristics.

CS 25.201 – 27.207 Stalls

Stall and stall warning margin demonstrations with applied thickened fluids are not practical or safe due to the effects of the fluids only being present when the aeroplane is close to the ground. Sufficiency of the safety margin between scheduled take-off speeds and stall is addressed through similarity or demonstrations of lift loss during the takeoff, AOA margin and early rotation as defined in the proposed AMC.

CS 25.251 Vibration and Buffeting

No in-service adverse vibration and buffeting events related to effects of thickened fluids are known to the group. FAA Policy PS-ANM-25-10 states that vibration and buffeting characteristics should be evaluated with flight tests to V_{MO} as soon as practicable after take-off. Review of the background for this evaluation revealed that the original concern was actually due to an event where fluid residue that accumulated over multiple fluid applications resulted in a control surface mass imbalance and subsequent flutter of the surface. Consideration of the effects of fluid residue accumulation over time is addressed further in the CS 25.629 discussion.

The group conclusion is that by the time an aeroplane reaches high speed after take-off, fluid shedding is sufficiently complete that vibration and buffet characteristics are not affected and evaluations at V_{MO} are not necessary. Given this understanding, the group is recommending the potential for applied thickened fluids to affect vibration and buffet characteristics as fluid flows off the wing should be assessed during the take-off testing. 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 such as decreased or increased speeds. The assessment should consider the vibration and buffeting requirements of CS 25.251(a).

CS 25.603 Suitability of materials
The effect of approved types of deicing/anti-icing fluids shall be considered with respect to compliance with CS 25.603.

EASA SIB 2015-27 "Potential Adverse Effect of Alkali Organic Salt-based Aircraft De-Icing Fluids on Anti-Icing Holdover Protection and Potential Aircraft Corrosion" addresses the potential issues caused by aircraft de-icing fluids based on alkali organic salt dilutions. The majority of the aircraft de-icing fluids use a glycol (or a glycol/water dilution) as freezing point depressant and comply with SAE AMS1424/1. 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 might present two adverse effects on the aeroplane and its operation: 1) interacting with thickening agents used in 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.

EUROCAE ED-12/RTCA DO 160 Environmental Qualification Requirements requires deicing/anticing fluids susceptibility tests for airborne equipment installed in exposed areas.

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

AMC 20-29 paragraph 6.e Composite Aircraft Structure Protection of Structure:

> *Weathering, abrasion, erosion, ultraviolet radiation, and chemical environment (glycol, hydraulic fluid, fuel, cleaning agents, etc.) may cause deterioration in a composite structure. Suitable protection against and/or consideration of degradation in material properties should be provided for and demonstrated by test.*

In AMC 23.613 Material strength properties and design values paragraph 4.3. Consideration of Environmental Conditions there is the text: Environmental conditions other than those mentioned may also have significant effects on material design values for some materials and should be considered.

CS 25.629 Aeroelastic stability requirements
Flutter as a result of mass imbalance may be a result of the following aspects of de/anti-icing fluids:

-fluids accumulating in or around balance bays – would need to be addressed in flutter analysis as that weight could be there on any dispatch with fluid treatment

-residues accumulating in or around balance bays – would need to be addressed though ICA cleaning/inspection – would need to consider mass of residue up to period of cleaning/inspection. Period for cleaning may be driven by what mass can be accepted

Each would be discovered through fluid treatment/inspection

Fluid affecting aerodynamics was discussed – residual fluid would only accumulate in an aerodynamically quiet area with no aerodynamic forces on it. Aerodynamic effects would not be seen in high-speed flight, but only possibly in low speed, near ground scenarios prior to fluid shedding.

CS 25.1301(a) Function and installation

CS 25.1309(a) Equipment, systems and installations

The aeroplane equipment and systems must be designed and installed so that they performed as intended under the aeroplane operating and environmental conditions.

Possible reasonable exposure of an equipment or system to deicing / anti-icing fluids should be evaluated and when applicable, the equipment and system should be qualified to be fluid tolerant.

Section 11 of the RTCA/DO-160G Environmental Qualification Requirements requires deicing/anti-icing fluids susceptibility tests for airborne equipment installed in exposed area .

CS 25.1501 Operating Limitations and Information: General

New paragraph CS 25.1597 is proposed to address establishing operating limitations and information related to operations with fluids.

25.1529 Instructions for Continued Airworthiness

CS 25.1529 is applicable to the cleaning procedures to prevent accumulation of fluid that does not flow off the aeroplane and to mitigate effects of re-hydration of fluid residues. Relevant information should be captured in the maintenance documentation.

CS 25.1581 – CS 1587 Aeroplane Flight Manual

New paragraphs CS 25.1583(m) and CS 25.1597 are proposed to address AFM requirements related to operations with fluids.

1.7 REVIEW OF OTHER REGULATORY GUIDELINES

In the interest of harmonization, differences between existing guidelines of other regulatory agencies and proposed AMC 25.1597 are provided.

Based on experience with several certification programs, TCCA produced a Working Note, dated 21 October 2010. This Working Note contains a description of the safety concerns leading to the guidelines, as well as a more detailed description of the intent and acceptability of test results. Current FAA Policy PS-ANM-25-10 draws significantly from the TCCA document. The majority of the requirements and guidance proposed as AMC 25.1597 originated in the cited FAA and TCCA policy and guidance.

The following are key differences between proposed AMC 25.1597, current FAA Policy PS-ANM-25-10 and TCCA document WN38. Recommendations marked with (*) differ from SAE ARP6852. It is recommended that SAE revisit ARP6852 with respect to FAA policy and proposed AMC 25.1597.

Topic	**FAA Policy**	**TCCA WN38**	**Proposed AMC 25.1597**	**Rationale for AMC**
Flight test technique for lift loss determination	Use data from normal take-offs conducted with and without thickened fluids applied to determine lift loss at liftoff.	Use data from fixed pitch take-offs conducted with and without thickened fluids applied to develop the CLLOF versus pitch attitude at liftoff relationship to determine the lift loss at liftoff.	Normal and fixed pitch take-offs are identified as acceptable techniques for determining lift loss at liftoff.*	Concerns have been raised with the appropriateness of data obtained with both the normal and fixed pitch techniques (SAE ARP6852). However, both techniques have been previously accepted and the group determined that each can be used to generate appropriate data if properly substantiated.
Stall demonstrations	It would be impractical to conduct airplane stall tests with a representative takeoff 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.	If there is evidence of significant fluid retention during climb, especially on the leading edge of flaps, consideration should be given to conduction 1 knot/s straight stalls in the takeoff configuration as soon as practicable after takeoff.	Stall demonstrations are not proposed.	The proposed lift loss and AOA margin evaluations were deemed sufficient to ensure sufficient margin to stall.
Early rotation speed for AOA margin flight tests	Conduct AEO take-off 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 AEO take-off using "performance" type rotation technique with rotation at VR – 10.	Same as FAA policy.*	Aligns with AMC No 2 to CS 25.107(e)(4) and is the same standard that is applied to basic certification requirements.

Topic	FAA Policy	TCCA WN38	Proposed AMC 25.1597	Rationale for AMC
Increased rotation forces	If rotation control forces are increased over the non-treated airplane, the Flight Standardization Board should determine if the increased force is a training emphasis item.	Control displacement and control force required to rotate the aeroplane should be substantially the same as for the clean aeroplane.	Similar to FAA policy except need for specific training is indicated in Operational Suitability Data (OSD).	FAA and EASA have satisfactory in-service experience with this approach.

Topic	FAA Policy	TCCA WN38	Proposed AMC 25.1597	Rationale for AMC
Applicability of controllability evaluations	Controllability considerations apply to aeroplanes with reversible (unpowered) longitudinal controls.	Notes that aeroplanes with unpowered flight controls have been particularly vulnerable to control problems during rotation but no applicability criteria related to flight control system characteristics are specified.	Controllability considerations apply as follows: • Powered longitudinal controls with sealed control surfaces – no rotation or post take-off controllability assessment • Powered longitudinal controls without sealed control surfaces – rotation assessment only • Unpowered longitudinal controls – rotation and post take-off controllability assessment • Unpowered lateral controls – post take-off controllability assessment • For all aeroplanes, the effects of spraying thickened fluids on the horizontal stabilizer underside surface must be considered if not prohibited by AFM procedure.	Fluid flow through gaps may affect longitudinal control surface effectiveness during rotation even if controls are powered. No rotation or controllability difficulties are known to have occurred on aeroplanes with powered controls and sealing of control surfaces. Post take-off characteristics are primarily sensitive to hinge moment effects which may impact aeroplanes with unpowered controls.

Topic	FAA Policy	TCCA WN38	Proposed AMC 25.1597	Rationale for AMC
Vibration and buffeting	Evaluate vibration and buffet characteristics in flight to VMO as soon as practicable after take-off per 25.251(d).	Evaluate vibration and buffet characteristics in flight to VMO if there is evidence of fluid retention in areas that could affect control hinge moments or on control surfaces that could affect control balance.	Evaluate vibration and buffeting characteristics during take-offs per 25.251(a). If there is evidence of fluid retention in areas that could affect control hinge moments or on control surfaces that could affect control balance then assessment should include flight to VMO.	See CS 25.251 discussion.
Flutter	Notes that collected fluid may result in unbalanced control surfaces leading to control surface vibration and buffeting or limit cycle oscillations.	References FAA AC 23.1419-2C regarding potential effects of fluid retention in areas that could affect control hinge moments or on control surfaces that could affect control balance in the context of vibration and buffeting.	Addresses potential for unbalanced control surfaces in the context of compliance with CS 25.629, Flutter.	See CS 25.629 discussion.
Consideration of CS 25.1309	Evaluation for adverse systems interactions with fluids is addressed but the evaluation is not tied to 25.1309.	Similar to FAA policy.	Considerations are similar to FAA and TCCA but the proposal explicitly relates evaluation of effects of fluids on aeroplane systems to CS 25.1309 compliance.	Completeness of compliance showing.

Topic	FAA Policy	TCCA WN38	Proposed AMC 25.1597	Rationale for AMC
Approval of type III fluids	Aeroplane performance considerations for approval of Type III fluids are based on the same criteria as for Types II and IV fluids which include a comparison of aeroplane performance to the SAE AS5900 high speed ramp test.	Specifies that a representative Type III fluid may be used for flight tests but does not address a comparison of the aeroplane acceleration characteristics to SAE AS5900 low or high speed ramp tests.	Aeroplane performance can be compared to the low speed ramp test for consideration of lift loss aspect of Type III approvals.	Define considerations for applicants seeking approval of Type III fluids only.
Applicability of performance evaluations	Ties applicability of performance evaluations to aeroplanes with a rotation speed and time to rotation that do not align with the SAE AS5900 ramp tests.	SAE AS5900 ramp tests are not considered in determining applicability of performance evaluations.	Applicability of performance lift loss evaluations is tied to parameters from the SAE AS5900 low and high speed ramp tests as appropriate.	Technically appropriate.
Methods of compliance	Defines flight tests to determine aerodynamic effects of thickened fluids.	Defines flight tests to determine aerodynamic effects of thickened fluids.	Defines flight tests, analysis and similarity methodologies to determine aerodynamic effects of thickened fluids.	Provide additional guidance for applicants using analysis and similarity to evaluate aerodynamic effects of thickened fluids.
Fluid selection considerations for flight tests	Test fluid should be applied undiluted at a test day temperature that results in a BLDT within 1mm of the maximum allowed per SAE AS5900.	Test fluid should be one "whose test results are closest to the SAE acceptance limit." The test fluid should be applied undiluted at the coldest test day temperature at which the fluid can be used undiluted.	Similar to FAA policy except for added discussion of considerations for when it is not practical to obtain a BLDT within 1mm of the maximum allowed per AS5900.	Provide additional guidance for accepting tests with fluid BLDT less than 1mm from the limit is needed due to practical difficulties of obtaining the ideal test conditions.
Instructions for continued airworthiness	Lists potential items to address in maintenance instructions.	Specifies that maintenance instructions should be developed in accordance with 25.1529.	Retains ICA considerations identified in the FAA policy and also includes an expanded discussion of fluid considerations for ICA.	No technical differences from FAA and TCCA material.

Topic	FAA Policy	TCCA WN38	Proposed AMC 25.1597	Rationale for AMC
Aeroplane flight manual	Includes specific language to be included in AFM related to types of fluids approved and not approved.	Specifies that any required limitations should be provided in the AFM and any changes in operating procedures be identified.	Includes less prescriptive AFM guidance but with the same intent as the FAA policy. Adds consideration of FCOM.	No technical differences from FAA and TCCA material.

1.8 DISSENTING POSITIONS

Two dissenting opinions to group consensus were generated during RMT deliberations. Dissenting Position 1 disagrees with the proposal that flight testing a single thickened fluid is sufficient demonstrate compliance with the proposed requirements. Dissenting Position 2 disagrees with the use of SAE AS5900 AAT as a surrogate for determination of lift loss at lift off and consequently as a discriminant for the need to conduct flight tests with fluids applied. Full dissenting positions and responses are provided in Section 4.

2 PROPOSED CHANGES - EASA CS 25

The most efficient implementation was determined to be through addition of two supplemental requirements. New paragraph CS 25.1597, Deicing and Anti-icing Fluids, would 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. A new subparagraph of CS 25.1583 would 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. Methods for demonstrating compliance with existing CS-25 paragraphs in the presence of fluids are addressed in new proposed AMC. No existing requirements are proposed to be changed.

2.1 REQUIREMENTS

2.1.1 NEW REQUIREMENTS

It is proposed to add the following new requirement in CS 25 SUBPART G – OPERATING LIMITATIONS AND INFORMATION – Supplementary information".

CS 25.1597 Deicing and Anti-Icing Fluids
Any operating limitations, operating procedures and performance information necessary for safe airplane operations with deicing/anti-icing fluids applied must be established and included in the aeroplane flight manual in accordance with CS 25.1581.

2.1.2 PROPOSED UPDATES TO EXISTING REQUIREMENTS

It is proposed that CS 25.1583 Operating limitations, is amended to include an additional subparagraph for deicing and anti-icing fluid limitations in the AFM.

CS 25.1583 (l) Deicing and Anti-icing Fluids
The following information must be furnished.

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

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

2.2 AMC

A new AMC shall be added for the Ground Deicing/Anti-icing Fluids requirements.

The team suggests the following text for the AMC implementation:

AMC 25.1597 Ground Deicing/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 requirements are identified as applicable to approval of deicing/anti-icing fluids as listed in paragraph 2.

2 RELATED REQUIREMENTS

In addition to CS 25.1597, the following paragraphs shall be considered by the applicant:

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 Manoeuvrability – 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 temperature range at which the fluid is to be used in service. SAE AS5900 identifies a high-speed ramp and low-speed ramp test. Typically, Type II and Type IV fluids are qualified to the high speed ramp test and Type III fluids are qualified to the low speed ramp test. However, Type III fluids may also be qualified to the high speed ramp at the discretion of the fluid manufacturer. For fluids qualified to multiple ramp tests, each approved aeroplane model is assumed to be operated according to the published guidelines appropriate for aeroplane performance conforming to the respective 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 on the aeroplane may not be adequately modelled and flight tests are required to validate acceptable lift loss characteristics. 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 taken into account. 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 AAT in AS5900 AAT 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/rotation events. Therefore, consideration of the effects of thickened fluids does not require a handling/rotation assessment 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 significant fluid path for accumulation on the lower (suction during rotation) surface. 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 (25.101, 25.105, 25.107, 25.109, 25.111, 25.113, 25.115)
- Controllability (25.143)
- Vibration and Buffeting (25.251)
- Suitability of materials (25.603)
- Aeroelastic stability requirements (25.629)
- Effects of fluid ingress on aeroplane systems (25.1301 and 25.1309)
- Fluid Considerations for ICA (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 FLOW-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 high speed ramp and DHC-8 for the low speed ramp) should be based on flight tests or similarity to a previously approved model.

4.1.2 FLUID EFFECTS ON ROTATION CHARACTERISTICS

As discussed in section 3 some aeroplane types with unpowered longitudinal controls exhibit the need for 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 significant or unusual flight or ground handling characteristics, applicants should conduct flight tests, complete analysis or show similarity to a previously tested model.

4.3 CONSIDERATIONS FOR APPROVAL OF SPECIFIC FLUID TYPES

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 as long as 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 complete 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 prior 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 the event the acceleration profiles do not meet those prescribed the AAT, further considerations and similarity to another previously approved model may be necessary. Take-off performance and controllability can also be established by similarity to previously approved 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 RevC 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.

In the event the acceleration profiles do not meet those prescribed the AAT, similarity for lift loss aspects of performance may be considered compared to a previously approved model. 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.

Effects on take-off rotation characteristics and controllability can also be established by similarity to previously approved 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 RevC Section 4.2). In addition, in-service history of similarly designed and previously approved models should be considered.

Similarity analyses can comprise of comparisons of aeroplane features, characteristics and takeoff 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 to 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, where accumulation of fluids may introduce adverse effects on flight control components. The review may include the aeroplanes design and maintenance practices to previously approved 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.

5.1.5 SUITABILITY OF 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 deicing/anti-icing fluids on common aircraft materials.

The majority 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 glycol 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.

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 provide appropriate information 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 time tables.

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 Deicing 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 odours, 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, 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 takeoffs with and without thickened fluid applied to determine the percentage of lift loss due to the presence of the thickened fluid. Tests at maximum pitch attitude are not needed. 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. 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 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-of-Attack (AOA) Margin Tests.

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 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 6.3.1. If VR was increased as a result 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.

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 Take-off Performance.

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.

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 for multi-engine airplanes 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 VARIATIONS 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 informed by design review or inspection. The effects of flight as well as the fluid application should be taken into account. 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 detail inspection may be informed 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 could be cause for special periodic inspections.

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 deicing/anti-icing fluids on common aircraft materials.

The majority 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 glycol 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 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 susceptible to fluid ingress and specify any procedures necessary to limit it (e.g. flight control positions, 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 SYSTEMS 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 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 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 considered for deicing/anti-icing operations, and prohibited as appropriate. Considerations should include how missing items may affect fluid migration patterns and susceptibility to fluid ingress. An example would be prohibiting missing side of body horizontal stabilizer seals during operations requiring de-icing or anti-icing applications.

8.2 UNAPPROVED OPERATIONAL INFORMATION

It is recommended that the manufacturer provide 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
- APU not operating whenever possible
- Flap position, elevator and/or stabilizer position
- 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.
- Supplemental cooling systems OFF whenever possible
- Ensure ditching mode is deselected prior to take-off
- Pre- take-off visual check of wings to assess need for repeat 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 for de-icing bay such as delaying arming the spoilers and not moving the flaps or the rudder trim and other flight control surfaces until after de-icing

The applicant should consider providing guidance in the unapproved operational manual or document emphasizing items or deviations from the standard training received by de-icing ground crews and de-icing practices applied by de-icing ground crews, such as those defined in AS 6286 and AS6285. These might include:

- Any specific spray techniques for the aircraft identified

- 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
  - 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
  - Cleaned surfaces may require subsequent re-lubrication
- Guidance and procedures. Provide guidance and procedures for the following items:
  - What to look for, for example, re-hydrated gel and/or dried fluid residues and what these look like
  - Where to look for such gel/residues on the airplane structure and control systems
  - How to effectively remove these gel/residues.
  - 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.)

3 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

4 Dissenting Positions

4.1 DISSENTING POSITION 1

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.

However, engineering judgment and limited available experience seem to 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 the dissenting 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 dissenting 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 accepts declaration by applicants stating that its airplane with powered flight 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 tailcone element. 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 fly-test the aircraft with this fluid applied and adjust AFM parameters based on the test results (Case 0).

If the applicant cannot provide a rational for the selection of a conservative fluid, the applicant need to test the aircraft with fluid A to assess for effects of the phenomena described above (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-23/25, 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 accepted by the Agency, 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 rest of commercial fluids (not tested) has the effect of fluid A plus the double of the delta between fluid B effects minus fluid A effects. Alternatively to these AFM corrections, the applicant may decide to test a third fluid agreed with the authority and propose lower corrections on AFM parameters.

In all tested cases, handling characteristics would need to be CS-23/25 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.

[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' (ie, 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.

4.2 RESPONSE TO DISSENTING POSITION 1

General

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.

4.3 DISSENTING POSITION 2

TCCA Position regarding use of AS900 AAT as a surrogate for determination of lift loss at lift off

The proposed AMC 25.1597, Ground Deicing/Anti-icing Fluids, contains guidance in Section 4.1.1, Assessment of Applicability of Fluid Qualification Assumptions, which would serve to exempt applicants from conducting flight tests to determine the lift loss at lift off when deicing/anti-icing fluids have been applied based on the Aerodynamic Acceptance Test (AAT) of SAE AS5900C: aeroplanes with rotation speeds or time to rotation equivalent or greater than the SAE AS5900 high or low speed ramp criteria would not need to be evaluated to determine if any adjustments to the published take-off speed schedule would need to be made.

Transport Canada (TCCA) recognizes that SAE AS5900C, Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 aircraft Deicing/Anti-icing Fluids, is a standard used to qualify fluids for ground de-icing/anti-icing operations, but does not accept that this test necessarily represents lift loss due to application of deicing/anti-icing fluids for individual aeroplane types/designs. As stated in the standard:

> *“The objective of this standard is to ensure acceptable aerodynamic characteristics of the deicing/anti-icing fluids as they flow off of aircraft lifting and control surfaces during takeoff ground acceleration and climb. Aerodynamic acceptance of an aircraft ground deicing/anti-icing fluid is based upon the fluid’s boundary layer displacement thickness (BLDT) on a flat plate, measure after experiencing the free stream velocity time history of a representative aircraft takeoff. Acceptability of the fluid is determined by comparing BLDT measurements of the candidate fluid with a datum established from the values of a reference fluid BLDT and the BLDT over the dry (clean) test plate. Testing is carried out in the temperature range at with the fluid, undiluted and diluted, is to be used in airline service.”*

Notwithstanding the technical background to the SAE aerodynamic acceptance test, aeroplane configurations and airfoil sections continue to evolve, as do fluids. The aerodynamic acceptance test is at best an indirect measure that there should be no severe performance or handling issues during takeoff. For these reasons, TCCA requires that limited flight tests be carried out on individual aeroplane types to confirm the lift loss at lift off and whether any adjustment to take-off speed schedules would be required.

During discussions of this subject for this NPA, three technical research papers were offered as justification to support the premise that aeroplanes with rotation speeds or time to rotation equivalent to or greater than the AAT would not require a flight test to determine lift loss at lift off. TCCA has reviewed these technical research papers but did not find that the purpose nor the conclusions of these papers directly addressed the question of whether the AAT generally represents the lift loss of individual aeroplanes. While TCCA acknowledges that there is incidental evidence in existing technical literature that the AS5900C AAT might possibly be used as a discriminant for exemption from conducting flight test to determine lift loss at lift off, there is at present no direct evidence. Before TCCA could accept this premise, an appropriate body should specifically investigate whether the AAT for fluid qualification sufficiently represents a maximum expected lift loss due to deicing/anti-icing fluid application for types/designs generally.

References:

1. SAE AS5900C, Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 Aircraft Deicing/Anti-icing Fluids

2. TCCA WN 38 Iss 3, Transport Canada Guidelines for Aeroplane Testing Following Deicing/Anti-icing Fluid Application.

3. AIAA 2010-7838 - Numerical Analysis of De-icing Fluid Flow Off from Aircraft Wings – Dart N.P.

4. Journal of Aircraft Vol. 53, No. 2, March-April 2016 - Aerodynamic Effects of Anti-Icing Fluids on a Thin High-Performance Wing Section – Broeren A.P, Lee S., and Clark C.

5. NASA/TM-2012-216014 - Review of the Aerodynamic Acceptance Test and Application to Anti-Icing Fluids Testing in the NRC propulsion and Icing Wind Tunnel. – Broeren A.P., Riley J.T.

<u>Attachment A: TCCA Review of Technical Research Papers</u>

The following summaries comments from review of technical research papers that have been used (but not cited) in this report as justification for exempting flight demonstration of lift loss at lift off.

AIAA 2010-7838 Numerical Analysis of De-icing Fluid Flow Off from Aircraft Wings – Dart N.P.

Salient extractions from paper:

Introduction:

This paper describes the development of the numerical model and some preliminary analysis of fluid flow off from a representative Airbus wing geometry. The overall objective of the study described in this paper was to quantify the degree of similarity between the fluid flow-off characteristics on the wings of Airbus aircraft compared with the aerofoils that were used as the basis for the SAE aerodynamic acceptance test. In doing so, the aim is to reinforce the premise that the qualification of SAE AMS 1424/1428 fluids using the associated aerodynamic acceptance test is sufficient to ensure satisfactory aerodynamic effects on different wings.

Conclusion:

A novel de-icing/anti-icing fluid flow-off prediction model has been derived from first principles. The model that has been developed during this study is relatively simple, and considers the transportation of the fluid film only under the influence of the aerodynamic shear force. The model is not able to predict wave and ripple formation in the fluid, but nevertheless the model is able to predict all of the other key characteristics of de-icing/anti-icing fluid transportation that are observed in practice. It is therefore concluded that the predictions from the model are qualitatively correct. Although it is recognised that more development and validation of the model would be required to have confidence in the absolute results, it is considered to be a useful engineering tool

in its current form that is able to simulate incremental changes and assess relative effects between different wing geometries.
Initial studies that have been performed using an Airbus research aerofoil, representative of a wing profile from a regional aircraft, have indicated that the flow off behaviour for an Airbus wing section is similar to the flow off from the Boeing research aerofoil that was used to derive the SAE aerodynamic acceptance test. These results, and also the absence of any significant in-service incidents associated with the use of de-icing/anti-icing fluids on any major large civil aircraft, reinforce the belief that SAE AMS 1424 and 1428 de-icing/anti-icing fluids can be used on a range of large civil aircraft without applying take-off performance adjustments.

These initial studies have been encouraging and indicate that an analytical method could be used in the future to evaluate the similarities between the characteristics of an aircraft and the geometries that were used to derive the aerodynamic acceptance test. If validated and used in conjunction with CFD methods to evaluate aerofoil performance degradation, an analytical process could potentially be developed to assess quantitatively the effects of de-icing fluids on aircraft aerodynamic and take-off performance.

TCCA review notes:

- Evaluation was for Newtonian Type I de-icing fluids only, not thickened non-Newtonian Type II, III, or IV anti-icing fluids. There was reference in the report to other work being done for non-Newtonian fluids.
- Model developed for flat plate, then extended to 2D aerofoil analysis for comparison between A320 aerofoil and B737-200ADV used for development of SAE AS5900C AAT.
- Idealized 2D airfoil shape – blended multi element aerofoil for simplification – considered acceptable for preliminary nature of analysis.
- Modeled 2D flow off characteristic but did not evaluate the effect on lift for the aeorfoil sections
- Compared flow off characteristics between idealized Boeing and Airbus airfoils
- Model does not predict secondary wave or ripple formation
- Useful to explore qualitative relative effects:
  This initial study “that an analytical method could be used In the future to evaluate the similarities between the characteristics of an aircraft and the geometries that were used to derive the aerodynamic acceptance test.” If *validated* … an analytical process could potentially be developed to assess quantitatively the effects of de-icing fluids on aircraft aerodynamic and take-off performance.
- Does not consider differences in 3D wing geometries.

NASA/TM-2012-216014 - Review of the Aerodynamic Acceptance Test and Application to Anti-Icing Fluids Testing in the NRC propulsion and Icing Wind Tunnel. – Broeren, Riley

Salient extractions from paper:

Introduction…

"Therefore, the purpose of this report is to review the research basis of the AAT and determine how it may be applied to the present aerodynamic testing of anti-icing fluids in the PIWT. A detailed review of the research basis of the AAT is performed in Section 2.0 of this report. Section 3.0 then provides a review of the anti-icing fluid aerodynamic testing conducted at the NRC PIWT with the uncontaminated fluid. These results were used in conjunction with results from the AAT performed for the same fluids to relate the aerodynamic degradation on the two-dimensional PIWT model to a B737-200ADV airplane. This relationship was then used to develop a lift loss criterion that could be used to establish allowance times for ice-pellet contamination. This report describes how this "scaling" method may address the concerns raised in regard to the NRC PIWT tests and implications for establishing ice-pellet allowance times.

Extracts from section 2.7 The AAT – Conclusions:

"Compliance with the acceptance test is considered a minimum requirement since the test's acceptance criterion is derived from fluid effects on a specific aircraft design [B737-200ADV] and only considers adequate takeoff safety speed margins. An airframe manufacturer may impose additional requirements which reflect considerations for specific airplane designs and performance criteria not addressed by the acceptance test."

Conclusion…

This review of the research basis of the AAT and the subsequent PIWT model analysis has shown that any differences such as model size, geometry, installation and Reynolds number, are accounted for in the correlation presented in Figure 24. Furthermore, this report shows that concerns about the thin, high performance wing model testing in the PIWT do not compromise the applicability of the AAT scaling methodology for PIWT model lift loss determined at 8° angle of attack. The PIWT testing was carried out in a manner that was consistent with the methods used in the AAT research and with standard wind tunnel testing methods. There are, however, some remaining concerns such as rotation speed, applicability to Type IV fluids and model configuration that could be addressed in future research.

TCCA review notes:

- Review of the research basis of the AAT:
- 2D results useful for determining the relative fluid-to-fluid lift losses … however they cannot be used directly to estimate lift losses on an aeroplane.
- Developed correlation between the lift loss from ice pellet contamination of anti-icing fluid determined with the 2D model from the NRC PIWT with the 3D model measurements for the B737-200ADV for use in determine allowance times for ice pellet precipitation
- Additional concern that the AAT was developed prior to the current widespread use of Type IV anti-icing fluids such as those used in the PIWT tests

JofA Vol. 53, No. 2, March-April 2016 - Aerodynamic Effects of Anti-Icing Fluids on a Thin High-Performance Wing Section – Broeren, Lee, and Clark (NRC)

Salient extractions from paper:

Introduction:

"The objective of the present research was to characterize the aerodynamic behavior of the thin high-performance wing used for aerodynamic testing of ground anti-icing fluids. Aerodynamic performance measurements, flow visualization, and boundary-layer surveys were conducted on the clean, dry wing. Tests were performed with leading-edge roughness (simulating ice roughness) and roughness applied to the entire upper surface (simulating frost). Additional tests were conducted to simulate the specific effects of the transitory nature of Type IV anti-icing fluids. This characterization is important to understanding the adverse aerodynamic effects of Type IV anti-icing fluids and ice-pellet contamination on this model because the results are used, in part, to develop ice-pellet allowance times that are applicable to many different airplanes."

Conclusion:

"The objective of this paper is to characterize the aerodynamic behavior of the thin high-performance wing that is important to understanding the adverse aerodynamic effects of anti-icing fluids and ice-pellet contamination."

"This aerodynamic characterization of the thin high-performance wing in the National Research Council Propulsion and Icing Wind Tunnel has yielded important information about the suitability of this model for anti-icing fluid and ice-pellet contamination testing. The clean baseline aerodynamics of the model was consistent with expected 2-D aerodynamics and showed no anomalies that could adversely affect the evaluation of anti-icing fluids and ice-pellet contamination. Tests conducted with roughness and leading-edge flow disturbances helped to explain the aerodynamic impact of the anti-icing fluids and contamination. In the linear portion of the lift curve, the primary aerodynamic effect was the thickening of the downstream boundary layer due to the accumulation of fluid and contamination. This causes a reduction in lift coefficient and increase in pitching moment (nose up) due to an effective decambering of the wing. The stalling characteristics of the wing with fluid and contamination appear to be driven at least partially by the effects of a secondary wave of fluid that forms near the leading edge as the wing is rotated in the simulated takeoff profile. These results have provided a much more complete understanding of the adverse aerodynamic effects of Type IV anti-icing fluids and ice-pellet contamination on this wing. This is important, since these results are used, in part, to develop the ice-pellet allowance times that are applicable to many different airplanes."

TCCA review notes:

- Undertaken to investigate the effect of ice pellet contamination of applied Type IV fluids
- Aid in the determination of allowance time for ice pellet precipitation
- *"Effective decambering of the wing"* refers to the loss of effectiveness of a deflected flap
- Secondary wave identified at rotation whereby fluid from lower surface migrates around leading edge to upper surface as the stagnation point shifts at rotation – results from sand paper roughness did not match
- Secondary wave effects can be highly configuration dependent due to the evolution of local shear forces in the LE region, particularly for slotted aircraft
- Thin high performance with section (without slat) exhibited typically LE stall

- Correlates thin high-performance 2D aerofoil wind tunnel results with B737-200ADV aerofoil of the AAT reference aircraft

4.4 RESPONSE TO DISSENTING POSITION 2

Background

The use of thickened fluids on aircraft began in the early 1990's prior to development of aerodynamic considerations with the use of the fluids. The SAE G-12 Aircraft Deicing Fluids (ADF) committee initially addressed the aerodynamic performance aspects with the use of thickened de/anti-icing fluids through development of a consensus standard. This "Aerodynamic Standard" (AS) was published to establish a repeatable aerodynamic qualification criterion for the use of thickened fluids on aircraft. This resulting lab test became known as the Aerodynamics Acceptance Test (AAT) through the publication of SAE AS5900. In short, the development of SAE AS5900 was based on measured lift loss impacts from flight test and wind tunnel testing on the Boeing 737-200ADV model aircraft, correlated to a measurable and repeatable boundary layer displacement thickness test on 2-D flat plate wind tunnel test.

The ADF committee later commissioned the Aerodynamics Working Group (AWG) in 2001 to develop an "Aerospace Recommended Practice" (ARP) which culminated in the publication of SAE ARP6852 in 2015. ARP6852 prescribes means for an aircraft manufacturer to show safe operations with thickened fluids as applied to a specific type model aircraft. ARP6852 includes flight testing with fluids already qualified per SAE AS5900. The flight tests evaluate considerations in addition to the lift impacts targeted by the AAT, such as controllability and systems compatibility, ARP6852 also recommends material for inclusion in manuals for the flight crews and maintenance crews of the aircraft.

Independent Expert Review of SAE AS5900

An independent expert review of the SAE AS5900 Aerodynamic Acceptance Test (AAT) was completed at the FAA and TCCA's request by NASA in 2012, and the summary of this work was published in "Review of the Aerodynamic Acceptance Test and Application to Anti-Icing Fluids testing in the NRC Propulsion and Icing Wind Tunnel" [Ref 1]. This work was further summarized directly to the RMT .0118 group by the author of that independent review, Andy Broeren, on 19 Jul 2017 [Ref 2].

This work is presented not to directly substantiate the application of AAT acceleration profiles to the various type design aircraft, but it does substantiate the original assumptions in the development of the AS5900 and its objective to develop a generic aerodynamic fluid qualification test based on a quite simplified 2-D flat plate wind tunnel test. This assumption has been commonly accepted in the industry, and extends much further than the differences between airfoil types.

Independent Research related to performance impacts of fluids on common research model airfoils

There are several industry available research topics that can support the position that the flow-off characteristics of the thickened fluids across different airfoil types, from flat plate to high curvature commuter airfoils. Two key research projects include *Aerodynamic Effects of Anti-Icing Fluids on a Thin High-Performance Wing Section* [Ref 3] and the yet to be published work shared with SAE G-12 AWG and EASA RMT .0118 related to the LS(1)-0417 thicker, high light airfoil more typical of the commuter aircraft types [Ref 4]. These works similarly concluded that *"...the effect of fluids and contamination was analogous to the effect of surface roughness location downstream of the leading edge. This aerodynamic effect was observed as a shift in the lift and pitching moment curves consistent with a de-cambering of the wing due to increasing boundary-layer displacement thickness."* This concludes that the underlying flow physics as the fluid sheds away from the leading edge are similar across the different airfoil types typically encompassing design variations of modern commuter aircraft in service today.

The von Karman Institute for Fluid Dynamics published a report in August 1991 titled Study of Aerodynamic Effects of Ground De/Anti-Icing Fluid for Commuters [Ref 5] which studies the key parameters in the thickened anti-icing fluid flow-off characteristics on the surface. This demonstrates that the effects of the fluids will decrease with the amount of time above a certain speed (a speed that produces enough shear force on the fluid to drive the viscosity reduction of the non-Newtonian fluid). This is today a commonly accepted baseline assumption in more recent research on the topic, and key even to the development of the AAT itself.

Review of commuter aircraft acceleration profiles

A review of AAT acceleration profiles through a study of various aircraft types acceleration profiles was completed by the SAE G-12 AWG (Nov 2006) [Ref 6]. These were developed for consideration of a third, mid-speed, ramp test and not explicitly for the comparison of each of these aircraft for the AAT applicability. However, they are significant in portraying a comparison across the existing type designs in operation and relation to the speed and time criterion targeted in the EASA RMT .0118 rulemaking task. These diagrams of these acceleration profiles (speed and time to a common point in the takeoff) across type models can be seen in Figure 1. The acceleration profiles for the AS5900 baseline aircraft (737-200ADV) are shown independently in Figure 2.

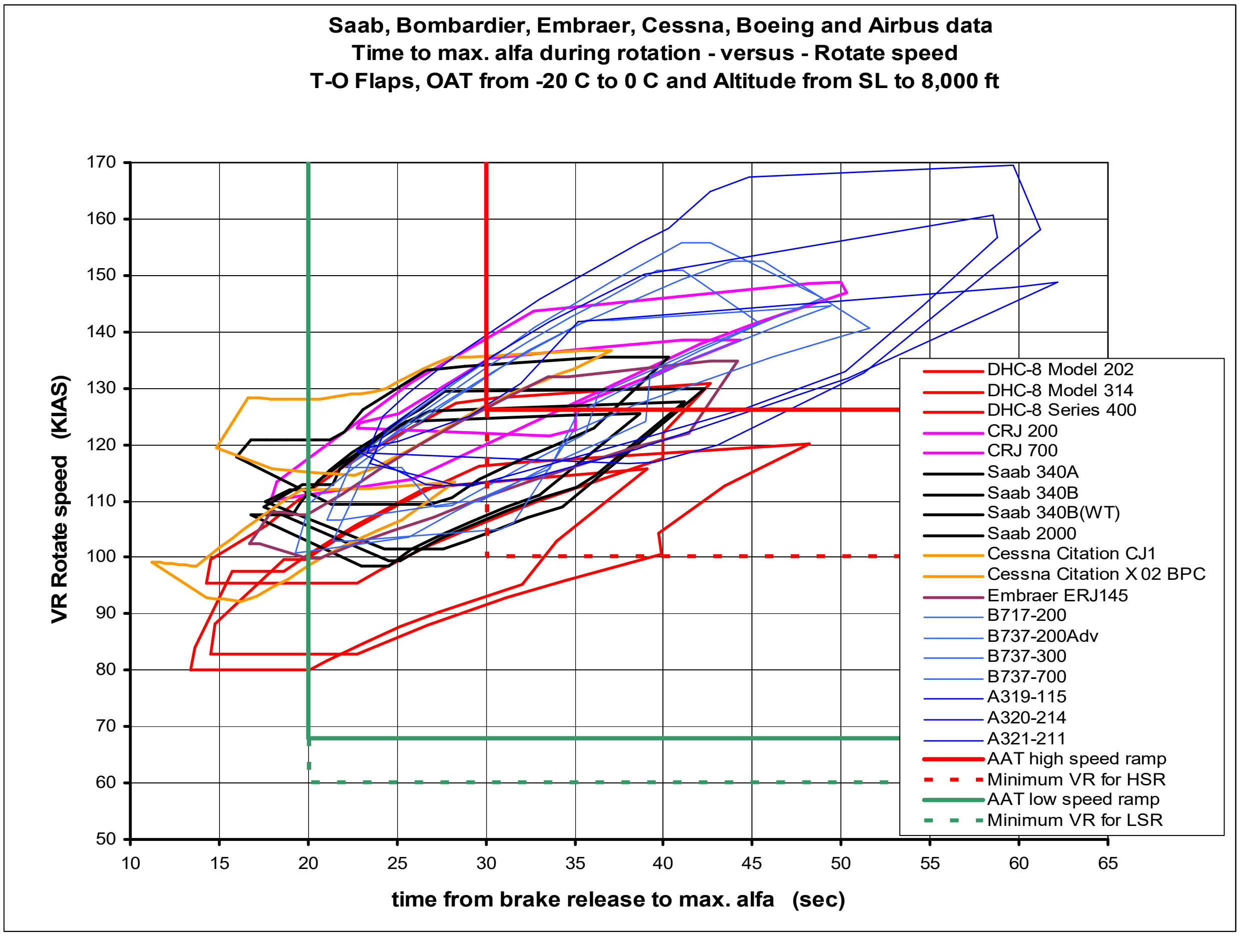


Figure 1. Combined Aircraft Acceleration Profiles (per Ref. 6)

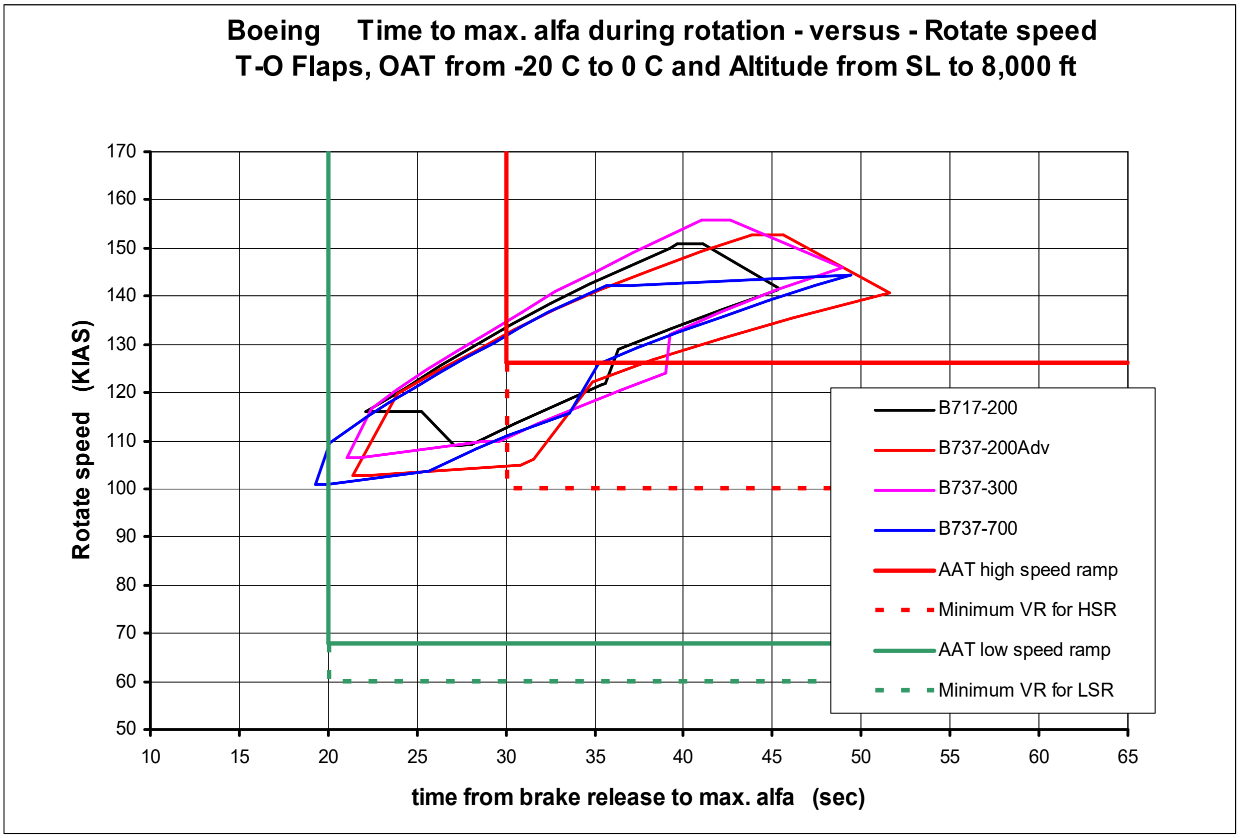


Figure 2. Basis Aircraft Acceleration Profile (per Ref. 6)

It should also be noted, that this study included many aircraft that have time-to-rotation and lift off speeds far less than the basis aircraft (737-200ADV) leading to the AAT high speed ramp, and none have implemented performance adjustments to account for lift loss shortfalls with the use of thickened fluids. This conclusion was further supported during the initial safety review of this EASA RMT .0118 group, as it concluded that no aircraft is known to have included any performance adjustments to account for lift loss to date. The particular models that include performance (e.g. speed) adjustments were only to address controllability concerns (e.g. increased stick forces at rotation) and not for performance impacts (e.g. lift loss). This is a key differentiation to understand the applicability of the speed profiles of the AAT are *only* intended to be used as an applicability criterion for the lift loss aspects.

This nearly 20 years of flight test experience, in combination with nearly 30 years of safe fleet service history across all of these models without a single performance adjustment due to a 6% lift loss exceedance, would support that the AS5900 AAT criterion could be applicable to an even broader range of acceleration profiles as related to the performance impacts. However, the proposal of the Subgroup B report directly bounds the applicability of the performance aspects of the prescribed guidance solely to those aircraft more closely matching the speed and acceleration profiles of SAE AS5900. It is expected those models that do not fall within these criteria shall still demonstrate adequate performance margins.

EASA RMT .0118 Majority Position

It is the RMT .0118 majority position that the speed and acceleration profiles prescribed in the SAE AS5900 AAT's for high speed and low speed ramps, are directly relevant to determine applicability criteria for further demonstration of aerodynamic performance impacts while ensuring safe operation with the use of thickened fluids on a particular type model.

Increased knowledge of the fluid flow-off characteristics and associated performance impacts, since the inception and application of thickened fluids on aircraft in the early 1990's, strongly supports this majority position. This industry knowledge comprises targeted industry and governmental research as well as extensive safe fleet history with the use of thickened fluids.

The OEM's have reviewed, through the SAE G-12 Aero Working Group and through EASA RMT .0118, that no type model has found a need to adjust performance to address a lift degradation during liftoff. The particular models that include performance adjustments were solely to address controllability concerns (e.g. increased stick forces at rotation).

It is understood that a drastically new wing design (e.g. blended wing body) may drive additional verification of the performance impacts, but the modern aircraft design, airfoils, and acceleration (thrust) capabilities are considered to be enveloped by the existing assumptions of the AAT prescribed in SAE AS5900. These configuration differences are additionally addressed in Section 4.1.1 of the report to be considered in addition to the related time-to-rotation and liftoff speeds.

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5 AIAA 1991-762 Flight and WT Tests

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