CS-25 AMENDMENT 2 CHANGE INFORMATION

The Agency publishes amendments to Certification Specifications as consolidated documents. These documents are used for establishing the certification basis for applications made after the date of entry into force of the amendment.

Except for a note under the amended paragraph the detailed amendments in the text of the consolidated version are not visible. To allow readers to also see these detailed amendments this information is provided in this document, in the same format as used for publication of Notices of Proposed Amendments.

The text of the amendment is arranged to show deleted text and new text as shown below:

1. ~~Text to be deleted is shown with a line through it.~~
2. New text to be inserted is highlighted with grey shading.
3. ....
   Indicates that remaining text is unchanged in front of or following the reflected amendment.
   ....

BOOK 1

SUBPART B – FLIGHT

CS 25.101 General

In CS 25.101 (b)(2), correct the figure of 10 ºC to 28 ºC as follows:

….

(2) 34%, at and above standard temperatures plus ~~10~~28 ºC (50ºF).

….

SUBPART C- STRUCTURE

CS 25.399 Dual control system

In CS 25.399 (a)(1), replace the reference to JAR 25.395 with reference to CS 25.395 as follows:

(a) Each dual control system must be designed for the pilots operating in opposition, using individual pilot forces not less than –

(1) 0·75 times those obtained under ~~JAR~~CS 25.395; or

….

SUBPART D- DESIGN AND CONSTRUCTION

CS 25.735 Brakes and braking systems

In CS 25.735 (f) (2), delete the word “landing” and add “take-off” in its place as follows:

….
(f) *Kinetic energy capacity*-
….
(2) *Maximum kinetic energy accelerate-stop.* The maximum kinetic energy accelerate-stop is a rejected take-off for the most critical combination of aeroplane ~~landing~~ take-off weight and speed. ….

CS 25.745 Nose-wheel steering

In CS 25.745(c), delete the reference to 25.1309 (d) as follows:

….
(c) Under failure conditions the system must comply with CS 25.1309 (b)~~,~~ and (c) ~~and (d)~~. The arrangement ….
….

SUBPART F - EQUIPMENT

CS 25.1301 Function and installation

In CS 25.1301 (c), delete the “; and” at the end of the sentence and replace it with full dot as follows:

….

(c) Be installed according to limitations specified for that equipment~~; and~~.

CS 25.1365 Electrical appliances, motors and transformers

In CS 25.1365(a), delete the reference to 25.1309 (d) as follows:

(a) Domestic appliances must be so designed and installed that in the event of failures of the electrical supply or control system, the requirements of CS 25.1309(b)~~,~~ and (c) ~~and (d)~~ will be satisfied.

CS 25.1423 Public address system

In CS 25.1423, amend the introductory sentence as follows:

A public address system required by ~~this CS~~ operational rules must –

….

CS 25.1435 Hydraulic Systems

In CS 25.1435 (b) (2) replace the reference to JAR 25.1435(a)(1) with reference to CS 24.1435(a)(1) as follows:

….

(b) *System design.*

….

(2) …. they meet the requirements defined in ~~JAR~~CS 25.1435(a)(1) through CS 25.1435(a)(5) inclusive;

SUBPART G - OPERATING LIMITATIONS AND INFORMATION

Existing CS 25.1591 is deleted and replaced with a new CS 25.1591 as follows:

CS 25.1591 Performance Information for Operations with Contaminated Runway Surface Conditions
(See AMC 25.1591)

(a) Supplementary performance information applicable to aeroplanes operated on runways contaminated with standing water, slush, snow or ice may be furnished at the discretion of the applicant. If supplied, this information must include the expected performance of the aeroplane during take-off and landing on hard-surfaced runways covered by these contaminants. If information on any one or more of the above contaminated surfaces is not supplied, the AFM must contain a statement prohibiting operation(s) on the contaminated surface(s) for which information is not supplied. Additional information covering operation on contaminated surfaces other than the above may be provided at the discretion of the applicant.

(b) Performance information furnished by the applicant must be contained in the AFM. The information may be used to assist operators in producing operational data and instructions for use by their flight crews when operating with contaminated runway surface conditions. The information may be established by calculation or by testing.

(c) The AFM must clearly indicate the conditions and the extent of applicability for each contaminant used in establishing the contaminated runway performance information. It must also state that actual conditions that are different from those used for establishing the contaminated runway performance information may lead to different performance.

Appendix F

Part II – Flammability of Seat Cushions

In Appendix F, Part II, paragraph (a)(3), last sentence, replace the reference to "CS 25.853(b)" by the reference to "CS 25.853(c)" as follows:

(a) *Criteria for Acceptance.*
….
(3) …. If a cushion, including outer dress covering, is demonstrated to meet the requirements of this Appendix using the oil burner test, the dress covering of that cushion may be replaced with a similar dress covering provided the burn length of the replacement covering, as determined by the test specified in CS 25.853(~~b~~c), does not exceed the corresponding burn length of the dress covering used on the cushion subjected to the oil burner test.

Appendix J

Emergency Demonstration

In Appendix J, first sentence, replace the reference to JAR 25.803 with reference to CS 25.803 as follows:

The following test criteria and procedures must be used for showing compliance with ~~JAR~~CS 25.803:

BOOK 2 – ACCEPTABLE MEANS OF COMPLIANCE

AMC – SUBPART C

AMC 25.335(b)(2)
Design Dive Speed

In AMC 25.335(b)(2) amend the title of paragraph 2 as follows:

2. RELATED ~~CS PARAGRAHS~~ CERTIFICATION SPECIFICATIONS.

AMC 25.571(a), (b) and (e)
Damage Tolerance and Fatigue Evaluation of Structure

In AMC 25.571(a),(b) and (e) sub-paragraph 3.2.2 a., replace "ACJ" with "AMC" as follows:

3.2.2 *Scatter Factor for Safe-Life Determination.*
….
a. The base scatter factors applicable to test results are: BSF_1 = 3.0, and BSF_2 = (see paragraph 3.2.2(e) of this ~~ACJ~~AMC)….

AMC – SUBPART D

AMC 25.703
Take-off Configuration Warning Systems

1 - In AMC 25.703, sub-paragraph 3.a, add after item (6), a new item (7) as follows:

….
(6) ….
(7) EASA AMC 20-115() Recognition of EUROCAE ED-12()/RTCA DO-178().
….

2 - In AMC 25.703, sub-paragraph 3.b (2), complete the reference to EUROCAE ED-12B/RTCA document DO-178B as follows:

b. *Industry Documents*.

(2) EUROCAE ED-14D/RTCA document DO-160D or latest version, Environmental Conditions and Test Procedures for Airborne Equipment; EUROCAE ED-12~~B~~()/RTCA document DO-178~~B~~() ~~or latest version~~ as recognized by EASA AMC 20-115(), Software Considerations in Airborne Systems and Equipment Certification. RTCA documents can be obtained from the RTCA, One McPherson Square, Suite 500, 1425 K Street Northwest, Washington, D.C. 20005.

3 - In AMC 25.703, sub-paragraph 5.b (4), complete the reference to "the applicable version of EUROCAE ED-12/RTCA document DO-178" by a reference to "AMC 20-115()" as follows:

(4) If such systems use digital electronic technology, a software level should be used, in accordance with the applicable version of EUROCAE ED-12()/RTCA document DO-178(), as recognized by AMC 20-115() (Recognition of EUROCAE ED-12()/RTCA DO-178()), which is compatible with the system integrity determined by the AMC 25.1309 analysis.

….

AMC 25.735
Brakes and Braking Systems Certification Tests and Analysis

1 - In AMC 25.735, sub-paragraph 2 a., correct the cross-reference to IR-21, IR 21.303 and IR 21.101 and their titles as follows:

….
2. ….
a. Related EASA Certification Specifications

IR-21 Part-21 and CS-25 paragraphs …
IR 21A.303 Compliance with applicable Requirements
….
Additional IR-21 Part-21and CS-25 paragraphs….
IR 21A.101 Designation of applicable requirements certification specifications and environmental protection requirements

2 - In AMC 25.735, sub-paragraph.2. b.(ii), amend the existing text and add the cross-reference to AMC 20-115() as follows:

(ii) Advisory Circulars/MaterialAcceptable Means of Compliance

AC 25.1309-1A System Design and Analysis
AC 25-7A Flight Test Guide for Certification of Transport Category Airplanes
AC 21-29A Detecting and Reporting Suspected Unapproved Parts
AC 91-6A Water, Slush, and Snow on the Runway (
AMC 25.1591 Supplementary Performance Information for Take-off from Wet Runways and for Operation on Runways Contaminated by Standing Water, Slush, Loose Snow, Compacted Snow, or Ice. The derivation and methodology of performance information for use when taking-off and landing with contaminated runway surface conditions.)

AMC 20-115() Recognition of EUROCAE ED-12()/RTCA DO-178()
….

3 - In AMC 25.735, sub-paragraph 2. b. (vi), amend the reference to ED-12B/RTCA DO-178B as follows:

(vi) The European Organisation for Civil Aviation Equipment Documents

ED-14D/RTCA DO-160D Environmental Conditions and Test Procedures for Airborne Equipment. Issued 29 July 1997
ED-12B()/RTCA DO-178B() Software Considerations in Airborne Systems and Equipment Certification. Issued 1 December 1992 , as recognized by AMC 20-115().

4 - In AMC 25.735, sub-paragraph 4. a.(1)(e), amend the reference to IR 21.101 as follows:

(e) Protect against the ingress or effects of foreign bodies or materials (water, mud, oil, and other products) that may adversely affect their satisfactory performance. Following initial aeroplane certification, any additional wheel and brake assemblies should meet the applicable airworthiness requirements specified in IR 21A.101(a) and (b) to eliminate situations that may have adverse consequences on aeroplane braking control and performance. This includes the possibility of the use of modified brakes either alone (i.e., as a ship set) or alongside the OEM's brakes and the mixing of separately approved assemblies.

AMC 25.785(c)
Seats and Safety Belts

Change the designation of AMC 25.785 (c) to read AMC 25.785 (d) as follows:

AMC 25.785(~~c~~d)
Seats and Safety Belts

….

AMC – SUBPART F

AMC 25.1309
System Design and Analysis

1 - In AMC 25.1309, sub-paragraph 3.a.(3), replace the reference to AC 20-115B document by reference to AMC 20-115 () as follows:

….
(3) ~~AC 20-115B Radio Technical Commission for Aeronautics Document RTCA DO-178B/AMC 20-115B EUROCAE ED-12B~~ AMC 20-115() Recognition of EUROCAE ED-12()/RTCA DO-178().
….

2 - In AMC 25.1309, sub-paragraph 3.a.(4), amend the existing text as follows:

….
(4) ~~AC/~~AMC 25~~-~~.901 (c) Safety Assessment of Powerplant Installations.
….

3 - In AMC 25.1309, sub-paragraph.3.b.(2), amend the reference to RTCA DO-178B/EUROCAE ED-12B as follows:

….
(2) RTCA, Inc., Document No. DO-178~~B~~()/EUROCAE ED-12~~B~~(), Software Considerations in Airborne Systems and Equipment Certification, as recognized by AMC 20-115().
….

4 - In AMC 25.1309, insert after sub-paragraph 6. c. (2) the following heading of paragraph 7:

AMC 25.1309 System Design and Analysis

….
6. *BACKGROUND*

….
c. *Highly Integrated Systems.*
….

(2) Considering the above developments, ….
….
….but not replace, qualitative methods based on engineering and operational judgement.

7. FAILURE CONDITION CLASSIFICATIONS AND PROBABILITY TERMS

a. *Classifications.* Failure Conditions ….

5 – In Appendix 2 to AMC 25.1309(d)(2) amend the existing text as follows:

(2) A list of the parts and equipment of which the system is comprised, including their performance specifications or design standards and development assurance levels if applicable. This list may reference other documents, e.g., ~~Certification Specification~~ European Technical Standard Orders (~~CS-~~ETSOs), manufacturers or military specifications, etc.

AMC 25.1322
Alerting Systems

In AMC 25.1322, paragraph 2.1, replace the reference to CS 25B1305 with reference to CS 25J1305 as follows:

2.1
….
CS 25~~B~~J1305 APU fire warning
….

AMC 25.1435
Hydraulic Systems - Design, Test, Analysis and Certification

In AMC 25.1435, sub-paragraph 2. (b) (i), amend the existing text as follows:

(i) CS-European Technical Standard Orders (CS-ETSO's)

~~CS-~~ETSO-C47 Pressure Instruments - Fuel, Oil and Hydraulic
~~CS-~~ETSO-2C75 Hydraulic Hose Assemblies

AMC 25.1457
Cockpit Voice Recorders

In AMC 25.1457, amend the existing text as follows:

In showing compliance with CS 25.1457, the applicant should take account of EUROCAE document No. ED-56 'Minimum Operational Performance Requirement for Cockpit Voice Recorder System', ~~which will be referred to in a TSO when published~~ as referred to in ETSO-C123a.

AMC – SUBPART G

AMC 25.1581
Aeroplane Flight Manual

In AMC 25.1581, sub-paragraph 6. b. (6) (i), amend the existing text as follows:

(i) State all limitations necessary to ensure safe operation of engines, propellers, fuel systems and powerplant accessories, including auxiliary powerplants (see CS 25.1521 and ~~25A1521~~ 25J1521). If the use of reduced ….

AMC 25.1581, APPENDIX 1 COMPUTERISED AEROPLANE FLIGHT MANUAL

In AMC 25.1581, APPENDIX 1, sub-paragraph 6. b. (1), amend the existing text as follows:

(1) The applicant should propose the software development process in the plan for software aspects of certification. The application should document the methods, parameters and allowable range of conditions contained in the computerised AFM. The results obtained from the computerised AFM should be shown to meet all applicable CS 25 requirements. This compliance may be shown using substantiation documentation, demonstrations, or other means mutually agreed to by the Agency and the applicant. The software development process described in ~~AC 20-115B (RTCA DO-178B)/EUROCAE ED-12B)~~ AMC 20-115() “Recognition of EUROCAE ED-12()/RTCA DO-178()” is valid, in general, for developing either airborne or ground based software. It represents one acceptable approach, but not the only acceptable approach, for developing software for the computerised AFM. Some of the specific guidance provided in AMC 20-115~~B~~(), however, may not apply to the computerised AFM.

AMC 25.1583(k), MAXIMUM DEPTH OF RUNWAY CONTAMINANTS FOR TAKE-OFF OPERATIONS

In AMC 25.1583(k) references to CS 25X1591(c)(2) are replaced by reference to CS 25.1591 as follows:

….

a. Method 1. If information on the effect of runway contaminants on the expected take-off performance of the aeroplane is furnished in accordance with the provisions of ~~CS 25X1591(c)(2)~~ CS 25.1591, take-off operation should be limited to the contamination depths for which take-off information is provided.

b. Method 2. If information on the effect of runway contaminants on the expected take-off performance of the aeroplane in accordance with the provisions of ~~CS 25X1591(c)(2)~~ CS 25.1591 is not provided, take-off operation should be limited to runways where the degree of contamination does not exceed the equivalent of 3 mm (0·125 inch) of water, except in isolated areas not exceeding a total of 25% of the area within the required length and width being used.

….

AMC 25.1591, THE DERIVATION AND METHODOLOGY OF PERFORMANCE INFORMATION FOR USE WHEN TAKING-OFF AND LANDING WITH CONTAMINATED RUNWAY SURFACE CONDITIONS.

Add new AMC 25.1591 as follows:

1.0 Purpose

This AMC provides information, guidelines, recommendations and acceptable means of compliance for use by applicants in the production of performance information for aeroplanes when operated on runways that are contaminated by standing water, slush, snow, ice or other contaminants.

2.0 Technical Limitations of Data

The methodology specified in this AMC provides one acceptable means of compliance with the provisions of CS 25.1591. In general it does not require aeroplane testing on contaminated runway surfaces, although such testing if carried out at the discretion of the applicant may significantly improve the quality of the result or reduce the quantity of analytical work required.

Due to the nature of naturally occurring runway contaminants and difficulties associated with measuring aeroplane performance on such surfaces, any data that is either calculated or measured is subject to limitations with regard to validity. Consequently the extent of applicability should be clearly stated.

The properties specified in this AMC for various contaminants are derived from a review of the available test and research data and are considered to be acceptable for use by applicants. This is not an implied prohibition of data for other conditions or that other conditions do not exist.

It has been recently determined that the assumption to use wet runway surface field length performance data for operations on runway surfaces contaminated with dry snow (depths below 10 mm) and wet snow (depths below 5 mm) may be inappropriate. Flight test evidence together with estimations have indicated some measure of relatively low gear displacement drag and a measurable reduction in surface friction in comparison to the assumptions associated with wet runway field performance data. As a consequence it has been agreed that additional work is required to further develop the associated methodology. As an interim measure it has been concluded that it is reasonable to consider these surfaces by recommending that they be addressed by using the data for the lowest depth of the contaminant provided.

It is intended that the use of aeroplane performance data for contaminated runway conditions produced in accordance with CS 25.1591 should include recommendations associated with the operational use of the data. Where possible, this operational guidance should be provided by the applicant or its production co-ordinated with the applicant to ensure that its use remains valid.

Operators are expected to make careful and conservative judgments in selecting the appropriate performance data to use for operations on contaminated runways. Particular attention should be paid to the presence of any contaminant in the critical high speed portion of the runway. For takeoff, it may be appropriate to use different contaminant types or depths for the takeoff and the accelerate-stop portions. For example, it may be appropriate to use a greater contaminant depth or a contaminant type that has a more detrimental effect on acceleration for the takeoff portion than for the accelerate-stop portion of the takeoff analysis.

In considering the maximum depth of runway contaminants it may be necessary to take account of the maximum depth for which the engine air intakes have been shown to be free of ingesting hazardous quantities of water in accordance with CS 25.1091(d)(2).

3.0 Standard Assumptions

Due to the wide variation in possible conditions when operating on contaminated runways and the limitations inherent in representing the effects of these conditions analytically, it is not possible to produce performance data that will precisely correlate with each specific operation on a contaminated surface. Instead, the performance data should be determined for a standardised set of conditions that will generally and conservatively represent the variety of contaminated runway conditions occurring in service.

It should be assumed that:

- the contaminant is spread over the entire runway surface to an even depth (although rutting, for example, may have taken place).

- the contaminant is of a uniform specific gravity.

- where the contaminant has been sanded, graded (mechanically levelled) or otherwise treated before use, that it has been done in accordance with agreed national procedures.

4.0 Definitions

These definitions may be different to those used by other sources but are considered appropriate for producing acceptable performance data, suitable for use in aeroplane operations.

4.1 Standing Water

Water of a depth greater than 3mm. A surface condition where there is a layer of water of 3mm or less is considered wet for which AMC 25.1591 is not applicable.

4.2 Slush

Partly melted snow or ice with a high water content, from which water can readily flow, with an assumed specific gravity of 0.85. Slush is normally a transient condition found only at temperatures close to 0°C.

4.3 Wet Snow

Snow that will stick together when compressed, but will not readily allow water to flow from it when squeezed, with an assumed specific gravity of 0.5.

4.4 Dry Snow

Fresh snow that can be blown, or, if compacted by hand, will fall apart upon release (also commonly referred to as loose snow), with an assumed specific gravity of 0.2. The assumption with respect to specific gravity is not applicable to snow which has been subjected to the natural ageing process.

4.5 Compacted Snow

Snow which has been compressed into a solid mass such that the aeroplane wheels, at representative operating pressures and loadings, will run on the surface without causing significant rutting.

4.6 Ice

Water which has frozen on the runway surface, including the condition where compacted snow transitions to a polished ice surface.

4.7 Specially Prepared Winter Runway

A runway, with a dry frozen surface of compacted snow and/or ice which has been treated with sand or grit or has been mechanically or chemically treated to improve runway friction. The runway friction is measured and reported on a regular basis in accordance with national procedures.

4.8 Specific Gravity

The density of the contaminant divided by the density of water.

5.0 Contaminant Properties to be Considered

5.1 Range of Contaminants

The following general range of conditions or properties may by used. The list given in Table 1 is not necessarily comprehensive and other contaminants may be considered, provided account is taken of their specific properties.

Data should assume the contaminant to be uniform in properties and uniformly spread over the complete runway.

Contaminants can be classified as being:-

(i) Drag producing, for example by contaminant displacement or impingement,

(ii) Braking friction reducing, or

(iii) A combination of (i) and (ii).

Data to be produced should use the classification and assumptions of Table 1 and then the appropriate sections of the AMC as indicated.

Contaminant Type	***Range of Depths to be Considered - mm***	***Specific Gravity Assumed for Calculation***	***Is Drag Increased?***	***Is Braking Friction Reduced Below Dry Runway Value?***	***Analysis Paragraphs Relevant***
Standing water, Flooded runway	3-15 (see Note 1)	1.0	Yes	Yes	7.1, 7.3, 7.4
Slush	3-15 (see Note 1)	0.85	Yes	Yes	7.1, 7.3, 7.4
Wet Snow (see Note 2)	Below 5		No	Yes	7.3, 7.4
Wet Snow (see Note 3)	5-30	0.5	Yes	Yes	7.1, 7.3, 7.4
Dry Snow (see Note 2)	Below 10		No	Yes	7.3, 7.4
Dry Snow	10-130	0.2	Yes	Yes	7.2, 7.3, 7.4
Compacted Snow	0 (see Note 4)		No	Yes	7.3, 7.4
Ice	0 (see Note 4)		No	Yes	7.3, 7.4
Specially Prepared Winter Runway	0 (see Note 4)		No	Yes	7.3, 7.4

Table 1

Note 1: Runways with water depths or slush less than 3mm are considered wet, for which AMC 25.1591 is not applicable.

Note 2: Contaminant drag may be ignored.

Note 3: For conservatism the same landing gear displacement and impingement drag methodology is used for wet snow as for slush.

Note 4: Where depths are given as zero it is assumed that the aeroplane is rolling on the surface of the contaminant.

5.2 Other Contaminants

Table 1 lists the contaminants commonly found. It can be seen that the complete range of conditions or specific gravities has not been covered. Applicants may wish to consider other, less likely, contaminants in which case such contaminants should be defined in a manner suitable for using the resulting performance data in aeroplane operations.

6.0 Derivation of Performance Information

6.1 General Conditions

Take-off and landing performance information for contaminated runways should be determined in accordance with the assumptions given in paragraph 7.0.

Where performance information for different contaminants are similar, the most critical may be used to represent all conditions.

This AMC does not set out to provide a complete technical analytical process but rather to indicate the elements that should be addressed. Where doubt exists with regard to the accuracy of the methodology or the penalties derived, consideration should be given to validation by the use of actual aeroplane tests or other direct experimental measurements.

6.2 Take-off on a Contaminated Runway

6.2.1 Except as modified by the effects of contaminant as derived below, performance assumptions remain unchanged from those used for a wet runway, in accordance with the agreed certification standard. These include accelerate-stop distance definition, time delays, take-off distance definition, engine failure accountability and stopping means other than by wheel brakes (but see paragraph 7.4.3).

6.2.2 Where airworthiness or operational standards permit operations on contaminated runways without engine failure accountability, or using a V_{STOP} and a V_{GO} instead of a single V_1, these performance assumptions may be retained. In this case, a simple method to derive a single V_1 and associated data consistent with the performance assumptions of paragraph 6.2.1 must also be provided in the AFM.

NOTE: V_{STOP} is the highest decision speed from which the aeroplane can stop within the accelerate-stop distance available. V_{GO} is the lowest decision speed from which a continued take-off is possible within the take-off distance available.

6.3 Landing on a Contaminated Runway

6.3.1 Airborne distance

Assumptions regarding the airborne distance for landing on a contaminated runway are addressed in paragraph 7.4.2.

6.3.2 <u>Ground Distance</u>

Except as modified by the effects of contaminant as derived below, performance assumptions for ground distance determination remain unchanged from those used for a dry runway. These assumptions include:

- Touchdown time delays.
- Stopping means other than wheel brakes (but see paragraph 7.4.3).

7.0 Effects of Contaminant

7.1 <u>Contaminant Drag - Standing Water, Slush, Wet Snow</u>

General advice and acceptable calculation methods are given for estimating the drag force due to fluid contaminants on runways:

Total drag		Drag due to		Drag due to airframe
due to fluid	=	fluid displacement	+	impingement of fluid
contaminant		by tyres		spray from tyres

The essence of these simple calculation methods is the provision of appropriate values of drag coefficients below, at, and above tyre aquaplaning speed, V_P (see paragraph 7.1.1):

- Paragraphs 7.1.2.a and 7.1.2.b give tyre displacement drag coefficient values for speeds below V_P .
- Paragraph 7.1.3.b.2 gives tyre equivalent displacement drag coefficient values to represent the skin friction component of impingement drag for speeds below V_P .
- Paragraph 7.1.4 gives the variation with speed, at and above V_P, of drag coefficients representing both fluid displacement and impingement.

7.1.1 <u>Aquaplaning Speed</u>

An aeroplane will aquaplane at high speed on a surface contaminated by standing water, slush or wet snow. For the purposes of estimating the effect of aquaplaning on contaminant drag, the aquaplaning speed, V_P, is given by -

$$V_P = 9\sqrt{P}$$

where V_P is the ground speed in knots and P is the tyre pressure in lb/in^2.

Predictions (Reference 5) indicate that the effect of running a wheel over a low density liquid contaminant containing air, such as slush, is to compress it such that it essentially acts as high density contaminant. This means that there is essentially no increase in aquaplaning speed to be expected with such a lower density contaminant. For this reason, the aquaplaning speed given here is not a function of the density of the contaminant.

(See References 1, 5 and 10)

7.1.2 <u>Displacement Drag</u>

This is drag due to the wheel(s) running through the contaminant and doing work by displacing the contaminant sideways and forwards.

a. Single wheel.

The drag on the tyre is given by —

$$D = C_D \tfrac{1}{2} \rho V^2 S$$

Where ρ is the density of the contamination, S is the frontal area of the tyre in the contaminant and V is the groundspeed, in consistent units.

S = b x d where d is the depth of contamination and b is the effective tyre width at the contaminant surface and may be found from —

$$b = 2W\left[\left(\frac{\delta + d}{W}\right) - \left(\frac{\delta + d}{W}\right)^2\right]^{1/2}$$

Where W is the maximum width of the tyre and δ is the tyre deflection, which may be obtained from tyre manufacturers' load-deflection curves.

The value of C_D may be taken as 0.75 for an isolated tyre below the aquaplaning speed, V_P.

(See Reference 3)

b. Multiple wheels

A typical dual wheel undercarriage shows a drag 2.0 times the single wheel drag, including interference. For a typical four-wheel bogie layout the drag is 4 times the single wheel drag (again including interference). For a six-wheel bogie layout a reasonable conservative estimate suggests a figure of 4.2 times the single wheel drag. The drag of spray striking the landing gear structure above wheel height may also be important and should be included in the analysis for paragraph 7.1.3.b.1 but for multiple wheel bogies the factors above include centre spray impingement drag on gear structure below wheel height.

(See Reference 3)

7.1.3 Spray Impingement Drag

a. Determination of spray geometry

The sprays produced by aeroplane tyres running in a liquid contaminant such as slush or water are complex and depend on aeroplane speed, the shape and dimensions of the loaded tyre and the contaminant depth. The spray envelope should be defined, that is the height, width, shape and location of the sideways spray plumes and, in the case of a dual wheel undercarriage, the centre spray plumes. Additionally, a forward bow-wave spray will be present which may be significant in drag terms should it impinge on the aeroplane.

In order to assess the drag it is necessary to know the angles of the spray plumes so that they can be compared with the geometry of the aeroplane. The angle at which the plumes rise is generally between 10° and 20° but it varies considerably with speed and depth of precipitation and to a small extent with tyre geometry. A method for estimating the plume angles in the horizontal and vertical directions is given in References 1 and 7 and may be used in the absence of experimental evidence. This information may be used to indicate those parts of the airframe which will be struck by spray, in particular whether the nose-wheel plume will strike the main landing gear or open wheel-wells, the wing leading edges or the engine nacelles, and whether the main-wheel plumes will strike the rear fuselage or flaps.

b. Determination of the retarding forces

Following definition of the spray envelopes, the areas of contact between the spray and the airframe can be defined and hence the spray impingement drag determined. This will be in two parts, direct interaction of the spray with the aeroplane structure and skin friction.

For smaller jet aeroplanes, typically those where the wing-to-ground height is less than 2 metres (6 feet), the methods contained in this document may not be conservative. Drag estimates should be correlated with performance measurements taken, for example, during water trough tests for engine ingestion.

b.1. Drag caused by direct impact of the spray

For aeroplane designs where surface areas are exposed to direct spray impact, the resulting drag forces should be taken into account. These forces exist where a significant part of the spray flow is directed at part of the aeroplane structure at a normal or non-oblique angle. The drag, or momentum loss of the mass of fluid, so caused should be accounted for.

(See Reference 6)

b.2. Drag caused by skin friction

Reference 2 explains that the relative velocity between spray from the landing gear and wetted aeroplane components causes drag due to skin friction and provides a method for its calculation. Where more than one spray acts on the same wing or fuselage surface the skin friction forces are not cumulative and the single, higher calculated value should be used.

An alternative, simple, conservative empirical estimate of skin friction drag, which converts the skin friction drag into an equivalent displacement drag coefficient based on nose-wheel alone drag measurements, is given by

$$C_D \text{ spray} = 8 \times L \times 0.0025$$

where C_D spray is to be applied to the total nose-wheel displacement area (b x d x number of wheels) and L is the wetted fuselage length in feet behind the point at which the top of the spray plume reaches the height of the bottom of the fuselage. This relation can also be used in the case of a main-wheel spray striking the rear fuselage. In the case of any one main wheel unit only the inner plume from the innermost leading wheel is involved so the relevant displacement area is half that of one main wheel.

7.1.4 Effect of Speed on Displacement and Impingement Drag Coefficients at and above Aquaplaning Speed

The drag above V_P reduces to zero at lift off and one acceptable method is to reduce C_D as shown in the curve in Figure 1. This relationship applies to both displacement and spray impingement drag coefficients.

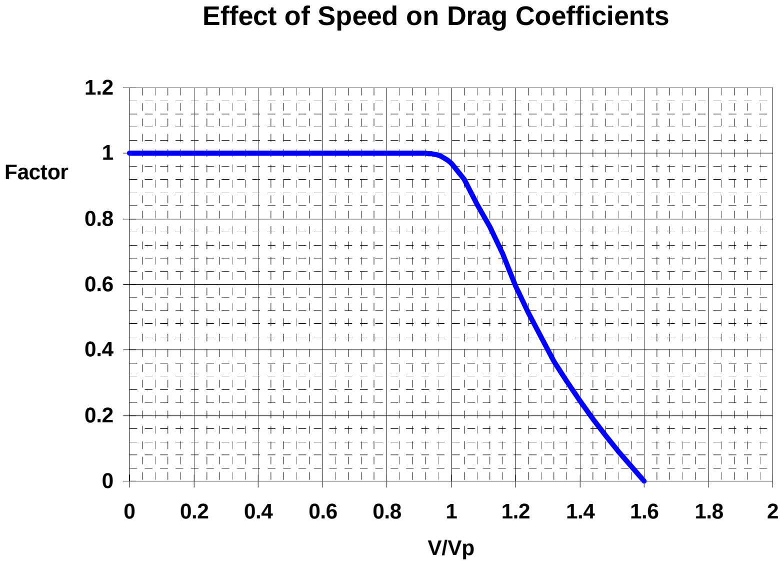

Figure 1

7.2 Contaminant Drag - Dry Snow

A basic method for calculating the drag of aeroplane tyres rolling in dry snow is given herein. The method is based on the theoretical model presented in References 8 and 9, using a specific gravity of 0.2 as provided in Table 1. Only snow of specific gravity of 0.2 is selected because it represents naturally occurring snow and results in the highest drag variation with ground speed for the range of snow specific gravities that are likely to be encountered. For other snow specific gravities, the more detailed methods of Reference 8 should be used.

7.2.1 Single Tyre Drag

The total displacement drag of a tyre rolling in dry snow is presented by the following equation:

$$D = D_C + D_D$$

The term D_C represents the drag due to the compression of the snow by the tyre. The term D_D represents the drag due to the displacement of the snow particles in a vertical direction.

The drag due to snow compression for a single tyre for snow with a specific gravity of 0.2 is given by:

Tyre pressure > 100 psi

$D_C = 74000\ bd$ (Newtons)

Tyre pressure $50 \leq p \leq 100$ psi

$D_C = 56000\ bd$ (Newtons)

In which:

d = snow depth in metres
b = is the tyre width at the surface in metres (see paragraph 7.1.2)

The drag due to the displacement of the snow particles in a vertical direction for a single tyre for snow with a specific gravity of 0.2 is given by:

Tyre pressure > 100 psi

$$D_D = \left(\frac{56}{R} + \frac{9}{d}\right) bd^2 V_g^2 \qquad \text{(Newtons)}$$

Tyre pressure 50 ≤ p ≤ 100 psi

$$D_D = \left(\frac{52}{R} + \frac{8}{d}\right) bd^2 V_g^2 \qquad \text{(Newtons)}$$

In which:

d = snow depth in metres
b = is the tyre width at the surface in metres (see paragraph 7.1.2)
V_g = the ground speed in m/s
R = tyre radius in metres

For other snow densities D_C and D_D can be calculated using the method presented in Reference 8.

7.2.2 Multiple Wheels

The drag on dual tyre landing gears (found on both nose and main gears) is simply the drag of both single tyres added together. The interference effects between both tyres, found on dual tyre configurations running through slush or water, are not likely to be present when rolling over a snow covered surface. The drag originates from the vertical compaction of the snow layer. Although there is some deformation perpendicular to the tyre direction of motion, this deformation occurs mainly at or below the bottom of the rut and therefore does not affect the deformation in front of the adjacent tyre. Hence, interference effects can be ignored.

In the case of a bogie landing gear only the leading tyres have to be considered for the drag calculation, as explained in Reference 8. After the initial compression of the snow by the leading tyres, the snow in the rut becomes stronger and a higher pressure must be applied to compress the snow further. Therefore, the drag on the trailing tyres can be neglected and the drag on a bogie landing gear is assumed to be equal to that of a dual tyre configuration. All other multiple-tyre configurations can be treated in the same manner.

7.2.3 Spray Impingement Drag

Experiments have shown that the snow spray coming from the tyres is limited with only small amounts striking the airframe. The speed and the density of the snow spray are much lower than, for instance, that of water spray. Therefore, the drag due to snow impingement on the airframe can be neglected.

7.2.4 Total Landing Gear Drag

To obtain the total drag on the tyres due to snow, D_C and D_D for each single tyre (excluding the trailing tyres of a bogie gear) should be calculated and summed.

7.3 Braking Friction (All Contaminants)

On most contaminant surfaces the braking action of the aeroplane will be impaired. Performance data showing these effects can be based on either the minimum conservative 'default' values, given in Table 2 or test evidence and assumed values (see paragraph 7.3.2). In addition the applicant may optionally provide performance data as a function of aeroplane braking coefficient or wheel braking coefficient.

7.3.1 Default Values

To enable aeroplane performance to be calculated conservatively in the absence of any direct test evidence, default friction values as defined in Table 2 may be used. These friction values represent the effective braking coefficient of an anti-skid controlled braked wheel/tyre.

Contaminant	***Default Friction Value*** μ
Standing Water and Slush	$= -0.0632\left(\frac{V}{100}\right)^3 + 0.2683\left(\frac{V}{100}\right)^2 - 0.4321\left(\frac{V}{100}\right) + 0.3485$ where V is groundspeed in knots Note: For V greater than the aquaplaning speed, use μ = 0.05 constant
Wet Snow below 5mm depth	0.17
Wet Snow	0.17
Dry Snow below 10mm depth	0.17
Dry Snow	0.17
Compacted Snow	0.20
Ice	0.05

Note: Braking Force = load on braked wheel x Default Friction Value μ

Table 2

Note: For a specially prepared winter runway surface no default friction value can be given due to the diversity of conditions that will apply.

(See reference 10)

7.3.2 Other Than Default Values

In developing aeroplane braking performance using either test evidence or assumed friction values other than the default values provided in Table 2, a number of other brake related aspects should be considered. Brake efficiency should be assumed to be appropriate to the brake and anti-skid system behaviour on the contaminant under consideration or a conservative assumption can be used. It can be assumed that wheel brake torque capability and brake energy characteristics are unaffected. Where the tyre wear state significantly affects the braking performance on the contaminated surface, it should be assumed that there is 20% of the permitted wear range remaining.

Where limited test evidence is available for a model predecessor or derivative this may be used given appropriate conservative assumptions.

7.3.3 Use of Ground Friction Measurement Devices

Ideally it would be preferable to relate aeroplane braking performance to a friction index measured by a ground friction device that would be reported as part of a Surface Condition Report. However, there is not, at present, a common friction index for all ground friction measuring devices. Hence it is not practicable at the present time to determine aeroplane performance on the basis of an internationally accepted friction index measured by ground friction devices. Notwithstanding this lack of a common index, the applicant may optionally choose to present take-off and landing performance data as a function of an aeroplane braking coefficient or wheel braking coefficient constant with ground speed for runways contaminated with wet snow, dry snow, compacted snow or ice. The responsibility for relating this data to a friction index measured by a ground friction device will fall on the operator and the operating authority.

7.4 Additional Considerations

7.4.1 Minimum V_1

For the purpose of take-off distance determination, it has been accepted that the minimum V_1 speed may be established using the V_{MCG} value established in accordance with CS 25.149(g). As implied in paragraph 8.1.3, this may not ensure that the lateral deviation after engine failure will not exceed 30 ft on a contaminated runway.

7.4.2 Landing Air Distance

For contaminated surfaces, the airborne distance should be calculated by assuming that 7 seconds elapse between passing through the 50 ft screen height and touching down on the runway. In the absence of flight test data to substantiate a lower value, the touchdown speed should be assumed to be 93% of the threshold speed.

7.4.3 Reverse Thrust

Performance information may include credit for reverse thrust where available and controllable.

8.0 Presentation of Supplementary Performance Information

8.1 General

Performance information for contaminated runways, derived in accordance with the provisions of paragraphs 5.0 to 7.0, should be accompanied by appropriate statements such as:

8.1.1 Operation on runways contaminated with water, slush, snow, ice or other contaminants implies uncertainties with regard to runway friction and contaminant drag and therefore to the achievable performance and control of the aeroplane during take-off, since the actual conditions may not completely match the assumptions on which the performance information is based. Where possible, every effort should be made to ensure that the runway surface is cleared of any significant contamination.

8.1.2 The performance information assumes any runway contaminant to be of uniform depth and density.

8.1.3 The provision of performance information for contaminated runways should not be taken as implying that ground handling characteristics on these surfaces will be as good as can be achieved on dry or wet runways, in particular following engine failure, in crosswinds or when using reverse thrust.

8.1.4 The contaminated runway performance information does not in any way replace or amend the Operating Limitations and Performance Information listed in the AFM, unless otherwise stated.

8.2 Procedures

In addition to performance information appropriate to operating on a contaminated runway, the AFM should also include recommended procedures associated with this performance information. Differences in other procedures for operation of the aeroplane on a contaminated surface should also be presented, e.g., reference to crosswinds or the use of high engine powers or derates.

8.3 Take-off and Landing Data

This should be presented either as separate data appropriate to a defined runway contaminant or as incremental data based on the AFM normal dry or wet runway information. Information relating to the use of speeds higher than V_{REF} on landing, that is speeds up to the maximum recommended approach speed additive to V_{REF}, and the associated distances should also be included.

The landing distance must be presented either directly or with the factors required by the operating manuals, with clear explanation where appropriate.

Where data is provided for a range of contaminant depths, for example 3, 6, 9, 12, 15mm, then the AFM should clearly indicate how to define data for contaminant depths within the range of contaminant depths provided.

Where the AFM presents data using V_{STOP} and V_{GO}, it must be stated in the AFM that use of this concept is acceptable only where operation under this standard is permitted.

9 References

Reference sources containing worked methods for the processes outlined in 7.1 to 7.3.3 are identified below:

1. ESDU Data Item 83042, December 1983, with Amendment A, May 1998. “Estimation of Spray Patterns Generated from the Side of Aircraft Tyres Running in Water or Slush”.

2. ESDU Data Item 98001, May 1998. “Estimation of Airframe Skin-Friction Drag due to Impingement of Tyre Spray”.

3. ESDU Data Item 90035, November 1990, with Amendment A, October 1992. “Frictional and Retarding Forces on Aircraft Tyres. Part V: Estimation of Fluid Drag Forces”.

4. ESDU Memorandum No.97, July 1998. “The Order of Magnitude of Drag due to Forward Spray from Aircraft Tyres”.

5. ESDU Memorandum No. 96, February 1998. “Operations on Surfaces Covered with Slush”.

6. ESDU Memorandum No. 95, March 1997, “Impact Forces Resulting From Wheel Generated Spray: Re-Assessment Of Existing Data”.

7. NASA Report TP-2718 “Measurement of Flow Rate and Trajectory of Aircraft Tire-Generated Water Spray”.

8. Van Es, G.W.H., “Method for Predicting the Rolling Resistance of Aircraft Tires in Dry Snow”. AIAA Journal of Aircraft, Volume 36, No.5, September-October 1999.

9. Van Es, G.W.H., “Rolling Resistance of Aircraft Tires in Dry Snow”, National Aerospace Laboratory NLR, Technical Report TR-98165, Amsterdam, 1998.

10. ESDU Data Item 72008, May 1972. 'Frictional and retarding forces on aircraft tyres. Part III: planning.

GENERAL AMCs

AMC 25-11
Electronic Display Systems

1 - In Book 2, AMC 25-11, sub-paragraph 3 a., amend the last listed reference as follows:

….
25.~~B~~J1305 APU instruments

2 – In AMC 25-11, sub-paragraphs 3 b. and 3 d. (1), amend the existing test as follows:

….
b. *Advisory Circulars, AMCs*

AC 20-88A Guidelines on the Marking of Aircraft Powerplant Instruments (Displays).
AMC 25.1309~~-1~~ System Design and Analysis.
AMC 25.1329 Automatic Pilot Systems Approval.
AC 90-45A Approval of Area Navigation Systems for Use in the U.S. National Airspace System.
AMC 25.1322 Alerting Systems
AMC 20-115() Recognition of EUROCAE ED-12()/RTCA DO-178()
….

d. *Industry Documents*

….

ED12~~A~~()/RTCA DO-178() Software Considerations in Airborne Systems and Equipment Certification, as recognized by AMC 20-115().
….

3 – In AMC 25-11, sub-paragraph 4 a. (1), amend the text as follows:

(1) Criticality of flight and navigation data displayed should be evaluated in accordance with the requirements in CS 25.1309 and 25.1333. AMC 25.1309~~-1~~ clarifies the meaning of these requirements and the types of analyses that are appropriate to show that systems meet them. AMC 25.1309~~-1~~ also provides criteria to correlate the depth of analyses required with the type of function the system performs (non-essential, essential or critical); however, a system may normally be

performing non-essential or essential functions from the standpoint of required availability and have potential failure modes that could be more critical. In this case, a higher level of criticality applies. Pilot evaluation may be a necessary input in making the determination of criticality for electronic displays. AMC 25.1309-1 recommends that the flight test pilot –

4 - In AMC 25-11, sub-paragraph 4 a. (2), replace the reference to the ED12A/RTCA DO-178A by the reference to the AMC 20-115() Recognition of EUROCAE ED-12()/RTCA DO-178() as follows:

…
(2) Software-based systems should have the computer software verified and validated in an
acceptable manner. One acceptable means of compliance for the verification and validation of computer software is outlined in ED12A/DO-178A AMC 20-115() Recognition of EUROCAE ED-12()/RTCA DO-178(). Software documentation appropriate to the level to which the verification and validation of the computer software has been accomplished should be provided as noted in ED12A/DO178A.

5 - In AMC 25-11, sub-paragraph 4 b. (2) (ii), replace the reference to CS 25.1309 (d) with the reference to AMC 25.1309 as follows:

….

(ii) Pilot-initiated pre-flight tests may be used to reduce failure exposure times associated with the safety analysis required under CS 25.1309(d) performed according to AMC 25.1309, sub-paragraph 9.b.(1). However, ….

6 - In AMC 25-11, sub-paragraph 7 b. (1), replace the reference to JAR 25.1321 with the reference to CS 25.1321 as follows:

….
(1) …. The concepts and requirements of JARCS 25.1321, as discussed in paragraph 7.a., still apply;
….

AMC 25–19
Certification Maintenance Requirements

1 - In AMC 25-19, sub-paragraph 3 b., amend the text as follows:

3 *RELATED DOCUMENTS*

a. AC 25.1309–1A, System Design and Analysis.

b. Acceptable Means of Compliance AMC 25.1309-1, System Design and Analysis.

2 - In AMC 25-19, section 6, delete the reference to CS 25.1309 (d) as follows:
….

6 OTHER DEFINITIONS
The following terms apply to the system design and analysis requirements of CS 25.1309 (b), and (c), and (d), and the guidance material provided in this AMC. For a complete definition of these terms, refer to….

3 - In AMC 25-19, section 7, replace the references to CS 25.1309 (d) with the references to AMC 25.1309, sub-paragraph 9 b.(1) as follows:
….

7 *SYSTEM SAFETY ASSESSMENTS (SSA)*

CS 25.1309(b) provides general requirements for a logical and acceptable inverse relationship between the probability and severity of each Failure Condition, and ~~CS 25.1309(d)~~ AMC 25.1309, sub-paragraph 9 b.(1) ~~requires~~ specifies that compliance should be shown primarily by analysis. In recent years there has been an increase in the degree of system complexity and integration, and in the number of safety-critical functions performed by systems. This increase in complexity has led to the use of structured means for showing compliance with the requirements of CS 25.1309.

a. CS 25.1309(b) ~~and (d)~~ specifies required safety levels in qualitative terms, and AMC 25.1309, sub-paragraph 9 b.(1) ~~require~~ specifies that a safety assessment should be made. Various assessment techniques have been developed to assist applicants and the Agency in determining that a logical and acceptable inverse relationship exists between the probability and the severity of each Failure Condition. These techniques include the use of service experience data of similar, previously approved systems, and thorough qualitative analyses.

4 - In AMC 25-19, section 8, delete the reference to CS 25.1309 (d)(4) as follows:

8 *DESIGN CONSIDERATIONS RELATED TO CANDIDATE CMRs*
A decision to create a candidate CMR should follow the guidelines given in AMC 25.1309~~-1~~ (i.e the use of candidate CMRs in lieu of practical and reliable failure monitoring and warning systems to detect significant latent failures when they occur does not comply with CS 25.1309(c) ~~and (d)(4)~~)….