M(i): Mixed phase icing conditions: icing conditions that contain both supercooled water and ice crystals.

G(i): Glaciated conditions: icing conditions totally composed of ice crystals.

R(i): Rain conditions

SD: supercooled droplet

SLD: supercooled large drop

WC: water content

2. Wind Tunnels

All conditions must be appropriately corrected to respect the similarity relationship between actual and wind tunnel conditions (due to pressure and scale differences for example). It is the applicant responsibility to determine and justify the various derivations and corrections to be made to the upstream conditions in order to determine actual test conditions (local and scaled). When the tests are conducted in non-altitude conditions, the system power supply and the external aerodynamic and atmospheric conditions should be so modified as to represent the required altitude condition as closely as possible.

The icing wind tunnel calibration should have been verified, in accordance with SAE ARP 5905 with an established programme to maintain calibration of the facility. Calibration records should be examined to ensure the local liquid water concentration at the location of the probe complies with values required in the test specification.

3. Test setup

The test setup installation in the wind tunnel must be shown to be equivalent to the installation on the aircraft. In particular, the probe must be installed in such a way that the heat sink capacity of the mount is equal to or greater than the aircraft installation.

Surface temperature measurements of the probe mounting are typically made during icing wind tunnel tests to verify thermal analysis and to allow extrapolation to conditions not reachable due to the wind tunnel limitations.

4. Local conditions

The Water Content (WC) values provided in this AMC or in the Appendices C, O and P to CS-25 are upstream values, independent of the aircraft installation. Local WC values (at the probe location) need to be derived from the upstream values according to the streamline behaviour around the aircraft. Overconcentration of the WC at the probe location may occur due to the aerodynamic effects of the fuselage in particular.

Local conditions should be determined based on many parameters which could include:

— Aircraft specific
  — Aircraft fuselage shape
  — Probe location on aircraft fuselage (X, Y, Z coordinates)
  — Aircraft speed and altitude (Climb, Cruise, Descent …)
— Environmental Conditions specific
  — Type (SD, SLD, Crystals, Rain)
  — Size (from 0 to 2 000 micron)

  - — Density
- — Probe specific:
  - — mast/strut length

Concerning the type and size of the particles, the local WC should be computed considering the full distribution of the particles sizes that is actually present in the real atmosphere, even if the wind tunnel tests are then performed at a given single size (20 micron for supercooled droplets, 150 micron for ice crystals, 500 to 2 000 micron for rain drops). The local conditions may also be affected by the “bouncing effect” and “shattering effect” for solid particles or the “splashing effects” for large liquid particles. As no model exists today to represent ice particles trajectories and these particular effects, an assessment based on the best available state of the art shall be made.

5. Operational Conditions

The conditions are to be tested at several Mach and Angle of Attack (AoA) values in order to cover the operational flight envelope of the aircraft. It is the applicant responsibility to select and justify, for each of the conditions listed in each Cloud Matrix below, the relevant operational conditions to be tested (Mach, AoA and Mode…).

It is expected that several operational conditions will be identified for each environmental conditions but exhaustive testing is not intended.

6. Power supply

The heating power supply used during the tests should be the minimum value expected at the probe location on the aircraft. It is commonly accepted to test the probe at 10 % below the nominal rated voltage.

7. Flight deck indication

When a flight instrument external probe heating system is installed, CS 25.1326 requires an alert to be provided to the flight crew when that flight instrument external probe heating system is not operating or not functioning normally.

All performances of the probe ice protection system, in particular the icing tests described in this AMC are expected to be demonstrated with equipment selected with heating power set to the minimum value triggering the flight deck indication.

8. Test article selection

To be delivered, an article has to meet an Acceptance Test Procedure (ATP) established by the equipment supplier. The ATP is a production test performed on each item to show it meets the performance specification. Both the performance of the ice protection system and the icing tests described hereafter are expected to be demonstrated with an equipment selected at the lowest value of the ATP with respect to the acceptability of the heating performance. This can be accomplished by adjusting the test voltage, heating cycles and/or any other applicable parameters, to simulate the lowest performing probe. Note that this has to be applied in addition to the power supply reduction mentioned in paragraph 6 above.

9. Mode of Operation

The modes of operation of the probe are to be assessed in the two following tests. However, depending on the mode of operation of the heating systems, other intermediate modes may have to be tested (e.g. if heating power is varied as a function of the outside temperature, etc.)

a. Anti-icing test:

During this test, the icing protection of the probe (typically resistance heating) is assumed to be switched “on” prior exposure to icing conditions.

b. De-icing test:

During this test, the icing protection of the probe (typically resistance heating) should be ‘off’ until 0.5 inch of ice has accumulated on the probe. For ice crystal tests in de-icing mode, since no accretion is usually observed, an ‘off’ time duration should be agreed before the test. In the past, a 1-minute time duration without heating power has been accepted. This mode need not be tested if, in all operational scenarios (including all dispatch cases), the probe heating systems are activated automatically at aircraft power ‘On’ and cannot be switched to manual operation later during the flight. Furthermore, in assessing whether or not this mode needs to be tested, any failure conditions that are not demonstrated to be extremely improbable, and that may lead to probe heating supply interruptions, should be considered.

10. Supercooled Liquid (SL) Conditions

The following proposed test points are intended to provide the most critical conditions of the complete CS-25 Appendix C icing envelope, however, a Critical Points Analysis (CPA) may be used to justify different values.

10.1 Stabilized conditions

Table 1: Stabilized Liquid icing test conditions

Test #	SAT (°C)	Altitude Range		LWC(*) (g/m³)	Duration (min)	MVD(*) (µm)
SL1	– 20	0 to 22000 ft.	0 to 6706 m	0.22 to 0.3	15	15 to 20
SL2	– 30	0 to 22000 ft.	0 to 6706 m	0.14 to 0.2	15	15 to 20
SL3	– 20	4000 to 31000 ft.	1219 to 9449m	1.7 to 1.9	5	15 to 20
SL4	– 30	4000 to 31000 ft.	1219 to 9449 m	1 to 1.1	5	15 to 20

(*) Note:

The upstream LWC values of the table are based on CS-25 Appendix C and correspond to a droplet diameter of 20 µm or 15 µm. Considering that the local collection efficiency is function of the MVD and the probe location with respect to the boundary layer, and that the upstream LWC value is higher for an MVD of 15 µm as compared to 20 µm, the applicant shall establish the conditions leading to the highest local LWC at probe location and test accordingly.

It is acceptable to run the tests at the highest determined local LWC but using a droplet diameter of 20 µm since most of the wind tunnel are calibrated for that value.

10.2 - Cycling conditions

A separate test should be conducted at each temperature condition of Table 2 below, the test being made up of repetitions of either the cycle:

a. 28 km in the conditions of column (a) appropriate to the temperature, followed by 5 km in the conditions of column (b) appropriate to the temperature, for a duration of 30 minutes, or

b. 6 km in the conditions of column (a) appropriate to the temperature, followed by 5 km in the conditions of column (b) appropriate to the temperature, for a duration of 10 minutes.

Table 2: Cycling Liquid icing test conditions

Test #	SAT (°C)	Altitude Range		LWC (g/m³)		MVD (µm)
		(ft)	(m)			
				(a)	(b)	20
SL6	– 10	17 000	5182	0.6	2.2	
SL7	– 20	20 000	6096	0.3	1.7	
SL8	– 30	25 000	7620	0.2	1.0	

11. Supercooled Large Drop Liquid Conditions

Based on the design of the probe, the drop size may not be a significant factor to consider as compared to the other parameters and in particular the Liquid Water Content (LWC). The SLD LWC defined in Appendix O (between 0.18 and 0.44 g/m^3) is largely covered by the Appendix C continuous maximum LWC (between 0.2 and 0.8 g/m^3) and the Appendix C intermittent maximum LWC (between 0.25 and 2.9 g/m^3).

Testing SLD conditions may not be necessary if it can be shown that the Supercooled Liquid Conditions of Appendix C are more critical. If some doubt exists, the applicant shall propose a set of critical test points to cover adequately the Icing Environment defined in the Appendix O.

For showing compliance with the CS-25 certification specifications relative to SLD icing conditions represented by Appendix O, the applicant may use a comparative analysis. AMC 25.1420(f) provides guidance for comparative analysis.

12. Mixed Phase (M) and Glaciated (G) Conditions

The applicant should propose a set of critical test points to cover adequately the Icing Environment as proposed in Appendix P of CS-25.

Testing should be performed at representative altitude as the effect of altitude on probe behaviour is not yet fully understood, unless demonstration can be made that application of scaling laws leads to conservative approach of testing.

The following considerations shall be taken into account.

12.1 Glaciated Conditions

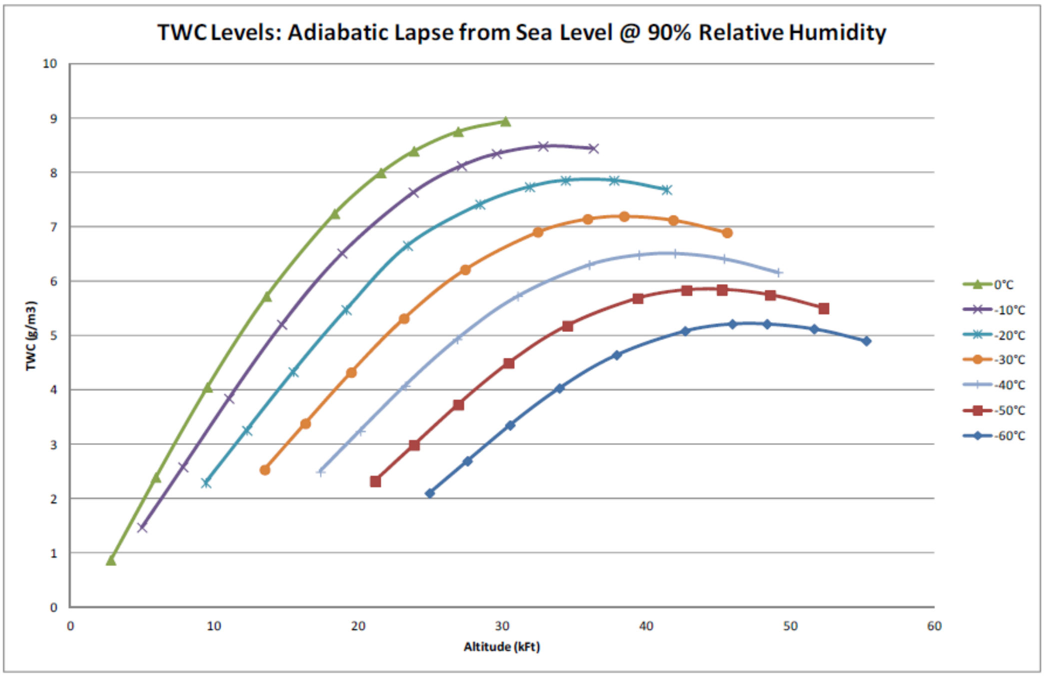
As indicated in the Appendix P, the total water content (TWC) in g/m3 has been assessed based upon the adiabatic lapse defined by the convective rise of 90 % relative humidity air from sea level to higher altitudes and scaled by a factor of 0.65 to a standard cloud length of 17.4 nautical miles (NM).

In service occurrences show that several pitot icing events in Glaciated Conditions, above 30 000 ft are outside of the Appendix P domain in term of altitude and outside air temperature. In that context, the Appendix P, Figure 1 (Convective cloud ice crystal envelope) should be enlarged to encompass ISA +30°C conditions. Furthermore, a reported event occurred at a temperature of – 70 °C. Testing may not be possible at such a low temperature due to simulation tool limitations. However, the presence of Ice Crystals has been observed, and it is anticipated that an extrapolation of existing test data at higher temperature should allow assessing the predicted performance of the probe heating down to this minimum temperature.

In addition, based on several sources of information including the EUROCAE WG-89, the Agency is of the opinion that the standard cloud of 17.4 NM and the associated average

TWC concentration values provided by Appendix P may not provide the most conservative conditions for Flight Instrument External Probes testing.

The 'max' or 'peak' TWC concentration values should be considered instead of the '17.4 NM' values provided by the Appendix P. These 'max' or 'peak' values are available in FAA document DOT/FAA/AR-09/13. They correspond to the '17.4 NM' values multiplied by a factor of 1.538 (1/0.65). The 'max' concentration values (TWC) are provided below:

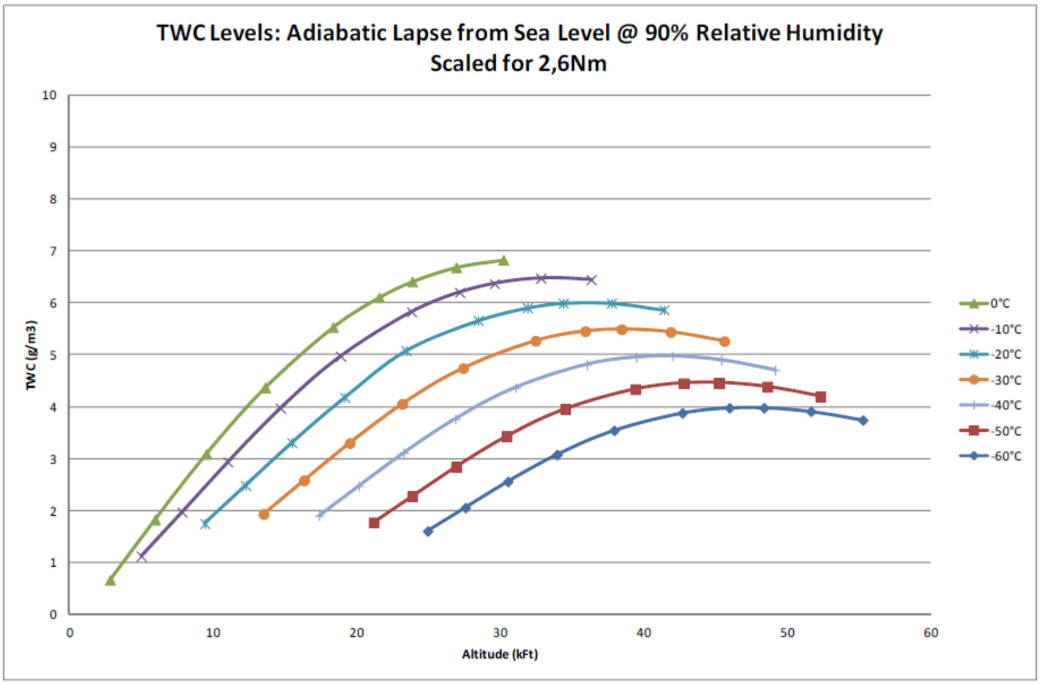


12.2 Mixed Phase Conditions

In service occurrences show several pitot icing events in Mixed phase conditions, between 20 000 and 30,000 feet, outside of the Appendix P domain in term of altitude and outside air temperature.

Based on several sources of information including the EUROCAE WG-89, the Agency is of the opinion that the '2.6 NM' TWC concentration values should be considered instead of the '17.4 NM' values, as the CS-25 Appendix C Intermittent conditions provide data for a 2.6 NM cloud.

The '2.6 NM' values are given by the '17.4 NM' values scaled by the F factor for 2.6 NM clouds which is 1.175 and are provided below:



It is commonly recognised that below -40°C no liquid conditions exist anymore. Therefore testing in mixed phase conditions does not need to consider temperatures below -40°C.

12.3 Ice Particles

Several methods of generating ice particles are used in testing and produce a wide range of particle sizes. Some methods of generating ice particles results in irregular shapes which are difficult to quantify in terms of mean particle diameter. It is acceptable to specify ice particle sizes based on the available range of ice particle generation techniques in the MMD range of 50 to 200 µm as provided in Appendix P to CS-25. Higher values may be used if justified.

For mixed phase icing, the heat requirements are driven primarily by the quantity of ice collected in the probe rather than the size of the ice particles. Supercooled liquid droplet MVD size of 20 µm should be used.

12.4 Duration

For each condition a minimum of two minutes exposure time should be tested. This is the minimum time needed to reach a steady state and stabilised condition.

12.5 Total Air Temperature probe design consideration

It is recognised that due to the intrinsic function of the total air temperature probes it may not be possible to design the temperature sensor with sufficient heating capability to ensure both adequate protection across the complete icing environment of CS-25 Appendix P and accurate temperature measurements. In this case, it may be acceptable that the temperature probe is not fully protected over a portion of the Appendix P icing environment provided that the malfunction of the probe will not prevent continued safe flight and landing. System safety assessments must include common mode failure conditions. Mitigation for potential icing related failures at the aircraft level should be accomplished as required by the Air Data System and/or by the primary data consumers. Examples of mitigation methods include comparing air data from multiple sources and from sources of dissimilar technologies.

13. Rain (R) Conditions

Flight instrument external probes must be evaluated in the heavy rain conditions provided in Table 1 of CS 25.1324. A test temperature below 10°C is considered acceptable. Testing may be performed at a higher temperature if it can be demonstrated that the increase in evaporation rate due to the higher ambient temperature does not decrease the severity of the test.

The efficiency of the drainage of the probe may depend on the aircraft airspeed. The applicant should, therefore, consider testing conditions including, at a minimum, low and high airspeed values in the rain conditions envelope.

14. Pass/fail criteria

The pass/fail criteria of a given test are as follows:

The output of the probe should quickly stabilize to the correct value after the start of an anti-icing test or once the icing protection is restored in a de-icing test. This value has to be agreed before the test between the applicant and the Agency, and it must stay correct as long as the icing protection is maintained. The measurement is considered to be correct if any observed fluctuation, when assessed by the applicant, has no effect at the aircraft level.

In addition, for pitot probes and especially during ice crystal or mixed phase conditions tests, it should be observed that the measured pressure is not 'frozen' (pressure signal without any noise, i.e. completely flat), which would indicate an internal blockage resulting in a captured pressure measurement.

After each test, any water accumulating in the probe connection line should be collected and assessed. The amount of water trapped in the probe (i.e. in the line conveying the air to the electronics) should not interfere with the output correctness when the probe is installed on the aeroplane.

[Amdt 25/16]
[Amdt 25/18]
[Amdt 25/21]

CS 25.1325 Static pressure systems

ED Decision 2015/008/R

(a) Each instrument with static air case connections must be vented to the outside atmosphere through an appropriate piping system.

(b) Each static port must be designed and located so that:

(1) the static pressure system performance is least affected by airflow variation, or by moisture or other foreign matter, and

(2) the correlation between air pressure in the static pressure system and true ambient atmospheric static pressure is not changed when the aeroplane is exposed to icing conditions. The static pressure system shall comply with CS 25.1324.

(c) The design and installation of the static pressure system must be such that –

(1) Positive drainage of moisture is provided; chafing of the tubing and excessive distortion or restriction at bends in the tubing is avoided; and the materials used are durable, suitable for the purpose intended, and protected against corrosion; and

(2) It is airtight except for the port into the atmosphere. A proof test must be conducted to demonstrate the integrity of the static pressure system in the following manner:

(i) *Unpressurised aeroplanes*. Evacuate the static pressure system to a pressure differential of approximately 33.86 HPa, (1 inch of mercury) or to a reading on the altimeter, 305 m (1 000 ft) above the aeroplane elevation at the time of the test. Without additional pumping for a period of 1 minute, the loss of indicated altitude must not exceed 30 m (100 ft) on the altimeter.

(ii) *Pressurised aeroplanes*. Evacuate the static pressure system until pressure differential equivalent to the maximum cabin pressure differential for which the aeroplane is type certificated is achieved. Without additional pumping for a period of 1 minute, the loss of indicated altitude must not exceed 2% of the equivalent altitude of the maximum cabin differential pressure or 30 m (100 ft), whichever is greater.

(d) Each pressure altimeter must be approved and must be calibrated to indicate pressure altitude in a standard atmosphere, with a minimum practicable calibration error when the corresponding static pressures are applied.

(e) Each system must be designed and installed so that the error in indicated pressure altitude, at sea-level, with a standard atmosphere, excluding instrument calibration error, does not result in an error of more than ±9 m (±30 ft) per 185 km/hr (100 knots) speed for the appropriate configuration in the speed range between 1·23 V_{SR0} with wing-flaps extended and 1·7 V_{SR1} with wing-flaps retracted. However, the error need not be less than ±9 m (±30 ft).

(f) If an altimeter system is fitted with a device that provides corrections to the altimeter indication, the device must be designed and installed in such manner that it can be bypassed when it malfunctions, unless an alternate altimeter system is provided. Each correction device must be fitted with a means for indicating the occurrence of reasonably probable malfunctions, including power failure, to the flight crew. The indicating means must be effective for any cockpit lighting condition likely to occur.

(g) Except as provided in sub-paragraph (h) of this paragraph, if the static pressure system incorporates both a primary and an alternate static pressure source, the means for selecting one or the other source must be designed so that –

(1) When either source is selected, the other is blocked off; and

(2) Both sources cannot be blocked off simultaneously.

(h) For un-pressurised aeroplanes, sub-paragraph (g)(1) of this paragraph does not apply if it can be demonstrated that the static pressure system calibration, when either static pressure source is selected, is not changed by the other static pressure source being open or blocked.

[Amdt 25/16]

CS 25.1326 Flight instrument external probes heating systems alert

ED Decision 2015/008/R

(See AMC 25.1326)

If a flight instrument external probe heating system is installed, an alert must be provided to the flight crew when the flight instrument external probe heating system is not operating or not functioning normally. The alert must comply with the following requirements:

(a) The alert provided must conform to the Caution alert indications.

(b) The alert provided must be triggered if either of the following conditions exists:

(1) The flight instrument external probe heating system is switched ‘off’.

(2) The flight instrument external probe heating system is switched ‘on’ and is not functioning normally.

[Amdt 25/16]

AMC 25.1326 Flight instrument external probes heating systems alert

ED Decision 2015/008/R

CS 25.1326 requires that if a flight instrument external probe heating system is installed, an alert must be provided to the flight crew when the flight instrument external probes heating system is not operating or not functioning normally.

It is expected that probe heating system failures are indicated to the flight crew if such failures have an impact on the performance of the heating system to the extent of having an “effect on operational capability or safety” (see CS 25.1309).

In accordance with CS 25.1309(c) and CS 25.1322(b), a Caution category of alert is required by CS 25.1326 for immediate crew awareness and subsequent crew action.

It should be assumed that icing conditions exist during the failure event. The decision to provide heating system failure indication should not be based on the numerical probability of the failure event. If the failure could potentially have hazardous or catastrophic consequences, then this failure must be indicated.

The reliability of the system performing the probe heating system failure detection and alerting should be consistent with the safety effect induced by the failure. Refer to AMC 25.1309, chapter 9(c) for more detailed guidance.

[Amdt No: 25/16]

CS 25.1327 Direction Indicator

ED Decision 2003/2/RM

(See AMC 25.1327)

(a) Each magnetic direction indicator must be installed so that its accuracy is not excessively affected by the aeroplane’s vibration or magnetic fields.

(b) The magnetic direction indicator required by CS 25.1303(a)(3) may not have a deviation, after compensation, in normal level flight, greater than 10 degrees on any heading.

(c) Direction indicators required by CS 25.1303(b)(6) must have an accuracy adequate for the safe operation of the aeroplane.

AMC 25.1327 Direction Indicator

ED Decision 2018/005/R

This AMC addresses the accuracy of stabilised magnetic heading systems, required for safe operation of the aeroplane. These systems include means to compensate or correct for errors induced by stable magnetic effects in the aeroplane. Additional effects due to electromagnetic transients and configuration changes are not normally "compensated" by the magnetic heading system and are also included in this AMC.

Should the correction become unavailable (either intentionally or unintentionally), the effects of the resulting heading indication should be considered for safe operation of the aeroplane. This AMC addresses the condition where correction is available and the condition where correction is not available (or failed).

In most circumstances, heading information is not directly used as the primary means of navigation. This condition should permit the applicant to show that the accuracy adequate for the safe operation of the aeroplane may be different than what is defined in this AMC.

1. After correction the cumulative deviation on any heading should not exceed 5°, based on the following:

   a. A change in deviation due to the equipment of the heading system components, the total of which should not exceed 2°.

   b. A change in deviation due to the current flow in any item of electrical equipment and its associated wiring is permissible, but should not exceed 1°. The total cumulative effect for all combinations of equipment, with all combinations of electrical load, should not exceed 2°.

   c. A change in deviation due to the movement of any component, (e.g. controls or undercarriage) in normal flight is permissible, but should not exceed 1°.

2. If correction fails or is not available, the change in deviation due to the proximity of all equipment containing magnetic material should not exceed 2°.

3. For magnetic heading indications obtained via geographic (true) heading, the accuracy of the heading indication should account for the accuracy of the magnetic variation data based on geographic position. This variation may change over time.

   Acceptable accuracy values have been found to be:

   2 degrees (Latitudes between 50°S and 50°N)

   3 degrees (Latitudes between 50°N and 73°N)

   3 degrees (Latitudes between 50°S and 60°S)

   5 degrees (Latitudes between 73°N and 79°N)

   8 degrees (Latitudes between 79°N and 82°N)

   The applicant may propose different accuracy values after consultation with the EASA.

   In areas of known magnetic unreliability (e.g. the magnetic poles), the magnetic variation error can be very large, so the magnetic heading indications (if output) should not be relied upon.

4. For geographic (true) heading indications (such as those provided by Inertial Reference Units), the accuracy should be better or equal to 1°.

   Note: On aeroplanes with a short cruising range, the above limits may be extended after consultation with EASA. For aeroplanes that do not depend on direction or heading information for navigation (VOR, ILS, FMS, GPS), the above limits may be extended after consultation with EASA.

[Amdt 25/21]