CS-25 AMENDMENT 3 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.

Consequently, except for a note "Amdt. 25/3" under the amended paragraph, the consolidated text of CS-25 does not allow readers to see the detailed changes introduced by the new amendment. To allow readers to also see these detailed changes this document has been created. The same format as for publication of Notices of Proposed Amendments has been used to show the changes:

1. text not affected by the new amendment remains the same: unchanged
2. deleted text is shown with a strike through: ~~deleted~~
3. new text is highlighted with grey shading: new
4. ....
   Indicates that remaining text is unchanged in front of or following the reflected amendment.
   ....

1. Introduce a new sub-paragraph (g) in CS 25.21 to read as follows:

CS 25.21 Proof of compliance

....

(g) The requirements of this subpart associated with icing conditions apply only if the applicant is seeking certification for flight in icing conditions.

(1) Each requirement of this subpart, except CS 25.121(a), 25.123(c), 25.143(b)(1) and (b)(2), 25.149, 25.201(c)(2), 25.207(c) and (d), and 25.251(b) through (e), must be met in icing conditions. Compliance must be shown using the ice accretions defined in Appendix C, assuming normal operation of the aeroplane and its ice protection system in accordance with the operating limitations and operating procedures established by the applicant and provided in the Aeroplane Flight Manual.

(2) No changes in the load distribution limits of CS 25.23, the weight limits of CS 25.25 (except where limited by performance requirements of this subpart), and the centre of gravity limits of CS 25.27, from those for non-icing conditions, are allowed for flight in icing conditions or with ice accretion.

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2. Amend CS 25.103(b)(3) to read:

CS 25.103 Stall speed

….

(b) ....

(3) The aeroplane in other respects (such as flaps, ~~and~~ landing gear, and ice accretions) in the condition existing in the test or performance standard in which V_{SR} is being used;

....

3. Amend CS 25.105 (a) to read:

CS 25.105 Take-off

(a) The take-off speeds ~~de~~prescribed ~~in~~by CS 25.107, the accelerate-stop distance ~~de~~prescribed ~~in~~by CS 25.109, the take-off path ~~de~~prescribed ~~in~~by CS 25.111, ~~and~~ the take-off distance and take-off run ~~de~~prescribed ~~in~~by CS 25.113, ~~must be determined –~~

~~(1) At each weight, altitude, and ambient temperature within the operational limits selected by the applicant; and~~

~~(2) In the selected configuration for take-off.~~

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 -

(1) In non-icing conditions; and

(2) In icing conditions, if in the configuration of CS 25.121(b) with the "Take-off Ice" accretion defined in Appendix C:

(i) 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 V_{SR}; or

(ii) 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).

….

4. Amend CS 25.107 to read :

CS 25.107 Take-off speeds

….

(c) ....

(3) A speed that provides the manoeuvring capability specified in CS 25.143(~~g~~h).

....

(g) ....

(2) A speed that provides the manoeuvring capability specified in CS 25.143(~~g~~h).

(h) In determining the take-off speeds V_1, V_R, and V_2 for flight in icing conditions, the values of V_{MCG}, V_{MC}, and V_{MU} determined for non-icing conditions may be used.

5. Amend CS 25.111 to read:

CS 25.111 Take-off path
(See AMC 25.111)

(c) ....

(3) ....

(iii) 1·7% for four-engined aeroplanes, ~~and~~

(4) ~~Except for gear retraction and automatic propeller feathering, the aeroplane configuration may not be changed.~~ The aeroplane configuration may not be changed, except for gear retraction and automatic propeller feathering, and no change in power or thrust that requires action by the pilot may be made until the aeroplane is 122 m (400 ft) above the take-off surface; and

(5) If CS 25.105(a)(2) requires the take-off path to be determined for flight in icing conditions, the airborne part of the take-off must be based on the aeroplane drag:

(i) With the "Take-off Ice" accretion defined in Appendix C, from a height of 11 m (35 ft) above the take-off surface up to the point where the aeroplane is 122 m (400 ft) above the take-off surface; and

(ii) With the "Final Take-off Ice" accretion defined in Appendix C, from the point where the aeroplane is 122 m (400 ft) above the take-off surface to the end of the take-off path.

....

6. Amend CS 25.119 to read:

CS 25.119 Landing climb: all-engines-operating

In the landing configuration, the steady gradient of climb may not be less than 3·2%, with -

(a) the engines at the power or thrust that is available 8 seconds after initiation of movement of the power or thrust controls from the minimum flight idle to the go-around power or thrust setting (see AMC 25.119(a)); and

(b) A climb speed which is –

(1) Not less than –

(i) 1·08 V_{SR} for aeroplanes with four engines on which the application of power results in a significant reduction in stall speed; or

(ii) 1·13 V_{SR} for all other aeroplanes;

(2) Not less than V_{MCL}; and

(3) Not greater than V_{REF}.

(a) In non-icing conditions, with a climb speed of V_{REF} determined in accordance with CS 25.125(b)(2)(i); and

(b) In icing conditions with the "Landing Ice" accretion defined in Appendix C, and with a climb speed of V_{REF} determined in accordance with CS 25.125(b)(2)(ii).

7. Amend CS 25.121 to read

CS 25.121 Climb: one-engine-inoperative
(See AMC 25.121)

....

(b) *Take-off; landing gear retracted.* In the take-off configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in CS25.111 but without ground effect,

(1) the steady gradient of climb may not be less than 2·4% for two-engined aeroplanes, 2·7% for three-engined aeroplanes and 3·0% for four-engined aeroplanes, at V_2 and with–

(1)(i) The critical engine inoperative, the remaining engines at the take-off power or thrust available at the time the landing gear is fully retracted, determined under CS 25.111, unless there is a more critical power operating condition existing later along the flight path but before the point where the aeroplane reaches a height of 122 m (400 ft) above the take-off surface (see AMC 25.121(b)(1)(i)) ; and

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

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

(i) In non-icing conditions; and

(ii) In icing conditions with the "Take-off Ice" accretion defined in Appendix C, if in the configuration of CS 25.121(b) with the "Take-off Ice" accretion:

(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 V_{SR}; or

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

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

(1) The steady gradient of climb may not be less than 1.2% for two-engined aeroplanes, 1.5% for three-engined aeroplanes, and 1.7% for four-engined aeroplanes, at V_{FTO} with -

(~~1~~i) The critical engine inoperative and the remaining engines at the available maximum continuous power or thrust; and

(~~2~~ii) The weight equal to the weight existing at the end of the take-off path, determined under CS 25.111.

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

(i) In non-icing conditions; and

(ii) In icing conditions with the “Final Take-off Ice” accretion defined in Appendix C, if in the configuration of CS 25.121(b) with the “Take-off Ice” accretion:

(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 V_{SR}; 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).

(d) *Approach*. In a configuration corresponding to the normal all-engines-operating procedure in which V_{SR} for this configuration does not exceed 110% of the V_{SR} for the related all-engines-operating landing configuration, ~~the~~:

(1) The steady gradient of climb may not be less than 2.1% for two-engined aeroplanes, 2.4% for three-engined aeroplanes, and 2.7% for four-engined aeroplanes, with -

(~~1~~i) The critical engine inoperative, the remaining engines at the go-around power or thrust setting;

(~~2~~ii) The maximum landing weight;

(~~3~~iii) A climb speed established in connection with normal landing procedures, but not exceeding 1.4 V_{SR}: and

(~~4~~iv) Landing gear retracted.

(2) The requirements of sub-paragraph (d)(1) of this paragraph must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the Approach Ice accretion defined in Appendix C. The climb speed selected for non-icing conditions may be used if the climb speed for icing conditions, computed in accordance with sub-paragraph (d)(1)(iii) of this paragraph, does not exceed that for non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3%.

8. Amend CS 25.123 to read:

CS 25.123 En-route flight paths
(See AMC 25.123)

(a) For the en-route configuration, the flight paths prescribed in sub-paragraphs (b) and (c) of this paragraph must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the aeroplane. The variation of weight along the flight path, accounting for the progressive consumption of fuel and oil by the operating engines, may be included in the computation. The flight paths must be determined at ~~any~~ a selected speed not less than V_{FTO}, with –

....

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1·1% for two-engined aeroplanes, 1·4% for three-engined aeroplanes, and 1·6% for four-engined aeroplanes.

(1) In non-icing conditions; and

(2) In icing conditions with the “En-route Ice” accretion defined in Appendix C, if:

(i) A speed of $1.18V_{SR}$ with the “En-route Ice ” accretion exceeds the en-route speed selected in non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3% of V_{SR}, or

(ii) The degradation of the gradient of climb is greater than one-half of the applicable actual-to-net flight path reduction defined in sub-paragraph (b) of this paragraph.

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9. Amend CS 25.125 to read:

CS 25.125 Landing

(a) The horizontal distance necessary to land and to come to a complete stop from a point 15 m (50 ft) above the landing surface must be determined (for standard temperatures, at each weight, altitude and wind within the operational limits established by the applicant for the aeroplane) ~~as follows~~:

(1) In non-icing conditions; and

(2) In icing conditions with the “Landing Ice” accretion defined in Appendix C if V_{REF} for icing conditions exceeds V_{REF} for non-icing conditions by more than 9.3 km/h (5 knots) CAS at the maximum landing weight

(b) In determining the distance in (a):

(1) The aeroplane must be in the landing configuration.

(2) A stabilised approach, with a calibrated airspeed of not less than V_{REF}, must be maintained down to the 15 m (50 ft) height.

(i) In non-icing conditions, V_{REF} may not be less than:

(~~i~~A) $1.23V_{SR0}$;

(~~ii~~B) V_{MCL} established under CS 25.149(f); and

(~~iii~~C) A speed that provides the manoeuvring capability specified in CS25.143(~~g~~h).

(ii) In icing conditions, V_{REF} may not be less than:

(A) The speed determined in sub-paragraph (b)(2)(i) of this paragraph;

(B) 1.23 V_{SR0} with the "Landing Ice" accretion defined in Appendix C if that speed exceeds V_{REF} for non-icing conditions by more than 9.3 km/h (5 knots) CAS; and

(C) A speed that provides the manoeuvring capability specified in CS 25.143(h) with the landing ice accretion defined in appendix C.

(3) Changes in configuration, power or thrust, and speed, must be made in accordance with the established procedures for service operation. (See AMC 25.125(~~a~~b)(3).)

(4) The landing must be made without excessive vertical acceleration, tendency to bounce, nose over or ground loop.

(5) The landings may not require exceptional piloting skill or alertness.

(~~b~~c) The landing distance must be determined on a level, smooth, dry, hard-surfaced runway. (See AMC 25.125(~~b~~c) In addition –

(1) The pressures on the wheel braking systems may not exceed those specified by the brake manufacturer;

(2) The brakes may not be used so as to cause excessive wear of brakes or tyres (see AMC 25.125(~~b~~c)(2)); and

(3) Means other than wheel brakes may be used if that means –

(i) Is safe and reliable;

(ii) Is used so that consistent results can be expected in service; and

(iii) Is such that exceptional skill is not required to control the aeroplane.

(~~c~~d) ~~Not required for CS–25~~*Reserved*.

(~~d~~e) ~~Not required for CS–25~~*Reserved*.

(~~e~~f) The landing distance data must include correction factors for not more than 50% of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150% of the nominal wind components along the landing path in the direction of landing.

(~~f~~g) If any device is used that depends on the operation of any engine, and if the landing distance would be noticeably increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of compensating means will result in a landing distance not more than that with each engine operating.

10. Amend CS 25.143 to read:

CS 25.143 General

....

(c) The aeroplane must be shown to be safely controllable and manoeuvrable with the critical ice accretion appropriate to the phase of flight defined in appendix C, and with the critical engine inoperative and its propeller (if applicable) in the minimum drag position:

(1) At the minimum V_2 for take-off;
(2) During an approach and go-around; and
(3) During an approach and landing.

(~~c~~d) The following table prescribes, for conventional wheel type controls, the maximum control forces permitted during the testing required by sub-paragraphs (a) ~~and (b)~~ through (c) of this paragraph. (See AMC 25.143(~~c~~d)):

Force, in newton (pounds), applied to the control wheel or rudder pedals	Pitch	Roll	Yaw
For short term application for pitch and roll control – two hands available for control	334 (75)	222 (50)	–
For short term application for pitch and roll control – one hand available for control	222 (50)	111 (25)	–
For short term application for yaw control	–	–	667 (150)
For long term application	44,5 (10)	22 (5)	89 (20)

(~~d~~e) Approved operating procedures or conventional operating practices must be followed when demonstrating compliance with the control force limitations for short term application that are prescribed in sub-paragraph (~~c~~d) of this paragraph. The aeroplane must be in trim, or as near to being in trim as practical, in the immediately preceding steady flight condition. For the take-off condition, the aeroplane must be trimmed according to the approved operating procedures.

(~~e~~f) When demonstrating compliance with the control force limitations for long term application that are prescribed in sub-paragraph (~~c~~d) of this paragraph, the aeroplane must be in trim, or as near to being in trim as practical.

(~~f~~g) When manoeuvring at a constant airspeed or Mach number (up to V_{FC}/M_{FC}), the stick forces and the gradient of the stick force versus manoeuvring load factor must lie within satisfactory limits. The stick forces must not be so great as to make excessive demands on the pilot's strength when manoeuvring the aeroplane (see AMC No. 1 to CS 25.143 (~~f~~g)), and must not be so low that the aeroplane can easily be overstressed inadvertently. Changes of gradient that occur with changes of load factor must not cause undue difficulty in maintaining control of the aeroplane, and local gradients must not be so low as to result in a danger of over-controlling. (See AMC No. 2 to CS 25.143 (~~f~~g)).

(~~g~~h) (See AMC 25.143(~~g~~h)). The manoeuvring capabilities in a constant speed coordinated turn at forward centre of gravity, as specified in the following table, must be free of stall warning or other characteristics that might interfere with normal manoeuvring.

CONFIGURATION	**SPEED**	**MANOEUVRING BANK ANGLE IN A COORDINATED TURN**	**THRUST/POWER SETTING**
TAKE-OFF	V_2	30°	ASYMMETRIC WAT-LIMITED (1)
TAKE-OFF	V_2 + xx (2)	40°	ALL ENGINES OPERATING CLIMB (3)
EN-ROUTE	V_{FTO}	40°	ASYMMETRIC WAT-LIMITED (1)
LANDING	V_{REF}	40°	SYMMETRIC FOR –3° FLIGHT PATH ANGLE

(1) A combination of weight, altitude and temperature (WAT) such that the thrust or power setting produces the minimum climb gradient specified in CS 25.121 for the flight condition.

(2) Airspeed approved for all-engines-operating initial climb.

(3) That thrust or power setting which, in the event of failure of the critical engine and without any crew action to adjust the thrust or power of the remaining engines, would result in the thrust or power specified for the take-off condition at V_2, or any lesser thrust or power setting that is used for all-engines-operating initial climb procedures.

(i) When demonstrating compliance with CS 25.143 in icing conditions -

(1) Controllability must be demonstrated with the ice accretion described in Appendix C, that is most critical for the particular flight phase.

(2) It must be shown that a push force is required throughout a pushover manoeuvre down to a zero g load factor, or the lowest load factor obtainable if limited by elevator power or other design characteristic of the flight control system. It must be possible to promptly recover from the manoeuvre without exceeding a pull control force of 222 N. (50 lbf); and

(3) Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength.

(j) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, the following requirements apply:

(1) If activating the ice protection system depends on the pilot seeing a specified ice accretion on a reference surface (not just the first indication of icing), the requirements of CS 25.143 apply with the ice accretion defined in appendix C, part II(e).

(2) For other means of activating the ice protection system, it must be demonstrated in flight with the ice accretion defined in appendix C, part II(e) that:

(i) The aeroplane is controllable in a pull-up manoeuvre up to 1.5 g load factor; and

(ii) There is no pitch control force reversal during a pushover manoeuvre down to 0.5 g load factor.

11. Amend CS 25.207 to read:

CS 25.207 Stall warning

....

(b) The warning ~~may~~ must be furnished either through the inherent aerodynamic qualities of the aeroplane or by a device that will give clearly distinguishable indications under expected conditions of flight. However, a visual stall warning device that requires the attention of the crew within the cockpit is not acceptable by itself. If a warning device is used, it must provide a warning in each of the aeroplane configurations prescribed in sub-paragraph (a) of this paragraph at the speed prescribed in sub-paragraphs (c) and (d) of this paragraph. Except for the stall warning prescribed in paragraph (h)(2)(ii) of this section, the stall warning for flight in icing conditions prescribed in paragraph (e) of this section must be provided by the same means as the stall warning for flight in non-icing conditions. (See AMC 25.207(b).)

....

….

(e) In icing conditions, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling (as defined in CS 25.201(d)) when the pilot starts a recovery manoeuvre not less than three seconds after the onset of stall warning. When demonstrating compliance with this paragraph, the pilot must perform the recovery manoeuvre in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with the speed reduced at rates not exceeding 0.5 m/sec^2 (one knot per second), with –

(1) The more critical of the takeoff ice and final takeoff ice accretions defined in appendix C for each configuration used in the takeoff phase of flight;

(2) The en route ice accretion defined in appendix C for the en route configuration;

(3) The holding ice accretion defined in appendix C for the holding configuration(s);

(4) The approach ice accretion defined in appendix C for the approach configuration(s); and

(5) The landing ice accretion defined in appendix C for the landing and go-around configuration(s);

(ef) The stall warning margin must be sufficient in both non-icing and icing conditions to allow the pilot to prevent stalling ~~(as defined in CS 25.201(d))~~ when ~~recovery is initiated~~ the pilot starts a recovery manoeuvre not less than one second after the onset of stall warning in slow-down turns with at least 1.5 g load factor normal to the flight path and airspeed deceleration rates of at least 1m/sec^2 (2 knots per second), ~~with the flaps and landing gear in any normal position, with the aeroplane trimmed for straight flight at a speed of 1.3 V_{SR}, and with the power or thrust necessary to maintain level flight at 1.3 V_{SR}.~~ When demonstrating compliance with this paragraph for icing conditions, the pilot must perform the recovery manoeuvre in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with –

(1) The flaps and landing gear in any normal position;

(2) The aeroplane trimmed for straight flight at a speed of 1.3 V_{SR}; and

(3) The power or thrust necessary to maintain level flight at 1.3 V_{SR}.

(fg) Stall warning must also be provided in each abnormal configuration of the high lift devices that is likely to be used in flight following system failures (including all configurations covered by Aeroplane Flight Manual procedures).

(h) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, the following requirements apply, with the ice accretion defined in appendix C, part II(e):

(1) If activating the ice protection system depends on the pilot seeing a specified ice accretion on a reference surface (not just the first indication of icing), the requirements of this section apply, except for paragraphs (c) and (d).

(2) For other means of activating the ice protection system, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling without encountering any adverse flight characteristics when the speed is reduced at rates not exceeding 0.5 m/sec^2 (one knot per second) and the pilot performs the recovery manoeuvre in the same way as for flight in non-icing conditions.

(i) If stall warning is provided by the same means as for flight in non-icing conditions, the pilot may not start the recovery manoeuvre earlier than one second after the onset of stall warning.

(ii) If stall warning is provided by a different means than for flight in non-icing conditions, the pilot may not start the recovery manoeuvre earlier than 3 seconds after the onset of stall warning. Also, compliance must be shown with CS 25.203 using the demonstration prescribed by CS 25.201, except that the deceleration rates of CS 25.201(c)(2) need not be demonstrated.

12. Amend CS 25.237 to read:

CS 25.237 Wind velocities

(a) The following applies:

(a1) A 90º cross component of wind velocity, demonstrated to be safe for take-off and landing, must be established for dry runways and must be at least 37 km/h (20 kt) or 0·2 V_{SR0}, whichever is greater, except that it need not exceed 46 km/h (25 kt).

(2) The crosswind component for takeoff established without ice accretions is valid in icing conditions.

(3) The landing crosswind component must be established for:

(i) Non-icing conditions, and

(ii) Icing conditions with the landing ice accretion defined in appendix C.

....

13. Amend CS 25.253 to read:

CS 25.253 High-speed characteristics

....

(b) *Maximum speed for stability characteristics, V_{FC}/M_{FC}.* V_{FC}/M_{FC} is the maximum speed at which the requirements of CS 25.143(~~f~~g), 25.147(e), 25.175(b)(1), 25.177(a) through (c), and 25.181 must be met with wing-flaps and landing gear retracted. Except as noted in CS 25.253(c), ~~It~~ V_{FC}/M_{FC} may not be less than a speed midway between V_{MO}/M_{MO} and V_{DF}/M_{DF}, except that, for altitudes where Mach Number is the limiting factor, M_{FC} need not exceed the Mach Number at which effective speed warning occurs.

(c) *Maximum speed for stability characteristics in icing conditions*. The maximum speed for stability characteristics with the ice accretions defined in Appendix C, at which the requirements of CS 25.143(g), 25.147(e), 25.175(b)(1), 25.177(a) through (c) and 25.181 must be met, is the lower of:

(1) 556 km/h (300 knots) CAS,

(2) V_{FC}, or

(3) A speed at which it is demonstrated that the airframe will be free of ice accretion due to the effects of increased dynamic pressure."

14. Correct the content of the table in CS 25.405 as follows:

CS 25.405 Secondary control system

….

PILOT CONTROL FORCE LIMITS (SECONDARY CONTROLS).

Control	Limit pilot forces
Miscellaneous: *Crank, wheel, or lever	~~$\left(\frac{1+R}{3}\right)$~~ $\left(\frac{25.4+R}{76.2}\right)$ x 222 N (50 lbf), but not less than 222 N (50 lbf) nor more than 667 N (150 lbf) (R = radius in mm). (Applicable to any angle within 20º of plane of control).
Twist	15 Nm (133 in.lbf)
Push-pull	To be chosen by applicant

15. Amend existing CS 25.721 to read:

CS 25.721 General
(See AMC 25.963(d))

(a) The ~~main~~ landing gear system must be designed so that ~~if~~ when it fails due to overloads during take-off and landing ~~(assuming the overloads to act in the upward and aft directions)~~, the failure mode is not likely to cause spillage of enough fuel to constitute a fire hazard. The overloads must be assumed to act in the upward and aft directions in combination with side loads acting inboard and outboard. In the absence of a more rational analysis, the side loads must be assumed to be up to 20% of the vertical load or 20% of the drag load, whichever is greater.

~~(1) For aeroplanes that have a passenger seating configuration, excluding pilots seats, of nine seats or less, the spillage of enough fuel from any fuel system in the fuselage to constitute a fire hazard.; and~~

~~(2) For aeroplanes that have a passenger seating configuration, excluding pilots seats, of 10 seats or more, the spillage of enough fuel from any part of the fuel system to constitute a fire hazard.~~

(b) ~~Each aeroplane that has a passenger seating configuration, excluding pilots seats, of 10 or more must be designed so that with the aeroplane under control it can be landed on a paved runway with any one or more landing gear legs not extended without sustaining a structural component failure that is likely to cause the spillage of enough fuel to constitute a fire hazard.~~ The aeroplane must be designed to avoid any rupture leading to the spillage of enough fuel to constitute a fire hazard as a result of a wheels-up landing on a paved runway, under the following minor crash landing conditions:

(1) Impact at 1.52 m/s (5 fps) vertical velocity, with the aeroplane under control, at Maximum Design Landing Weight,

(i) with the landing gear fully retracted and, as separate conditions,

(ii) with any other combination of landing gear legs not extended.

(2) Sliding on the ground, with -

(i) the landing gear fully retracted and with up to a 20° yaw angle and, as separate conditions,

(ii) any other combination of landing gear legs not extended and with 0° yaw angle.

(c) ~~Compliance with the provisions of this paragraph may be shown by analysis or tests, or both.~~For configurations where the engine nacelle is likely to come into contact with the ground, the engine pylon or engine mounting must be designed so that when it fails due to overloads (assuming the overloads to act predominantly in the upward direction and separately predominantly in the aft direction), the failure mode is not likely to cause the spillage of enough fuel to constitute a fire hazard.

16. Amend CS 25.773 (b)(1)(ii) to read:

CS 25.773 Pilot compartment view

….

(b) ….

(1) ….

(i) ….

(ii) The icing conditions specified in CS 25.1419 if certification ~~with ice protection provisions~~ for flight in icing conditions is requested. (See AMC 25.773(b)(1)(ii).)

17. Amend existing CS 25.811(g) to read :

CS 25.811 Emergency exit marking

....

(g) Each sign required by sub-paragraph (d) of this paragraph may use the word ‘exit’ in its legend in place of the term ‘emergency exit’ or a universal symbolic exit sign (See AMC 25.812(b)(1), AMC 25.812(b)(2) and AMC 25.812(e)(2)). The design of exit signs must be chosen to provide a consistent set throughout the cabin.

18. Amend existing CS 25.812 to read:

CS 25.812 Emergency lighting

(See AMC 25.812)

….

(b) ….

(1)….

(i) Each passenger emergency exit locator sign required by CS 25.811(d)(1) and each passenger emergency exit marking sign required by CS 25.811(d)(2) must have red letters ~~at least 38 mm (1·5 inches) high~~ on an illuminated white background~~, and must have an area of at least 135 cm2 (21 square inches) excluding the letters. The lighted background-to-letter contrast must be at least 10:1. The letter height to stroke-width ratio may not be more than 7:1 nor less than 6:1.~~or a universal symbol, of adequate size (See AMC 25.812(b)(1)). These signs must be internally electrically illuminated with a background brightness of at least 86 candela/m^2 (25 foot-lamberts) and a high-to-low background contrast no greater than 3:1.

(ii) Each passenger emergency exit sign required by CS 25.811(d)(3) must have red letters ~~at least 38 mm (1·5 inches) high~~ on a white background ~~having an area of at least 135 cm2 (21 square inches) excluding the letters.~~ or a universal symbol, of adequate size (See AMC 25.812(b)(1)). These signs must be internally electrically illuminated or self illuminated by other than electrical means and must have an initial brightness of at least 1.27 candela/m^2 (400 micro-lamberts). The colours may be reversed in the case of a sign that is self-illuminated by other than electrical means.

(2) For aeroplanes that have a passenger seating configuration, excluding pilot seats, of 9 seats or less, ~~that are~~ each sign required by CS 25.811(d)(1), (2) and (3) must have red letters ~~at least 25 mm (1 inch) high~~ on a white background ~~at least 51 mm (2 inches) high.~~ or a universal symbol, of adequate size (See AMC 25.812(b)(2)). These signs must be internally electrically illuminated, or self-illuminated by other than electrical means, with an initial brightness of at least 0.51 candela/m^2 (160 microlamberts). The colours may be reversed in the case of a sign that is self-illuminated by other than electrical means.

….

(e) ….

(2) Readily identify each exit from the emergency escape path by reference only to markings and visual features not more than 1.2 m (4 ft) above the cabin floor. (See AMC 25.812(e)(2)).

19. Amend existing CS 25.855(c) to read:

CS 25.855 Cargo or baggage compartments
(See AMC 25.857)

….

(c) ceiling and sidewall liner panels of Class C ~~and D~~ compartments must meet the test requirement of Part III of Appendix F or other approved equivalent methods.

…

20. Delete the existing text of sub-paragraph (d) in CS 25.857 and mark it "(Reserved)" as follows:

CS 25.857 Cargo compartment classification
(See AMC 25.857)

….

(d) ~~*Class D*. (See AMC 25.857 (d).) A Class D cargo or baggage compartment is one in which –~~

~~(1) A fire occurring in it will be completely confined without endangering the safety of the aeroplane or the occupants;~~

~~(2) There are means to exclude hazardous quantities of smoke, flames, or other noxious gases, from any compartment occupied by the crew or passengers;~~

~~(3) Ventilation and draughts are controlled within each compartment so that any fire likely to occur in the compartment will not progress beyond safe limits;~~

~~(4) Reserved.~~

~~(5) Consideration is given to the effect of heat within the compartment on adjacent critical parts of the aeroplane.~~

~~(6) The compartment volume does not exceed 28.32 m3 (1000 cubic ft).~~

~~For compartments of 14.16 m3 (500 cubic ft) or less, an airflow of 42.48 m3/hr (1500 cubic ft per hour) is acceptable~~

(Reserved)

21. Amend existing CS 25.858 to read:

CS 25.858 Cargo or baggage compartment smoke or fire detection systems

If certification with cargo or baggage compartment smoke or fire detection provisions is requested, the following must be met for each cargo or baggage compartment with those provisions:

(a) ….

(b) ….

(c) There must be means to allow the crew to check in flight, the functioning of each smoke or fire detector circuit.

(d)….

22. Amend existing CS 25.901 (b)(1) (ii) to read:

CS 25.901 Installation

….

(b) ….

(ii) The applicable provisions of this Subpart (see also ~~AMC 25.901(b)(1)(ii))~~ AMC 20-1.

23. Amend existing CS 25.905 to read:

CS 25.905 Propellers

(a) ….

(b) Engine power and propeller shaft rotational speed may not exceed the limits for which the propeller is certificated. (See ~~CS P 80~~ CS-P 50.)

(c) Each component of the propeller blade pitch control system must meet the requirements of ~~CS P 200~~ CS-P 420.

24. Amend existing heading of CS 25.907 to read:

CS 25.907 Propeller vibration
(See ~~CS P 190~~ CS-P 530 and CS-P 550.)

….

25. Amend CS 25.941 (c) to read:

CS 25.941 Inlet, engine, and exhaust compatibility

….

(c) In showing compliance with sub-paragraph (b) of this paragraph, the pilot strength required may not exceed the limits set forth in CS 25.143(~~c~~d) subject to the conditions set forth in sub-paragraphs (~~d~~e) and (~~e~~f) of CS 25.143.

26. Amend existing CS 25.963 to read:

CS 25.963 Fuel tanks: general

….

(d) Fuel tanks must, so far as it is practicable, be designed, located, and installed so that no fuel is released, in or near the fuselage or near the engines in quantities sufficient to start a serious fire, in otherwise survivable ~~crash~~ emergency landing conditions~~.~~; and:

(1) Fuel tanks must be able to resist rupture and to retain fuel under ultimate hydrostatic design conditions in which the pressure P within the tank varies in accordance with the formula:

$$\mathbf{P = K\rho g L}$$

where:

P = fuel pressure in Pa (lb/ft^2) at each point within the tank

L = a reference distance in m (ft) between the point of pressure and the tank farthest boundary in the direction of loading.

ρ = typical fuel density in kg/m^3 (slugs/ft^3)

g = acceleration due to gravity in m/s^2 (ft/s^2)

K = 4.5 for the forward loading condition for fuel tanks outside the fuselage contour

K = 9 for the forward loading condition for fuel tanks within the fuselage contour

K = 1.5 for the aft loading condition

K = 3.0 for the inboard and outboard loading conditions for fuel tanks within the fuselage contour

K = 1.5 for the inboard and outboard loading conditions for fuel tanks outside of the fuselage contour

K = 6 for the downward loading condition

K = 3 for the upward loading condition

(2) For those (parts of) wing fuel tanks near the fuselage or near the engines, the greater of the fuel pressures resulting from subparagraphs (i) and (ii) must be used:

(i) the fuel pressures resulting from subparagraph (d)(1) above, and:

(ii) the lesser of the two following conditions:

(A) Fuel pressures resulting from the accelerations as specified in CS 25.561(b)(3) considering the fuel tank full of fuel at maximum fuel density. Fuel pressures based on the 9.0g forward acceleration may be calculated using the fuel static head equal to the streamwise local chord of the tank. For inboard and outboard conditions, an acceleration of 1.5g may be used in lieu of 3.0g as specified in CS 25.561(b)(3); and:

(B) Fuel pressures resulting from the accelerations as specified in CS 25.561(b)(3) considering a fuel volume beyond 85% of the maximum permissible volume in each tank using the static head associated with the 85% fuel level. A typical density of the appropriate fuel may be used. For inboard and outboard conditions, an acceleration of 1.5g may be used in lieu of 3.0g as specified in CS 25.561(b)(3).

(3) Fuel tank internal barriers and baffles may be considered as solid boundaries if shown to be effective in limiting fuel flow.

(4) For each fuel tank and surrounding airframe structure, the effects of crushing and scraping actions with the ground should not cause the spillage of enough fuel, or generate temperatures that would constitute a fire hazard under the conditions specified in CS 25.721(b).

(5) Fuel tank installations must be such that the tanks will not rupture as a result of an engine pylon or engine mount or landing gear, tearing away as specified in CS 25.721(a) and (c).

(See ~~also~~ AMC 25.963(d).)

(e) ~~Fuel tanks within the fuselage contour must be able to resist rupture, and to retain fuel, under the inertia forces prescribed for the emergency landing conditions in CS 25.561. In addition, these tanks must be in a protected position so that exposure of the tanks to scraping action with the ground is unlikely.~~ Fuel tank access covers must comply with the following criteria in order to avoid loss of hazardous quantities of fuel:

(1) All covers located in an area where experience or analysis indicates a strike is likely, must be shown by analysis or tests to minimise penetration and deformation by tyre fragments, low energy engine debris, or other likely debris.

(2) All covers must have the capacity to withstand the heat associated with fire at least as well as an access cover made from aluminium alloy in dimensions appropriate for the purpose for which

they are to be used, except that the access covers need not be more resistant to fire than an access cover made from the base fuel tank structural material.

(See AMC 25.963(e).)

(f) ….

(g) Fuel tank access covers must comply with the following criteria in order to avoid loss of hazardous quantities of fuel:

(1) All covers located in an area where experience or analysis indicates a strike is likely, must be shown by analysis or tests to minimise penetration and deformation by tyre fragments, low energy engine debris, or other likely debris.

(2) Reserved

(See AMC 25.963 (g).) (Reserved)

27. Amend existing CS 25.994 to read as follows:

CS 25.994 Fuel system components
(See AMC 25.994)

Fuel system components in an engine nacelle or in the fuselage must be protected from damage which could result in spillage of enough fuel to constitute a fire hazard as a result of a wheels-up landing on a paved runway under each of the conditions prescribed in CS 25.721(b).

28. Add a new CS 25. 1302 to read:

25.1302 Installed systems and equipment for use by the flight crew
(See AMC 25.1302.)

This paragraph applies to installed equipment intended for flight-crew members' use in the operation of the aeroplane from their normally seated positions on the flight deck. This installed equipment must be shown, individually and in combination with other such equipment, to be designed so that qualified flight-crew members trained in its use can safely perform their tasks associated with its intended function by meeting the following requirements:

(a) Flight deck controls must be installed to allow accomplishment of these tasks and information necessary to accomplish these tasks must be provided.

(b) Flight deck controls and information intended for flight crew use must:

(1) Be presented in a clear and unambiguous form, at resolution and precision appropriate to the task.

(2) Be accessible and usable by the flight crew in a manner consistent with the urgency, frequency, and duration of their tasks, and

(3) Enable flight crew awareness, if awareness is required for safe operation, of the effects on the aeroplane or systems resulting from flight crew actions.

(c) Operationally-relevant behaviour of the installed equipment must be:

(1) Predictable and unambiguous, and

(2) Designed to enable the flight crew to intervene in a manner appropriate to the task.

(d) To the extent practicable, installed equipment must enable the flight crew to manage errors resulting from the kinds of flight crew interactions with the equipment that can be reasonably expected in service, assuming the flight crew is acting in good faith. This sub-paragraph (d) does not apply to skill-related errors associated with manual control of the aeroplane.

29. Amend CS 25.1419 to read :

CS 25.1419 Ice Protection
(See AMC 25.1419)

If the applicant seeks certification for flight in icing conditions ~~is desired~~, the aeroplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of Appendix C. To establish ~~that the aeroplane can operate within the continuous maximum and intermittent maximum conditions of Appendix C~~ this –

(a) ….

30. Amend existing CS 25J994 to read as follows:

CS 25J994 Fuel system components

Fuel system components in ~~the~~ an APU compartment or in the fuselage must be protected from damage which could result in spillage of enough fuel to constitute a fire hazard as a result of a wheels-up landing on a paved runway under each of the conditions prescribed in CS 25.721(b).

31. Amend Appendix C as follows:

1) Introduce a new header preceding the existing first paragraph of Appendix C to read as follows:

Part I - Atmospheric Icing Conditions

(a) *Continuous maximum icing*

.....

(b) *Intermittent maximum icing.*

.....

2) Introduce a new sub-paragraph (c) to this newly introduced Part I of Appendix C to read as follows:

(c) Takeoff maximum icing. The maximum intensity of atmospheric icing conditions for takeoff (takeoff maximum icing) is defined by the cloud liquid water content of 0.35 g/m^3, the mean effective diameter of the cloud droplets of 20 microns, and the ambient air temperature at ground level of minus 9 degrees Celsius (-9° C). The takeoff maximum icing conditions extend from ground level to a height of 457 m (1500 ft) above the level of the takeoff surface.

3) Introduce a new Part II of Appendix C to read as follows:

Part II - Airframe Ice Accretions for Showing Compliance with Subpart B

(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 lift-off and 122 m (400 ft) above the take-off surface, assuming accretion starts at lift-off in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix.

(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 takeoff to the en route configuration is completed and V_{FTO} is reached, whichever is higher. Ice accretion is assumed to start at lift-off in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix.

(3) En-route Ice is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the en-route phase.

(4) Holding Ice is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the holding flight phase.

(5) Approach ice is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation following exit from the holding flight phase and transition to the most critical approach configuration.

(6) Landing ice is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation following exit from the approach flight phase and transition to the final landing configuration.

(b) In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of paragraph CS 25.21(g), any of the ice accretions defined in sub-paragraph (a) of this section may be used for any other flight phase if it is shown to be more critical than the specific ice accretion defined for that flight phase. Configuration differences and their effects on ice accretions must be taken into account.

(c) The ice accretion that has the most adverse effect on handling characteristics may be used for aeroplane performance tests provided any difference in performance is conservatively taken into account.

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

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

(2) The ice accretion starts at lift-off;

(3) The critical ratio of thrust/power-to-weight;

(4) Failure of the critical engine occurs at V_{EF}; and

(5) Crew activation of the ice protection system is in accordance with a normal operating procedure provided in the Aeroplane Flight Manual, except that after beginning the takeoff roll, it must be assumed that the crew takes no action to activate the ice protection system until the airplane is at least 122 m (400 ft) above the takeoff surface.

(e) The ice accretion before the ice protection system has been activated and is performing its intended function is the critical ice accretion formed on the unprotected and normally protected surfaces before activation and effective operation of the ice protection system in continuous maximum atmospheric icing conditions. This ice accretion only applies in showing compliance to CS 25.143(j) and 25.207(h).

BOOK 2 – ACCEPTABLE MEANS OF COMPLIANCE – AMC

32. Introduce the following new AMC 25.21(g):

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

Table of Contents

1 *PURPOSE*.

1.1 This AMC describes an acceptable means for showing compliance with the requirements related to performance and handling characteristics of Large Aeroplanes as affected by flight in the icing conditions that are defined in Appendix C to CS-25. The means of compliance described in this AMC is intended to provide guidance to supplement the engineering and operational judgement that should form the basis of any compliance findings relative to handling characteristics and performance in Appendix C icing conditions.

1.2 The guidance information is presented in sections 4 to 6 and three appendices.

1.3 Section 4 explains the various performance and handling requirements in relation to the flight conditions that are relevant for determining the shape and texture of ice accretions for the aeroplane in the atmospheric conditions of CS-25, Appendix C.

1.4 Section 5 describes acceptable methods and procedures that an applicant may use to show that an aeroplane meets these requirements. Depending on the design features of a specific aeroplane as discussed in Appendix 3 of this AMC, its similarity to other types or models, and the service history of those types or models, some judgement will often be necessary for determining that any particular method or procedure is adequate for showing compliance with a particular requirement.

1.5 Section 6 provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the Authority as being the primary means of compliance.

1.6 The three appendices provide additional reference material associated with ice accretion, artificial ice shapes, and aeroplane design features.

2 *Related Requirements.* The following paragraphs of CS-25 are related to the guidance in this AMC:

- CS 25.21 (Proof of compliance)
- CS 25.103 (Stall speed)
- CS 25.105 (Takeoff)
- CS 25.107 (Takeoff speeds)
- CS 25.111 (Takeoff path)

- CS 25.119 (Landing climb)
- CS 25.121 (Climb: One-engine-inoperative)
- CS 25.123 (En-route flight paths)
- CS 25.125 (Landing)
- CS 25.143 (Controllability and Manoeuvrability - General)
- CS 25.207 (Stall warning)
- CS 25.237 (Wind velocities)
- CS 25.253 (High-speed characteristics)
- CS 25.1309 (Equipment, systems, and installations)
- CS 25.1419 (Ice protection)
- CS 25.1581 (Aeroplane Flight Manual)
- CS-25, Appendix C

3 *Reserved.*

4 *Requirements and Guidance.*

4.1 *General.* This section provides guidance for showing compliance with Subpart B requirements for flight in the icing conditions of Appendix C to CS-25.

4.1.1 Operating rules for commercial operation of large aeroplanes (e.g. JAR-OPS 1.345) require that the aeroplane is free of any significant ice contamination at the beginning of the take-off roll due to application of appropriate ice removal and ice protection procedures during flight preparation on the ground.

4.1.2 Appendix C to CS-25 defines the ice accretions to be used in showing compliance with CS 25.21(g). Appendix 1 of this AMC provides details on ice accretions, including accounting for delay in the operation of the ice protection system and consideration of ice detection systems.

4.1.3 Certification experience has shown that it is not necessary to consider ice accumulation on the propeller, induction system or engine components of an inoperative engine for handling qualities substantiation. Similarly, the mass of the ice need not normally be considered.

4.1.4 Flight in icing conditions includes operation of the aeroplane after leaving the icing conditions, but with ice accretion remaining on the critical surfaces of the aeroplane.

4.2 *Proof of Compliance (CS 25.21(g)).*

4.2.1 Demonstration of compliance with certification requirements for flight in icing conditions may be accomplished by any of the means discussed in paragraph 5.1 of this AMC.

4.2.2 Certification experience has shown that aeroplanes of conventional design do not require additional detailed substantiation of compliance with the requirements of the following paragraphs of CS-25 for flight in icing conditions or with ice accretions:

25.23,
25.25,
25.27,
25.29,
25.31,
25.231,
25.233,
25.235,
25.253(a) and (b), and
25.255

4.2.3 Where normal operation of the ice protection system results in changing the stall warning system and/or stall identification system activation settings, it is acceptable to establish a procedure to return to the non icing settings when it can be demonstrated that the critical wing surfaces are free of ice accretion.

4.3 *Propeller Speed and Pitch Limits (CS 25.33).* Certification experience has shown that it may be necessary to impose additional propeller speed limits for operations in icing conditions.

4.4 *Performance - General (CS 25.101).*

4.4.1 The propulsive power or thrust available for each flight condition must be appropriate to the aeroplane operating limitations and normal procedures for flight in icing conditions. In general, it is acceptable to determine the propulsive power or thrust available by suitable analysis, substantiated when required by appropriate flight tests (e.g. when determining the power or thrust available after 8 seconds for CS 25.119). The following aspects should be considered:

a. Operation of induction system ice protection.

b. Operation of propeller ice protection.

c. Operation of engine ice protection.

d. Operation of airframe ice protection system.

4.4.2 The following should be considered when determining the change in performance due to flight in icing conditions:

a. Thrust loss due to ice accretion on propulsion system components with normal operation of the ice protection system, including engine induction system and/or engine components, and propeller spinner and blades.

b. The incremental airframe drag due to ice accretion with normal operation of the ice protection system.

c. Changes in operating speeds due to flight in icing conditions.

4.4.3 Certification experience has shown that any increment in drag (or decrement in thrust) due to the effects of ice accumulation on the landing gear, propeller, induction system and engine components may be determined by a suitable analysis or by flight test.

4.4.4 Apart from the use of appropriate speed adjustments to account for operation in icing conditions, any changes in the procedures established for take-off, balked landing, and missed approaches should be agreed with the Authority.

4.4.5 Performance associated with flight in icing conditions is applicable after exiting icing conditions until the aeroplane critical surfaces are free of ice accretion and the ice protection systems are selected "Off."

4.4.6 Certification experience has also shown that runback ice may be critical for propellers, and propeller analyses do not always account for it. Therefore, runback ice on the propeller should be addressed, which may necessitate airplane performance checks in natural icing conditions or the use of an assumed (conservative) loss in propeller efficiency.

4.5 *Stall speed (CS 25.103)*. Certification experience has shown that for aeroplanes of conventional design it is not necessary to make a separate determination of the effects of Mach number on stall speeds for the aeroplane with ice accretions.

4.6 *Failure Conditions (CS 25.1309)*.

4.6.1 The failure modes of the ice protection system and the resulting effects on aeroplane handling and performance should be analysed in accordance with CS 25.1309. In determining the probability of a failure condition, it should be assumed that the probability of entering icing conditions is one. The "Failure Ice" configuration is defined in Appendix 1, paragraph A1.3.

4.6.2 For probable failure conditions that are not annunciated to the flight crew, the guidance in this AMC for a normal condition is applicable with the "Failure Ice" configuration.

4.6.3 For probable failure conditions that are annunciated to the flight crew, with an associated procedure that does not require the aeroplane to exit icing conditions, the guidance in this AMC for a normal condition is applicable with the "Failure Ice" configuration.

4.6.4 For probable failure conditions that are annunciated to the flight crew, with an associated operating procedure that requires the aeroplane to leave the icing conditions as soon as practicable, it should be shown that the aeroplane's resulting performance and handling characteristics with the failure ice accretion are commensurate with the hazard level as determined by a system safety analysis in accordance with CS 25.1309. The operating procedures and related speeds may restrict the aeroplane's operating envelope, but the size of the restricted envelope should be consistent with the safety analysis.

4.6.5 For failure conditions that are improbable but not extremely improbable, the analysis and substantiation of continued safe flight and landing, in accordance with CS 25.1309, should take into consideration whether annunciation of the failure is provided and the associated operating procedures and speeds to be used following the failure condition.

4.7 *Flight-related Systems*. In general, systems aspects are covered by the applicable systems and equipment requirements in other subparts of CS-25, and associated guidance material. However, certification experience has shown that other flight related systems aspects should be considered when determining compliance with the flight requirements of subpart B. For example, the following aspects may be relevant:

a. The ice protection systems may not anti-ice or de-ice properly at all power or thrust settings. This may result in a minimum power or thrust setting for operation in icing conditions which affects descent and/or approach capability. The effect of power or thrust setting should also be considered in determining the applicable ice accretions. For example, a thermal bleed air system may be running wet resulting in the potential for runback ice.

b. Ice blockage of control surface gaps and/or freezing of seals causing increased control forces, control restrictions or blockage.

c. Airspeed, altitude and/or angle of attack sensing errors due to ice accretion forward of the sensors (e.g. radome ice). Dynamic pressure ("q") operated feel systems using separate sensors also may be affected.

d. Ice blockage of unprotected inlets and vents that may affect the propulsive thrust available, aerodynamic drag, powerplant control, or flight control.

e. Operation of stall warning and stall identification reset features for flight in icing conditions, including the effects of failure to operate.

f. Operation of icing condition sensors, ice accretion sensors, and automatic or manual activation of ice protection systems.

g. Automatic flight control systems operation. Stall characteristics with critical ice accretions may be affected in stalls following autopilot disconnect or stall approaches with the autopilot engaged. (e.g. because of the trim setting at autopilot disconnect)

h. Installed thrust. This includes operation of ice protection systems when establishing acceptable power or thrust setting procedures, control, stability, lapse rates, rotor speed margins, temperature margins, Automatic Reserve Power (ARP) operation, and power or thrust lever angle functions.

4.8 *Aeroplane Flight Manual (CS 25.1581)*.

4.8.1 *Limitations.*

4.8.1.1 Where limitations are required to ensure safe operation in icing conditions, these limitations should be stated in the AFM.

4.8.1.2 The Limitations section of the AFM should include, as applicable, a statement similar to the following: “In icing conditions the aeroplane must be operated, and its ice protection systems used, as described in the operating procedures section of this manual. Where specific operational speeds and performance information have been established for such conditions, this information must be used."

4.8.2 *Operating Procedures.*

4.8.2.1 AFM operating procedures for flight in icing conditions should include normal operation of the aeroplane including operation of the ice protection system and operation of the aeroplane following ice protection system failures. Any changes in procedures for other aeroplane system failures that affect the capability of the aeroplane to operate in icing conditions should be included.

4.8.2.2 Normal operating procedures provided in the AFM should reflect the procedures used to certify the aeroplane for flight in icing conditions. This includes configurations, speeds, ice protection system operation, power plant and systems operation, for take-off, climb, cruise, descent, holding, go-around, and landing.

4.8.2.3 Abnormal operating procedures should include the procedures to be followed in the event of annunciated ice protection system failures and suspected unannunciated failures. Any changes to other abnormal procedures contained in the AFM, due to flight in icing conditions, should also be included.

4.8.3 *Performance Information.* Performance information, derived in accordance with subpart B of CS-25, must be provided in the AFM for all relevant phases of flight.

5 *Acceptable Means of Compliance - General.*

5.1 *General.*

5.1.1 This section describes acceptable methods and procedures that an applicant may use to show that an aeroplane meets the performance and handling requirements of subpart B in the atmospheric conditions of Appendix C to CS-25.

5.1.2 Compliance with CS 25.21(g) should be shown by one or more of the methods listed in this section.

5.1.3 The compliance process should address all phases of flight, including take-off, climb, cruise, holding, descent, landing, and go-around as appropriate to the aeroplane type, considering its typical operating regime.

5.1.4 The design features included in Appendix 3 of this AMC should be considered when determining the extent of the substantiation programme.

5.1.5 Appropriate means for showing compliance include the actions and items listed in Table 1. These are explained in more detail in the following sections of this AMC.

TABLE 1: Means for Showing Compliance

Flight Testing	Flight testing in dry air using artificial ice shapes or with ice shapes created in natural icing conditions.
Wind Tunnel Testing and Analysis	An analysis of results from wind tunnel tests with artificial or actual ice shapes.
Engineering Simulator Testing and Analysis	An analysis of results from engineering simulator tests.
Engineering Analysis	An analysis which may include the results from executing an agreed computer code.
Ancestor Aeroplane Analysis	An analysis of results from a closely related ancestor aeroplane.

5.1.6 Various factors that affect ice accretion on the airframe with an operative ice protection system and with ice protection system failures are discussed in Appendix 1 of this AMC.

5.1.7 An acceptable methodology to obtain agreement on the artificial ice shapes is given in Appendix 2 of this AMC. That appendix also provides the different types of artificial ice shapes to be considered.

5.2 *Flight Testing.*

5.2.1 *General*.

5.2.1.1 The extent of the flight test programme should consider the results obtained with the non-contaminated aeroplane and the design features of the aeroplane as discussed in Appendix 3 of this AMC.

5.2.1.2 It is not necessary to repeat an extensive performance and flight characteristics test programme on an aeroplane with ice accretion. A suitable programme that is sufficient to demonstrate compliance with the requirements can be established from experience with aeroplanes of similar size, and from review of the ice protection system design, control system design, wing design, horizontal and vertical stabiliser design, performance characteristics, and handling characteristics of the non-contaminated aeroplane. In particular, it is not necessary to investigate all weight and centre of gravity combinations when results from the non-contaminated aeroplane clearly indicate the most critical combination to be tested. It is not necessary to investigate the flight characteristics of the aeroplane at high altitude (i.e. above the upper limit specified in Appendix C to CS-25). An acceptable flight test programme is provided in section 6 of this AMC.

5.2.1.3 Certification experience has shown that tests are usually necessary to evaluate the consequences of ice protection system failures on handling characteristics and performance and to demonstrate continued safe flight and landing.

5.2.2 *Flight Testing Using Approved Artificial Ice Shapes*.

5.2.2.1 The performance and handling tests may be based on flight testing in dry air using artificial ice shapes that have been agreed with the Authority.

5.2.2.2 Additional limited flight tests are discussed in paragraph 5.2.3, below.

5.2.3 *Flight Testing In Natural Icing Conditions.*

5.2.3.1 Where flight testing with ice accretion obtained in natural atmospheric icing conditions is the primary means of compliance, the conditions should be measured and recorded. The tests should ensure good coverage of Appendix C conditions and, in particular, the critical conditions. The conditions for accreting ice (including the icing atmosphere, configuration, speed and duration of exposure) should be agreed with the Authority.

5.2.3.2 Where flight testing with artificial ice shapes is the primary means of compliance, additional limited flight tests should be conducted with ice accretion obtained in natural icing conditions. The objective of these tests is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes. As such, it is not necessary to measure the atmospheric characteristics (i.e. liquid water content (LWC) and median volumetric diameter (MVD)) of the flight test icing conditions. For some derivative aeroplanes with similar aerodynamic characteristics as the ancestor, it may not be necessary to carry out additional flight test in natural icing conditions if such tests have been already performed with the ancestor.

5.3 *Wind Tunnel Testing and Analysis.* Analysis of the results of dry air wind tunnel testing of models with artificial ice shapes, as defined in Part II of Appendix C to CS-25, may be used to substantiate the performance and handling characteristics.

5.4 *Engineering Simulator Testing and Analysis.* The results of an engineering simulator analysis of an aeroplane that includes the effects of the ice accretions as defined in Part II of Appendix C to CS-25 may be used to substantiate the handling characteristics. The data used to model the effects of ice accretions for the engineering simulator may be based on results of dry air wind tunnel tests, flight tests, computational analysis, and engineering judgement.

5.5 *Engineering Analysis.* An engineering analysis that includes the effects of the ice accretions as defined in Part II of Appendix C to CS-25 may be used to substantiate the performance and handling characteristics. The effects of the ice shapes used in this analysis may be determined by an analysis of the results of dry air wind tunnel tests, flight tests, computational analysis, engineering simulator analysis, and engineering judgement.

5.6 *Ancestor Aeroplane Analysis.*

5.6.1 An ancestor aeroplane analysis that includes the effect of the ice accretions as defined in Part II of Appendix C to CS-25 may be used to substantiate the performance and handling characteristics. This analysis should consider the similarity of the configuration, operating envelope, performance and handling characteristics, and ice protection system of the ancestor aeroplane.

5.6.2 The analysis may include flight test data, dry air wind tunnel test data, icing tunnel test data, engineering simulator analysis, service history, and engineering judgement.

6 *Acceptable Means of Compliance - Flight Test Programme.*

6.1 *General.*

6.1.1 This section provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the Authority as being the primary means for showing compliance.

6.1.2 Where an alternate means of compliance is proposed for a specific paragraph in this section, it should enable compliance to be shown with at least the same degree of confidence as flight test would provide (see CS 25.21(a)(1)).

6.1.3 This test programme is based on the assumption that the applicant will choose to use the holding Ice accretion for the majority of the testing assuming that it is the most conservative ice accretion. In general, the applicant may choose to use an ice accretion that is either conservative or is the specific ice accretion that is appropriate to the particular phase of flight. In accordance with part II(a) of appendix C to CS-25, if the holding ice accretion is not as conservative as the ice accretion appropriate to the flight phase, then the ice accretion appropriate to the flight phase (or a more conservative ice accretion) must be used.

6.2 *Stall Speed (CS 25.103).*

6.2.1 The stall speed for intermediate high lift configurations can normally be obtained by interpolation. However if a stall identification system (e.g. stick pusher) firing point is set as a function of the high lift configuration and/or the firing point is reset for icing conditions, or if significant configuration changes occur with extension of trailing edge flaps (such as wing leading edge high-lift device position movement), additional tests may be necessary.

6.2.2 *Acceptable Test Programme*. The following represents an acceptable test programme subject to the provisions outlined above:

a. Forward centre of gravity position appropriate to the configuration.

b. Normal stall test altitude.

c. In the configurations listed below, trim the aeroplane at an initial speed of 1.13 to 1.30 V_{SR}. Decrease speed until an acceptable stall identification is obtained.

i. High lift devices retracted configuration, "Final Take-off Ice."

ii. High lift devices retracted configuration, "En-route Ice."

iii. Holding configuration, "Holding Ice."

iv. Lowest lift take-off configuration, "Holding Ice."

v. Highest lift take-off configuration, "Take-off Ice."

vi. Highest lift landing configuration, "Holding Ice."

6.3 *Accelerate-stop Distance (CS 25.109).* The effect of any increase in V_1 due to take-off in icing conditions may be determined by a suitable analysis.

6.4 *Take-off Path (CS 25.111).* If V_{SR} in the configuration defined by CS 25.121(b) with the “Takeoff Ice" accretion defined in Appendix C to CS-25 exceeds V_{SR} 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.

6.5 *Landing Climb: All-engines-operating (CS 25.119). Acceptable Test Programme*. The following represents an acceptable test programme:

a. "Holding Ice."

b. Forward centre of gravity position appropriate to the configuration.

c. Highest lift landing configuration, landing climb speed no greater than V_{REF}.

d. Stabilise at the specified speed and conduct 2 climbs or drag polar checks as agreed with the Authority.

6.6 *Climb: One-engine-inoperative (CS 25.121). Acceptable Test Programme*. The following represents an acceptable test programme:

a. Forward centre of gravity position appropriate to the configuration.

b. In the configurations listed below, stabilise the aeroplane at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs in each configuration or drag polar checks substantiated for the asymmetric drag increment as agreed with the Authority.

i. High lift devices retracted configuration, final take-off climb speed, "Final Take-off Ice."

ii. Lowest lift take-off configuration, landing gear retracted, V_2 climb speed, "Take-off Ice."

iii. Approach configuration appropriate to the highest lift landing configuration, landing gear retracted, approach climb speed, "Holding Ice."

6.7 *En-route Flight Path (CS 25.123)*. *Acceptable Test Programme*. The following represents an acceptable test programme:

a. "En-route Ice."

b. Forward centre of gravity position appropriate to the configuration.

c. En-route configuration and climb speed.

d. Stabilise at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs or drag polar checks substantiated for the asymmetric drag increment as agreed with the Authority.

6.8 *Landing (CS 25.125).* The effect of landing speed increase on the landing distance may be determined by a suitable analysis.

6.9 *Controllability and Manoeuvrability - General (CS 25.143 and 25.177).*

6.9.1 A qualitative and quantitative evaluation is usually necessary to evaluate the aeroplane's controllability and manoeuvrability. In the case of marginal compliance, or the force limits or stick force per g limits of CS 25.143 being approached, additional substantiation may be necessary to establish compliance. In general, it is not necessary to consider separately the ice accretion appropriate to take-off and en-route because the "Holding Ice" is usually the most critical.

6.9.2 *General Controllability and Manoeuvrability*. The following represents an acceptable test programme for general controllability and manoeuvrability, subject to the provisions outlined above:

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed in Table 2, trim at the specified speeds and conduct the following manoeuvres:

i. 30° banked turns left and right with rapid reversals;

ii. Pull up to 1.5g (except that this may be limited to 1.3g at V_{REF}), and pushover to 0.5g (except that the pushover is not required at V_{MO} and V_{FE}); and

iii. Deploy and retract deceleration devices.

TABLE 2: Trim Speeds

Configuration	*Trim Speed*
High lift devices retracted configuration:	• 1.3 V_{SR}, and • V_{MO} or 463 km/h (250 knots) IAS , whichever is less
Lowest lift takeoff configuration:	• 1.3 V_{SR}, and • V_{FE} or 463 km/h (250 knots) IAS, whichever is less
Highest lift landing configuration:	• V_{REF}, and

	• V_{FE} or 463 km/h (250 knots) IAS, whichever is less.

d. Lowest lift take-off configuration: At the greater of 1.13 VSR or V2 MIN, with the critical engine inoperative (or simulated inoperative if all effects can be taken into account), conduct 30° banked turns left and right with normal turn reversals and, in wings-level flight, a 9.3 km/h (5 knot) speed decrease and increase.

e. Conduct an approach and go-around with all engines operating using the recommended procedure.

f. Conduct an approach and go-around with the critical engine inoperative (or simulated inoperative if all effects can be taken into account) using the recommended procedure.

g. Conduct an approach and landing using the recommended procedure. In addition satisfactory controllability should be demonstrated during a landing at V_{REF} minus 9.3 km/h (5 knots). These tests should be done at heavy weight and forward centre of gravity.

h. Conduct an approach and landing with the critical engine inoperative (or simulated inoperative if all effects can be taken into account) using the recommended procedure.

6.9.3 *Evaluation of Lateral Control Characteristics*. Aileron hinge moment reversal and other lateral control anomalies have been implicated in icing accidents and incidents. The following manoeuvre, along with the evaluation of lateral controllability during a deceleration to the stall warning speed covered in paragraph 6.17.2(e) of this AMC and the evaluation of static lateral-directional stability covered in paragraph 6.15 of this AMC, is intended to evaluate any adverse effects arising from both stall of the outer portion of the wing and control force characteristics.

(a) Holding configuration, holding ice accretion, maximum landing weight, forward centre-of-gravity position, minimum holding speed (highest expected holding angle-of-attack); and

(b) Landing configuration, most critical of holding, approach, and landing ice accretions, medium to light weight, forward centre-of-gravity position, V_{REF} (highest expected landing approach angle-of-attack).

1 Establish a 30-degree banked level turn in one direction.

2 Using a step input of approximately 1/3 full lateral control deflection, roll the aeroplane in the other direction.

3 Maintain the control input as the aeroplane passes through a wings level attitude.

4 At approximately 20 degrees of bank in the other direction, apply a step input in the opposite direction to approximately 1/3 full lateral control deflection.

5 Release the control input as the aeroplane passes through a wings level attitude.

6 Repeat this test procedure with 2/3 and up to full lateral control deflection unless the roll rate or structural loading is judged excessive. It should be possible to readily arrest and reverse the roll rate using only lateral control input, and the lateral control force should not reverse with increasing control deflection.

6.9.4 *Low g Manoeuvres and Sideslips.* The following represents an example of an acceptable test program for showing compliance with controllability requirements in low g manoeuvres and in sideslips to evaluate susceptibility to ice-contaminated tailplane stall.

6.9.4.1 CS25.143(i)(2) states: “It must be shown that a push force is required throughout a pushover manoeuvre down to zero g or the lowest load factor obtainable if limited by elevator power or other design characteristic of the flight control system. It must be possible to promptly recover from the manoeuvre without exceeding 222 N. (50 lbf) pull control force”.

6.9.4.2 Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength. Discontinuities in the control force characteristic, unless so small as to be unnoticeable, would not be considered to meet the requirement that the force be steadily increasing. A gradual change in control force is a change that is not abrupt and does not have a steep gradient that can be easily managed by a pilot of average skill, alertness, and strength. Control forces in excess of those permitted by CS25.143(c) would be considered excessive.
(See paragraph 6.15.1 of this AMC for lateral-directional aspects).

6.9.4.3 The test manoeuvres described in paragraphs 6.9.4.1 and 6.9.4.2, above, should be conducted using the following configurations and procedures:

a. "Holding Ice." For aeroplanes with unpowered elevators, these tests should also be performed with "Sandpaper Ice."

b. Medium to light weight, the most critical of aft or forward centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, with the aeroplane in trim, or as nearly as possible in trim, at the specified trim speed, perform a continuous manoeuvre (without changing trim) to reach zero g normal load factor or, if limited by elevator control authority, the lowest load factor obtainable at the target speed.

i. Highest lift landing configuration at idle power or thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not <u>more</u> than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not <u>less</u> than V_{FE} - 37 km/h (20 knots)

ii. Highest lift landing configuration at go-around power or thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not <u>more</u> than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not <u>less</u> than V_{FE} - 37 km/h (20 knots)

iii. Conduct steady heading sideslips to full rudder authority, 356 N. (180 lbf) rudder force or full lateral control authority (whichever comes first), with highest lift landing configuration, trim speed 1.23 V_{SR}, and power or thrust for -3° flight path angle.

6.9.5 *Controllability prior to Normal Operation of the Ice Protection System*. The following represents an acceptable test programme for compliance with controllability requirements with the ice accretion prior to normal operation of the ice protection system.

6.9.5.1 Where the ice protection system is activated as described in paragraph A1.2.3.3.a of Appendix 1 of this AMC, paragraphs 6.9.1, 6.9.2 and 6.9.4 of this AMC are applicable with the ice accretion prior to normal system operation.

6.9.5.2 Where the ice protection system is activated as described in paragraphs A1.2.3.3.b,c,d or e of Appendix 1 of this AMC, it is acceptable to demonstrate adequate controllability with the ice accretion prior to normal system operation, as follows:

a. In the configurations listed below, trim the aeroplane at the specified speed. Conduct pull up to 1.5g and pushover to 0.5g without longitudinal control force reversal.

i. High lift devices retracted configuration (or holding configuration if different), holding speed, power or thrust for level flight.

ii. Landing configuration, V_{REF} for non-icing conditions, power or thrust for landing approach (limit pull up to stall warning).

6.10 *Longitudinal Control (CS 25.145).*

6.10.1 No specific quantitative evaluations are required for demonstrating compliance with CS 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.10.2 *Acceptable Test Programme*. The following represents an acceptable test programme for compliance with CS 25.145(a):

a. "Holding ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at 1.3 V_{SR}. Reduce speed using elevator control to stall warning plus one second and demonstrate prompt recovery to the trim speed using elevator control.

i. High lift devices retracted configuration, maximum continuous power or thrust.

ii. Maximum lift landing configuration, maximum continuous power or thrust.

6.11 *Directional and Lateral Control (CS 25.147).* Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.12 Trim (CS 25.161).

6.12.1 Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice. In addition a specific check should be made to demonstrate compliance with CS 25.161(c)(2).

6.12.2 The following represents a representative test program for compliance with 25.161(c)(2).

a. Holding ice
b. Most critical landing weight, forward centre of gravity position, symmetric fuel loading
c. In the configurations below, trim the aircraft at the specified speed

i. Maximum lift landing configuration, landing gear extended, and the most critical of:
- Speed 1.3VSR1 with Idle power or thrust; or,
- Speed VREF with power or thrust corresponding to a 3 deg glidepath'

6.13 *Stability - General (CS 25.171).* Qualitative evaluations should be combined with the other testing. Any tendency to change speed when trimmed or requirement for frequent trim inputs should be specifically investigated.

6.14 *Demonstration of Static Longitudinal Stability (CS 25.175).*

6.14.1 Each of the following cases should be tested. In general, it is not necessary to test the cruise configuration at low speed (CS 25.175(b)(2)) or the cruise configuration with landing gear extended (CS 25.175(b)(3)); nor is it necessary to test at high altitude. The maximum speed for substantiation of stability characteristics in icing conditions (as prescribed by CS 25.253(c)) is the lower of 556 km/h (300 knots) CAS, VFC, or a speed at which it is demonstrated that the airframe will be free of ice accretion due to the effects of increased dynamic pressure.

6.14.2 *Acceptable Test Programme*. The following represents an acceptable test programme for demonstration of static longitudinal stability:

a. "Holding Ice."

b. High landing weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed. The power or thrust should be set and stability demonstrated over the speed ranges as stated in CS 25.175(a) through (d), as applicable.

i. Climb: With high lift devices retracted, trim at the speed for best rate-of-climb, except that the speed need not be less than 1.3 VSR.

ii. Cruise: With high lift devices retracted, trim at V_{MO} or 463 km/h (250 knots) CAS, whichever is lower.

iii. Approach: With the high lift devices in the approach position appropriate to the highest lift landing configuration, trim at 1.3 V_{SR}.

iv. Landing: With the highest lift landing configuration, trim at 1.3V_{SR}.

6.15 *Static Directional and Lateral Stability (CS 25.177).*

6.15.1 Compliance should be demonstrated using steady heading sideslips to show compliance with directional and lateral stability. The maximum sideslip angles obtained should be recorded and may be used to substantiate a crosswind value for landing (see paragraph 6.19 of this AMC).

6.15.2 *Acceptable Test Programme*. The following represents an acceptable test programme for static directional and lateral stability:

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed and conduct steady heading sideslips to full rudder authority, 801 N. (180 lbf) rudder pedal force, or full lateral control authority, whichever comes first.

i. High lift devices retracted configuration: Trim at best rate-of-climb speed, but need not be less than 1.3 V_{SR}.

ii. Lowest lift take-off configuration: Trim at the all-engines-operating initial climb speed.

iii. Highest lift landing configuration: Trim at V_{REF}.

6.16 *Dynamic Stability (CS 25.181).* Provided that there are no marginal compliance aspects with the non-contaminated aeroplane, it is not necessary to demonstrate dynamic stability in specific tests. Qualitative evaluations should be combined with the other testing. Any tendency to sustain oscillations in turbulence or difficulty in achieving precise attitude control should be investigated.

6.17 *Stall Demonstration (CS 25.201).*

6.17.1 Sufficient stall testing should be conducted to demonstrate that the stall characteristics comply with the requirements. In general, it is not necessary to conduct a stall programme which encompasses all weights, centre of gravity positions (including lateral asymmetry), altitudes, high lift configurations, deceleration device configurations, straight and turning flight stalls, power off and power on stalls. Based on a review of the stall characteristics of the non-contaminated aeroplane, a reduced test matrix can be established. However, additional testing may be necessary if:

- the stall characteristics with ice accretion show a significant difference from the non-contaminated aeroplane,
- testing indicates marginal compliance, or
- a stall identification system (e.g. stick pusher) is required to be reset for icing conditions.

6.17.2 *Acceptable Test Programme*. Turning flight stalls at decelerations greater than 1 knot/sec are not required. Slow decelerations (much slower than 1 knot/sec) may be critical on aeroplanes with anticipation logic in their stall protection system or on aeroplanes with low directional stability, where large sideslip angles could develop. The following represents an acceptable test programme subject to the provisions outlined above.

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. Normal stall test altitude.

d. In the configurations listed below, trim the aeroplane at the same initial stall speed factor used for stall speed determination. For power-on stalls, use the power setting as defined in CS 25.201(a)(2) but with ice accretions on the aeroplane. Decrease speed at a rate not to exceed 1 knot/sec to stall identification and recover using the same test technique as for the non-contaminated aeroplane.

i. High lift devices retracted configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

ii. Lowest lift take-off configuration: Straight/Power On, Turning/Power Off.

iii. Highest lift take-off configuration: Straight/Power Off, Turning/Power On.

iv. Highest lift landing configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

e. For the configurations listed in paragraph 6.17.2(d)i and iv, and any other configuration if deemed more critical, in 1 knot/second deceleration rates down to stall warning with wings level and power off, roll the airplane left and right up to 10 degrees of bank using the lateral control.

6.18 *Stall Warning (CS 25.207).*

6.18.1 Stall warning should be assessed in conjunction with stall speed testing and stall demonstration testing (CS 25.103, CS 25.201 and paragraphs 6.2 and 6.17 of this AMC, respectively) and in tests with faster entry rates.

6.18.2 *Normal Ice Protection System Operation*. The following represents an acceptable test programme for stall warning in slow down turns of at least 1.5g and at entry rates of at least 1 m/sec^2 (2 knot/sec):

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. Normal stall test altitude.

d. In the configurations listed below, trim the aeroplane at 1.3V_{SR} with the power or thrust necessary to maintain straight level flight. Maintain the trim power or thrust during the test demonstrations. Increase speed as necessary prior to establishing at least 1.5g and a deceleration of at least 1 m/sec^2 (2 knot/sec). Decrease speed until 1 sec after stall warning and recover using the same test technique as for the non-contaminated aeroplane.

i. High lift devices retracted configuration;

ii. Lowest lift take-off configuration; and

iii. Highest lift landing configuration.

6.18.3 *Ice Accretion Prior to Normal System Operation*. The following represent acceptable means for evaluating stall warning margin with the ice accretion prior to normal operation of the ice protection system.

6.18.3.1 Where the ice protection system is activated as described in paragraph A1.2.3.3.a, of Appendix 1 of this AMC, paragraphs 6.18.1 and 6.18.2 of this AMC are applicable with the ice accretion prior to normal system operation.

6.18.3.2 Where the ice protection system is activated as described in paragraphs A1.2.3.3.b,c,d or e of Appendix 1 of this AMC, it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation, as follows:

a. In the configurations listed below, trim the aeroplane at 1.3 V_{SR}.

i. High lift devices retracted configuration: Straight/Power Off.

ii. Landing configuration: Straight/Power Off.

b. At decelerations of up to 0.5 m/sec^2 (1 knot per second), reduce the speed to stall warning plus 1 second, and demonstrate that stalling can be prevented using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics (e.g., a rapid roll-off). As required by CS 25.207(h)(2)(ii), where stall warning is provided by a different means than for the aeroplane without ice accretion, the stall characteristics must be satisfactory and the delay must be at least 3 seconds.

6.19 *Wind Velocities (CS 25.237).*

6.19.1 Crosswind landings with "Landing Ice" should be evaluated on an opportunity basis.

6.19.2 The results of the steady heading sideslip tests with “Landing Ice” may be used to establish the safe cross wind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated aeroplane, and the flight characteristics (e.g. control forces and deflections) are similar, then the non-contaminated aeroplane crosswind component is considered valid.

6.19.3 If the results of the comparison discussed in paragraph 6.19.2, above, are not clearly similar, and in the absence of a more rational analysis, a conservative analysis based on the results of the steady heading sideslip tests may be used to establish the safe crosswind component. The crosswind value may be estimated from:

$$V_{CW} = V_{REF} * \sin(\text{sideslip angle}) / 1.5$$

Where:

V_{CW} is the crosswind component,
V_{REF} is the landing reference speed appropriate to a minimum landing weight, and *sideslip angle* is that demonstrated at V_{REF} (see paragraph 6.15 of this AMC).

6.20 *Vibration and Buffeting (CS 25.251).*

6.20.1 Qualitative evaluations should be combined with the other testing, including speeds up to the maximum speed obtained in the longitudinal stability tests (see paragraph 6.14 of this AMC).

6.20.2 It is also necessary to demonstrate that the aeroplane is free from harmful vibration due to residual ice accumulation. This may be done in conjunction with the natural icing tests.

6.20.3 An aeroplane with pneumatic de-icing boots should be evaluated to V_{DF}/M_{DF} with the de-icing boots operating and not operating. It is not necessary to do this demonstration with ice accretion.

6.21 *Natural Icing Conditions.*

6.21.1 *General.*

6.21.1.1 Whether the flight testing has been performed with artificial ice shapes or in natural icing conditions, additional limited flight testing described in this section should be conducted in natural icing conditions. Where flight testing with artificial ice shapes is the primary means for showing compliance, the objective of the tests described in this section is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes.

6.21.1.2 It is acceptable for some ice to be shed during the testing due to air loads or wing flexure, etc. However, an attempt should be made to accomplish the test manoeuvres as soon as possible after exiting the icing cloud to minimise the atmospheric influences on ice shedding.

6.21.1.3 During any of the manoeuvres specified in paragraph 6.21.2, below, the behaviour of the aeroplane should be consistent with that obtained with artificial ice shapes. There should be no unusual control responses or uncommanded aeroplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

6.21.2 *Ice Accretion/Manoeuvres*.

6.21.2.1 *Holding scenario.*

a. The manoeuvres specified in Table 3, below, should be carried out with the following ice accretions representative of normal operation of the ice protection system:

i. *On unprotected Parts*: A thickness of 75 mm (3 inches) on those parts of the aerofoil where the collection efficiency is highest should be the objective. (A thickness of 50 mm (2 inches) is normally a minimum value, unless a lesser value is agreed by the Authority.)

ii. *On protected parts*: The ice accretion thickness should be that resulting from normal operation of the ice protection system.

b. For aeroplanes with control surfaces that may be susceptible to jamming due to ice accretion (e.g. elevator horns exposed to the air flow), the holding speed that is critical with respect to this ice accretion should be used.

TABLE 3: Holding Scenario - Manoeuvres

Configuration	*c.g.*	*Trim speed*	*Manoeuvre*
Flaps up, gear up	Optional (aft range)	Holding, except 1.3 V_{SR} for the stall manoeuvre	• Level, 40° banked turn, • Bank-to-bank rapid roll, 30° - 30°, • Speedbrake extension, retraction, • Full straight stall (1 knot/second deceleration rate, wings level, power off).
Flaps in intermediate positions, gear up	Optional (aft range)	1.3 V_{SR}	Deceleration to the speed reached 3 seconds after activation of stall warning in a 1 knot/second deceleration.
Landing flaps, gear down	Optional (aft range)	V_{REF}	• Level, 40° banked turn, • Bank-to-bank rapid roll, 30° - 30°, • Speedbrake extension, retraction (if approved), • Full straight stall (1 knot/second deceleration rate, wings level, power off).

6.21.2.2 *Approach/Landing Scenario.* The manoeuvres specified in Table 4, below, should be carried out with successive accretions in different configurations on unprotected surfaces. Each test condition should be accomplished with the ice accretion that exists at that point. The final ice accretion (Test Condition 3) represents the sum of the amounts that would accrete during a normal descent from holding to landing in icing conditions.

TABLE 4: Approach/Landing Scenario - Manoeuvres

Test Condition	*Ice accretion thickness (*)*	*Configuration*	*c.g.*	*Trim speed*	*Manoeuvre*
_	First 13 mm (0.5 in.)	Flaps up, gear up	Optional (aft range)	Holding	No specific test
1	Additional 6.3 mm (0.25 in.) (19 mm (0.75 in.) total)	First intermediate flaps, gear up	Optional (aft range)	Holding	• Level 40° banked turn, • Bank-to-bank rapid roll, 30°-30°, • Speed brake extension and retraction (if approved), • Deceleration to stall warning.
2	Additional 6.3 mm (0.25 in.) (25 mm (1.00 in.) total)	Further intermediate flaps, gear up (as applicable)	Optional (aft range)	1.3 V_{SR}	• Bank-to-bank rapid roll, 30° - 30°, • Speed brake extension and retraction (if approved), • Deceleration to stall warning.
3	Additional 6.3 mm (0.25 in.) (31 mm (1.25 in.) total)	Landing flaps, gear down	Optional (aft range)	V_{REF}	• Bank-to-bank rapid roll, 30° - 30°, • Speed brake extension and retraction (if approved), • Bank to 40°, • Full straight stall.

(*) The indicated thickness is that obtained on the parts of the unprotected aerofoil with the highest collection efficiency.

6.21.3 For aeroplanes with unpowered elevator controls, in the absence of an agreed substantiation of the criticality of the artificial ice shape used to demonstrate compliance with the controllability requirement, the pushover test of paragraph 6.9.3 should be repeated with a thin accretion of natural ice.

6.21.4 Existing propeller speed limits or, if required, revised propeller speed limits for flight in icing, should be verified by flight tests in natural icing conditions.

6.22 *Failure Conditions (CS 25.1309).*

6.22.1 For failure conditions which are annunciated to the flight crew, credit may be taken for the established operating procedures following the failure.

6.22.2 *Acceptable Test Programme*. In addition to a general qualitative evaluation, the following test programme (modified as necessary to reflect the specific operating procedures) should be carried out for the most critical probable failure condition where the associated procedure requires the aeroplane to exit the icing condition:

a. The ice accretion is defined as a combination of the following:

i. On the unprotected surfaces - the “Holding ice” accretion described in paragraph A1.2.1 of this AMC;

ii. On the normally protected surfaces that are no longer protected - the “Failure ice” accretion described in paragraph A1.3.2 of this AC; and

iii. On the normally protected surfaces that are still functioning following the segmental failure of a cyclical de-ice system – the ice accretion that will form during the rest time of the de-ice system following the critical failure condition.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed. Conduct 30° banked turns left and right with normal reversals. Conduct pull up to 1.5g and pushover to 0.5g.

i. High lift devices retracted configuration (or holding configuration if different): Holding speed, power or thrust for level flight. In addition, deploy and retract deceleration devices.

ii. Approach configuration: Approach speed, power or thrust for level flight.

iii. Landing configuration: Landing speed, power or thrust for landing approach (limit pull up to 1.3g). In addition, conduct steady heading sideslips to angle of sideslip appropriate to type and landing procedure.

d. In the configurations listed below, trim the aeroplane at estimated 1.3 V_{SR}. Decrease speed to stall warning plus 1 second, and demonstrate prompt recovery using the same test technique as for the non-contaminated aeroplane. Natural stall warning is acceptable for the failure case.

i. High lift devices retracted configuration: Straight/Power Off.

ii. Landing configuration: Straight/Power Off.

e. Conduct an approach and go-around with all engines operating using the recommended procedure.

f. Conduct an approach and landing with all engines operating (unless the one-engine-inoperative condition results in a more critical probable failure condition) using the recommended procedure.

6.22.3 For improbable failure conditions, flight test may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) is commensurate with the failure probability or to verify the results of analyses and/or wind tunnel tests. The extent of any required flight test should be similar to that described in paragraph 6.22.2, above, or as agreed with the Authority for the specific failure condition.

Appendix 1 - Airframe Ice Accretion

A1.1 *General.*

The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered include:

- the flight conditions (e.g. aeroplane configuration, speed, angle of attack, altitude) and
- the icing conditions of Appendix C to CS-25 (e.g. temperature, liquid water content, mean effective drop diameter).

A1.2 *Operative Ice Protection System.*

A1.2.1 *All flight phases except take-off.*

A1.2.1.1 For unprotected parts, the ice accretion to be considered should be determined in accordance with CS 25.1419.

A1.2.1.2 Unprotected parts consist of the unprotected aerofoil leading edges and all unprotected airframe parts on which ice may accrete. The effect of ice accretion on protuberances such as antennae or flap hinge fairings need not normally be investigated. However aeroplanes that are characterised by unusual unprotected airframe protuberances, e.g. fixed landing gear, large engine pylons, or exposed control surface horns or winglets, etc., may experience significant additional effects, which should therefore be taken into consideration.

A1.2.1.3 For holding ice, the applicant should determine the effect of a 45-minute hold in continuous maximum icing conditions. The analysis should assume that the aeroplane remains in a rectangular "race track" pattern, with all turns being made within the icing cloud. Therefore, no horizontal extent correction should be used for this analysis. For some previous aeroplane certification programs, the maximum pinnacle height was limited to 75 mm (3 inches). This method of compliance may continue to be accepted for follow-on products if service experience has been satisfactory, and the designs are similar enough to conclude that the previous experience is applicable. The applicant should substantiate the critical mean effective drop diameter, liquid water content, and temperature that result in the formation of an ice accretion that is critical to the aeroplane's performance and handling qualities. The shape and texture of the ice are important and should be agreed with the Authority.

A1.2.1.4 For protected parts, the ice protection systems are normally assumed to be operative. However, the applicant should consider the effect of ice accretion on the protected surfaces that result from:

a. The rest time of a de-icing cycle. Performance may be established on the basis of a representative intercycle ice accretion for normal operation of the de-icing system (consideration should also be given to the effects of any residual ice accretion that is not shed.) The average drag increment determined over the de-icing cycle may be used for performance calculations.

b. Runback ice which occurs on or downstream of the protected surface.

c. Ice accretion prior to normal operation of the ice protection system (see paragraph A1.2.3, below).

A1.2.2 *Take-off phase.*

A1.2.2.1 For both unprotected and protected parts, the ice accretion identified in Appendix C to CS-25 for the take-off phase may be determined by calculation, assuming that the Takeoff Maximum icing conditions defined in Appendix C exist, and:

- aerofoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off;
- the ice accretion starts at lift-off;
- the critical ratio of thrust/power-to-weight;
- failure of the critical engine occurs at V_{EF}; and
- flight crew activation of the ice protection system in accordance with an AFM procedure, except that after commencement of the take-off roll no flight crew action to activate the ice protection system should be assumed to occur until the aeroplane is 122 m (400 ft) above the take-off surface.

A1.2.2.2 The ice accretions identified in Appendix C to CS-25 for the take-off phase are:

- "Take-off ice": The most critical ice accretion between lift-off and 122 m (400 ft) above the takeoff surface, assuming accretion starts at lift-off in the icing environment.
- "Final Take-off ice": The most critical ice accretion between 122 m (400 ft) and 457 m (1500 ft) above the take-off surface, assuming accretion starts at lift-off in the icing environment.

A1.2.3 ***Ice accretion prior to normal system operation.***

A1.2.3.1 Ice protection systems are normally operated as anti-icing systems (i.e. designed to prevent ice accretion on the protected surface) or de-icing systems (i.e. designed to remove ice from the protected surface). In some cases, systems may be operated as anti-icing or de-icing systems depending on the phase of flight. Operation of ice protection systems can also include a resetting of stall warning and/or stall identification system (e.g. stick pusher) activation thresholds.

A1.2.3.2 The aeroplane Flight Manual contains the operating limitations and operating procedures established by the applicant. Since ice protection systems are normally only operated when icing conditions are encountered or when airframe ice is detected, means of flight crew determination of icing conditions and/or airframe ice should be considered in determining the ice accretion prior to normal system operation. This includes the ice accretion appropriate to the specified means of identification of icing conditions and an additional ice accretion, represented by a time in the Continuous Maximum icing conditions of Appendix C. This additional ice accretion is to account for flight crew delay in either identifying the conditions and activating the ice protection systems (see paragraphs A1.2.3.3(a), (b) and (c) below), or activating the ice protection system following indication from an ice detection system (see paragraph A1.2.3.3 (d) below). In addition the system response time should be considered. System response time is defined as the time interval between activation of the ice protection system and the performance of its intended function (e.g. for a thermal ice protection system, the time to heat the surface and remove the ice).

A1.2.3.3 An ice detection system may be installed that will provide information either to the flight crew or directly to the ice protection system regarding in-flight icing conditions or ice accretions. There are basically two classes of ice detection systems:
A. A primary ice detection system, when used in conjunction with approved AFM procedures, can be relied upon as the sole means of detecting ice accretion or icing conditions. The ice protection system may be automatically activated by the primary ice detection system, or it may be manually activated by

the flight crew following an annunciation from the primary ice detection system.
B. advisory ice detection system provides an advisory annunciation of the presence of ice accretion or icing conditions, but is not relied on as the sole, or primary, means of detection. The flight crew is responsible for monitoring the icing conditions using a primary method as directed in the AFM. The advisory ice detection system provides information to advise the cockpit crew of the presence of ice accretion or icing conditions, but it can only be used in conjunction with other primary methods to determine the need for operating the ice protection system.

A1.2.3.4 The following examples indicate the ice accretion to be considered on the unprotected and normally protected aerodynamic surfaces:

a. If activation of normal operation of any ice protection system is dependent on visual recognition of a specified ice accretion on a reference surface (e.g. ice accretion probe, wing leading edge), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the specified ice accretion and operation of the system, determined as follows:

i. the specified accretion, plus

ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

b. If activation of normal operation of any ice protection system is dependent on visual recognition of the first indication of ice accretion on a reference surface (e.g. ice accretion probe), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the ice accreted and operation of the system, determined as follows:

i. the ice accretion corresponding to first indication on the reference surface, plus

ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

c. If activation of normal operation of any ice protection system is dependent upon pilot identification of icing conditions (as defined by an appropriate static or total air temperature and visible moisture conditions), the ice accretion should not be less than that corresponding to the ice accreted during probable crew delays in recognition of icing conditions and operation of the system, determined as follows:

i. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

ii. the ice accretion during the system response time.

d. If activation of normal operation of any ice protection system is dependent on pilot action following an annunciation from a primary ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to annunciation from the ice detection system, plus that accreted due to probable flight crew delays in activating the ice protection system and operation of the system, determined as follows:

i. the ice accretion corresponding to the time between entry into the icing conditions and indication from the ice detection system, plus

ii. the ice accretion equivalent to ten seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

e. If activation of normal operation of any ice protection system is automatic following an annunciation from a primary ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to annunciation from the ice protection system and operation of the system, determined as follows:

i. the ice accretion on the protected surfaces corresponding to the time between entry into the icing conditions and activation of the system, plus

ii. the ice accretion during the system response time.

f. If the airplane is equipped with an advisory ice detection system that supplements the means of detection referenced in paragraphs (a) through (c) above, the ice accretions should continue to be determined as specified in paragraph (a), (b), or (c) above, as appropriate for the primary means of detecting icing conditions specified in the AFM procedures.

A1.3 *Ice Protection System Failure Cases.*

A1.3.1 *Unprotected parts.* The same accretion as in paragraph A1.2.1 is applicable.

A1.3.2 *Protected parts following system failure*. "Failure Ice" is defined as follows:

A1.3.2.1 In the case where the failure condition is not annunciated, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

A1.3.2.2 In the case where the failure condition is annunciated and the associated procedure does not require the aeroplane to exit icing conditions, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

A1.3.2.3 In the case where the failure condition is annunciated and the associated procedure requires the aeroplane to exit icing conditions as soon as possible, the ice accretion on normally protected parts where the ice protection has failed, should be taken as one-half of the accretion specified for unprotected parts unless another value is agreed by the Authority.

Appendix 2 - Artificial Ice Shapes

A2.1 *General.*

A2.1.1 The artificial ice shapes used for flight testing should be those which have the most adverse effects on handling characteristics. If analytical data show that other reasonably expected ice shapes could be generated which could produce higher performance decrements, then the ice shape having the most adverse effect on handling characteristics may be used for performance tests provided that any difference in performance can be conservatively taken into account.

A2.1.2 The artificial shapes should be representative of natural icing conditions in terms of location, general shape, thickness and texture. Following determination of the form and surface texture of the ice shape under paragraph A2.2, a surface roughness for the shape should be agreed with the Authority as being representative of natural ice accretion.

A2.1.3 "Sandpaper Ice" is addressed in paragraph A2.3.

A2.2 *Shape and Texture of Artificial Ice*.

A2.2.1 The shape and texture of the artificial ice should be established and substantiated by agreed methods. Common practices include:

- use of computer codes,
- flight in measured natural icing conditions,
- icing wind tunnel tests, and
- flight in a controlled simulated icing cloud (e.g. from an icing tanker).

A2.2.2 In absence of another agreed definition of texture the following may be used:

- roughness height: 3 mm
- particle density: 8 to 10/cm²

A2.3 *"Sandpaper Ice."*

A2.3.1 "Sandpaper Ice" is the most critical thin, rough layer of ice. Any representation of "Sandpaper Ice" (e.g. carborundum paper no. 40) should be agreed by the Authority.

A2.3.2 The spanwise and chordwise coverage should be consistent with the areas of ice accretion determined for the conditions of CS-25, Appendix C except that, for the zero g pushover manoeuvre of paragraph 6.9.3 of this AMC, the "Sandpaper Ice" may be restricted to the horizontal stabiliser if this can be shown to be conservative.

Appendix 3 - Design Features

A3.1 *Aeroplane Configuration and Ancestry*. An important design feature of an overall aeroplane configuration that can affect performance, controllability and manoeuvrability is its size. In addition, the safety record of the aeroplane's closely-related ancestors may be taken into consideration.

A3.1.1 *Size.* The size of an aeroplane determines the sensitivity of its flight characteristics to ice thickness and roughness. The relative effect of a given ice height (or ice roughness height) decreases as aeroplane size increases.

A3.1.2 *Ancestors.* If a closely related ancestor aeroplane was certified for flight in icing conditions, its safety record may be used to evaluate its general arrangement and systems integration.

A3.2 *Wing*. Design features of a wing that can affect performance, controllability, and manoeuvrability include aerofoil type, leading edge devices and stall protection devices.

A3.2.1 *Aerofoil.* Aerofoils with significant natural laminar flow when non-contaminated may show large changes in lift and drag with ice. Conventional aerofoils operating at high Reynolds numbers make the transition to turbulent flow near the leading edge when non-contaminated, thus reducing the adverse effects of the ice.

A3.2.2 *Leading Edge Device.* The presence of a leading edge device (such as a slat) reduces the percentage decrease in C_{LMAX} due to ice by increasing the overall level of C_L. Gapping the slat may improve the situation further. Leading edge devices can also reduce the loss in angle of attack at stall due to ice.

A3.2.3 *Stall Protection Device.* An aeroplane with an automatic slat-gapping device may generate a greater C_{LMAX} with ice than the certified C_{LMAX} with the slat sealed and a non-contaminated leading edge. This may provide effective protection against degradation in stall performance or characteristics.

A3.2.4 *Lateral Control.* The effectiveness of the lateral control system in icing conditions can be evaluated by comparison with closely related ancestor aeroplanes.

A3.3 *Empennage*. The effects of size and aerofoil type also apply to the horizontal and vertical tails. Other design features include tailplane sizing philosophy, aerofoil design, trimmable stabiliser, and control surface actuation. Since tails are usually not equipped with leading edge devices, the effects of ice on tail aerodynamics are similar to those on a wing with no leading edge devices. However, these effects usually result in changes to aeroplane handling and/or control characteristics rather than degraded performance.

A3.3.1 *Tail Sizing.* The effect on aeroplane handling characteristics depends on the tailplane design philosophy. The tailplane may be designed and sized to provide full functionality in icing conditions without ice protection, or it may be designed with a de-icing or anti-icing system.

A3.3.2 *Horizontal Stabiliser Design.* Cambered aerofoils and trimmable stabilisers may reduce the susceptibility and consequences of elevator hinge moment reversal due to ice-induced tailplane stall.

A3.3.3 *Control Surface Actuation.* Hydraulically powered irreversible elevator controls are not affected by ice-induced aerodynamic hinge moment reversal.

A3.3.4 *Control Surface Size.* For mechanical elevator controls, the size of the surface significantly affects the control force due to an ice-induced aerodynamic hinge moment reversal. Small surfaces are less susceptible to control difficulties for given hinge moment coefficients.

A3.3.5 *Vertical Stabiliser Design.* The effectiveness of the vertical stabiliser in icing conditions can be evaluated by comparison with closely-related ancestor aeroplanes.

A3.4 *Aerodynamic Balancing of Flight Control Surfaces.* The aerodynamic balance of unpowered or boosted reversible flight control surfaces is an important design feature to consider. The design should be carefully evaluated to account for the effects of ice accretion on flight control system hinge moment characteristics. Closely balanced controls may be vulnerable to overbalance in icing. The effect of ice in front of the control surface, or on the surface, may upset the balance of hinge moments leading to either increased positive force gradients or negative force gradients.

A3.4.1 This feature is particularly important with respect to lateral flight control systems when large aileron hinge moments are balanced by equally large hinge moments on the opposite aileron. Any asymmetric disturbance in flow which affects this critical balance can lead to a sudden uncommanded deflection of the control. This auto deflection, in extreme cases, may be to the control stops.

A3.5 *Ice Protection/Detection System*. The ice protection/detection system design philosophy may include design features that reduce the ice accretion on the wing and/or tailplane.

A3.5.1 *Wing Ice Protection/Detection.* An ice detection system that activates a wing de-icing system may ensure that there is no significant ice accretion on wings that are susceptible to performance losses with small amounts of ice.

A3.5.1.1 If the entire wing leading edge is not protected, the part that is protected may be selected to provide good handling characteristics at stall, with an acceptable performance degradation.

A3.5.2 *Tail Ice Protection/Detection.* An ice detection system may activate a tailplane de-icing system on aeroplanes that do not have visible cues for system operation.

A3.5.2.1 An ice protection system on the unshielded aerodynamic balances of aeroplanes with unpowered reversible controls can reduce the risk of ice-induced aerodynamic hinge moment reversal."

33. <u>Amend the designations and references in AMC 25.119(a) to AMC 25.143(g) as follows:</u>

AMC 25.119~~(a)~~
Landing Climb: All-engines-operating

In establishing the thrust specified in CS 25.119~~(a)~~, either –

a. Engine acceleration tests should be conducted using the most critical combination of the following parameters:

i. Altitude;

ii. Airspeed;

iii. Engine bleed;

iv. Engine power off-take;

likely to be encountered during an approach to a landing airfield within the altitude range for which landing certification is sought; or

b. The thrust specified in CS 25.119~~(a)~~ should be established as a function of these parameters.

AMC 25.121(b)(1)(i)
Climb: One-engine-inoperative

.....

AMC 25.125(~~a~~b)(3)
Change of Configuration

.....

AMC 25.125(~~b~~c)
Landing

.....

AMC 25.125(~~b~~c)(2)
Landing

To ensure compliance with CS 25.125(~~b~~c)(2), a series of six measured landings should be conducted on the same set of wheel brakes and tyres.

.....

AMC 25.143(~~c~~d)
Controllability and Manoeuvrability

1 The maximum forces given in the table in CS 25.143(~~c~~d) for pitch and roll control for short term application are applicable to manoeuvres in which the control force is only needed for a short period.

.....

AMC No. 1 to CS 25.143(~~f~~g)
Controllability and Manoeuvrability

.....

AMC No. 2 to CS 25.143(~~f~~g)
Controllability and Manoeuvrability

1 The objective of CS 25.143(~~f~~g) is to ensure that the limit strength of any critical component on the aeroplane would not be exceeded in manoeuvring flight.

.....

2.2 This minimum stick force applies in the en-route configuration with the aeroplane trimmed for straight flight, at all speeds above the minimum speed at which the limit strength condition can be achieved without stalling. No minimum stick force is specified for other configurations, but the requirements of CS 25.143 (~~f~~g) are applicable in these conditions.

.....

AMC 25.143(~~g~~h)
Manoeuvre Capability

1 As an alternative to a detailed quantitative demonstration and analysis of coordinated turn capabilities, the levels of manoeuvrability free of stall warning required by CS 25.143(~~g~~h) can normally be assumed where the scheduled operating speeds are not less than –

.....

34. Introduce a new AMC 25.812(b)(1) to read :

AMC 25.812(b)(1)
Emergency Lighting

Two acceptable methods of demonstrating compliance with the requirement of CS 25.812(b)(1) are as follows:

A locator sign, marking sign and bulkhead or divider sign should either:

- have red letters at least 38 mm (1.5 inches) high on an illuminated white background, and should have an area of at least 135 cm^2 (21 square inches) excluding the letters. For locator and marking signs required by CS 25.811(d)(1) and (d)(2), the lighted background - to - letter contrast should be at least 10:1. The letter height to stroke-width ratio should not be more than 7:1 nor less than 6:1 ;

or,

- be a symbolic exit sign as derived from ISO/WD 3864-3 and ISO/CD 16069 "Safety Way Guidance System" and Draft BS 5499: Part 4 "Code of Practice for Escape Route Signing".

The symbols should be white on a green background according to ISO 3864. The sign should have an area of at least 148 cm^2 (23 square inches) including white symbols. The lighted background-to-symbol contrast should be at least 1:10.

For the symbolic sign required by CS 25.811(d)(2) (See Figure 2), the height of the symbols should be at least 38mm (1.5 inches).

For the symbolic sign required by CS 25.811(d)(1) (See Figure 1) and for the symbolic sign required on each bulkhead or divider by CS 25.811(d)(3) (See Figure 3), the formula given in draft British Specification 5499 Part 4: "Code of practice for escape route signing", applies. The formula is as follows:

$$D = Z \cdot a_s$$ (where a_s and D have the same units)

D: Maximum viewing distance
Z: Distance factor
a_s: Overall height of the symbolic sign

The maximum viewing distance "D" can be calculated from the overall height of the symbolic sign (a_s) by using the appropriate distance factor Z obtained from Table 1 below.

Table 1

Mean luminance of white contrast colour candela/m^2 (ft-L)	***Distance factor Z***
≥ 10 candela/m^2 (2.91 ft-L)	150
≥ 30 candela/m^2 (8.75 ft-L)	175
≥ 80 candela/m^2 (23.35 ft-L)	200
≥ 200 candela/m^2 (53.37 ft-L)	215
≥ 500 candela/m^2 (145.9 ft-L)	230

Note 1 : *The table given for reference is deduced from Table 2 in BS 5499.*

The maximum viewing distance "D" to be considered should be the maximum distance found between two adjacent exits on one side. If the minimum overall height calculated for the symbolic sign is less than 38mm (1.5 inches), 38 mm (1.5 inches) should be taken.

Examples of acceptable designs of symbolic exit signs

CS 25.811(d)(1) (exit locator sign)	 FIGURE 1

CS 25.811(d)(2) (exit marking sign)	 FIGURE 2

CS 25.811(d)(3) (exit sign on bulkhead or divider)	 FIGURE 3

The design of symbolic exit signs should be chosen to provide a consistent set throughout the cabin.

35. Introduce a new AMC 25.812(b)(2) to read:

AMC 25.812(b)(2)
Emergency Lighting

Two acceptable methods of demonstrating compliance with the requirement of CS 25.812(b)(2) are as follows:

A Locator sign, marking sign and bulkhead or divider sign should either:

- have red letters at least 25 mm (1 inch) high on an illuminated white background at least 51 mm (2 inches) high.

<u>or,</u>

- be a symbolic exit sign as derived from ISO/WD 3864-3 and ISO/CD 16069 “Safety Way Guidance System” and Draft BS 5499: Part 4 "Code of Practice for Escape Route Signing".

The symbols should be white on a green background according to ISO 3864. The lighted background-to-symbol contrast must be at least 1:10. The height of the symbols should be at least 38 mm (1.5 inch).

36. <u>Introduce a new AMC 25.812(e)(2) to read</u> :

AMC 25.812(e)(2)
Emergency Lighting

An acceptable method of demonstrating compliance with the requirement of CS 25.812(e)(2) regarding identifiers of floor level exits is to have a symbolic sign showing a white arrow on a green background as indicated in the figure.

Note: Mixing language signs with symbolic signs is not an acceptable method of demonstrating compliance with CS 25.812(b)(1), (b)(2) and (e)(2).

<u>CS 25.812(e)</u>
(exit identifier)

37. <u>Amend existing AMC 25.963(d) by deleting the current text and replacing it by a new one to read as follows :</u>

AMC 25.963(d)
Fuel Tank Strength in Emergency Landing Conditions

~~Fuel tank installations should be such that the tanks will not be ruptured by the aeroplane sliding with its landing gear retracted, nor by a landing gear, nor an engine mounting tearing away.~~
~~Fuel tanks inboard of the landing gear or inboard of or adjacent to the most outboard engine, should have the strength to withstand fuel inertia loads appropriate to the accelerations specified in CS~~

~~25.561(b)(3) considering the maximum likely volume of fuel in the tank(s). For the purposes of this substantiation it will not be necessary to consider a fuel volume beyond 85% of the maximum permissible volume in each tank. For calculation of inertia pressures a typical density of the appropriate fuel may be used.~~

1. PURPOSE. This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the strength of fuel tanks in emergency landing conditions.

2. RELATED CERTIFICATION SPECIFICATIONS.

CS 25.561 “Emergency Landing Conditions – General”,
CS 25.721 “Landing Gear – General”
CS 25.994 “Fuel System Components”
CS 25J994 “Fuel System Components”

3. BACKGROUND. For many years the JAA/EASA has required fuel tanks within the fuselage contour to be designed to withstand the inertial load factors prescribed for the emergency landing conditions as specified in JAR/CS 25.561. These load factors have been developed through many years of experience and are generally considered conservative design criteria applicable to objects of mass that could injure occupants if they came loose in a minor crash landing.

a. A minor crash landing is a complex dynamic condition with combined loading. However, in order to have simple and conservative design criteria, the emergency landing forces were established as conservative static ultimate load factors acting in each direction independently.

b. Recognising that the emergency landing load factors were applicable to objects of mass that could cause injury to occupants and that the rupture of fuel tanks in the fuselage could also be a serious hazard to the occupants, § 4b.420 of the Civil Air Regulations (CAR) part 4b (the predecessor of FAR 25) extended the emergency landing load conditions to fuel tanks that are located within the fuselage contour. Even though the emergency landing load factors were originally intended for solid items of mass, they were applied to the liquid fuel mass in order to develop hydrostatic pressure loads on the fuel tank structure. The application of the inertia forces as a static load criterion (using the full static head pressure) has been considered a conservative criterion for the typical fuel tank configuration within the fuselage contour. This conservatism has been warranted considering the hazard associated with fuel spillage.

c. CS 25.963 has required that fuel tanks, both in and near the fuselage, resist rupture under survivable crash conditions. The advisory material previously associated with CS 25.963 specifies design requirements for all fuel tanks that, if ruptured, could release fuel in or near the fuselage or near the engines in quantities sufficient to start a serious fire.

d. In complying with this CS requirement for wing tanks, several different techniques have been used by manufacturers to develop the fuel tank pressure loads due to the emergency landing inertia forces. The real emergency landing is actually a dynamic transient condition during which the fuel must flow in a very short period of time to re-establish a new level surface normal to the inertial force. For many tanks such as large swept wing tanks, the effect is that the actual pressure forces are likely to be much less than that which would be calculated from a static pressure based on a steady state condition using the full geometric pressure head. Because the use of the full pressure head results in unrealistically high pressures and creates a severe design penalty for wing tanks in swept wings, some manufacturers have used the local streamwise head rather than the full head. Other manufacturers have used the full pressure head but with less than a full tank of fuel. These methods of deriving the pressures for wing tanks have been accepted as producing design pressures for wing tanks that would more closely represent actual emergency landing conditions. The service record has shown no deficiency in strength for wing fuel tanks designed using these methods.

e. FAR 25 did not contain a requirement to apply fuel inertia pressure requirements to fuel tanks outside the fuselage contour, however, the FAA (like the JAA) has published Special Conditions to accomplish this for fuel tanks located in the tail surfaces. The need for Special Conditions was justified by the fact that these tanks are located in a rearward position from which fuel spillage could directly affect a large portion of the fuselage, possibly on both sides at the same time.

4. GENERAL. CS 25.963(d) requires that fuel tanks must be designed, located, and installed so that no fuel is released in quantities sufficient to start a serious fire in otherwise survivable emergency landing conditions. The prescribed set of design conditions to be considered is as follows:

a. Fuel tank pressure loads. CS 25.963(d)(1) provides a conservative method for establishing the fuel tank ultimate emergency landing pressures. The phrase “fuel tanks outside the fuselage contour” is intended to include all fuel tanks where fuel spillage through any tank boundary would remain physically and environmentally isolated from occupied compartments by a barrier that is at least fire resistant as defined in CS-Definitions. In this regard, cargo compartments that share the same environment with occupied compartments would be treated the same as if they were occupied. The ultimate pressure criteria are different depending on whether the fuel tank under consideration is inside, or outside the fuselage contour. For the purposes of this paragraph a fuel tank should be considered inside the fuselage contour if it is inside the fuselage pressure shell. If part of the fuel tank pressure boundary also forms part of the fuselage pressure boundary then that part of the boundary should be considered as being within the fuselage contour. Figures 1 and 2 show examples of an underslung wing fuel tank and a fuel tank within a moveable tailplane, respectively, both of which would be considered as being entirely outside of the fuselage contour.

The equation for fuel tank pressure uses a factor L, based upon fuel tank geometry. Figure 3 shows examples of the way L is calculated for fuel pressures arising in the forward loading condition, while Figure 4 shows examples for fuel pressures arising in the outboard loading condition.
For Jet A(-1) fuel, a typical density of 785.0 kg/m^3 (6.55 lb/US gallon) may be assumed.

Any internal barriers to free flow of fuel may be considered as a solid pressure barrier provided:

(1) It can withstand the loads due to the expected fuel pressures arising in the conditions under consideration; and
(2) The time “T” for fuel to flow from the upstream side of the barrier to fill the cell downstream of the barrier is greater than 0.5 second. “T” may be conservatively estimated as:

$$T = \frac{V}{\sum_{i=1}^{j} C_{di}\, a_i \sqrt{2 g\, h_i\, K}}$$

where:

V= the volume of air in the fuel cell downstream of the barrier assuming a full tank at 1g flight conditions. For this purpose a fuel cell should be considered as the volume enclosed by solid barriers. In lieu of a more rational analysis, 2% of the downstream fuel volume should be assumed to be trapped air;

j = the total number of orifices in baffle rib;

Cd_i = the discharge coefficient for orifice i. The discharge coefficient may be conservatively assumed to be equal to 1.0 or it may be rationally based upon the orifice size and shape;

a_i = the area for orifice i;

g = the acceleration due to gravity;

h_i = the hydrostatic head of fuel upstream of orifice i, including all fuel volume enclosed by solid barriers;

K = the pressure design factor for the condition under consideration.

b. Near the fuselage/near the engines (Compliance with CS 25.963(d)(2).)

(1) For aircraft with wing mounted engines:

(i) The phrase "near the fuselage" is addressing those (parts of) wing fuel tanks located between the fuselage and the most inboard engine;

(ii) The phrase "near the engine" is addressing those (parts of) wing fuel tanks as defined in AMC 20-128A, figure 2, minimum distance of 10 inches (254 mm) laterally from potential ignition sources of the engine nacelle.

(2) For aircraft with fuselage mounted engines, the phrase "near the fuselage" is addressing those (parts of) wing fuel tanks located within one maximum fuselage width outside the fuselage boundaries.

c. Protection against crushing and scraping action (Compliance with CS 25.963(d)(4) and CS 25.721(b) and (c).).

Each fuel tank should be protected against the effects of crushing and scraping action (including thermal effects) of the fuel tank and surrounding airframe structure with the ground under the following minor crash landing conditions:

(i) An impact at 1.52 m/s (5 fps) vertical velocity on a paved runway at maximum landing weight, with all landing gears retracted and in any other possible combination of gear legs not extended. The unbalanced pitching and rolling moments due to the ground reactions are assumed to be reacted by inertia and by immediate pilot control action consistent with the aircraft under control until other structure strikes the ground. It should be shown that the loads generated by the primary and subsequent impacts are not of a sufficient level to rupture the tank. A reasonable attitude should be selected within the speed range from V_{L1} to 1.25 V_{L2} based upon the fuel tank arrangement.
V_{L1} equals to V_{S0} (TAS) at the appropriate landing weight and in standard sea-level conditions, and V_{L2} equals to V_{S0} (TAS) at the appropriate landing weight and altitudes in a hot day temperature of 22.8 degrees C (41 degrees F) above standard.

(ii) Sliding on the ground starting from a speed equal to V_{L1} up to complete stoppage, all gears retracted and with up to a 20° yaw angle and as a separate condition, sliding with any other possible combination of gear legs not extended and with a 0° yaw angle. The effects of runway profile need not be considered.

(iii) The impact and subsequent sliding phases may be treated as separate analyses or as one continuous analysis. Rational analyses that take into account the pitch response of the aircraft may be utilised, however care must be taken to assure that abrasion and heat transfer effects are not inappropriately reduced at critical ground contact locations.

(iv) For aircraft with wing mounted engines, if failure of engine mounts, or failure of the pylon or its attachments to the wing occurs during the impact or sliding phase, the subsequent effect on the integrity of the fuel tanks should be assessed. Trajectory analysis of the engine/pylon subsequent to the separation is not required.

(v) The above emergency landing conditions are specified at maximum landing weight, where the amount of fuel contained within the tanks may be sufficient to absorb the frictional energy (when the aircraft is sliding on the ground)without causing fuel ignition. When lower fuel states exist in the affected fuel tanks these conditions should also be considered in order to prevent fuel-vapour ignition.

d. Engine / Pylon separation. (Compliance with CS 25.721(c) and CS 25.963(d)(5).)
For configurations where the nacelle is likely to come into contact with the ground, failure under overload should be considered. Consideration should be given to the separation of an engine nacelle (or nacelle + pylon) under predominantly upward loads and under predominantly aft loads. The predominantly upward load and the predominantly aft load conditions should be analysed separately. It should be shown that at engine/pylon failure the fuel tank itself is not ruptured at or near the engine/pylon attachments.

e. Landing gear separation. (Compliance with CS 25.721(a) and CS 25.963(d)(5).) Failure of the landing gear under overload should be considered, assuming the overloads to act in any reasonable combination of vertical and drag loads, in combination with side loads acting both inboard and outboard. In the absence of a more rational analysis, the side loads must be assumed to be up to 20% of the vertical load or 20% of the drag load, whichever is greater. It should be shown that at the time of separation the fuel tank itself is not ruptured at or near the landing gear attachments. The assessment of secondary impacts of the airframe with the ground following landing gear separation is not required. If the subsequent trajectory of a separated landing gear would likely puncture an adjacent fuel tank, design precautions should be taken to minimise the risk of fuel leakage.

f. Compliance with the provisions of this paragraph may be shown by analysis or tests, or both.

5. OTHER CONSIDERATIONS

a. Supporting structure. In accordance with CS 25.561(c) all large mass items that could break loose and cause direct injury to occupants must be restrained under all loads specified in CS 25.561(b). To meet this requirement, the supporting structure for fuel tanks, should be able to withstand each of the emergency landing load conditions, as far as they act in the 'cabin occupant sensitive directions', acting statically and independently at the tank centre of gravity as if it were a rigid body. Where an empennage includes a fuel tank, the empennage structure supporting the fuel tank should meet the restraint conditions applicable to large mass items in the forward direction.

Figure 1: Diagram of Fuel Tank in Underslung Wing that is Outside of the Fire Resistant Boundary

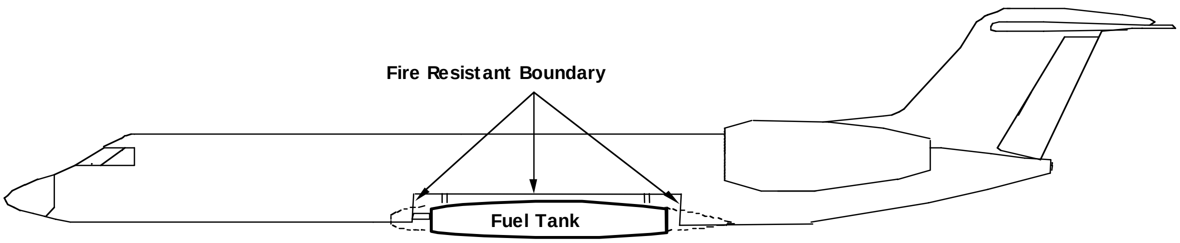


Figure 2: Diagram of Fuel Tank Within a Movable Tailplane

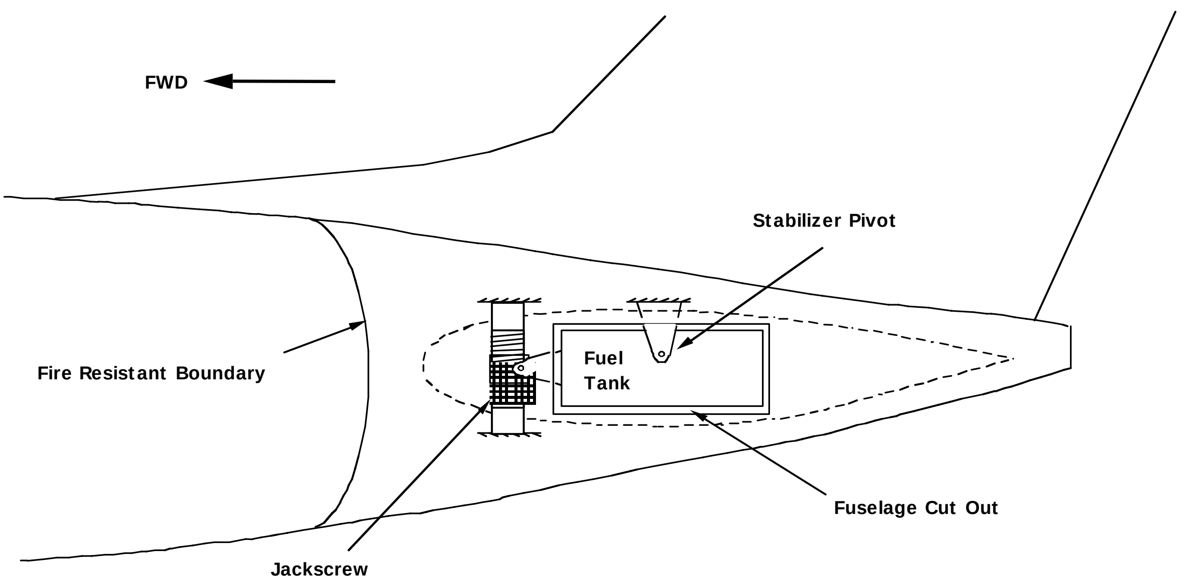


Figure 3- Example of Distances For Fuel Forward Acting Design Pressure Calculations

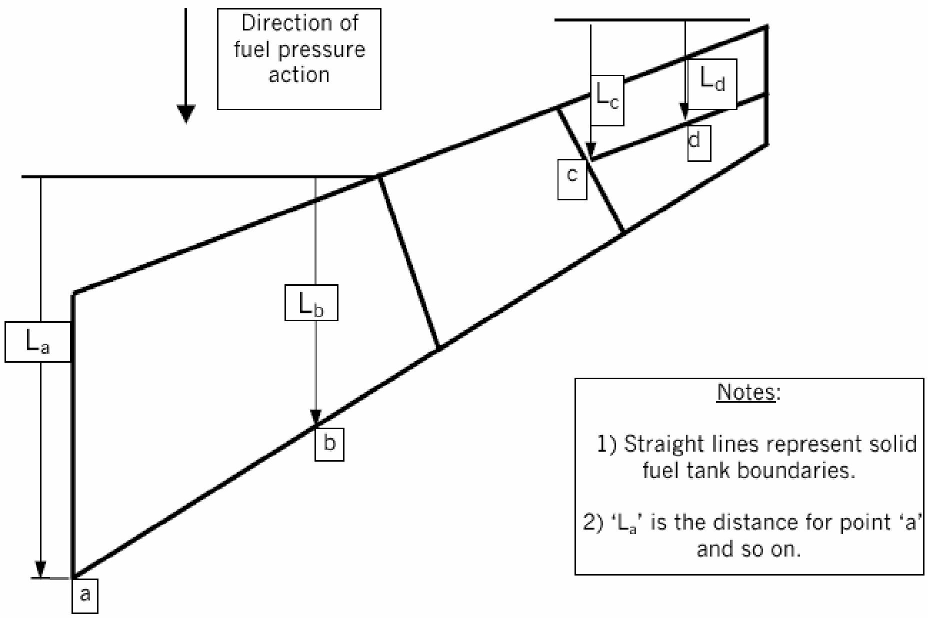
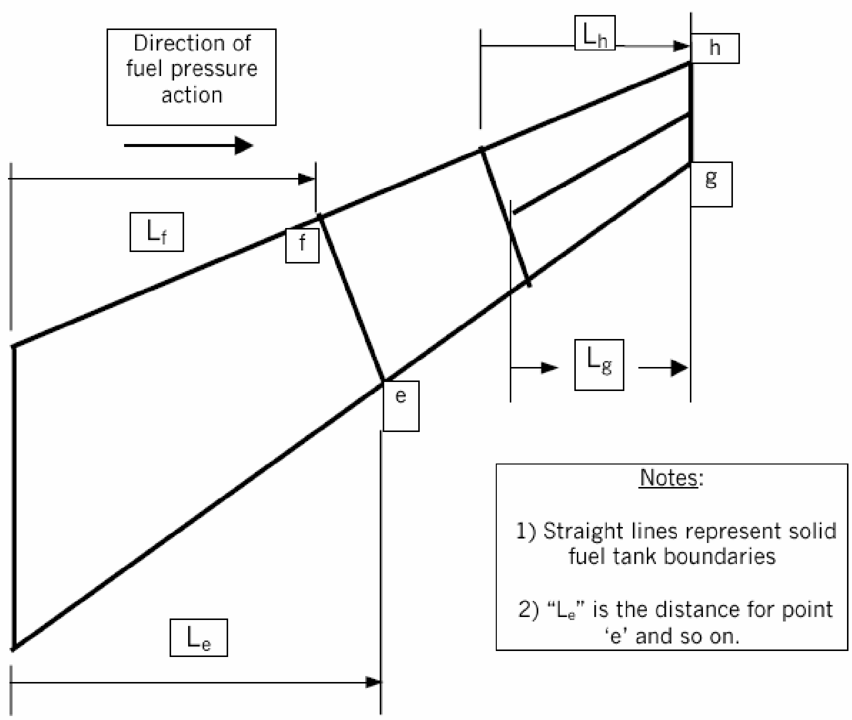


Figure 4 - Example of Distances For Fuel Outboard Acting Design Pressure Calculations



38. Add a new AMC 25.963(e) to read:

AMC 25.963(e)
Fuel Tank Access Covers

1. PURPOSE. This AMC sets forth a means of compliance with the provisions of CS-25 dealing with the certification requirements for fuel tank access covers on large aeroplanes. Guidance information is provided for showing compliance with the impact and fire resistance requirements of CS 25.963(e).

2. BACKGROUND. Fuel tank access covers have failed in service due to impact with high speed objects such as failed tyre tread material and engine debris following engine failures. Failure of an access cover on a fuel tank may result in loss of hazardous quantities of fuel which could subsequently ignite.

3. IMPACT RESISTANCE.

a. All fuel tanks access covers must be designed to minimise penetration and deformation by tyre fragments, low energy engine debris, or other likely debris, unless the covers are located in an area where service experience or analysis indicates a strike is not likely. The rule does not specify rigid standards for impact resistance because of the wide range of likely debris which could impact the covers. The applicant should, however, choose to minimise penetration and deformation by analysis or test of covers using debris of a type, size, trajectory and velocity that represents conditions anticipated in actual service for the aeroplane model involved. There should be no hazardous quantity of fuel leakage after impact. It may not be practical or even necessary to provide access covers with properties which are identical to those of the adjacent skin panels since the panels usually vary in thickness from station to station and may, at certain stations, have impact resistance in excess of that needed for any likely impact. The access covers, however, need not be more impact resistant than the average thickness of the adjacent tank structure at the same location, had it been designed without access covers. In the case of resistance to tyre debris, this comparison should be shown by tests or analysis supported by test.

b. In the absence of a more rational method, the following may be used for evaluating access covers for impact resistance to tyre and engine debris.

(i) Tyre Debris - Covers located within 30 degrees inboard and outboard of the tyre plane of rotation, measured from centre of tyre rotation with the gear in the down and locked position and the oleo strut in the nominal position, should be evaluated. The evaluation should be based on the results of impact tests using tyre tread segments equal to 1 percent of the tyre mass distributed over an impact area equal to 1.5 percent of the total tread area. The velocities used in the assessment should be based on the highest speed that the aircraft is likely to use on the ground under normal operation.

(ii) Engine Debris - Covers located within 15 degrees forward of the front engine compressor or fan plane measured from the centre of rotation to 15 degrees aft of the rearmost engine turbine plane measured from the centre of rotation, should be evaluated for impact from small fragments. The evaluation should be made with energies referred to in AMC 20-128A “Design Considerations for Minimising Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure”. The covers need not be designed to withstand impact from high energy engine fragments such as engine rotor segments or propeller fragments. In the absence of relevant data, an energy level corresponding to the impact of a 9·5 mm (3/8 inch) cube steel debris at 213·4 m/s (700 fps), 90 degrees to the impacted surface or area should be used.

For clarification, engines as used in this advisory material is intended to include engines used for thrust and engines used for auxiliary power (APU's).

4. RESISTANCE TO FIRE.

Fuel tank access covers meet the requirements of CS 25.963(e)(2) if they are fabricated from solid aluminium or titanium alloys, or steel. They also meet the above requirement if one of the following criteria is met.

a. The covers can withstand the test of AC 20-135, "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria", issued 2/9/90, or ISO 2685-1992(E), "Aircraft Environment conditions and test procedures for airborne equipment - Resistance to fire in designated fire zones", for a period of time at least as great as an equivalent aluminium alloy in dimensions appropriate for the purpose for which they are used.

b. The covers can withstand the test of AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria, issued 2/9/90, or ISO 2685-1992(E), Aircraft - Environment conditions and test procedures for airborne equipment - Resistance to fire in designated fire zones, for a period of time at least as great as the minimum thickness of the surrounding wing structure.

c. The covers can withstand the test of AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria, issued 2/9/90, or ISO 2685-1992(E), Aircraft - Environment conditions and test procedures for airborne equipment - Resistance to fire in designated fire zones, for a period of 5 minutes. The test cover should be installed in a test fixture representative of actual installation in the aeroplane. Credit may be allowed for fuel as a heat sink if covers will be protected by fuel during all likely conditions. The maximum amount of fuel that should be allowed during this test is the amount associated with reserve fuel. Also, the static fuel pressure head should be accounted for during the burn test. There should be no burn-through or distortion that would lead to fuel leakage at the end of the tests; although damage to the cover and seal is permissible.

39. Delete the text of existing AMC 25.963(g) and mark it as "(Revoked)"as follows:

AMC 25.963(g)
Fuel Tanks: General

~~1 *Purpose*. This AMC sets forth an acceptable means of showing compliance with the provisions of CS–25 dealing with the certification requirements for fuel tank access covers. Guidance information is provided for showing compliance with the impact resistance requirements of 25.963(g).~~

~~2 *Background*. Fuel tank access covers have failed in service due to impact with high speed objects such as failed tyre tread material and engine debris following engine failures. Failure of an access cover on a wing fuel tank may result in the loss of hazardous quantities of fuel which could subsequently ignite.~~

~~3 *Impact Resistance*~~

~~a. All fuel tank access covers must be designed to minimise penetration and deformation by tyre fragments, low energy engine debris, or other likely debris, unless the covers are located in an area where service experience or analysis indicates a strike is not likely. The rule does not specify rigid standards for impact resistance because of the wide range of likely debris which could impact the covers. However, 'minimise penetration and deformation' should be achieved by testing covers using debris of a type, size, trajectory, and velocity that represents conditions anticipated in actual service for the aeroplane model involved. There should be no hazardous~~

~~quantity of fuel leakage after impact. The access covers, however, need not be more impact resistant than the contiguous tank structure.~~

~~b. In the absence of a more rational method, the following criteria should be used for evaluating access covers for impact resistance.~~

~~i. Covers located within 15° inboard and outboard of the tyre plane of rotation, measured from the centre plane of tyre rotation with olco strut in the nominal position, should be evaluated. The evaluation should be based on the results of impact tests using tyre tread segments having width and length equal to the full width of the tread, with thickness of the full tread plus casing. The velocities used in the assessment should be based on the highest speed that the aircraft is likely to use on the ground. Generally, this will be the higher of the aircraft rotation speed (V_R) and the flapless landing speed.~~
~~ii. Covers located within 15° forward of the front compressor or fan plane measured from the centre of rotation to 15° aft of the rearmost turbine plane measured from the centre of rotation, should be evaluated for impact from small fragments (shrapnel). The covers need not be designed to withstand impact from high energy engine fragments such as rotor segments.~~
(Revoked)

40. Add a new AMC 25.1302 to read:

AMC 25.1302
Installed Systems and Equipment for Use by the Flight Crew

Table of content

1. PURPOSE

This Acceptable Means of Compliance (AMC) provides guidance material for demonstrating compliance with the requirements of CS 25.1302 and several other paragraphs in CS-25 that relate to the installed equipment used by the flight crew in the operation of an aeroplane. In particular, this AMC addresses the design and approval of installed equipment intended for the use of flight-crew members from their normally seated positions on the flight deck. This AMC also provides recommendations for the design and evaluation of controls, displays, system behaviour, and system integration, as well as design guidance for error management.

Applicants should use Paragraphs 4, 5 and 6 of this AMC together to constitute an acceptable means of compliance. Paragraph 4 “Certification Planning”, describes the activities and communication between the applicant and the Agency for certification planning. Paragraph 5 “Design Considerations and Guidance”, is organised in accordance with the sub-paragraphs of CS 25.1302 and identifies HF related design issues that should be addressed to show compliance with CS 25.1302 and other relevant rules. Paragraph 6 “Means of Compliance” describes general means of compliance and how they may be used.

2. BACKGROUND

Flight crews make a positive contribution to the safety of the air transportation system because of their ability to assess continuously changing conditions and situations, analyse potential actions, and make reasoned decisions. However, even well trained, qualified, healthy, alert flight-crew members make errors. Some of these errors may be influenced by the design of the systems and their flight crew interfaces, even with those that are carefully designed. Most of these errors have no significant safety effects, or are detected and/or mitigated in the normal course of events,. Still, accident analyses have identified flight crew performance and error as significant factors in a majority of accidents involving transport category aeroplanes.

Accidents most often result from a sequence or combination of errors and safety related events (e.g., equipment failure and weather conditions). Analyses show that the design of the flight deck and other systems can influence flight crew task performance and the occurrence and effects of some flight crew errors.

Some current regulatory requirements mean to improve aviation safety by requiring that the flight deck and its equipment be designed with certain capabilities and characteristics. Approval of flight deck systems with respect to design-related flight crew error has typically been addressed by referring to system specific or general applicability requirements, such as CS 25.1301(a), CS 25.771(a), and CS 25.1523. However, little or no guidance exists to show how the applicant may address potential crew limitations and errors. That is why CS 25.1302 and this guidance material have been developed.

Often, showing compliance with design requirements that relate to human abilities and limitations is subject to a great deal of interpretation. Findings may vary depending on the novelty, complexity, or degree of integration related to system design. The EASA considers that guidance describing a structured approach to selecting and developing acceptable means of compliance is useful in aiding standardised certification practices.

3. SCOPE AND ASSUMPTIONS

This AMC provides guidance for showing compliance with CS 25.1302 and guidance related to several other requirements associated with installed equipment the flight crew uses in operating the aeroplane. Table 1 below contains a list of requirements related to flight deck design and flight crew interfaces for which this AMC provides guidance. Note that this AMC does not provide a comprehensive means of compliance for any of the requirements beyond CS 25.1302.

This material applies to flight crew interfaces and system behaviour for installed systems and equipment used by the flight crew on the flight deck while operating the aeroplane in normal and non-normal conditions. It applies to those aeroplane and equipment design considerations within the scope of CS-25 for type certificate and supplemental type certificate (STC) projects. It does not apply to flight crew training, qualification, or licensing requirements. Similarly, it does not apply to flight crew procedures, except as required within CS-25.

In showing compliance to the requirements referenced by this AMC, the applicant may assume a qualified flight crew trained in the use of the installed equipment. This means a flight crew that is allowed to fly the aeroplane by meeting the requirements in the operating rules for the relevant Authority.

Paragraph 3 - Table 1: Requirements relevant to this AMC.

CS-25 BOOK 1 Requirements	***General topic***	***Referenced material in this AMC***
CS 25.771(a)	Unreasonable concentration or fatigue	Error, 5.6. Integration, 5.7. Controls, 5.3 System Behaviour, 5.5.
CS 25.771(c)	Controllable from either pilot seat	Controls, 5.3 Integration, 5.7.
CS 25.773	Pilot compartment view	Integration, 5.7.

CS-25 BOOK 1 Requirements	***General topic***	***Referenced material in this AMC***
CS 25.777(a)	Location of cockpit controls.	Controls, 5.3. Integration, 5.7.
CS 25.777(b)	Direction of movement of cockpit controls	Controls, 5.3. Integration, 5.7.
CS 25.777(c)	Full and unrestricted movement of controls	Controls, 5.3. Integration, 5.7.
CS 25.1301(a)	Intended function of installed systems	Error, 5.6. Integration, 5.7. Controls, 5.3. Presentation of Information, 5.4, System Behaviour, 5.5.
CS 25.1302	Flight crew error	Error, 5.6. Integration, 5.7. Controls, 5.3. Presentation of Information, 5.4. System Behaviour, 5.5.
CS 25.1303	Flight and navigation instruments	Integration, 5.7.
CS 25.1309(a)	Intended function of required equipment under all operating conditions	Controls, 5.3. Integration, 5.7.
CS 25.1309(c)	Unsafe system operating conditions and minimising crew errors which could create additional hazards	Presentation of information, 5.4. Errors, 5.6.
CS 25.1321	Visibility of instruments	Integration, 5.7.
CS 25.1322	Warning caution and advisory lights	Integration, 5.7.
CS 25.1329	Autopilot, flight director and autothrust	System Behaviour, 5.5.
CS 25.1523	Minimum flight crew	Controls, 5.3. Integration, 5.7.
CS 25.1543(b)	Visibility of instrument markings	Presentation of Information, 5.4.
CS 25.1555 (a)	Control markings	Controls, 5.3.
CS 25 Appendix D	Criteria for determining minimum flight crew	Integration, 5.7.

CS 25.1302 is a general applicability requirement. Other CS-25 requirements exist for specific equipment and systems. Where guidance in other AMCs is provided for specific equipment and systems, that guidance is assumed to have precedence if a conflict exists with guidance provided here. Appendix 1 of this AMC lists references to other related regulatory material and documents.

4. CERTIFICATION PLANNING

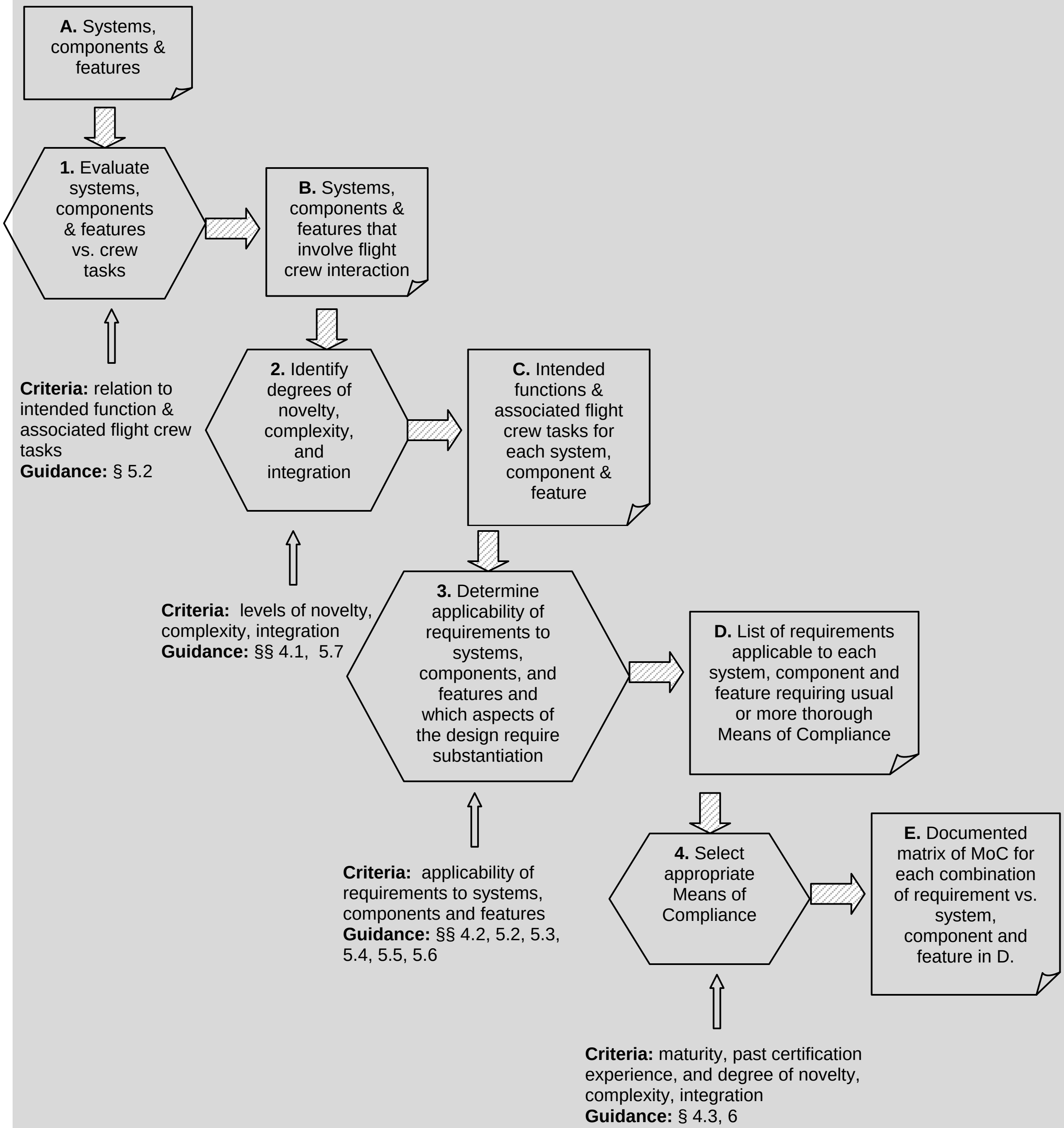
This paragraph describes applicant activities, communication between the applicant and the Agency, and the documentation necessary for finding compliance in accordance with this AMC. Requirements for type certification related to complying with CS-25 may be found in Part 21.

Applicants can gain significant advantages by involving the Agency in the earliest possible phases of application and design. This will enable timely agreements on potential design related human factors issues to be reached and thereby reduce the applicant's risk of investing in design features that may not be acceptable to the Agency.

Certain activities that typically take place during development of a new product or a new flight deck system or function, occur before official certification data is submitted to demonstrate compliance with the requirements. The applicant may choose to discuss or share these activities with the Agency on an information-only basis. Where appropriate, the Agency may wish to participate in assessments the applicant is performing with mock-ups, prototypes, and simulators.

When the Agency agrees, as part of the certification planning process, that a specific evaluation, analysis, or assessment of a human factors issue will become part of the demonstration that the design is in compliance with requirements, that evaluation, analysis, or assessment is given “certification credit”.

Figure 1 illustrates the interaction between paragraph 4, 5 and 6 of this AMC. These paragraphs are used simultaneously during the certification process. Paragraph 4 details applicant activities and communication between the applicant and the Agency. Paragraph 5 provides means of compliance on specific topics. Paragraphs 5.2, 5.6 and 5.7 assist the applicant in determining inputs required for the scoping discussions outlined in paragraph 4.1. Paragraphs 5.3 through 5.5 provide guidance in determining the list of applicable requirements for discussion, outlined in paragraph 4.2. Paragraph 6 provides a list of acceptable general means of compliance used to guide the discussions for paragraph 4.3. Paragraph 4.4 lists items that may be documented as a result of the above discussions.



Paragraph 4 - Fig. 1: Methodical approach to planning certification for design related Human performance issues

4.1 Scope of the flight deck certification programme

This paragraph provides means of establishing the scope of the certification programme.

In a process internal to the applicant, the applicant should consider the flight deck controls, information and system behaviour that involve flight crew interaction. The applicant should relate the intended functions of the system(s), components and features to the flight crew tasks. The objective is to improve understanding about how flight crew tasks might be changed or modified as a result of introducing the proposed system(s), components and features. Paragraph 5.2, Intended Function and Associated Flight Crew Tasks, provides guidance.

The certification programme may be impacted by the level of integration, complexity and novelty of the design features, each of which is described in the sub-paragraphs that follow. Taking these features into account, the applicant should reach an agreement with the Agency on the scope of flight deck controls, information and system behaviour that will require extra scrutiny during the certification process. Applicants should be aware that the impact of a novel feature might also be affected by its complexity and the extent of its integration with other elements of the flight deck. A novel but simple feature will likely require less rigorous scrutiny than one that is both novel and complex.

a) Integration

In this document, the term “level of systems integration”, refers to the extent to which there are interactions or dependencies between systems affecting the flight crew’s operation of the aeroplane. The applicant should describe such integration among systems, because it may affect means of compliance. Paragraph 5.7 also refers to integration. In the context of that paragraph, integration defines how specific systems are integrated into the flight deck and how the level of integration may affect the means of compliance.

b) Complexity

Complexity of the system design from the flight crew’s perspective is an important factor that may also affect means of compliance in this process. Complexity has multiple dimensions. The number of information elements the flight crew has to use (the number of pieces of information on a display, for instance) may be an indication of complexity. The level of system integration may be a measure of complexity of the system from the flight crew’s perspective. Design of controls can also be complex. An example would be a knob with multiple control modes. Paragraph 5 addresses several aspects of complexity.

c) Novelty

The applicant should identify the degree of design novelty based on the following factors:

- Are new technologies introduced that operate in new ways for either established or new flight deck designs?
- Are unusual or additional operational procedures needed as a result of the introduction of new technologies?
- Does the design introduce a new way for the flight crew to interact with systems using either conventional or innovative technology?
- Does the design introduce new uses for existing systems that change the flight crew’s tasks or responsibilities?

Based on the above criteria, the applicant should characterise features by their novelty. More novel features may require extra scrutiny during certification. Less novel features must still be shown to be compliant with requirements, but will usually follow a typical certification process that may be less rigorous than the process described below.

4.2 Applicable Requirements

The applicant should identify design requirements applicable to each of the systems, components, and features for which means of demonstrating compliance must be selected. This can be accomplished in part by identifying design characteristics that can adversely affect flight crew performance, or that pertain to avoidance and management of flight crew errors.

Specific design considerations for requirements involving human performance are discussed in Paragraph 5. The applicability of each design consideration in Paragraph 5 will depend on the design characteristics identified in paragraph 4.1.

The expected output of the analysis is a list of requirements that will be complied with and for which design considerations will be scrutinised. This list of requirements will be the basis for a compliance matrix identifying the means of compliance proposed for each requirement.

4.3 Select appropriate means of compliance

After identifying what should be shown in order to demonstrate compliance, the applicant should review paragraph 6.1 for guidance on selecting the means, or multiple means of compliance, appropriate to the design. In general, it is expected that the level of scrutiny or rigour represented by the means of compliance should increase with higher levels of novelty, complexity and integration of the design.

Paragraph 6 identifies general means of compliance that have been used on many certification programmes and discusses their selection, appropriate uses, and limitations. The applicant may propose other general means of compliance, subject to approval by the Agency.

Once the human performance issues have been identified and means of compliance have been selected and proposed to the Agency, the Agency may agree, as part of the certification planning process, that a specific evaluation, analysis or assessment of a human factors issue will become part of the demonstration that the design is in compliance with requirements. Certification credit can be granted when data is transmitted to and accepted by the Agency using standard certification procedures. This data will be a part of the final record of how the applicant has complied with the requirements.

The output of this step will consist of the means that will be used to show compliance to the requirements.

4.4 Certification plan

The applicant should document the certification process, outputs and agreements described in the previous paragraphs. This may be done in a separate plan or incorporated into a higher level certification plan. The following is a summary of what may be contained in the document:

- The new aeroplane, system, control, information or feature(s)
- The design feature(s) being evaluated and whether or not the feature(s) is(are) new or novel
- The integration or complexity of the new feature(s)
- Flight crew tasks that are affected or any new tasks that are introduced
- Any new flight crew procedures
- Specific requirements that must be complied with
- The means (one or several) that will be used to show compliance
- The method for transferring data to the Agency

5. DESIGN CONSIDERATIONS AND GUIDANCE

This paragraph contains a discussion of CS 25.1302 and guidance on complying with it and other requirements.

The applicant should first complete the following steps.

- Identify systems, components, and features of a new design that are potentially affected by the requirements.
- Assess degrees of novelty, complexity, and level of integration using the initial process steps in paragraph 4.

Once these steps have been completed, use the contents of this paragraph to identify what should be shown to demonstrate compliance.

To comply with the requirements of CS-25, the design of flight deck systems should appropriately address foreseeable capabilities and limitations of the flight crew. To aid the applicant in complying with this overall objective, this paragraph has been divided into sub-paragraphs. They provide guidance on the following topics:

- Applicability and Explanatory material to CS 25.1302 (See paragraph 5.1),

- Intended function and associated flight crew tasks(See paragraph 5.2),
- Controls (See paragraph 5.3),
- Presentation of information(See paragraph 5.4),
- System behaviour (See paragraph 5.5),
- Flight crew error management(See paragraph 5.6),
- Integration (See paragraph 5.7),

Each sub-paragraph discusses what the applicant should show to establish compliance with applicable requirements. We are not describing here what might otherwise be referred to as industry “best practices.” The guidance presented here is the airworthiness standard for use in compliance. Obviously, not all criteria can or should be met by all systems. Because the nature of the guidance in this AMC is broad and general, some of it will conflict in certain instances. The applicant and the Agency must apply some judgment and experience in determining which guidance applies to what parts of the design and in what situations. Headings indicate the regulations to which the guidance applies. First, however, we provide a more detailed discussion of CS 25.1302.

As described in the Background and Scope paragraphs of this document, flight crew error is a contributing factor in accidents. CS 25.1302 was developed to provide a regulatory basis for, and this AMC provides guidance to address design-related aspects of avoidance and management of flight crew error by taking the following approach:

First, by providing guidance about design characteristics that are known to reduce or avoid flight crew error and that address flight crew capabilities and limitations. Requirements in sub-paragraphs (a) through (c) of CS 25.1302 are intended to reduce the design contribution to such errors by ensuring information and controls needed by the flight crew to perform tasks associated with the intended function of installed equipment are provided, and that they are provided in a usable form. In addition, operationally relevant system behaviour must be understandable, predictable, and supportive of flight crew tasks. Guidance is provided in this paragraph on the avoidance of design-induced flight crew error.

Second, CS 25.1302(d) addresses the fact that since flight crew errors will occur, even with a well-trained and proficient flight crew operating well-designed systems, the design must support management of those errors to avoid safety consequences. Paragraph 5.6 below on flight crew error management provides relevant guidance.

5.1 Applicability and Explanatory Material to CS 25.1302

CS-25 contains requirements for the design of flight deck equipment that are system-specific (e.g., CS 25.777, CS 25.1321, CS 25.1329, CS 25.1543 etc.), generally applicable (e.g., CS 25.1301(a), CS 25.1309(c), CS 25.771(a)), and that establish minimum flight crew requirements (e.g. CS 25.1523 and CS-25 Appendix D). CS 25.1302 augments previously existing generally applicable requirements by adding more explicit requirements for design attributes related to avoidance and management of flight crew error. Other ways to avoid and manage flight crew error are regulated through requirements governing licensing and qualification of flight-crew members and aircraft operations. Taken together, these complementary approaches provide a high degree of safety.

The complementary approach is important. It is based upon recognition that equipment design, training/licensing/ qualification, and operations/procedures each provide safety contributions to risk mitigation. An appropriate balance is needed among them. There have been cases in the past where design characteristics known to contribute to flight crew error were accepted based upon the rationale that training or procedures would mitigate that risk. We now know that this can often be an inappropriate approach. Similarly, due to unintended consequences, it would not be appropriate to require equipment design to provide total risk mitigation. If a flight-crew member misunderstands a controller's clearance, it does not follow that the Agency should mandate datalink or some other design solution as Certification Specifications. Operating rules currently require equipment to provide some error mitigations (e.g., Terrain Awareness and Warning Systems), but not as part of the airworthiness requirements.

As stated, a proper balance is needed among design approval requirements in the minimum airworthiness standards of CS-25 and requirements for training/ licensing/ qualification and operations/procedures. CS 25.1302 and this AMC were developed with the intent of achieving that appropriate balance.

Introduction The introductory sentence of CS 25.1302 states that the provisions of this paragraph apply to each item of installed equipment intended for the flight crew’s use in operating the aeroplane from their normally seated positions on the flight deck.

"Intended for the flight-crew member's use in the operation of the aeroplane from their normally seated position," means that intended function of the installed equipment includes use by the flight crew in operating the aeroplane. An example of such installed equipment would be a display that provides information enabling the flight crew to navigate. The phrase "flight-crew members" is intended to include any or all individuals comprising the minimum flight crew as determined for compliance with CS 25.1523. The phrase "from their normally seated position" means flight-crew members are seated at their normal duty stations for operating the aeroplane. This phrase is intended to limit the scope of this requirement so that it does not address systems or equipment not used while performing their duties in operating the aeroplane in normal and non-normal conditions. For example, this paragraph is not intended to apply to items such as certain circuit breakers or maintenance controls intended for use by the maintenance crew (or by the flight crew when not operating the aeroplane).

The words "This installed equipment must be shown…" in the first paragraph means the applicant must provide sufficient evidence to support compliance determinations for each of the CS 25.1302 requirements. This is not intended to require a showing of compliance beyond that required by Part 21A.21(b). Accordingly, for simple items or items similar to previously approved equipment and installations, we do not expect the demonstrations, tests or data needed to show compliance with CS 25.1302 to entail more extensive or onerous efforts than are necessary to show compliance with previous requirements.

The phrase "individually and in combination with other such equipment" means that the requirements of this paragraph must be met when equipment is installed on the flight deck with other equipment. The installed equipment must not prevent other equipment from complying with these requirements. For example, applicants must not design a display so that information it provides is inconsistent or in conflict with information from other installed equipment.

In addition, provisions of this paragraph presume a qualified flight crew trained to use the installed equipment. This means the design must meet these requirements for flight-crew members who are allowed to fly the aeroplane by meeting operating rules qualification requirements. If the applicant seeks type design or supplemental type design approval before a training programme is accepted, the applicant should document any novel, complex, or highly integrated design features and assumptions made during design that have the potential to affect training time or flight crew procedures. The requirement and associated material are written assuming that either these design features and assumptions, or knowledge of a training programme (proposed or in the process of being developed) will be coordinated with the appropriate operational approval organisation when judging the adequacy of the design.

The requirement that equipment be designed so the flight crew can safely perform tasks associated with the equipment's intended function, applies in both normal and non-normal conditions. Tasks intended for performance under non-normal conditions are generally those prescribed by non-normal (including emergency) flight crew procedures. The phrase "safely perform their tasks" is intended to describe one of the safety objectives of this requirement. The requirement is that equipment design enables the flight crew to perform the tasks with sufficient accuracy and in a timely manner, without unduly interfering with other required tasks. The phrase "tasks associated with its intended function" is intended to characterise either tasks required to operate the equipment or tasks for which the equipment's intended function provides support.

CS 25.1302 (a) requires the applicant to install appropriate controls and provide necessary information for any flight deck equipment identified in the first paragraph of CS 25.1302. Controls and information displays must be sufficient to allow the flight crew to accomplish their tasks. Although this may seem obvious, this requirement is included because a review of CS-25 on the subject of human factors revealed that a specific requirement for flight deck controls and information to meet the needs of the flight crew is necessary. This requirement is not reflected in other parts of the rules, so it is important to be explicit.

CS 25.1302 (b) addresses requirements for flight deck controls and information that are necessary and appropriate so the flight crew can accomplish their tasks, as determined through (a) above. The intent is to ensure that the design of the control and information devices makes them usable by the flight crew. This sub-paragraph seeks to reduce design-induced flight crew errors by imposing design requirements on flight deck information presentation and controls. Sub-paragraphs (1) through (3) specify these design requirements.

Design requirements for information and controls are necessary to:

- Properly support the flight crew in planning their tasks,
- Make available to the flight crew appropriate, effective means to carry-out planned actions,
- Enable the flight crew to have appropriate feedback information about the effects of their actions on the aeroplane.

CS 25.1302(b)(1) specifically requires that controls and information be provided in a clear and unambiguous form, at a resolution and precision appropriate to the task. As applied to information, "clear and unambiguous" means that it:

- Can be perceived correctly (is legible).
- Can be comprehended in the context of the flight crew task.
- Supports the flight crew's ability to carry out the action intended to perform the tasks.

For controls, the requirement for "clear and unambiguous" presentation means that the crew must be able to use them appropriately to achieve the intended function of the equipment. The general intent is to foster design of equipment controls whose operation is intuitive, consistent with the effects on the parameters or states they affect, and compatible with operation of other controls on the flight deck.

Sub-paragraph 25.1302(b)(1) also requires that the information or control be provided, or operate, at a level of detail and accuracy appropriate to accomplishing the task. Insufficient resolution or precision would mean the flight crew could not perform the task adequately. Conversely, excessive resolution has the potential to make a task too difficult because of poor readability or the implication that the task should be accomplished more precisely than is actually necessary.

CS 25.1302(b)(2) requires that controls and information be accessible and usable by the flight crew in a manner consistent with the urgency, frequency, and duration of their tasks. For example, controls used more frequently or urgently must be readily accessed, or require fewer steps or actions to perform the task. Less accessible controls may be acceptable if they are needed less frequently or urgently. Controls used less frequently or urgently should not interfere with those used more urgently or frequently. Similarly, tasks requiring a longer time for interaction should not interfere with accessibility to information required for urgent or frequent tasks.

CS 25.1302(b)(3) requires that equipment presents information advising the flight crew of the effects of their actions on the aeroplane or systems, if that awareness is required for safe operation. The intent is that the flight crew be aware of system or aeroplane states resulting from flight crew actions, permitting them to detect and correct their own errors.

This sub-paragraph is included because new technology enables new kinds of flight crew interfaces that previous requirements don't address. Specific deficiencies of existing requirements in addressing human factors are described below:

- CS 25.771 (a) addresses this topic for controls, but does not include criteria for information presentation.
- CS 25.777 (a) addresses controls, but only their location.
- CS 25.777(b) and CS 25.779 address direction of motion and actuation but do not encompass new types of controls such as cursor devices. These requirements also do not encompass types of control interfaces that can be incorporated into displays via menus, for example, thus affecting their accessibility.
- CS 25.1523 and CS-25 Appendix D have a different context and purpose (determining minimum crew), so they do not address these requirements in a sufficiently general way.

CS 25.1302 (c) requires that installed equipment be designed so its behaviour that is operationally relevant to flight crew' tasks is:

- Predictable and unambiguous.
- Designed to enable the flight crew to intervene in a manner appropriate to the task (and intended function).

Improved flight deck technologies involving integrated and complex information and control systems, have increased safety and performance. However, they have also introduced the need to ensure proper interaction between the flight crew and those systems. Service experience has found that some equipment behaviour (especially from automated systems) is excessively complex or dependent upon logical states or mode transitions that are not well understood or expected by the flight crew. Such design characteristics can confuse the flight crew and have been determined to contribute to incidents and accidents.

The phrase "operationally-relevant behaviour" is meant to convey the net effect of the equipment's system logic, controls, and displayed information upon flight crew awareness or perception of the system's operation to the extent that this is necessary for planning actions or operating the system. The intent is to distinguish such system behaviour from the functional logic within the system design, much of which the flight crew does not know or need to know and which should be transparent to them.

CS 25.1302(c)(1) requires that system behaviour be such that a qualified flight crew can know what the system is doing and why. It requires that operationally relevant system behaviour be "predictable and unambiguous". This means that a crew can retain enough information about what their action or a changing situation will cause the system to do under foreseeable circumstances, that they can operate the system safely. System behaviour must be unambiguous because crew actions may have different effects on the aeroplane depending on its current state or operational circumstances.

CS 25.1302(c) (2) requires that the design be such that the flight crew will be able to take some action, or change or alter an input to the system in a manner appropriate to the task.

CS 25.1302 (d) addresses the reality that even well-trained, proficient flight crews using well-designed systems will make errors. It requires that equipment be designed to enable the flight crew to manage such errors. For the purpose of this rule, errors "resulting from flight crew interaction with the equipment" are those errors in some way attributable to, or related to, design of the controls, behaviour of the equipment, or the information presented. Examples of designs or information that could cause errors are indications and controls that are complex and inconsistent with each other or other systems on the flight deck. Another example is a procedure inconsistent with the design of the equipment. Such errors are considered to be within the scope of this requirement and AMC.

What is meant by design which enables the flight crew to "manage errors" is that:

- The flight crew must be able to detect and/or recover from errors resulting from their interaction with the equipment, or
- Effects of such flight crew errors on the aeroplane functions or capabilities must be evident to the flight crew and continued safe flight and landing must be possible, or
- Flight crew errors must be discouraged by switch guards, interlocks, confirmation actions, or other effective means, or
- Effects of errors must be precluded by system logic or redundant, robust, or fault tolerant system design.

The requirement to manage errors applies to those errors that can be reasonably expected in service from qualified and trained flight crews. The term "reasonably expected in service" means errors that have occurred in service with similar or comparable equipment. It also means error that can be projected to occur based on general experience and knowledge of human performance capabilities and limitations related to use of the type of controls, information, or system logic being assessed.

CS 25.1302(d) includes the following statement: "This sub-paragraph does not apply to skill-related errors associated with manual control of the aeroplane". That statement means to exclude errors resulting from flight crew proficiency in control of flight path and attitude with the primary roll, pitch, yaw and thrust controls, and which are related to design of the flight control systems. These issues are considered to be adequately addressed by existing requirements, such as CS-25 Subpart B and CS 25.671(a). It is not intended that design be required to compensate for deficiencies in flight crew training or experience. This assumes at least the minimum flight crew requirements for the intended operation, as discussed at the beginning of Paragraph 5.1 above.

This requirement is intended to exclude management of errors resulting from decisions, acts, or omissions by the flight crew that are not in good faith. It is intended to avoid imposing requirements on the design to accommodate errors committed with malicious or purely contrary intent. CS 25.1302 is not intended to require applicants to consider errors resulting from acts of violence or threats of violence.

This "good faith" exclusion is also intended to avoid imposing requirements on design to accommodate errors due to obvious disregard for safety by a flight-crew member. However, it is recognised that errors committed intentionally may still be in good faith but could be influenced by design characteristics under certain circumstances. An example would be a poorly designed procedure not compatible with the controls or information provided to the flight crew.

The intent of requiring errors to be manageable only "to the extent practicable" is to address both economic and operational practicability. It is meant to avoid imposing requirements without considering economic feasibility and commensurate safety benefits. It is also meant to address operational practicability, such as the need to avoid introducing error management features into the design that would inappropriately impede flight crew actions or decisions in normal or non-normal conditions. For example, it is not intended to require so many guards or interlocks on the means to shut down an engine that the flight crew would be unable to do this reliably within the available time. Similarly, it is not intended to reduce the authority or means for the flight crew to intervene or carry out an action when it is their responsibility to do so using their best judgment in good faith.

This sub-paragraph was included because managing errors that result from flight crew interaction with equipment (that can be reasonably expected in service), is an important safety objective. Even though the scope of applicability of this material is limited to errors for which there is a contribution from or relationship to design, CS 25.1302(d) is expected to result in design changes that will contribute to safety. One example, among others, would be the use of an "undo" functions in certain designs.

5.2 Intended Function and Associated Flight Crew Tasks

CS 25.1301(a) requires that: "*each item of installed equipment must - (a) Be of a kind and design appropriate to its intended function*". CS 25.1302 establishes requirements to ensure the design supports flight-crew member's ability to perform tasks associated with a system's intended function. In order to show compliance with CS 25.1302, the intended function of a system and the tasks expected of the flight crew must be known.

An applicant's statement of intended function must be sufficiently specific and detailed that the Agency can evaluate whether the system is appropriate for the intended function(s) and the associated flight crew tasks. For example, a statement that a new display system is intended to "enhance situation awareness" must be further explained. A wide variety of different displays enhance situation awareness in different ways. Examples are;, terrain awareness, vertical profile, and even the primary flight displays). The applicant may need more detailed descriptions for designs with greater levels of novelty, complexity or integration.

An applicant should describe intended function(s) and associated task(s) for:

- Each item of flight deck equipment,
- Flight crew indications and controls for that equipment,
- Individual features or functions of that equipment.

This type of information is of the level typically provided in a pilot handbook or an operations manual. It would describe indications, controls, and flight crew procedures.

As discussed in paragraph 4, novel features may require more detail, while previously approved systems and features typically require less. Paragraph 4.1 discusses functions that are sufficiently novel that additional scrutiny is required. Applicants may evaluate whether statements of intended function(s) and associated task(s) are sufficiently specific and detailed by using the following questions:

- Does each feature and function have a stated intent?
- Are flight crew tasks associated with the function described?
- What assessments, decisions, and actions are flight-crew members expected to make based on information provided by the system?
- What other information is assumed to be used in combination with the system?
- Will installation or use of the system interfere with the ability of the flight crew to operate other flight deck systems?
- Are there any assumptions made about the operational environment in which the equipment will be used?
- What assumptions are made about flight crew attributes or abilities beyond those required in regulations governing flight operations, training, or qualification?

5.3 Controls

5.3.1 Introduction

For purposes of this AMC, we define controls as devices the flight crew manipulates in order to operate, configure, and manage the aeroplane and its flight control surfaces, systems, and other equipment. This may include equipment in the flight deck such as;

- Buttons
- Switches
- Knobs
- Keyboards
- Keypads
- Touch screens
- Cursor control devices

- Graphical user interfaces, such as pop-up windows and pull-down menus that provide control functions
- Voice activated controls

5.3.2 Showing Compliance with CS 25.1302 (b)

Applicants should propose means of compliance to show that controls in the proposed design comply with CS 25.1302 (b). The proposed means should be sufficiently detailed to demonstrate that each function, method of control operation, and result of control actuation complies with the requirements, i.e.:

- Clear
- Unambiguous
- Appropriate in resolution and precision
- Accessible
- Usable
- Enables flight crew awareness (provides adequate feedback)

For each of these requirements, the proposed means of compliance should include consideration of the following control characteristics for each control individually and in relation to other controls:

- Physical location of the control
- Physical characteristics of the control (e.g., shape, dimensions, surface texture, range of motion, colour)
- Equipment or system(s) that the control directly affects
- How the control is labelled
- Available control settings
- Effect of each possible actuation or setting, as a function of initial control setting or other conditions
- Whether there are other controls that can produce the same effect (or affect the same target parameter) and conditions under which this will happen
- Location and nature of control actuation feedback

The following discussion provides additional guidance for design of controls that comply with CS 25.1302. It also provides industry accepted best practices.

5.3.3 Clear and Unambiguous Presentation of Control Related Information

a. Distinguishable and Predictable Controls [CS 25.1301(a), CS 25.1302]

Each flight-crew member should be able to identify and select the current function of the control with speed and accuracy appropriate to the task. Function of a control should be readily apparent so that little or no familiarisation is required. The applicant should evaluate consequences of control activation to show they are predictable and obvious to each flight-crew member. This includes control of multiple displays with a single device and shared display areas that flight-crew members access with individual controls. Controls can be made distinguishable or predictable by differences in form, colour, location, and/or labelling. Colour coding is usually not sufficient as a sole distinguishing feature. This applies to physical controls as well as to controls that are part of an interactive graphical user interface.

b. Labelling [CS 25.1301(b), CS 25.1543(b), CS 25.1555(a)]

For general marking of controls see CS 25.1555(a). Labels should be readable from the crewmember’s normally seated position in all lighting and environmental conditions. If a control performs more than one function, labelling should include all intended functions unless function of the control is obvious. Labels of graphical controls accessed by a cursor device such as a trackball should be included on the graphical display. When menus lead to additional choices (submenus), the menu label should provide a reasonable description of the next submenu.

The applicant can label with text or icons. Text and icons should be shown to be distinct and meaningful for the function that they label. The applicant should use standard and/or non-ambiguous abbreviations, nomenclature, or icons, consistent within a function and across the flight deck. ICAO 8400 provides standard abbreviations and is an acceptable basis for selection of labels.

The design should avoid hidden functions (such as clicking on empty space on a display to make something happen), However, such hidden functions may be acceptable if adequate alternate means are available for accessing the function. The design should still be evaluated for ease of use and crew understanding.

When using icons instead of text labelling, the applicant should show that the flight crew requires only brief exposure to the icon to determine the function of a control and how it operates. Based on design experience, the following guidelines for icons have been shown to lead to usable designs:

- The icon should be analogous to the object it represents
- The icon should be in general use in aviation and well known to flight crews
- The icon should be based on established standards, when they exist, and conventional meanings.

In all cases, the applicant should show use of icons to be at least equivalent to text labels in terms of speed and error rate. Alternatively, the applicant should show that the increased error rate or task times have no unacceptable effect on safety or flight crew workload and do not cause flight crew confusion.

c. Interaction of Multiple Controls [CS 25.1302]

If multiple controls for the flight crew are provided for a function, the applicant should show that there is sufficient information to make the flight crew aware of which control is currently functioning. As an example, crewmembers need to know which flight-crew member's input has priority when two cursor control devices can access the same display. Designers should use caution when dual controls can affect the same parameter simultaneously.

5.3.4 Accessibility of controls [CS 25.777(a), CS 25.777(b), CS 25.1302]

The applicant must show that each flight-crew member in the minimum flight crew, as defined by CS 25.1523, has access to and can operate all necessary controls. Accessibility is one factor in determining whether controls support the intended function of equipment used by the flight crew. Any control required for flight-crew member operation in the event of incapacitation of other flight-crew members (in both normal and non-normal conditions) must be shown to be viewable, reachable, and operable by flight-crew members with the stature specified in CS 25.777(c), from the seated position with shoulder restraints on. If shoulder restraints are lockable, this may be shown with shoulder restraints unlocked.

CS 25.777(c) requires that the location and arrangement of each flight deck control permit full and unrestricted movement of that control without interference from other controls, equipment, or structure in the flight deck.

Layering of information, as with menus or multiple displays, should not hinder flight crew in identifying the location of the desired control. In this context, location and accessibility are not only the physical location of the control function (on a display device) or any multifunction control (for example,, a cursor control device) used to access them. Location and accessibility also includes consideration of where the control functions may be located within various menu layers and how the flight-crew member navigates those layers to access the functions. Accessibility should be shown in conditions of system failures (including crew incapacitation) and minimum equipment list dispatch.

Control position and direction of motion should be oriented from the vantage point of the flight-crew member. Control/display compatibility should be maintained from that regard. For example, a control on an overhead panel requires movement of the flight-crew member's head backwards and orientation of the control movement should take this into consideration.

5.3.5 Use of controls

a. Environmental issues affecting controls [CS 25.1301(a) and CS 25.1302]

Turbulence or vibration and extremes in lighting levels should not prevent the crew from performing all their tasks at an acceptable level of performance and workload. If use of gloves is anticipated for cold weather operations, the design should account for the effect of their use on the size and precision of controls. Sensitivity of controls should afford precision sufficient to perform tasks even in adverse environments as defined for the aeroplane's operational envelope. Analysis of environmental issues as a means of compliance (see 6.3.3) is necessary, but not sufficient for new control types or technologies or for novel use of controls that are themselves not new or novel.

The applicant should show that controls required to regain aeroplane or system control and controls required to continue operating the aeroplane in a safe manner are usable in conditions such as dense smoke in the flight deck or severe vibrations. An example of the latter condition would be after a fan blade loss..

b. Control-display compatibility [CS 25.777(b)]

To ensure that a control is unambiguous, the relationship and interaction between a control and its associated display or indications should be readily apparent, understandable, and logical. A control input is often required in response to information on a display or to change a parameter setting on a display. The applicant should specifically asses any rotary knob that has no obvious “increase” or “decrease” function with regard to flight crew expectations and its consistency with other controls on the flight deck. The Society of Automotive Engineers’ (SAE) publication ARP 4102, section 5.3, is an acceptable means of compliance for controls used in flight deck equipment.

When a control is used to move an actuator through its range of travel, the equipment should provide, within the time required for the relevant task, operationally significant feedback of the actuator’s position within its range. Examples of information that could appear relative to an actuator’s range of travel include trim system positions, target speed, and the state of various systems valves.

Controls associated with a display should be located so that they do not interfere with the performance of the crew task. Controls whose function is specific to a particular display surface should be mounted near to the display or function being controlled. Locating controls immediately below a display is generally preferable as mounting controls immediately above a display has, in many cases, caused the flight-crew member’s hand to obscure viewing of the display when operating controls. However, controls on the bezel of multifunction displays have been found to be acceptable.

Spatial separation between a control and its display may be necessary. This is the case with a system’s control located with others for that same system, or when it is one of several controls on a panel dedicated to controls for that multifunction display. When there is large spatial separation between a control and its associated display, the applicant should show that use of the control for the associated task(s),is acceptable in terms of types of errors, error rate(s) and access time(s).

In general, control design and placement should avoid the possibility that the visibility of information could be blocked. If range of control movement temporarily blocks the flight crew’s view of information, the applicant should show that this information is either not necessary at that time or available in another accessible location.

Annunciations/labels on electronic displays should be identical to labels on related switches and buttons located elsewhere on the flight deck. If display labels are not identical to related controls, the applicant should show that flight-crew members can quickly, easily, and accurately identify associated controls.

5.3.6 Adequacy of Feedback [CS 25.771(a), CS 25.1301(a), CS 25.1302)]

Feedback for control inputs is necessary to give the flight crew awareness of the effects of their actions. Each control should provide feedback to the crewmember for menu selections, data entries, control actions, or other inputs. There should be clear and unambiguous indication when crew input is not accepted or followed by the system. This feedback can be visual, auditory, or tactile. Feedback, in whatever form, should be provided to inform the crew that:

- A control has been activated (commanded state/value)
- The function is in process (given an extended processing time)
- The action associated with the control has been initiated (actual state/value if different from the commanded state).

The type, duration and appropriateness of feedback, will depend upon the crew’s task and the specific information required for successful operation. As an example, switch position alone is insufficient feedback if awareness of actual system response or the state of the system as a result of an action is required.

Controls that may be used while the user is looking outside or at unrelated displays should provide tactile feedback. Keypads should provide tactile feedback for any key depression. In cases when this is omitted, it should be replaced with appropriate visual or other feedback that the system has received the inputs and is responding as expected.

Equipment should provide appropriate visual feedback, not only for knob, switch, and pushbutton position, but also for graphical control methods such as pull-down menus and pop-up windows. The user interacting with a graphical control should receive positive indication that a hierarchical menu item has been selected, a graphical button has been activated, or other input has been accepted.

The applicant should show that feedback in all forms is obvious and unambiguous to the flight crew in performance of the tasks associated with the intended function of the equipment.

5.4 Presentation of Information

5.4.1 Introduction.

Applicants should propose means of compliance to show that information displayed in the proposed design complies with CS 25.1302(b). The proposed means should be sufficiently detailed to show that the function, method of control operation and result, complies with the requirements, i.e.:

- Clear
- Unambiguous
- Appropriate in resolution and precision
- Accessible
- Usable
- Enables Flight Crew awareness (provides adequate feedback)

Presentation of information to the flight crew can be visual (for instance, on an LCD), auditory (a “talking” checklist) or tactile (for example, control feel). Information presentation on the integrated flight deck, regardless of the medium used, should meet all of the requirements bulleted above. For visual displays, this AMC addresses mainly display format issues and not display hardware characteristics. The following provides design considerations for requirements found in CS 25.1301(a), CS 25.1301(b), CS 25.1302, and CS 25.1543(b). In the event of a conflict between this document and AMC 25-11 regarding guidance on specific electronic visual display functions, AMC 25-11 takes precedence.

5.4.2 Clear and Unambiguous Presentation of Information

a. Qualitative and quantitative display formats [CS 25.1301(a) and CS 25.1302]

Applicants should show that display formats include the type of information the flight crew needs for the task, specifically with regard to the speed and precision of reading required. For example, the information could be in the form of a text message, numerical value, or a graphical representation of state or rate information). State information identifies the specific value of a parameter at a particular time. Rate information indicates the rate of change of that parameter.

If the flight crew’s sole means of detecting non-normal values is by monitoring values presented on the display, the equipment should offer qualitative display formats. Qualitative display formats better convey rate and trend information. If this is not practical, the applicant should show that the flight crew can perform the tasks for which the information is used. Quantitative presentation of information is better for tasks requiring precise values.

Digital readouts or present value indices incorporated into qualitative displays should not make the scale markings or graduations unusable as they pass the present value index.

b. Consistency [CS 25.1302]

If similar information is presented in multiple locations or modes (visual and auditory, for example), consistent presentation of information is desirable. Consistency in information presentation within the system tends to minimise flight crew error. If information cannot be presented consistently within the flight deck, the applicant should show that differences do not increase error rates or task times leading to significant safety or flight crew workload and do not cause flight crew confusion.

c. Characters, fonts, lines and scale markings [CS 25.1301(b) and CS 25.1543(b)]

The applicable crew members, seated at their stations and using normal head movement, should be able to see and read display format features such as fonts, symbols, icons and markings. In some cases, cross flight deck readability may be required. Examples of situations where this might be needed are cases of display failure or when cross checking flight instruments. Readability must be maintained in sunlight viewing conditions (per CS 25.773(a)) and under other adverse conditions such as vibration. Figures and letters should subtend not less than the visual angles defined in SAE ARP 4102-7 at the design eye position of the flight-crew member who normally uses the information.

d. Colour [CS 25.1302]

Avoid using many different colours to convey meaning on displays. However, judicious use of colour can be very effective in minimising display interpretation workload and response time. Colour can be used to group logical electronic display functions or data types. A common colour philosophy across the flight deck is desirable, although deviations may be approved with acceptable justification. Applicants should show that the chosen colour set is not susceptible to confusion or misinterpretation due to differences in colour usage between displays. Improper colour coding increases response times for display item recognition and selection, and increases likelihood of errors in situations where the speed of performing a task is more important than accuracy. Extensive use of the colours red and amber for other than alerting functions or potentially unsafe conditions is discouraged. Such use diminishes the attention-getting characteristics of true warnings and cautions.

Use of colour as the sole means of presenting information is also discouraged. It may be acceptable however, to indicate the criticality of the information in relation to the task. Colour, when used for task essential information, should be in addition to other coding characteristics, such as texture or differences in luminance. AMC 25-11 contains recommended colour sets for specific display features.

Applicants should show that layering information on a display does not add to confusion and clutter as a result of the colour standards and symbols used. Designs requiring flight-crew members to manually de-clutter such displays should also be avoided.

e. Symbology, Text, and Auditory Messages [CS 25.1302]

Designs can base many elements of electronic display formats on established standards and conventional meanings. For example, ICAO 8400 provides abbreviations and is one standard that could be applied to flight deck text. SAE ARP 4102-7, Appendix A-C and SAE ARP 5289 are acceptable standards for avionic display symbols.

The position of a message or symbol within a display also conveys meaning to the flight-crew member. Without the consistent or repeatable location of a symbol in a specific area of the electronic display, interpretation errors and response times may increase. Applicants should give careful attention to symbol priority (priority of displaying one symbol overlaying another symbol by editing out the secondary symbol) to ensure that higher priority symbols remain viewable.

New symbols (a new design or a new symbol for a function which historically had an associated symbol) should be tested for distinguishability and flight crew comprehension and retention.

The applicant should show that display text and auditory messages are distinct and meaningful for the information presented. Assess messages for whether they convey the intended meaning. Equipment should display standard and/or non-ambiguous abbreviations and nomenclature, consistent within a function and across the flight deck.

5.4.3 Accessibility and Usability of Information

a. Accessibility of information [CS 25.1302]

Some information may at certain times be immediately needed by the flight crew, while other information may not be necessary during all phases of flight. The applicant should show that the flight crew can access and manage (configure) all necessary information on the dedicated and multifunction displays for the phase of flight. The applicant should show that any information required for continued safe flight and landing is accessible in the relevant degraded display modes following failures as defined by CS 25.1309. The applicant should specifically assess what information is necessary in those conditions, and how such information will be simultaneously displayed. The applicant should also show that supplemental information does not displace or otherwise interfere with required information.

Analysis as the sole means of compliance is not sufficient for new or novel display management schemes. The applicant should use simulation of typical operational scenarios to validate the flight crew's ability to manage available information.

b. Clutter [CS 25.1302]

Clutter is the presentation of information in a way that distracts flight-crew members from their primary task. Visual or auditory clutter is undesirable. To reduce flight-crew member's interpretation time, equipment should present information simply and in a well-ordered way. Applicants should show that an information delivery method (whether visual or auditory) presents the information the flight-crew member actually requires to perform the task at hand. The flight crew can use their own discretion to limit the amount of information that needs to be presented at any point in time. For instance, a design might allow the flight crew to program a system so that it displays the most important information all the time, and less important information on request. When a design allows, flight crew selection of additional information, the basic display modes should remain uncluttered.

Automatically de-cluttering display options can hide needed information from the flight-crew member. The applicant should show that equipment that uses automatic de-selection of data to enhance the flight-crew member's performance in certain emergency conditions provides the information the flight-crew member requires. Use of part-time displays depends not only on information de-clutter goals but also on display availability and criticality. Therefore, when designing such features, the applicant should follow the guidance in AMC 25-11.

Because of the transient nature of auditory information presentation, designers should be careful to avoid the potential for competing auditory presentations that may conflict with each other and hinder interpretation. Prioritisation and timing may be useful to avoid this potential problem.

Prioritise information according to task criticality. Lower priority information should not mask higher priority information and higher priority information should be available, readily detectable, easily distinguishable and usable. This does not mean that the display format needs to change based on phase of flight.

c. System response to control input [CS 25.1302]

Long or variable response times between control input and system response can adversely affect system usability. The applicant should show that response to control input, such as setting values, displaying parameters, or moving a cursor symbol on a graphical display is fast enough to allow the flight crew to complete the task at an acceptable performance level. For actions requiring noticeable system processing time equipment should indicate that system response is pending.

5.5 System Behaviour

5.5.1 Introduction

Flight crew task demands vary depending on the characteristics of the system design. Systems differ in their responses to relevant flight crew input. The response can be direct and unique as in mechanical systems or it can vary as a function of an intervening subsystem (such as hydraulics or electrics). Some systems even automatically vary their response to capture or maintain a desired aeroplane or system state.

As described in paragraph 5.1, CS 25.1302(c) states that installed equipment must be designed so that the behaviour of the equipment that is operationally relevant to the flight crew's tasks is: (1) predictable and unambiguous, and (2) designed to enable the flight crew to intervene in a manner appropriate to the task (and intended function).

The requirement for operationally relevant system behaviour to be predictable and unambiguous will enable a qualified flight crew to know what the system is doing and why. This means that a crew should have enough information about what the system will do under foreseeable circumstances as a result of their action or a changing situation that they can operate the system safely. This distinguishes system behaviour from the functional logic within the system design, much of which the flight crew does not know or need to know.

If flight crew intervention is part of the intended function or non-normal procedures for the system, the crewmember may need to take some action, or change an input to the system. The system must be designed accordingly. The requirement for flight crew intervention capabilities recognises this reality.

Improved technologies, which have increased safety and performance, have also introduced the need to ensure proper cooperation between the flight crew and the integrated, complex information and control systems. If system behaviour is not understood or expected by the flight crew, confusion may result.

Some automated systems involve tasks that require flight crew attention for effective and safe performance. Examples include the flight management system (FMS) or flight guidance systems. Alternatively, systems designed to operate autonomously, in the sense that they require very limited or no human interaction, are referred to as 'automatic systems'. Such systems are switched 'on' or 'off 'or run automatically and are not covered in this paragraph. Examples include fly-by-wire systems, full authority digital engine controls (FADEC), and yaw dampers. Detailed specific guidance for automatic systems can be found in relevant parts of CS-25.

Service experience shows that automated system behaviour that is excessively complex or dependent on logical states, or mode transitions are not understood or expected by the flight crew can lead to flight crew confusion. Design characteristics such as these have been determined to contribute to incidents and accidents.

This sub-paragraph provides guidance material for showing compliance with these design considerations for requirements found in CS 25.1302(c), CS 25.1301 (a), CS 25.1309 (c), or any other relevant paragraphs of CS-25.

5.5.2 System Function Allocation

The applicant should show that functions of the proposed design are allocated so that:

- The flight crew can be expected to complete their allocated tasks successfully in both normal and non-normal operational conditions, within the bounds of acceptable workload and without requiring undue concentration or causing undue fatigue. (See CS 25.1523 and CS-25 Appendix D for workload evaluation);

- Flight crew interaction with the system enables them to understand the situation, and enables timely detection of failures and crew intervention when appropriate;
- Task sharing and distribution of tasks among flight-crew members and the system during normal and non-normal operations is considered.

5.5.3 System Functional Behaviour

A system's behaviour results from the interaction between the flight crew and the automated system and is determined by:

- The system's functions and the logic that governs its operation; and
- The user interface, which consists of the controls and information displays that communicate the flight crew's inputs to the system and provide feedback on system behaviour to the crew.

It is important that the design reflect a consideration of both of these together. This will avoid a design in which the functional logic governing system behaviour can have an unacceptable effect on crew performance. Examples of system functional logic and behaviour issues that may be associated with errors and other difficulties for the flight crew are the following:

- Complexity of the flight crew interface for both inputs (entering data) and outputs.
- Inadequate understanding and inaccurate expectations of system behaviour by the flight crew following mode selections and transitions.
- Inadequate understanding and incorrect expectations by the flight crew of system intentions and behaviour.

<u>Predictable and Unambiguous System Behaviour (CS 25.1302 (c) (1))</u>

Applicants should propose the means they will use to show that system or system mode behaviour in the proposed design is predictable and unambiguous to the flight crew.

System or system mode behaviour that is ambiguous or unpredictable to the flight crew has been found to cause or contribute to flight crew errors. It can also potentially degrade the flight crew's ability to perform their tasks in both normal and non-normal conditions. Certain design characteristics have been found to minimise flight crew errors and other crew performance problems.

The following design considerations are applicable to operationally relevant system or system mode behaviours:

- Simplicity of design (for example, number of modes, mode transitions).
- Clear and unambiguous mode annunciation. For example, a mode engagement or arming selection by the flight crew should result in annunciation, indication or display feedback adequate to provide awareness of the effect of their action.
- Accessible and usable methods of mode arming, engagement and de-selection. For example, the control action necessary to arm, engage, disarm or disengage a mode should not depend on the mode that is currently armed or engaged, on the setting of one or more other controls, or on the state or status of that or another system.
- Predictable un-commanded mode change and reversions. For example, there should be sufficient annunciation, indication or display information to provide awareness of uncommanded changes of the engaged or armed mode of a system.

Note that formal descriptions of modes typically define them as mutually exclusive, so that a system cannot be in more than one mode at a particular time. For instance, a display can be in “north up” mode or “track up” mode, but not both at the same time.

For specific guidance on flight guidance system modes, see AMC 25.1329.

<u>Flight Crew Intervention (CS 25.1302 (c) (2))</u>

Applicants should propose the means that they will use to show that system behaviour in the proposed design allows the flight crew to intervene in operation of the system without compromising safety. This should include descriptions of how they will determine that functions and conditions in which intervention should be possible have been addressed.

If done by analysis, the completeness of the analysis may be established either by defining acceptable criteria for the depth and breadth of the analysis, or by proposing an analysis method that is inherently complete. In addition, applicant's proposed methods should describe how they would determine that each intervention means is appropriate to the task.

Controls for Automated Systems

Automated systems can perform various tasks selected by and under supervision of the flight crew. Controls should be provided for managing functionalities of such a system or set of systems. The design of such "automation specific" controls should enable the crew to:

- Safely prepare the system for the task to be executed or the subsequent task to be executed. Preparation of a new task (for example, new flight trajectory) should not interfere with, or be confused with, the task being executed by the automated system.
- Activate the appropriate system function without confusion about what is being controlled, in accordance with crew expectations. For example, the flight crew should have no confusion when using a vertical speed selector which could set either vertical speed or flight path angle.
- Manually intervene in any system function, as required by operational conditions, or to revert to manual control. For example, manual intervention might be needed during loss of system functionality, system abnormalities, or failure conditions.

Displays for Automated Systems

Automated systems can perform various tasks with minimal crew interventions, but under the supervision of the flight crew. To ensure effective supervision and maintain crew awareness of system state and system "intention" (future states), displays should provide recognisable feedback on:

- Entries made by the crew into the system so that the crew can detect and correct errors.
- Present state of the automated system or mode of operation. (What is it doing?)
- Actions taken by the system to achieve or maintain a desired state. (What is it trying to do?)
- Future states scheduled by the automation. (What is it going to do next?)
- Transitions between system states.

The applicant should consider the following aspects of automated system design:

- Indications of commanded and actual values should enable the flight crew to determine whether the automated systems will perform according to their expectations;
- If the automated system nears its operational authority or is operating abnormally for the conditions, or is unable to perform at the selected level, it should inform the flight crew, as appropriate for the task;
- The automated system should support crew coordination and cooperation by ensuring shared awareness of system status and crew inputs to the system; and
- The automated system should enable the flight crew to review and confirm the accuracy of commands constructed before being activated. This is particularly important for automated systems because they can require complex input tasks.

5.6 Flight Crew Error Management

5.6.1 Showing Compliance with CS 25.1302(d)

It is important to recognise that flight crews will make errors, even when well trained, experienced and rested individuals are using well-designed systems. Therefore, CS 25.1302(d) requires that "To the extent practicable, the installed equipment must enable the flight crew to manage errors resulting from flight crew interaction with the equipment that can be reasonably expected in service, assuming flight crews acting in good faith. This sub-paragraph does not apply to skill-related errors associated with manual control of the aeroplane."

To comply with CS 25.1302(d), the design should meet at least one of the following criteria. It should:

- Enable the flight crew to detect (see 5.6.2), and/or recover from errors (see 5.6.3); or
- Ensure that effects of flight crew errors on the aeroplane functions or capabilities are evident to the flight crew and continued safe flight and landing is possible (see 5.6.4); or
- Discourage flight crew errors by using switch guards, interlocks, confirmation actions, or similar means, or preclude the effects of errors through system logic and/or redundant, robust, or fault tolerant system design (see 5.6.5).

These objectives:

- Are, in a general sense, in a preferred order.
- Recognise and assume that flight crew errors cannot be entirely prevented, and that no validated methods exist to reliably predict either their probability or all the sequences of events with which they may be associated.
- Call for means of compliance that are methodical and complementary to, and separate and distinct from, aeroplane system analysis methods such as system safety assessments.

As discussed previously in paragraph 5.1, Compliance with CS 25.1302(d) is not intended to require consideration of errors resulting from acts of violence or threats of violence. Additionally, the requirement is intended to require consideration of only those errors that are design related.

Errors that do have a design-related component are considered to be within the scope of this regulatory and advisory material. Examples are a procedure that is inconsistent with the design of the equipment, or indications and controls that are complex and inconsistent with each other or other systems on the flight deck.

When demonstrating compliance, the applicant should evaluate flight crew tasks in both normal and non-normal conditions, considering that many of the same design characteristics are relevant in either case. For example, under non-normal conditions, the flying tasks (navigation, communication and monitoring), required for normal conditions are generally still present, although they may be more difficult in some non-normal conditions. So tasks associated with the non-normal conditions should be considered as additive. The applicant should not expect the errors considered to be different from those in normal conditions, but any evaluation should account for the change in expected tasks.

To show compliance with CS 25.1302(d), an applicant may employ any of the general types of methods of compliance discussed in Paragraph 6, singly or in combination. These methods must be consistent with an approved certification plan as discussed in Paragraph 4, and account for the objectives above and the considerations described below. When using some of these methods, it may be helpful for some applicants to refer to other references relating to understanding error occurrence. Here is a brief summary of those methods and how they can be applied to address flight crew error considerations:

- Statement of Similarity (paragraph 6.3.1): A statement of similarity may be used to substantiate that the design has sufficient certification precedent to conclude that the ability of the flight crew to manage errors is not significantly changed. Applicants may also use service experience data to identify errors known to commonly occur for similar crew interfaces or system behaviour. As part of showing compliance, the applicant should identify steps taken in the new design to avoid or mitigate similar errors.
- Design Descriptions (paragraph 6.3.2): Applicants may structure design descriptions and rationale to show how various types of errors are considered in the design and addressed, mitigated or managed. Applicants can also use a description of how the design adheres to an established and valid design philosophy to substantiate that the design enables flight crews to manage errors.
- Calculation and Engineering Analysis (paragraph 6.3.3): As one possible means of showing compliance with CS 25.1302(d), an applicant may document means of error management through analysis of controls, indications, system behaviour, and related flight crew tasks. This would need to be done in conjunction with an understanding of potential error opportunities and the means available for the flight crew to manage those errors. In most cases it is not considered feasible to predict the probability of flight crew errors with sufficient validity or precision to support a means of compliance. If an applicant chooses to use a quantitative approach, the validity of the approach should be established.
- Evaluations, Demonstrations, and Tests (paragraph 6.3.4-6): For compliance purposes, evaluations are intended to identify error possibilities that may be considered for mitigation in design or training. In any case, scenario objectives and assumptions should be clearly stated before running the evaluations, demonstrations, or tests. In that way, any discrepancy in those expectations can be discussed and explained in the analysis of the results.

As discussed further in Paragraph 6, these evaluations, demonstrations, or tests should use appropriate scenarios that reflect intended function and tasks, including use of the equipment in normal and non-normal conditions. Scenarios should be designed to consider flight crew error. If inappropriate scenarios are used or important conditions are not considered, incorrect conclusions can result. For example, if no errors occur during an evaluation it may mean only that the scenarios are too simple. On the other hand, if some errors do occur, it may mean any of the following:

- The design, procedures, or training should be modified,
- The scenarios are unrealistically challenging, or
- Insufficient training occurred prior to the evaluation.

In such evaluations it is not considered feasible to establish criteria for error frequency.

5.6.2 Error Detection

Applicants should design equipment to provide information so the flight crew can become aware of an error or a system/aeroplane state resulting from a system action. Applicants should show that this information is available to the flight crew, adequately detectable, and clearly related to the error in order to enable recovery in a timely manner.

Information for error detection may take three basic forms:

Indications provided to the flight crew during normal monitoring tasks. As an example, if an incorrect knob was used, resulting in an unintended heading change, the change would be detected through the display of target values. Presentation of a temporary flight plan for flight crew review before accepting it would be another way of providing crew awareness of errors.

Indications on instruments in the primary field of view that are used during normal operation may be adequate if the indications themselves contain information used on a regular basis and are provided in a readily accessible form. These may include mode annunciations and normal aeroplane state information such as altitude or heading. Other locations for the information may be appropriate depending on the flight crew's tasks, such as on the control-display unit when the task involves dealing with a flight plan. Paragraph 5.4, Presentation of Information, contains additional guidance to determine whether information is adequately detectable.

Flight crew indications that provide information of an error or a resulting aeroplane system condition. An example might be an alert to the flight crew about the system state resulting from accidentally shutting down a hydraulic pump. Note that if the indication is an alert, it is related to the resulting system state, not necessarily directly to the error itself. Existence of a flight crew alert that occurs in response to flight crew error may be sufficient to establish that information exists and is adequately detectable, if the alert directly and appropriately relates to the error. Definitions of alert levels in CS 25.1322 are sufficient to establish that the urgency of the alert is appropriate. Content of the indication should directly relate to the error. Indications for indirect effects of an error may lead the flight crew to believe there may be non-error causes for the annunciated condition.

"Global" alerts that cover a multitude of possible errors by annunciating external hazards or aeroplane envelope or operational conditions. Examples include monitoring systems such as terrain awareness warning systems (TAWS) and traffic collision avoidance systems (TCAS). An example would be a TAWS alert resulting from turning the wrong direction in a holding pattern in mountainous terrain.

The applicant should consider the following when establishing whether the degree or type of information is available to the flight crew, adequately detectable, and clearly related to the error:

- Effects of some errors are easily and reliably determined by the system (by design), and some are not. For those that cannot be sensed by the system, design and arrangement of the information monitored and scanned by the flight crew can facilitate error detection. An example would be alignment of engine speed indicator needles in the same direction during normal operation.
- Aeroplane alerting and indication systems may not detect whether an action is erroneous because systems cannot know flight crew intent for many operational circumstances. In these cases, reliance is often placed on the flight crew's ability to scan and observe indications that will change as a result of an action such as selecting a new altitude or heading, or making a change to a flight plan in a flight management system. For errors of this nature, detection depends on flight crew interpretation of available information. Training, crew resource management, and monitoring systems such as TAWS and TCAS are examples of ways to provide a redundant level of safety if any or all flight-crew members fail to detect certain errors.

- From a design standpoint, some information, such as heading, altitude, and fuel state, should be provided as readily available indications rather than in the form of alerts when there is potential for them to contribute to excessive nuisance alerts.

The applicant may establish that information is available and clearly related to the error by design description when precedent exists or when a reasonable case may be made that the content of the information is clearly related to the error that caused it. In some cases, piloted evaluations (see 6.3.4) may be needed to assess whether the information provided is adequately available and detectable.

5.6.3 Error Recovery

Assuming that the flight crew detects errors or their effects, the next logical step is to ensure that the error can be reversed, or the effect of the error can be mitigated in some way so that the aeroplane is returned to a safe state.

An acceptable means to establish that an error is recoverable is to show that:

- Controls and indications exist that can be used either to reverse an erroneous action directly so that the aeroplane or system is returned to the original state, or to mitigate the effect so that the aeroplane or system is returned to a safe state, and
- The flight crew can be expected to use those controls and indications to accomplish the corrective actions in a timely manner.

To establish the adequacy of controls and indications that facilitate error recovery, a statement of similarity or design description of the system and crew interface may be sufficient. For simple or familiar types of system interfaces, or systems that are not novel, even if complex, a statement of similarity or design description of the crew interfaces and procedures associated with indications is an acceptable means of compliance.

To establish that the flight crew can be expected to use those controls and indications to accomplish corrective actions in a timely manner, evaluation of flight crew procedures in a simulated flight deck environment can be highly effective. This evaluation should include examination of nomenclature used in alert messages, controls, and other indications. It should also include the logical flow of procedural steps and the effects that executing the procedures have on other systems.

5.6.4 Error Effects

Another means of satisfying the objective of error mitigation is to ensure that effects of the error or relevant effects on aeroplane state:

- Are evident to the flight crew, and
- Do not adversely impact safety (do not prevent continued safe flight and landing).

Piloted evaluations in the aeroplane or in simulation may be relevant if flight crew performance issues are in question for determining whether a state following an error permits continued safe flight and landing. Evaluations and/or analyses may be used to show that, following an error, the flight crew has the information in an effective form and has the aeroplane capability required to continue safe flight and landing.

5.6.5 Precluding Errors or Their Effects

For irreversible errors that have potential safety implications, means to discourage the errors are recommended. Acceptable ways to discourage errors include switch guards, interlocks, or multiple confirmation actions. For example, generator drive controls on many aeroplanes have guards over the switches to discourage inadvertent actuation, because once disengaged, the drives cannot be re-engaged while in flight or with the engine running. An example of multiple confirmations would be presentation of a temporary flight plan that the flight crew can review before accepting.

Another way of avoiding flight crew error is to design systems to remove misleading or inaccurate information, (e.g., sensor failures), from displays. An example would be a system that removes flight director bars from a primary flight display or removing “own-ship” position from an airport surface map display when the data driving the symbols is incorrect.

The applicant should avoid applying an excessive number of protections for a given error. Excessive use of protections could have unintended safety consequences. They might hamper the flight-crew member‘s ability to use judgment and take actions in the best interest of safety in situations not predicted by the applicant. If protections become a nuisance in daily operation flight crews may use well-intentioned and inventive means to circumvent them. This could have further effects not anticipated by the operator or the designer.

5.7 Integration

5.7.1 Introduction

Many systems, such as flight management systems, are integrated physically and functionally into the flight deck and may interact with other flight deck systems. It is important to consider a design not just in isolation, but in the context of the overall flight deck. Integration issues include where a display or control is installed, how it interacts with other systems, and whether there is internal consistency across functions within a multi-function display, as well as consistency with the rest of the flight deck's equipment.

CS 25.1302 requires that "…installed equipment must be shown, individually and in combination with other such equipment, to be designed so that qualified flight-crew members trained in its use can safely perform their tasks associated with its intended function …". To comply with this integration requirement, all flight deck equipment must be able to be used by the flight crew to perform their tasks, in any combination reasonably expected in service. Flight deck equipment includes interfaces to aeroplane systems the flight crew interacts with, such as controls, displays, indications, and annunciators.

Analyses, evaluations, tests and other data developed to establish compliance with each of the specific requirements in CS 25.1302(a) through (d) should address integration of new or novel design features or equipment with previously approved features or equipment as well as with other new items. It should include consideration of the following integration factors:

- Consistency (see 5.7.2)
- Consistency trade-offs (see 5.7.3)
- Flight deck environment (see 5.7.4)
- Integration related workload and error (see 5.7.5)

5.7.2 Consistency

Consistency needs to be considered within a given system and across the flight deck. Inconsistencies may result in vulnerabilities, such as increased workload and errors, especially during stressful situations. For example, in some flight management systems, the format for entering latitude and longitude differs across the display pages. This may induce flight crew errors, or at least increase flight crew workload. Additionally, errors may result if latitude and longitude is displayed in a format that differs from formats on the most commonly used paper charts. Because of this, it is desirable to use formats that are consistent with other media whenever possible. Although trade-offs exist, as discussed in the next paragraph, the following are design attributes to consider for consistency within and across systems:

- Symbology, data entry conventions, formatting, colour philosophy, terminology, and labelling.
- Function and logic. For example, when two or more systems are active and performing the same function, they should operate consistently and use the same style interface.
- Information presented with other information of the same type that is used in the flight deck. For example, navigation symbology used on other flight deck systems or on commonly used paper charts should be considered when developing the symbology to be used on electronic map displays.
- The operational environment. It is important that a flight management system is consistent with the operational environment so that the order of the steps required to enter a clearance into the system is consistent with the order in which they are given by air traffic management.

Adherence to a flight deck design philosophy is one way to achieve consistency within a given system as well as within the overall flight deck. Another way is to standardise aspects of the design by using accepted, published industry standards such as the labels and abbreviations recommended in ICAO Annex 8400/5. The applicant might Standardise symbols used to depict navigation aids (the very high frequency omnidirectional ranges, VORs, for example), by following the conventions recommended in SAE ARP5289. However, inappropriate standardisation, rigidly applied, can be a barrier to innovation and product improvement. Additionally, standardisation may result in a standard to the lowest common denominator. Thus, guidance in this paragraph promotes consistency rather than rigid standardisation.

5.7.3 Consistency Trade-Offs

It is recognised that it is not always possible or desirable to provide a consistent flight crew interface. Despite conformance with the flight deck design philosophy, principles of consistency, etc, it is possible to negatively impact flight crew workload,. For example, all auditory alerts may adhere to a flight deck alerting philosophy, but the number of alerts may be unacceptable. Consistent format across the flight deck may not work when individual task requirements necessitate presentation of data in two significantly different formats. An example is a weather radar display formatted to show a sector of the environment, while a moving map display shows a 360 degree view. In such cases it should be demonstrated that the interface design is compatible with the requirements of the piloting task and can be used individually and in combination with other interfaces without interference to either system or function.

Additionally:

- The applicant should provide an analysis identifying each piece of information or data presented in multiple locations and show that the data is presented in a consistent manner or, where that is not true, justify why that is not appropriate.
- Where information is inconsistent, that inconsistency should be obvious or annunciated, and should not contribute to errors in information interpretation.
- There should be a rationale for instances where a system's design diverges from the flight deck design philosophy. Consider any impact on workload and errors as a result of this divergence.
- The applicant should describe what conclusion the flight crew is expected to draw and what action should be taken when information on the display conflicts with other information on the flight deck (either with or without a failure).

5.7.4 Flight Deck Environment

The flight deck system is influenced by physical characteristics of the aeroplane into which a system is integrated, as well as by operational environment characteristics. The system is subject to such influences on the flight deck as turbulence, noise, ambient light, smoke, and vibrations (such as those that may result from ice or fan blade loss). System design should recognise the effect of such influences on usability, workload, and crew task performance. Turbulence and ambient light, for example, may affect readability of a display. Flight deck noise may affect audibility of aural alerts. The applicant should also consider the impact of the flight deck environment for non-normal situations, such as unusual attitude recovery or regaining control of the aeroplane or system.

The flight deck environment includes the layout, or physical arrangement of the controls and information displays. Layout should take into account crew requirements in terms of:

- Access and reach (to controls).
- Visibility and readability of displays and labels.
- Task-oriented location and grouping of human-machine interaction elements.

An example of poor physical integration would be a required traffic avoidance system obscured by thrust levers in the normal operating position.

5.7.5 Integration Related Workload and Error

When integrating functions and/or equipment, designers should be aware of potential effects, both positive and negative, that integration can have on crew workload and its subsequent impact on error management. Systems must be designed and evaluated, both in isolation and in combination with other flight deck systems, to ensure that the flight crew is able to detect, reverse, or recover from errors. This may be more challenging when integrating systems that employ higher levels of automation or have a high degree of interaction and dependency on other flight deck systems.

Applicants should show that the integrated design does not adversely impact workload or errors given the context of the entire flight regime. Examples of such impacts would be increased time to:

- Interpret a function,
- Make a decision,
- Take appropriate actions.

Controls, particularly multi-function controls and/or novel control types, may present the potential for misidentification and increased response times. Designs should generally avoid multi-function controls with hidden functions, because they increase both crew workload and the potential for error.

Two examples of integrated design features that may or may not impact error and workload are as follows:

- <u>Presenting the same information in two different formats</u>. This may increase workload, such as when altitude information is presented concurrently in tape and round-dial formats. Yet different formats may be suitable depending on the design and the flight crew task. For example, an analog display of engine revolutions-per-minute can facilitate a quick scan, whereas a digital numeric display can facilitate precise inputs. The applicant is responsible for demonstrating compliance with CS 25.1523 and showing that differences in the formats do not result in unacceptable workload levels.

- Presenting conflicting information. Increases in workload and error may result from two displays depicting conflicting altitude information on the flight deck concurrently, regardless of format. Systems may exhibit minor differences between each flight-crew member station, but all such differences should be evaluated specifically to ensure that potential for interpretation error is minimised, or that a method exists for the flight crew to detect incorrect information, or that the effects of these errors can be precluded.

The applicant should show that the proposed function will not inappropriately draw attention away from other flight deck information and tasks in a way that degrades flight crew performance and decreases the overall level of safety. There are some cases where it may be acceptable for system design to increase workload. For example, adding a display into the flight deck may increase workload by virtue of the additional time flight-crew members spend looking at it, but the safety benefit the additional information provides may make it an acceptable trade-off.

Because each new system integrated into the flight deck may have a positive or negative effect on workload, each must be evaluated in isolation and combination with the other systems for compliance with CS 25.1523. This is to ensure that the overall workload is acceptable, i.e., that performance of flight tasks is not adversely impacted and that the crew's detection and interpretation of information does not lead to unacceptable response times. Special attention should be paid to CS-25 Appendix D and specifically compliance for items that the appendix lists as workload factors. They include "accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls."

6. MEANS OF COMPLIANCE

This paragraph discusses considerations in selecting means of compliance. It provides six general acceptable means to demonstrate compliance in addressing human performance issues. These means of compliance are generic and have been used in certification programmes. The acceptable means of compliance to be used on any given project should be determined on a case-by-case basis, driven by the specific compliance issues. They should be developed and proposed by the applicant, and then agreed to by the Agency. Uses and limitations of each type of compliance means are provided in paragraph 6.3.

6.1 Selecting Means of Compliance

The means of compliance discussed in this paragraph include:

- Statements of similarity (See paragraph 6.3.1),
- Design description (See paragraph 6.3.2),
- Calculations/analyses (See paragraph 6.3.3),
- Evaluations (See paragraph 6.3.4),
- Tests (See paragraph 6.3.5),

There is no generic method to determine appropriate compliance means for a specific project. The choice of an appropriate compliance means or combination of several different means depends on a number of factors specific to a project.

Some certification projects may necessitate more than one means of demonstrating compliance with a particular requirement. For example, when flight testing in a conforming aeroplane is not possible, a combination of design review and part-task simulation evaluation may be proposed.

Answering the following questions will aid in selecting means of compliance.

- With which means of compliance will it possible to gather the required certification data?
- Will a single means of compliance provide all of the data or will several means of compliance be used in series or in parallel?
- What level of fidelity of the facility is required to collect the required data?
- Who will be the participants?
- What level of training is required prior to acting as a participant?

- How will the data from an evaluation be presented to show compliance?
- Will results of a demonstration be submitted for credit?
- If a test is required, what conformed facility will be used?

6.2 Discussion and Agreement with the Agency on Compliance Demonstrations

The applicant's proposal for means of compliance must be coordinated with the Agency to ensure that all aspects necessary for desired credit towards certification are achieved. These could include the planned scenarios, the necessary types of human performance issues to be explored, or the conditions under which the test will be conducted to provide a realistic environment for the evaluation.

6.3 Description of Means of Compliance

The six general means of compliance found to be acceptable for use in demonstrating compliance related to flight deck design are described in the following sub-paragraphs.

6.3.1 Statement of Similarity

Description
A statement of similarity is a description of the system to be approved and a description of a previously approved system detailing the physical, logical, and operational similarities with respect to compliance with requirements.
Deliverable
A statement of similarity could be part of a certification report, containing references to existing certification data/documents.
Participants
Not applicable.
Conformity
Not applicable.
Uses
It may be possible to substantiate the adequacy of a design by comparing it to previously certificated systems shown to be robust with respect to lack of contribution to crew error and/or capability of the flight crew to manage the situation should an error occur. This avoids repetition of unnecessary effort to justify the safety of such systems.
Limitations
A statement of similarity to show compliance must be used with care. The flight deck should be evaluated as a whole, not as merely a set of individual functions or systems. Two functions or features previously approved on separate programmes may be incompatible when combined on a single flight deck. Also, changing one feature in a flight deck may necessitate corresponding changes in other features, to maintain consistency and prevent confusion.
Example
If the window design in a new aeroplane is identical to that in an existing aeroplane, a statement of similarity may be an acceptable means of compliance to meet CS 25.773.

6.3.2 Design Description

The applicant may elect to substantiate that the design meets the requirements of a specific paragraph by describing the design. Applicants have traditionally used drawings, configuration descriptions, and/or design philosophy to show compliance. Selection of participants and conformity are not relevant to this means of compliance.

a. Drawings

Description
Layout drawings or engineering drawings, or both, depicting the geometric arrangement of hardware or

display graphics.
Deliverable
The drawing, which can be part of a certification report.
Uses
Applicants can use drawings for very simple certification programmes when the change to the flight deck is very simple and straightforward. Drawings can also be used to support compliance findings for more complex interfaces.
Limitations
The use of drawings is limited to physical arrangements and graphical concerns.

b. Configuration Description

Description
A configuration description is a description of the layout, general arrangement, direction of movement, etc., of regulated item. It can also be a reference to documentation, giving such a description (for example from a different project with similar layout) . It could be used to show the relative locations of flight instruments, groupings of control functions, allocation of colour codes to displays and alerts, etc.
Deliverable
Explanation of functional aspects of crew interface: text description of certification item and/or functional aspects of the crew interface with the system (with visuals as appropriate).
Uses
Configuration descriptions are generally less formalised than engineering drawings. They are developed to point out features of the design that support a finding of compliance. In some cases, such configuration descriptions may provide sufficient information for a finding of compliance. More often, however, they provide important background information, while final confirmation of compliance is found through other means, such as demonstrations or tests. The background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with demonstrations or tests. The applicant will have already communicated how a system works with the configuration description and any discussions or assumptions may have already been coordinated.
Limitations
Configuration descriptions may provide sufficient information for a finding of compliance with a specific requirement. More often, though, they provide important background information, while final confirmation of compliance is found by other means, such as demonstrations or tests. Background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with the demonstrations or tests.

c. Design philosophy

Description
A design philosophy approach can be used to demonstrate that an overall safety-centred philosophy, as detailed in the design specifications for the product/system or flight deck, has been applied.
Deliverable
Text description of certification item and/or functional aspects of the crew interface with the system (with figures and drawings as appropriate) and its relationship to overall design philosophy.
Uses
Documents the ability of a design to meet requirements of a specific paragraph.
Limitations
In most cases, this means of compliance will be insufficient as the sole means to demonstrate compliance.
Example

Design philosophy may be used as a means of compliance when a new alert is added to the flight deck, if the new alert is consistent with the acceptable existing alerting philosophy.

6.3.3 Calculation/analysis

Description
Calculations or engineering analyses ("paper and pencil" assessments) that do not require direct participant interaction with a physical representation of the equipment.
Deliverable
Report detailing the analysis, its components, evaluation assumptions, and basis for decision making. The report details results and conclusions.
Participants
Conducted by the applicant.
Conformity
Not applicable.
Uses
Provides a systematic evaluation of specific or overall aspects of the human interface part of the product/system/flight deck. May be specified by guidance material.
Limitations
Carefully consider the validity of the assessment technique for analyses not based on advisory material or accepted industry standard methods. Applicants may be asked to validate any computational tools used in such analyses. If analysis involves comparing measured characteristics to recommendations derived from pre-existing research (internal or public domain), the applicant may be asked to justify the applicability of data to the project.
Example
An applicant may conduct a vision analysis to demonstrate that the flight crew has a clear and undistorted view out the windows. Similarly, an analysis may also demonstrate that flight, navigation and powerplant instruments are plainly visible from the flight-crew member station. The applicant may need to validate results of the analysis in ground or flight test.

6.3.4 Evaluations

The applicant may use a wide variety of part-task to full-installation representations of the product/system or flight deck for evaluations. These all have two characteristics in common: (1) the representation of the human interface and the system interface do not necessarily conform to the final documentation, and (2) the certification Agency is generally not present. The paragraphs below address mock-ups, part-task simulations, full simulations, and in-flight evaluations that typically make up this group of means of compliance. A mock-up is a full-scale, static representation of the physical configuration (form and fit). It does not include functional aspects of the flight deck and its installed equipment.

Description
Evaluations are assessments of the design conducted by the applicant, who then provides a report of the results to the Agency.
Deliverable
A report, delivered to the Agency.
Participants
Applicant and possibly Agency
Facilities
An evaluation can be conducted in a mock-up, on a bench, or in a laboratory, simulator or aeroplane.
Conformity
Conformity is not required.
Mock-up evaluation

Mock-ups can be used as representations of the design, allowing participants to physically interact with the design. Three-dimensional representations of the design in a CAD system, in conjunction with three-dimensional models of the flight deck occupants, have also been used as “virtual” mock-ups for certain limited types of evaluations. Reach assessments, for example, can use either type of mock-up.
Example of a mock-up evaluation
An analysis to demonstrate that controls are arranged so that flight-crew members from 1.58 m (5ft 2 inches) to 1.91 m (6ft 3 inches) in height can reach all controls. This analysis may use computer-generated data based on engineering drawings. The applicant may demonstrate results of the analysis in the actual aeroplane.
Bench or laboratory evaluation
The applicant can conduct an evaluation using devices emulating crew interfaces for a single system or a related group of systems. The applicant can use flight hardware, simulated systems, or combinations of these.
Example of a bench or laboratory evaluation
A bench evaluation for an integrated system could be an avionics suite installed in a mock-up of a flight deck, with the main displays and autopilot controls included. Such a tool may be valuable during development and for providing system familiarisation to the Agency. However, in a highly integrated architecture, it may be difficult or impossible to assess how well the avionics system will fit into the overall flight deck without more complete simulation or use of the actual aeroplane.
Simulator evaluation
A simulator evaluation uses devices that present an integrated emulation (using flight hardware, simulated systems, or combinations of these) of the flight deck and the operational environment. These devices can also be “flown” with response characteristics that replicate, to some extent, responses of the aeroplane. Simulation functional and physical fidelity (or degree of realism) requirements will typically depend on the configurations, functions, tasks, and equipment.
Aeroplane evaluation
This is an evaluation conducted in the actual aeroplane.
Uses
Traditionally, these types of activities have been used as part of the design process without formal certification credit. However, these activities can result in better designs that are more likely to be compliant with applicable requirements.
Limitations
Evaluations are limited by the extent to which the facilities actually represent the flight deck configuration and realistically represent flight crew tasks. As flight deck systems become more integrated, part-task evaluations may become less useful as a means of compliance, even though their utility as engineering tools may increase.

6.3.5 Tests

Tests are means of compliance conducted in a manner very similar to evaluations (described above in paragraph 6.3.4). There is, however, a significant difference. Tests require a conforming product/system and system interface. A test can be conducted on a bench, in a laboratory, in a simulator, or on an aeroplane.

Description
Tests are assessments of the design conducted with the Agency present.
Deliverable
A report, delivered to the Agency.
Participants
Applicant and possibly Agency
Facilities
A test can be conducted on a bench or in a laboratory, simulator or an aeroplane.
Conformity

The facility must be conforming.
Bench or laboratory test
This type of testing is usually confined to showing that components perform as designed. Bench tests are usually not enough to stand alone as a means of compliance. They can, however, provide useful supporting data in combination with other means.
Example of a bench or laboratory test
The applicant might show visibility of a display under the brightest of expected lighting conditions with a bench test, provided there is supporting analysis to define the expected lighting conditions. Such supporting information might include a geometric analysis to show potential directions from which the sun could shine on the display, with calculations of expected viewing angles. These conditions might then be reproduced in the laboratory.
Conformity related to a bench or laboratory test
The part or system would need to be conforming to show compliance.
Simulator test
A simulator test uses devices that present an integrated emulation (using flight hardware, simulated systems, or combinations of these) of the flight deck and the operational environment. They can also be "flown" with response characteristics that replicate the responses of the aeroplane. The applicant should determine the physical and functional fidelity requirements of the simulation as a function of the issue under evaluation.
Simulator test conformity and fidelity issues
Only conforming parts of the flight deck may be used for simulator tests. Applicants may use a flight crew training simulator to validate most of the normal and emergency procedures for the design, and any workload effects of the equipment on the flight crew. If the flight deck is fully conforming and the avionics are driven by conforming hardware and software, then the applicant may conduct and use integrated avionics testing for showing compliance. Note that not all aspects of the simulation must have a high level of fidelity for any given compliance issue. Rather, assess fidelity requirements in view of the issue being evaluated.
Aeroplane test
Aeroplane tests can be conducted either on the ground or in flight.
Example of an aeroplane test
An example of a ground test is an evaluation for the potential of reflections on displays. Such a test usually involves covering the flight deck windows to simulate darkness and setting the flight deck lighting to desired levels. This particular test may not be possible in a simulator, because of differences in the light sources, display hardware, and/or window construction. Flight testing during certification is the final demonstration of the design. These are tests conducted in a conforming aeroplane during flight. The aeroplane and its components (flight deck) are the most representative of the type design to be certified and will be the closest to real operations of the equipment. In-flight testing is the most realistic testing environment, although it is limited to those evaluations that can be conducted safely. Flight testing can be used to validate and verify other tests previously conducted during the development and certification programme. It is often best to use flight testing as final confirmation of data collected using other means of compliance, including analyses and evaluations.
Limitations of flight tests
Flight tests may be limited by the extent to which flight conditions of particular interest (for example, weather, failure, unusual attitudes) can be found/produced and then safely evaluated in flight. Also note that flight testing on the aeroplane provides the least control over conditions of any of the means of compliance. The Agency and the applicant should thoroughly discuss how and when flight tests and their results will be used to show compliance.

AMC 25.1302 APPENDIX 1: Related regulatory material and documents

The following is a list of requirements, acceptable means of compliance and other documents relevant to flight deck design and flight crew interfaces which may be useful when reviewing this AMC.

1.1 Related EASA Certification Specifications

Table 1.1 List of related regulations and AMCs referenced in this document:

CS-25 BOOK 1 Requirements	***General topic***	***CS-25 BOOK 2 Acceptable Means of Compliance***
CS 25.785 (g)	Seats, berths, safety belts and harnesses	AMC 25.785 (g)
CS 25.1309(c)	Minimising flight crew errors that could create additional hazards.	AMC 25.1309
CS 25.1523	Minimum flight crew and workload.	AMC 25.1523
CS 25.1321	Arrangement and visibility	
CS 25.1322	Colours for warning, caution, or advisory lights.	AMC 25.1322
CS 25.1329	Autopilot, flight director, autothrust	AMC 25.1329
	Electronic displays	AMC 25-11
CS 25.1543	Instrument markings - general	AMC 25.1543

Note: The table above does not list all requirements associated with flight deck design and human performance. This AMC does not provide guidance for requirements that already have specific design requirements, such as CS 25.777(e), which states that "Wing flap controls and other auxiliary lift device controls must be located on top of the pedestal, aft of the throttles, centrally or to the right of the pedestal centerline, and not less than 25 cm (10 inches) aft of the landing gear control."

1.2 RESERVED

1.3 FAA Orders and Policy

- Policy Memo ANM-99-2, Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks.
- Policy Memo ANM-0103, Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flight Deck Certification.
- FAA Notice 8110.98, Addressing Human Factors/Pilot Interface Issues of Complex, Integrated Avionics as Part of the Technical Standard Order (TSO) Process

1.4 Other documents

Following is a list of other documents relevant to flight deck design and flight crew interfaces that may be useful when reviewing this AMC. Some contain special constraints and limitations, however, particularly those that are not aviation specific. For example, International Standard ISO 9241-4 has much useful guidance that is not aviation specific. When using that document, applicants should consider environmental factors such as the intended operational environment, turbulence, and lighting as well as cross-side reach.

- SAE ARP 4033 (Pilot-System Integration), August 1995
- SAE ARP5289, Electronic Aeronautical Symbols
- SAE ARP-4102/7, Electronic Displays
- FAA Human Factors Team report on: The Interfaces Between Flightcrews and Modern Flight Deck Systems, 1996
- DOT/FAA/RD –93/5: Human Factors for Flight Deck Certification Personnel
- ICAO 8400/5, Procedures for Air Navigation Services ICAO Abbreviations and Codes. Fifth Edition, 1999
- ICAO Human Factors Training Manual: DOC 9683 – AN/950
- International Standards ISO 9241-4, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)

AMC 25.1302 APPENDIX 2: Definitions and acronyms.

Following is a list of terms, abbreviations, and acronyms used throughout this advisory material and in CS-25.

2.1 Abbreviations and acronyms

AC – Advisory circular

AMC – Acceptable Means of Compliance

CS – Certification Specifications

DOT – Department of Transportation

EASA – European Aviation Safety Agency

FAA – Federal Aviation Administration

ICAO – International Civil Aviation Organization

ISO – International Standards Organization

JAR – Joint Aviation Requirements

JAR OPS – Joint Aviation Requirements (Commercial Air Transportation - Aeroplanes)

MOC – Means of Compliance

SAE – Society of Automotive Engineers

STC – Supplemental Type Certificate

TAWS – Terrain Awareness Warning System

TCAS – Traffic Collision Avoidance System

TSO – Technical Standards Order

VOR – Very High Frequency Omnidirectional Range

2.2 Definitions

Following is a list of terms and definitions used in this AMC.

Alert – A generic term used to describe a flight deck indication meant to attract the attention of the flight crew, and identify to them a non-normal operational or aeroplane system condition. Warnings, Cautions, and Advisories are considered to be lerts. (Reference definition in AMC 25.1322)

Automation – The autonomous execution of a task (or tasks) by aeroplane systems started by a high-level control action of the flight crew.

Conformity – Official verification that the flight deck/system/product conforms to the type design data. Conformity of the facility is one parameter that distinguishes one means of compliance from another.

Control Device (Flight Deck Control) – Device used by the flight crew to transmit their intent to the aeroplane systems.

Cursor Control Device – Control device for interacting with virtual controls, typically used with a graphical user interface on an electro-optical display.

Design Philosophy – A high-level description of human-centred design principles that guide the designer and aid in ensuring that a consistent, coherent user interface is presented to the flight crew.

Display – Device (typically visual but may be auditory or tactile) that transmits data or information from the aeroplane to the flight crew.

Multifunction Control – A control device that can be used for many functions as opposed to a control device with a single dedicated function.

Task Analysis – A formal analytical method used to describe the nature and relationship of complex tasks involving a human operator.

41. Amend the references in AMC 25.1329 as follows:

AMC 25.1329
Automatic Pilot

.....

4.3 *Control Wheel Steering Mode (CWS).* Where the pilot has the ability to make inputs to the automatic pilot by movement of the normal control wheel (control wheel steering) –

a. It should be possible for the pilot to overpower the automatic pilot and to achieve the maximum available control surface deflection without using forces so high that the controllability requirements of CS 25.143(~~c~~d) are not met;

.....

e. In showing compliance with CS 25.143(~~f~~g) account should be taken of such adjustments to trim as may be carried out by the automatic pilot in the course of manoeuvres, which can reasonably be expected. Some alleviation may be acceptable in the case of unusually prolonged manoeuvres provided the reduced control forces would not be hazardous;

.....

5.3.1 *General*

.....

b. Following recognition of the Failure Condition b the pilot, a delay, as specified in paragraphs 5.3.2, 5.3.3, 5.3.4 and 5.3.5 should be applied before the commencement of recovery action. Following such delay the pilot should be able to return the aeroplane to its normal flight attitude under full manual control without engaging in any dangerous manoeuvres during recovery and without control forces exceeding the values given in CS 25.143(~~c~~d).

.....

42. Correct the existing title of AMC 25.1360(a) to read:

AMC 25.1360(a)
~~Protection~~ Precaution Against Injury

43. Correct the existing title of AMC 25.1360(b) to read:

AMC 25.1360(b)
~~Protection~~ Precaution Against Injury