Advisory Circular (AC)

Stalls, Compliance (Commuter Category Aeroplanes)

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this Advisory Circular (AC) is to provide guidance material for acceptable means, but not the only means, of demonstrating compliance with the requirements of Chapter 523 of the Airworthiness Manual (AWM) dealing with stall demonstration of commuter category aeroplanes. Like all advisory material, this AC is not mandatory and does not constitute a regulation. As a guidance document, its purpose is to outline a method of compliance with existing standards. The applicant may elect to follow an alternate method, which must be acceptable to Transport Canada as a means of compliance with the requirements of Chapter 523 of the Airworthiness Manual. Hence the terms "shall" and "must" used herein apply only to an applicant who chooses to follow this particular method without deviations.

1.2 Guidance Applicability

This document is applicable to all Transport Canada personnel, delegates and industry.

1.3 Description of Changes

This document, formerly AMA No. 523/1A, is reissued as an AC. With the exception of minor editorial changes, the content is unaltered.

1.4 Termination

This document does not have a terminating action. It will however, be reviewed periodically for suitability of content.

2.0 REFERENCES

2.1 Reference Documents

It is intended that the following reference material be used in conjunction with this document:

Chapter 523 of the Airworthiness Manual, (AWM)-*Normal, Utility, Aerobatic And Commuter Category Aeroplanes*.

2.2 Cancelled Document

As of the effective date of this document, AMA No. 523/1A dated 8 November 1999 is cancelled.

3.0 BACKGROUND

This advisory material together with the applicable airworthiness requirements variations published in Chapter 523 constitutes Transport Canada's requirements dealing with stall demonstration, stall warning and stall indication systems.

4.0 DEFINITIONS

"*Stall Indication System*" is that system which activates at the stall and includes all applicable elements contributing to the automatic control actuation device (e.g. stick pusher) as well as any tactile, visual and/or audible indications.

"*Stall Protection System*" consists of the elements of the stall warning system and the stall indication system.

"*Stall Warning System*" is that system which provides advance warning of the stall and consists of all elements contributing to and including the tactile, audible and visual functions.

5.0 DISCUSSION AND ACCEPTABLE TECHNIQUES

5.1 For aeroplanes

Fitted with stall warning systems, and/or stall indication systems, a demonstration at near maximum approved altitude is required (See 5.3 and 5.4).

5.2 Controllability and Manoeuvrability (523.143)

In showing compliance with the requirements of 523.143 the aeroplane must demonstrate a minimum manoeuvring capability at the reference speeds established by the applicant. Minimum normal load factors required at the onset of stall warning are given in Table 1. The load factor obtained at stall warning onset may be corrected for small variations from the specified reference speeds using agreed methods. The aeroplane should be trimmed at the specified speed. Usually only maximum take-off weight and maximum landing weight (as appropriate) with the associated forward c.g. position are tested.

Table 1 - Minimum Normal Load Factor (N) At Stall Warning Onset

Configuration	Load factor (n)	Speed	Power or Thrust
Take-off (all engines)	1.15	V_2	Critical engine at idle. Other engine(s) at setting for climb gradient limited to take-off. *
Take-off	1.31	**V_2 + XX	Any setting from that required for level flight to all engines take-off. *
En route (engine out)	1.31	V_{Final}	Critical engine at idle. Other engine(s) at any setting from that required for level flight to maximum continuous power. *
Landing (all engines)	1.31	V_{ref}	Any setting from that required for level flight to setting used for final approach in landing distance determination.

* *Not to exceed the power or thrust available for a climb-gradient limited take-off.*

** *V_2 + XX All engine safety speed.*

5.3 Stalls

For aeroplanes with stall indication systems, satisfactory operations of the stall indication system must be demonstrated at the maximum approved operating altitude unless a natural stall precedes the point at which the stall indicating system operates.

5.4 Stall-Warning (523.207)

A clearly distinguishable stall warning under expected conditions of flight must be provided to the pilot with sufficient margin to prevent inadvertent stalling. Such a warning is one, which cannot be misinterpreted or mistaken for other warnings.

(a) Where stall warning is provided by artificial means, a stall warning system demonstration at near maximum approved altitude is required unless compliance with 523.207 (a) is shown by inherent aerodynamic qualities of the aeroplane to precede the point at which the stall warning system activates.

(b) The artificial stall-warning device referred to in 523.207(b) must include means to provide a clearly audible warning to the flight crew. This rule recognises that with the advent of modern automatic flight control systems a stick shaker with purely tactile characteristics may not provide the required clear and distinct warning. A tactile device with suitable audible characteristics may be found acceptable.

(c) In evaluating the acceptability of the audible characteristics of a stall warning system the following operating conditions should be taken into consideration:

(i) Pilots wearing good quality exterior sound reducing earphones;

(ii) pilot workload such as monitoring VHF, navigation/approach aids, crew briefings (during evaluation, continuous audio should be present at normal volume levels);

(iii) presence of other audio warnings such as gear horn; and

(iv) any other flight deck pilot distractions, appropriate to the type being assessed (such as air conditioning duct or blower noise).

(d) In addition to the entry rate requirements of 523.201 and 523.203 in straight and turning flight, stall warning with sufficient margin to prevent inadvertent stalling must also be demonstrated under dynamic entry conditions. The following is acceptable:

(i) for the purpose of this demonstration, an adequate margin is one which prevents inadvertent stalling when normal corrective (recovery) action is taken by the pilot one second after the onset of unmistakable warning during the manoeuvre described in (ii), with:

1) the most adverse c.g.;

2) the stall warning system and, when applicable, the stall indication system set to production tolerances which would result in the smallest margin between warning and stall;

3) flaps rigged in the most critical position including the maximum tolerated asymmetry if such an asymmetry could produce an appreciable adverse effect;

(ii) the entry condition shall be a slow-down turn manoeuvre in the configurations specified in Table 2 at a load factor at stall warning onset of not less than 1.5 g or that assessed as appropriate to type, whichever is greater;

(iii) entry rates required are approximately one knot per second for normal manoeuvres and at higher rates appropriate to the type of aeroplane, but not less than three knots per second. Small thrust or power changes may be utilised to control entry rate;

(iv) for aeroplanes with a stall warning system the entry rate will be such as to verify any biasing of the system due to rate of change of angle of attack; and

(v) once the appropriate load factor and entry rate have been achieved they should be maintained until recovery action is initiated (warning plus one second).

Table 2 - Stall Warning Margin Tests

A/C Configuration *	Gross Weight	Trim Speed	Thrust or Power for Trim
Take-off	Maximum Take-off	1.4VS	Symmetric setting for Climb gradient limited take-off.
En route	Maximum at Altitude	1.4VS	Symmetric setting for level flight.
Approach	Maximum Landing Weight	1.4VS	Symmetric setting for level flight.
Landing	Maximum Landing Weight	1.4VS	Symmetric setting used for final approach in landing distance determination.
* *Configurations noted shall also include extension of lift/drag devices as permitted by the AFM*.			

5.5 Stall Protection System Design Considerations

(a) **System Design**

(i) **Arming and Disarming**

1) For aeroplanes which incorporate a stick pusher (i.e. a device which modifies the stalling characteristics by applying an abrupt and large forward force on the control column when the aeroplane is at an angle of attack below, equal to, or higher that that for the aerodynamic stall), the system for operating the device should be such that the system is automatically armed, and will remain armed, in each configuration in which operation of the system is necessary to show compliance with the stalling requirements, except that the system may be disarmed automatically at air speeds at and above which the risk of stalling as a result of an atmospheric disturbance is Extremely Remote (e.g. a 66 ft/sec gust), in which case the system should automatically re-arm when the airspeed falls below those speeds.

***Note 1**:*

Although desirable that full stall protection should be available immediately at lift-off it would normally be acceptable for a stick-pusher to be inhibited during the take-off rotation, typically 5 to 10 seconds. In addition it has previously been found acceptable to have an inhibition of the stick pusher below a specified radio altimeter height of 400 ft based on the aerodynamic stalling characteristics of the aircraft involved and the design philosophy of the stick pusher system installed.

***Note 2**:*

Although a similar inhibition of any phase advance on the stick-shaker would normally be acceptable, inhibition of the stick-shaker itself is not normally acceptable, except at low speeds during the take-off roll when the angle of attack sensors may be improperly aligned.

2) A means of disarming the system should be provided, and should be capable of being readily selected by the pilots. It should be effective at all times, and should be capable of preventing the system from making any input to the longitudinal control system, and of removing any input

which has already been applied (whether as a result of failures or normal operation of the system). Additional means to permanently disable the stick pusher function following a system failure are acceptable provided these means are not subject to inadvertent operation.

(ii) **Failures and Malfunctions**

1) The design of the system should be such that compliance can be shown with (2) and (3). This should be established by means of failure and reliability analyses of the system and its components according to the principles outlined in FAA AC 25.1309-1A.

***Note**:*

With reference to paragraph (3) on unwanted operation, where failures are only critical for a particular period of flight the hazard must be averaged over the whole of the expected mean flight time.

2) **Failure to Operate** - The probability of the device failing to operate should be on the order of 10^{-4} or less unless it is shown that stall characteristics without the stick pusher are not hazardous, in which case the probability of failure should be on the order of 10^{-3} or less. In addition, the probability of failure of stall warning together with stick pusher should be on the order of 10^{-7} or less. In making an assessment, potential failures and combinations of failures should be taken into account.

***Note**:*

The standard of reliability specified in (2) is the minimum necessary to provide an adequate level of protection for unintended stalls. The standard of protection required for deliberate stalls (eg. in the course of test flying and crew training) including fault survival capability of the system, and any additional instrumentation, inspection, and operating procedures should be agreed.

3) **Unwanted Operation**

(A) To ensure crew confidence in the device, experience has shown it is necessary that:

(1) no single failure should result in unwanted operation of the stick-pusher; and

(2) the probability of unwanted operation from all causes should not exceed 10^{-5} per hour.

(B) The probability of unwanted operation should not exceed 10^{-7} per hour if, taking into account corrective pilot action, this would result in the total normal acceleration of the aeroplane becoming negative, or in the design limit load in any part of the aeroplane structure being exceeded.

(C) The probability of unwanted operation should not exceed 10^{-9} per hour if, taking into account corrective pilot action, this would result in the ultimate load in any part of the aeroplane structure being exceeded.

(D) The probability of unwanted operation should not exceed 10^{-9} per hour if, taking into account corrective pilot action, this may result in a catastrophic ground contact during takeoff and landing operations.

Notes *to (B), (C) and (D)*:

In the climb, cruise and descent flight regimes, corrective pilot action should not be assumed to be initiated until 3 seconds after unwanted operation has been recognised. During final approach this minimum may be reduced to 1 second.

(iii) **Indicating and Warning Devices**

1) Warning that the system (including the stick pusher itself) has failed should be provided. As far as is practicable, this warning should cover all system failure modes.

***Note 1**:*

It would be acceptable on failure of the stick-pusher system to illuminate an amber light and Master Caution. Correct operation of the stick-pusher should not cause any such indication.

***Note 2**:*

In addition to the stick pusher it is acceptable to have stall aural devices (e.g. horn) and indications (e.g. discrete annunciator lights) to indicate the pusher activation point.

2) Clear and distinctive indication should be given, and should continue to be given, that the means of disarming the system required by (i)(2) has been operated.

(b) **Handling Characteristics**

(i) The operation of the device, in straight and turning flight stalls should be such that the aeroplane with the system operating normally complies with all relevant stalling requirements including the tests specified in this AC.

(ii) The design of the system should be such that flight in turbulence, up to the most severe that is likely to be encountered, is unlikely to result in such operation of the device as would significantly increase the difficulty of flying in those conditions.

(iii) The effect of operation of the device should be to reduce the angle of attack to a substantial margin below the stall, so as to make an inadvertent return to the stalled condition unlikely.

(iv) The characteristics of the stick-pusher should be such that it is unlikely that a member of the flight crew will prevent or delay its operation.

Note:

The required stick force, rate of application and stick travel will depend on the aeroplane's stall and stick force characteristics but a force in the region of 50 to 80 pounds applied virtually instantaneously has been accepted as providing this characteristic.

(v) Normal operation of the stick-pusher during a stall should not result in the total normal acceleration of the aeroplane becoming negative, nor in the design limit load in any part of the aeroplane structure being exceeded.

(vi) The longitudinal manoeuvring capability of the aeroplane in reasonably steady manoeuvres, at all speeds likely to be encountered in normal operations, should be substantially the same as would be expected to be available at the same speed for an aeroplane having conventional stalling characteristics (i.e. the manoeuvre capability should not be reduced below a normal level because of the operating characteristics of the system).

(c) **System Tolerances**

Flight tests to determine the stalling speeds under AWM 525.103 may be conducted with the system adjusted to operate at the nominal angle of attack within an acceptably narrow design range (eg. corresponding to +1 knot). Flight tests to determine stalling characteristics should be made with the system adjusted to the upper limit of tolerance on angle of attack.

6.0 HEADQUARTERS CONTACT

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