AMA: **549.101A**

Date: **1 April 1996**

AIRWORTHINESS MANUAL ADVISORY (AMA)

Subject: Amateur-Built Aircraft Aerobatic Demonstration And Evaluation
(This AMA supersedes AMA 549.101 dated 15 August 1987)

1. Purpose.

This advisory information (AMA) provides criteria for the evaluation of the suitability of amateur-built aircraft to perform aerobatic flights.

2. Reference Airworthiness Standards

Chapter 549, Amateur-Built Aircraft, Subchapters A and B.

3. Background.

A previous version of this AMA provided a detailed evaluation and procedure whereby amateur-built aircraft could be approved for aerobatic flight. The process, while providing comprehensive guidelines and a procedure, became unwieldy and could be very expensive, to the point where it was not satisfying industry needs. The simplified system used by the Federal Aviation Administration. USA (FAA) was studied and, with some modification, was determined to provide an acceptable level of safety in Canada, while at the same time providing a simplified, inexpensive method for obtaining an aerobatic authorisation for amateur-built aircraft in Canada.

4. Discussion.

(a) For aerobatic aircraft it is essential that any evaluation be accurate and precise so that a concise picture of the capabilities and shortcomings of a design can be noted and each design can be judged on its own merits.

(b) The removal of aerobatic restrictions should not be construed as a guarantee of aerobatic capability but simply an indication of structural and aerodynamic capability to survive the aerobatic environment.

(c) This AMA is divided into two parts. Section 5 (Part A) applies to those owners who wish to follow the simplified procedure for obtaining a one-off aerobatic authorisation for their own aircraft for the specific manoeuvres demonstrated in flight. Section 6 (Part B) applies to those owners desiring an unlimited aerobatic authorisation and may apply to the type providing they are built according to designers plans and instructions.

PART A

5. Simplified One-Off Aerobatic Demonstration Procedure.

This simplified procedure for the removal of the aerobatic restriction is valid for the specific aeroplane evaluated and is not considered a "type evaluation" as are the procedures of section 6 (Part B). This simplified procedure requires a flight demonstration of those manoeuvres the pilot/owner wishes to perform in his aeroplane.

(a) *Pilot Qualifications*. The pilot demonstrating the aerobatic manoeuvres should have some knowledge and experience in performing aerobatics. This may include the holder of a current Aerobatic Flight Demonstration Certificate issued by Transport Canada, a Designated Airworthiness Representative (Flight Test), the holder of a current Statement of Aerobatic Competency issued by the FAA, current aerobatic instructors and members of recognised aerobatic organisations, current and former military pilots with recognised training in aerobatics. Recreational aviation associations may be able to provide information and resources in pilot qualification determination.

(b) *Mechanical Evaluation*. Prior to performing the aerobatic manoeuvres, the pilot should perform a mechanical evaluation of the aircraft using section 6 (b) (Part B) of this AMA as a guide.

(c) *Flight Evaluation*. No violent or aerobatic manoeuvres shall be performed until sufficient flight experience has been gained to establish that the aircraft is satisfactorily controllable throughout its normal range of speeds and manoeuvres.

Prior to performing any aerobatic manoeuvres, the flutter, vibration, and buffeting, stall and departure manoeuvres, and spinning characteristics of the aircraft should be investigated and established, using paragraphs 6(c)(3) and 6(c)(4) (Part B) of this AMA as a guide. Those aerobatic manoeuvres for which an aerobatic authorisation is requested shall be performed. The pilot shall be satisfied that no unsafe features are evident; in this regard Part B of this AMA or other recognised publications may be used as a guide.

(d) *Documentation*. The pilot demonstrating the manoeuvres shall make entries in the aircraft technical records, including the Journey Log Book, listing the manoeuvres and stating his aerobatic pilot qualifications. A copy of the Journey Log containing these entries shall be forwarded to the closest Transport Canada regional or district office for the issuance of a revised Certificate of Airworthiness. The revised Special Certificate of Airworthiness will contain a statement to the effect that aerobatic manoeuvres listed may be performed in the aircraft.

(e) *Aircraft Placard*. subsections 549.115(d) requires that a placard listing the demonstrated manoeuvres be installed in plain view of the pilot. The placard does not need to include more than the basic manoeuvres of loop, roll, spin and stall-turn (hammerhead).

(f) *Modifications*. Should the aircraft be significantly modified as described in Chapter 549, section 549.23 subsequent to the aerobatic demonstration, the manoeuvres shall be demonstrated again by a pilot qualified as per subsection 5(a) above. The Aircraft Technical Records shall contain appropriate entries *(see also subsection (6)(d)).*

PART B

6. Comprehensive Type Aerobatic Evaluation.

This evaluation method may be used by those owners desiring a comprehensive aerobatic authorisation. Once authorised for a specific type, other owners of the same type may obtain an aerobatic authorisation for their aircraft providing it is not significantly changed from the initial type.

In addition to the criteria of subsection 5(a) Pilot Qualifications, 5(d) Documentation and 5(f) Modifications, the following applies:

(a) Structural Evaluation.

(1) *Limit Load Factor Classification.* Four levels of performance with increasing levels of airframe structural requirements are considered: Sportman, Intermediate, Advanced and Unlimited. The first two are adequately covered in Chapter 523 (section 523.337) by the conventional plus six, minus three load factors, although the Intermediate category would more realistically be a symmetric plus or minus six flight envelope. The Advanced and Unlimited categories are not adequately covered by Chapter 523. For these two categories symmetric flight envelopes are essential, and the design load factors should be plus and minus eight (for advanced), and nine (for unlimited) respectively. When existing regulations do not appear adequate, rational or conservative alternatives will be recommended.

(2) *Documentation.* It is the responsibility of the applicant to supply basic particulars and declare which class of aircraft was being considered. A detailed structural analysis should be provided, which would be evaluated using the appropriate load factors and Chapter 523, Appendix A, as a guide. However, complete structural analysis will not be performed for each application for the removal of aerobatic restrictions.

The integrity of the primary structure and the effect of aerobatic manoeuvre loads on airworthiness and safe operation of the aircraft would be assessed. Any performance or handling information supplied by the designer would be assessed for accuracy and applicability. Where little or no information is available entry speeds for aerobatic manoeuvres and operational limits would have to be established.

The evaluation would cover airframe strength under flight loads, the general operation of the aircraft, performance and handling characteristics and specify any deficiencies or restrictions, if necessary.

(3) *Structural Analysis.* A number of authoritative sources are available for the determination of applied air loads and the evaluation of structural capability. While structural tests would not normally be required in lieu of analysis, any unusual or questionable structure or design could result in a request for test. The use of unusual or non-standard material would require careful consideration. If a design or structural detail were found inadequate, it would be the responsibility of the applicant to rectify the problem.

(b) Mechanical Evaluation.

(1) *Cockpit Layout and Equipment.* The layout of cockpit controls should be evaluated on its own merits.

It is essential that sufficient volume and clearance be provided to allow protective and safety equipment, parachute, helmet, flight boots, etc., to be worn without compromising either comfort or aircraft operation. Pilot restraint, adequate for any proposed manoeuvres, shall be provided. The design and installation of such restraint shall preclude inadvertent release but allow easy and rapid intentional escape in any attitude and at any point within the flight envelope.

It should be possible, in an emergency, to secure all systems with the restraint harness fully tightened. Ignition switches, electrical system, fuel shut off, etc., should be positioned so that the pilot can reach them with ease.

Canopies or doors, where applicable, must be easily opened or jettisoned in flight at any point within the flight envelope, and must provide safe separation from the crew. Exit from the aircraft shall not be compromised by detail design or any inflight structural failure, at any speed up to V_D.

As required by section 549.113 subsection (d), the aircraft shall be equipped with at least one peak recording normal accelerometer. The maximum load factors experienced during aerobatic manoeuvres shall be noted in the aircraft technical records.

(2) *Systems.* Control inputs for manoeuvring and power management should not require unusual strength or dexterity. Friction and backlash in mechanical systems should not compromise ease and accuracy of operation.

The fuel system should be designed in such a manner that there will be no spillage of raw fuel or fumes into the fuselage or cockpit area during the execution of any proposed manoeuvres at any time while airborne. Equally as important, exhaust fumes shall not enter the cockpit, regardless of the air speed, attitude or manoeuvre being performed. In the event of any system deficiency, it would be the responsibility of the designer/constructor to effect a corrective modification. Such modification when accepted, would then become mandatory for the removal of aerobatic restrictions.

(3) *Weight and Balance.* The significant effects of centre of gravity location on the stability and control of an aircraft are well known. For aerobatic aircraft these effects are even more critical because of the extreme angular rates and unusual attitudes involved. If an aerobatic evaluation is to be carried out, it is essential that centre of gravity limits be determined and specified. Every aircraft must have a valid recent and up-to-date weight and balance before it can be considered for a flight test for the purpose of removing the aerobatic restriction.

Careful consideration would have to be given to any unusual mass distribution or deviation from normal light aircraft moment of inertia ratios because of the effects on high angular rate manoeuvres and post stall departure and recovery behaviour.

Flight tests are to be conducted at the fore and aft centre of gravity limits for which approval is requested.

(c) Flight Evaluation.

(1) *Flight Envelope.* Although it is not always practical to investigate every extreme of the design flight envelope, an attempt must be made to demonstrate as large a portion of the envelope as

possible. The demonstrated flight envelope, if limited for any reason, must still allow safe performance of aerobatics to the limit load factors recommended in paragraph 6(a)(1).

The main aim of the flight manoeuvring load demonstration is to assure structural capability of the aircraft under the combined moments and loads resulting from high accelerations and high angular rates. At the same time the maximum load factors experienced during various manoeuvres, as noted in paragraph 6(b)(1) shall be recorded, and any deterioration in control power or stability under high load factors should also be noted. Any apparent limitations or deficiencies in the demonstrated flight envelope shall be evaluated.

(2) *Stability and Control.* In case of lack of portable flight test instrumentation and/or recording package, the approach to evaluation of aerobatic aircraft may be more qualitative than quantitative. References (i), (j) and (k) of section 7 of this AMA contain the basis and purposes for the procedures to be followed in the evaluation.

The stability and control characteristics of the aircraft can be assessed on the basis of control forces and their variation with speed and load factor, response to pulse or double control inputs and an experienced estimate of the period and damping of the dynamic response.

(i) *Static Longitudinal Stability.* The aircraft shall have a positive static margin. In order to increase speed in steady unstalled flight a push force on the longitudinal control shall be required. A decrease in speed under the same conditions shall require a pull force. The control system friction shall not exceed the change in stick force associated with a 10% variation in the nominal trim speed.

The central force gradient (force vs speed) shall be positive (forward pressure increase to increase speed) and approximately linear at any speed from V_S to V_D using maximum continuous power and at all points within the approved W_t/C.G. envelope.

At any speed above $1.2V_s$ with the aircraft trimmed for $1.2V_s$, if the control is released, a positive pitch rate shall result. At progressively increasing airspeeds the longitudinal control shall be released and the maximum load factor attained noted and the speed that results in the design limit load factor for control release determined.

(ii) *Dynamic Longitudinal Stability.* The phugoid amplitude shall not be offensive to the pilot. The short period pitch oscillation when excited, from the stall to V_D, shall be heavily damped with controls fixed or free. The frequency and damping ratio of the short period oscillation must not be such that attempts to suppress the oscillation result in Pilot Induced Oscillation (PIO).

When longitudinal control forces are applied to achieve positive pitch rates in symmetrical pullouts from a dive or during wind-up turns, there shall be no marked decrease in stick force per G with increasing speed, nor shall there be an excessive decrease in stick force per G with increasing G at a fixed airspeed. Where a decrease in stick force per G is evident with either increasing speed or increasing G, it should be established whether this could result in any tendency to over-control in pitch or exceed G limits.

The longitudinal control forces to impose limit loads on the aircraft throughout the speed range must be of sign and magnitude such as to prevent inadvertent over-loading of the airframe.

(iii) *Lateral-Directional Stability and Control.* With the aircraft trimmed in level flight the rudder shall be slowly applied keeping the wings level with aileron. The control deflections and forces shall increase steadily, although not necessarily in constant proportions, until either control reaches full deflection or the maximum sideslip angle is reached. Increasing angles of sideslip shall require larger rudder forces and deflection and there shall be no tendency toward over balance, that is decreasing force deflection characteristics, rudder lock or force reversal.

The aircraft must exhibit positive dihedral effect with aileron forces increasing in the opposite sense to rudder forces.

In addition aileron deflection must increase with increasing sideslip to maintain wings level. When wing-tip stores are carried any loss of aileron effectiveness due to blanked airflow, such as buffeting or unusual aileron control demands will be noted. The magnitude and effect of such detrimental characteristics would have to be assessed and if necessary corrective modifications would have to be undertaken by the designer/constructor.

The aircraft should be tested in steady sideslip as described above in the speed range from $1.2V_s$ to V_D. At $1.2V_s$ rudder pulses to achieve large sideslip angles shall not result in uncontrollable flight characteristics.

A brief assessment of the lateral-directional oscillatory mode or Dutch Roll will be made to determine any adverse effects on controllability.

(iv) *Aileron Roll Rates.* Aileron stick forces and roll rates will be measured with rudder neutral and in co-ordinated rolls. When single control rolls are performed a qualitative assessment of aileron yaw and any other cross-coupling terms will be made to determine the overall effect of these characteristics on the aircraft handling and controllability. The aircraft would be evaluated over the speed range from $1.2V_S$ to V_{NE}. Full aileron deflection in both directions may be used at speeds up to V_A. Any asymmetry in control forces or aircraft response would require further investigation.

Maximum manoeuvre load factors up to two thirds the normal limit load factor will be demonstrated during rolls.

(3) *Flutter, Vibration and Buffeting.* Throughout the flight test program the pilot must make special note of any flutter, vibration or buffeting of any part of the aircraft with special attention to control surfaces and tabs.

At the first signs of any aeroelastic phenomenon an immediate assessment is required to determine whether the control of the aircraft is compromised or primary structural integrity is endangered. Such an inflight assessment relies heavily on the evaluation test pilot's experience and is one of the most critical aspects of an aerobatic flight evaluation.

Short, careful control pulses at speeds up to V_D should be employed to establish that no critical aeroelastic modes can be excited within the flight envelope of the aircraft.

(4) *Stall and Departure Manoeuvres.* Stall and departure manoeuvres cover the flight regime from partial loss of lift and control to manoeuvres resulting from the dynamic inertial coupling and residual aerodynamic forces when the maximum angle of attack is exceeded. Conventional spins, flick rolls and the more exotic tumbling manoeuvres seen in some unlimited category aerobatic displays all fall under this heading. Because of basic characteristics not all aircraft are capable of performing all of these manoeuvres. Each evaluation program would be designed to suit the particular capabilities of the aircraft under test.

(i) *Stall.* Although stall tests would likely have been done for the initial Flight Authority flight test, normal 1 g, power off stalls in all configurations should be done at airspeed reductions of 1 knot per second to confirm the applicant's tests and to establish a baseline of the aircraft handling characteristics.

Of particular interest and application to an aerobatic flight test are:

(A) Dynamic stalls in turns

(B) Power-on stalls

(C) Stalls in extreme attitudes

The aircraft shall be stalled in turns in each direction at a specified weight, centre of gravity and speed by increasing the pitch rate until the appropriate levels of stall symptoms are noted. The pilot must be alert to perceive and record any departures in roll or yaw, or lightening of the longitudinal control forces.

If practicable, the aircraft should be stalled at normal load factors approaching the design limit. This data may then be used to confirm the designer's flight envelope (V-G diagram).

An attempt will be made to stall the aircraft in a steady 1 G climb at maximum continuous power with special attention being paid to degradation of lateral and longitudinal controllability.

Stalls shall be performed at pitch attitudes approaching the vertical with both engine power off and maximum continuous power. When the stall has fully developed or the elevator has reached its stop it must be possible to regain level flight without:

(A) Excessive loss of altitude;

(B) Undue pitch-up; and

(C) An uncontrollable tendency to spin.

(ii) *Spins.* Both upright and inverted spins should be attempted. Providing that aircraft rates and attitudes stabilise, the tests may be limited to three turns prior to recovery. If the spin does not appear to be stabilised by the third turn, six turn spins should be done. The aircraft shall recover within 1½ turns from initiating recovery. The recovery technique should be conventional; i.e., full anti-spin rudder, control column forward until the spinning stops, then centralise the controls; or at the discretion of Transport Canada be such that one could easily master without any possibility of confusion. It must be impossible to obtain an uncontrollable spin with any use of the controls. Spin entries shall be initiated at pitch attitudes varying from level, 1 G entries to the extreme nose high entries that one may encounter in a Hammerhead turn.

In the event that the applicant wishes to perform in the Unlimited Category and expects to do flat, partial power spins, spin tests with partial power may be included in the test program.

For aeroplanes characteristically incapable of spinning. If it is desired to have the aircraft approved for aerobatics without showing compliance with he spin criteria (above) it must be shown that it does not spin with:

(A) The gross weight 5% greater than the maximum approved weight;

(B) The CG located at least 3% aft of the proposed limit;

(C) The available elevator-up travel 4° greater than that requested for approval;

(D) The available rudder travel 7° greater than requested approval in each direction.

(E) *Aerobatics.* The tests shall be designed to suit the particular aircraft capabilities and should cover at least the following manoeuvres:

(a) inside loop;

(b) half loop and roll out;

(c) half roll and dive out;

(d) stall turn;

(e) slow roll; and

(f) limited inverted flight within the aircraft limitations.

Where the aircraft capabilities fit into one of the four previously mentioned categories, the tests will be designed accordingly.

(d) If after aerobatic flight tests are completed, the aircraft capabilities are changed (inverted system, symmetrical aerofoils, etc.) or other major changes are made which may possibly affect the structure or handling qualities, Transport Canada will expect to be consulted with regard to further tests *(See also 5(f)).*

7. REFERENCE MATERIAL.

(a) Chapter 523 of the Airworthiness Manual, "Normal, Utility, Aerobatic and Commuter Category Aeroplanes".

(b) Official Contest Rules, Experimental Aircraft Association (EAA), Whitman Airfield, Oshkosh, WI, 54903-3086.

(c) Spanwise Air-Load Distribution. Army-Navy-Commerce Committee on Aircraft Requirements. ANC-1(1) (1938).

(d) DIEDERICH, F.W.: A Simple Approximate Method For Calculating Spanwise Lift Distributions and Aerodynamic Influence Coefficients at Subsonic Speeds. NACA TN2751 (1952).

(e) BRUHN, E.F.: Analysis and Design of Flight Vehicle Structures, Jacobs Publishing Inc., 101 East Carmel Drive, Suite 200, Carmel, Ind., 46032.

(f) Design of Wood Aircraft Structures, Munitions Board, Aircraft Committee. ANC-18 (1951).

(g) Composite Construction for Flight Vehicles: Fabrication, Inspection, Durability and Repair, MIL-HDBK-23, Part I. Material Properties and Design Criteria, ANC Bul. 23, Part II. Design Procedures, MIL-HDBK-23, Part III.

(h) Metallic Materials and Elements for Flight Vehicle Structures, Department of Defense, Military Handbook. MIL-HDBK-5.

(i) ETKIN, B.: Dynamics of Flight, Stability and Control. John Wiley and Sons, Inc. (1959).

(j) Flight Test Manual, Volume II, Stability and Control, Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization. (1959).

(k) KOTIK, M.G. et al.: Flight Test of Aircraft, NASA Technical Translation, NASA TT F-442 (1967).

(l) I.A.C. (International Aerobatic Club)Technical Tips Manual, Vol. 1 - 4 .

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