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Flight Test Certification of Primary Category Aircraft Using TP101-41E Sportplane Design Standard

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This article discusses certification standards, flight testing, and type certification of a primary category aircraft using the Transport Canada TP101-41E Ultra-Light Design Standard as the certification basis. For many years manufacturers maintained that certification standards were overly restrictive with regard to small aircraft of simple design, and therefore, restrict growth and innovation in the small airplane industry. Government agencies in conjunction with industry set forth to design a streamlined certification standard for these type aircraft. The primary category rule for type certification of aircraft of simple design intended for pleasure or personal use was adopted. Presented is an overview of certification and flight test of the Quicksilver GT 500 aircraft that was certified under the primary rule using the Transport Canada TP101-41E Ultra-Light Design Standard. Certification flight test plans and flight test techniques used to gather data are presented. Flight test data and compliance with TP101-41E are discussed. Noncompliant findings are discussed. The Quicksilver GT 500, the first aircraft certified in the primary category, was awarded a provisional-type certificate on August 1, 1993.

Nomenclature

$F_{S/G}$ = longitudinal stick force per g
gw = gross weight, lb
g = longitudinal acceleration
V_D = design dive speed, $1.1V_{NE}$
V_F = design flap operating speed
V_{NE} = never exceed speed
V_{S0} = stall speed in the landing configuration
V_{S1} = stall speed in a specified configuration
V_X = speed for best angle of climb
V_Y = speed for best rate of climb

Introduction

IN September, 1992, the primary category aircraft rule was established.[1] This new category includes airplanes powered by a single, naturally aspirated engine, with a 61-kn maximum stall speed, weighing no more than 2700 lb, and seating four people in an unpressurized cabin. Unlike airplanes in the experimental category, these airplanes may be used for rental and flight instruction under certain conditions, although the carriage of persons or property for hire is still prohibited. This category of aircraft was developed through a joint effort between the aviation industry, various aviation interest groups, and U.S. government regulatory agencies. The objective of creating the new category was to streamline the certification requirements and procedures for small aircraft of simple design without compromising the safety of the design.

Certification costs can be a large part of the total development cost of small aircraft, especially those used primarily for pleasure or flight training. The primary category rule, by effectively reducing certification costs, helps manufacturers fill a demand for smaller, low-cost aircraft. The requirements for type certification of an aircraft in the primary category are somewhat varied and may be proposed by those applying for type certification.

Certification regulations state that the administrator may find other airworthiness criteria appropriate to the specific design, and the aircraft intended use, in lieu of the corresponding established regulations.[2] The noise standards of Title 14 Code of Federal Regulations (commonly referred to as FAR) Part 36, however, are applicable to all primary category aircraft. Applicants seeking to type-certify an aircraft in the primary category may propose a set of airworthiness standards to the servicing Aircraft Certification Office (ACO) when applying for a type certificate. The Federal Aviation Administration (FAA) reviews and comments on the proposed standards. A notice of proposed rulemaking (NPRM) is then issued and comments gathered from the public. After all comments are addressed, if the proposed standards are found to be appropriate for the category, the FAA publishes a rule in the Federal Register. At this point, the certification standard becomes available to any applicant seeking a type certificate in the primary category. To date, the acceptable airworthiness standards for type certification under the primary category rule are FAR 23 and 27, Civil Air Regulation (CAR) 3 (amended), joint airworthiness requirements for very light aircraft (JAR-VLA), and TP101-41E.[3] The first aircraft type certified in the primary category was certified using the TP101-41E Ultra-Light Design Standard.

Sportplane Design Standard

The Transport Canada Design Standards for Ultra-Light Aeroplanes, TP101-41E, was renamed the Sportplane Design Standard to avoid any confusion with the ultralight category of vehicles. The Sportplane standard applies to propeller-driven aircraft designed to carry a maximum of two persons. Additionally, the two-place aircraft is limited to 1200 lb maximum gross weight and a V_{S0} not exceeding 45 miles per hour indicated airspeed (MIAS) or 39 kn indicated airspeed (KIAS).[3] Aircraft are restricted to day visual flight rules (VFR) nonaerobatic operations such as stalls, spins, lazy eights, chandelles, steep turns, and maneuvers incident to normal flying. The Sportplane Design Standard is a streamlined set of certification requirements that reduces the time and cost of other traditional design standards without compromising the safety of the design. In the area of required flight tests, some traditional flight test data are not required to be gathered or analyzed. For example, a pitot-static calibration is not explicitly required and no limits are set on the allowable magnitude of the total position error. Airspeeds, however, must be presented in the AFM in both indicated and calibrated

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airspeed. The airspeed calibration is therefore implied. Static directional and lateral stability is determined by examination of the spiral mode vice the conventional method of examining steady heading sideslips. Additionally, no requirement is stated for dynamic testing of modes other than the longitudinal short period mode. Other differences from classical standards are apparent when examining the test results presented below. Certain other areas such as spin testing, engine cooling, and unusable fuel demonstrations are not addressed in the Sportplane standard. The applicability of these other areas was determined as the flight test plan was developed and were added to the test plan where appropriate.

Certification Flight Test Plan

Flight Test Plan

The objectives of the flight test program were 1) to substantiate contractor furnished data, 2) to determine specification compliance, and 3) to ensure that the aircraft exhibited no unsafe flight characteristics.

The areas listed below and the flight test techniques selected for the evaluation were chosen to meet the objectives of the flight test plan. In some cases, additional tests not called out in the Sportplane Design Standard were performed to ensure the aircraft had no unsafe flight characteristics. These additional tests are authorized by FAR Part 21 and were deemed necessary by the flight test team.[4] Instrumentation consisted of simple measuring devices and hand-recorded readings. This simplistic approach was deemed appropriate given the amount and type of data to be recorded, and the subjective nature of the data required by the Sportplane standard.

Takeoff Performance

Takeoff performance was evaluated by measuring ground roll using flour bag markers and estimating the takeoff distance over a 50-ft obstacle using a simple theodolite-type apparatus.

Pitot-Static Calibration

Pitot-static system calibration was accomplished using a flight test airspeed boom with known position error to calibrate the ship's pitot-static system. Though not specifically required by the Sportplane Design Standard, the calibration was used to verify published calibrated airspeeds and was necessary for later flight testing at V_D.

V_X and Balked Climb Gradients

Best angle of climb and balked landing climb gradients were estimated by flying over a surveyed ground course laid out on the runway and recording altitude gained for a given horizontal distance. This technique is not exact, but was found acceptable if winds were calm and the observed gradients substantially exceeded the gradients required.

V_Y Climb

The speed for best rate of climb and climb rate were determined using the sawtooth climb technique.[5]

Stall Performance and Characteristics

Stall speeds and characteristics were determined using procedures specified in the Sportplane Design Standard. Where no guidance was given, the techniques outlined in Advisory Circular 23-8A were used.[6]

Spins

The Sportplane design standard does not state a requirement for spin characteristics or testing. The requirements of FAR paragraph 23.221(a)(1) were applied to evaluated aircraft spin and recovery characteristics.

Longitudinal Static Stability and Control

The stabilized method was used to evaluate longitudinal static stability with stick forces measured using a hand-held force gauge.[7] Longitudinal control was evaluated using power on and off stick-only accelerations. $F_{S/G}$ data was gathered using the wind-up turn technique while estimating g loading.[8] Accelerometer data were deemed unnecessary because only a subjective examination of gradient stability was required. This subjective evaluation was considered appropriate for this class of aircraft.

Lateral Directional Stability

Lateral directional stability was evaluated using steady heading sideslips and examination of the spiral mode. Steady heading sideslips were not required, but deemed necessary in the interest of safety. Ground handling characteristics were also evaluated in crosswinds of 15 kn.

Dynamics

The short period and dutch roll modes were evaluated using excitation doublets with controls free and fixed.[9] The Sportplane Design Standard required examination of only the short period mode. The dutch roll mode was evaluated to ensure no unsafe characteristics were present.

Vibration and Buffet

Vibration and buffet characteristics were evaluated at V_d using three axis control raps.

Propeller Overspeed

Propeller overspeed limits were evaluated at V_{NE} with power on and off.

Landing Performance

Landing performance data was gathered by measuring ground roll distances using flour bag markers and estimating the landing distance from 50 ft using a simple theodolite-type setup.

Flight Test Aircraft

The GT 500 aircraft, registration number N6573R and serial number 137, was equipped with a Rotax 582 uncowled, liquid cooled powerplant and a warp drive ground adjustable, fixed pitch propeller. A complete description of the aircraft can be found in the AFM.[10] An isometric view of the aircraft is shown in Fig. 1. Weight and balance data for each flight is shown in Table 1.

Flight nos. 1 and 3 were primarily performance flight tests with flying qualities tests completed as time allowed. Flight no. 2 was dedicated entirely to flying qualities testing. The c.g. envelope of the GT500 aircraft is very narrow at most aircraft weights, usually less than 4 in. of travel. The useful load with full fuel was 470 lb. Ballasting for extreme forward

Table 1 Flight test weight and balance

Flight no.	Takeoff *gw*, lb	Takeoff c.g., in.
1	1039	71.86
2	804	57.00
3	1095	69.82

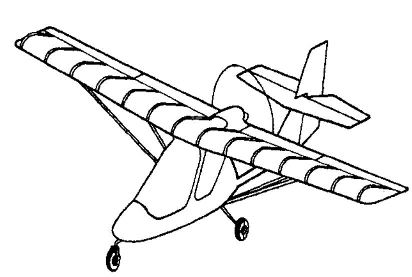

Fig. 1 GT 500 aircraft.

and aft c.g. for flight testing was impractical given the size of the aircraft, flight test crew requirements, and lack of suitable ballast locations. Considering the small c.g. travel involved between fore and aft limits at all aircraft weights, extreme c.g. testing was not considered critical to the flight test program.

Flight Test Results

Flight testing of the GT 500 aircraft was conducted from the Waukegan, Illinois airport from July 28 to July 30, 1993. Weather was clear throughout the flight test period. Performance testing was done during wind conditions of less than 10 kn. Flight test data were gathered by hand recording readings from the standard flight instruments. Control forces were estimated using a hand-held force gauge whenever possible.

All data were reduced to standard conditions. Data were reduced to sea level standard day conditions (SLSD) where required, unless data gathered at altitude exceeded requirements specified for sea level conditions. Specific flight test data are presented along with a brief summary of the associated Sportplane compliance requirement.

Propeller Speed

Requirement

No unsafe overspeeds are permitted under normal conditions to include max takeoff rpm during takeoff and 110% of maximum continuous rpm during power off V_{NE} dive.

Result

Propeller rpm did not exceed airplane flight manual (AFM) limits during takeoff and power off and on V_{NE} dives.

Stalling Speed

Requirement

V_{S0} must not exceed 45 mph, and V_{S1} (flaps up) must not exceed 60 mph. Conditions are power off, 1 mph bleed rate, maximum *gw*, forward c.g. Attitude and yaw control must be maintained to V_{S0}. The Sportplane standard is ambiguous in defining maximum stall speed as a calibrated or indicated speed. The intent of the requirement was interpreted to state the limits in calibrated airspeed.

Result

Demonstrated V_{S0} was 42 MIAS, and V_{S1} was 47 MIAS. Stall was defined by an uncontrollable pitch down. Attitude and yaw control were satisfactory at V_{S0}. Data were gathered as indicated airspeed, but were compared to calibrated values to ensure that the aircraft did in fact stall at or below the stated airspeed requirement.

Takeoff Distance

Requirement

Ground roll and takeoff distance over a 50-ft obstacle must be measured and published in AFM using specified procedures at SLSD conditions and maximum *gw*.

Result

Fifteen takeoffs were accomplished over the three day test period. Average ground roll was 220 ft and correlated with AFM data. Average takeoff distances to 50 ft were 700 ft and correlated with AFM data.

Climb

Requirement

At full throttle, the V_Y rate of climb must not be less than 300 feet per minute (fpm) at SLSD conditions, and V_X climb gradient must not be less than 1:12 at SLSD conditions.

Result

Data taken at 2000 ft pressure altitude (PA), 6100 rpm, and a V_Y of 54 MIAS yielded a rate of climb of 570 fpm and correlated with AFM data presented at 2000 ft PA. At a V_X of 45 MIAS and flaps 10 deg, a V_X climb gradient of 1:6.25 at 500 ft PA exceeded the certification requirement. Reduction to SLSD to determine compliance was deemed unnecessary.

Landing Distance

Requirement

Ground roll and 50 ft landing distance must be measured and published in AFM using specified procedures at SLSD conditions and maximum *gw*.

Result

Fifteen landings were accomplished over the three day test period. Average ground roll was 240 ft and correlated with AFM data. Average landing distance from 50 ft was 600 ft and correlated with AFM data.

Balked Landing Climb

Requirement

At $1.3V_{S0}$, full throttle and flaps extended, the climb gradient must not be less than 1:30. The rule was interpreted to allow 2 s of flap retraction to 20-deg flap as is allowed in FAR Part 23.[11]

Result

Data taken at 500 ft PA and 6100 rpm yielded a gradient of 1:8.25. Data reduction to SLSD to show compliance was not necessary. The flap retraction to 20-deg flap could be safely accomplished without large angle-of-attack changes or exceptional pilot skill.

Control and Maneuverability

Requirement

Pull-up must yield nose-up, and push right must yield right wing down. Right rudder must yield nose right. Smooth transitions must be possible without excessive control forces. The Sportplane Standard lists maximum forces for temporary and prolonged application. The listed maximums are very generous for this class of aircraft. The aircraft must at least be trimmable for level cruise at an average weight and c.g.

Result

Controls were in proper sense during all phases of flight. Control forces were well below temporary and prolonged maximums allowed. Aircraft was trimmable at average weight and c.g. at a variety of typical cruise speeds.

Longitudinal Control

Requirement

$F_{S/G}$ gradient should increase steadily. Full longitudinal control must be available when extending and retracting flaps. Accelerations using longitudinal control only from $1.1V_{S1}$ to $1.5V_{S1}$, and $1.1V_{S0}$ to V_F must occur in less than 3 s with power on and off.

Result

$F_{S/G}$ was stable at approximately 8 lb/g. Full control was available during flap extension and retraction. Longitudinal control only accelerations were acceptable, but required very steep attitudes with power off.

Directional and Lateral Control

Requirement

A 60-deg roll from 30 deg of bank through level flight must be done in 4 s or less at $1.3V_{S0}$ (full flaps with power off) and at $1.2V_{S1}$ (flaps up, power off). The aircraft must be capable of performing traffic patterns with rudder only and aileron only. Rapid roll and yaw inputs must not induce uncontrollable characteristics. Aileron and rudder forces must not reverse with increased control deflection.

Result

The time required to roll at $1.3V_{S0}$ was 1.75 s, and was 2.5 s at $1.2V_{S1}$. Rudder-only and aileron-only traffic patterns require normal pilot skills. Rapid control use yielded a docile response in all cases. Aileron and rudder forces increased with increased deflection and gradients were stable throughout the flight envelope.

Longitudinal Static Stability

Requirement

Longitudinal static stability must be positive from V_{S1} to V_{NE} at critical c.g. and power.

Result

Longitudinal static stability was positive throughout the flight envelope. Longitudinal stick force gradient was noticeably small, but not objectionable.

Directional and Lateral Static Stability

Requirement

Stability is acceptable if the spiral mode stability is at least neutral from $1.2V_{S1}$ to V_{NE}.

Result

Spiral mode was neutral to very slightly positive throughout the speed range. Steady heading sideslip tests showed directional stability only slightly positive with doors on. Stability was more positive with doors off. There is no requirement to do sideslip testing, but steady heading sideslip tests were added to ensure no undesirable characteristics were noted with the doors installed.

Dynamic Stability

Requirement

The longitudinal short period mode must be heavily damped with controls free and fixed.

Result

The short period mode was deadbeat from $1.1V_{S1}$ to V_{NE}. The dutch roll mode was also evaluated and found to be heavily damped throughout the same envelope.

Wings Level Stall

Requirement

Bank and yaw excursions must not exceed 15 deg with normal use of controls throughout the stall.

Result

The requirement was easily met if sideslip angle was normally managed. The aircraft was not equipped with a slip indicator, but did have a yaw string. Without the yaw string, sideslip management would have been more difficult.

Turning Flight and Accelerated Stalls

Requirement

Power on, flaps up and down accelerated stalls shall cause no tendency to spin, cause excessive altitude loss or airspeed buildup. When started from a 30-deg bank turn, stall recovery shall cause no speed buildup and return to level flight must be accomplished in less than 60 deg of roll.

Result

Accelerated stalls were docile with no unusual departure or spin tendencies and no large altitude loss. Bank excursions required 30–45 deg of roll to return to level flight. No excessive airspeed buildup was noted throughout the recovery. Once again, use of the yaw string was required to manage the sideslip angle.

Spins

Requirement

No requirement is specified in the Sportplane Design Standard. FAR paragraph 23.221 (a)(1) was applied to evaluate spin characteristics.

Result

Ten spins were attempted in all aircraft configurations and power settings. Pro-spin controls were held for one turn. Aircraft rotation was slow, smooth, and without oscillations. Recoveries using the AFM procedure and hands-free recoveries were accomplished in less than one-half turn. During several entries, the aircraft transitioned into a spiral dive in less than one-half turn and was easily recovered without excessive airspeed buildup.

Directional Stability and Control

Requirement

Use of right rudder must yield right turn. No special skill must be required for ground handling up to manufacturer's demonstrated crosswind limit.

Result

Rudder sense was proper throughout flight envelope. No unusual ground handling qualities were noticed during operations in crosswinds of 15 kn during taxi, takeoff, and landing.

Airplane Flight Manual

Requirement

Specific data must include operating limitations, normal procedures, and limited performance data.

Result

The original AFM was reviewed and found to be inadequate in airspeed and engine limitations, c.g. envelope description, usable fuel description, and performance data. Many references were made to ultralight vehicles and the ultralight category of vehicles and had to be deleted. Manufacturer's update included correct speed limitations, updated placards, and revised performance data. Engine cooling data provided by the applicant was accepted after observing the cooling characteristics of the uncowled, liquid cooled Rotax 582 engine during flight tests. Dedicated FAA conducted cooling climb tests were not deemed necessary.

Pilot Compartment

Requirement

Designed for "good" visibility, accessibility, exit, reach, and occupant protection.

Result

Cockpit layout and controls were found satisfactory except for the location of the fuel indicator sight gauges and the lack of a sideslip indicator.

Flutter

Requirement

No part of the aircraft shall exhibit heavy buffeting, flutter, control reversal, or divergence up to V_D. Advisory Circular 23.629-1A lists several analytical methods used to determine susceptibility to flutter.[12]

Result

Report 45 analysis allowed by Advisory Circular 23.629-1A indicated the aircraft to be flutter-free throughout the flight envelope.[13] V_D dive was accomplished to 124 MIAS. Three axis control raps were accomplished at V_D. No undesirable vibration, buffet, or control divergence was noted.

Noncompliant Findings

Three areas were discovered during flight testing that were not in compliance with the Sportplane design standard. Before an unrestricted-type certificate could be issued, the noncompliant findings from the engineering review and flight test had to be resolved.

Sideslip Indicator

The lack of a sideslip indicator combined with near neutral directional stability made sideslip control more difficult during low-speed flight and stalls. A yaw string was successfully employed during flight test and was added to the type design to provide sideslip indications during all phases of flight.

Fuel Indicating System

The fuel-indicating system consisted of sight lines painted on the plastic fuel tanks located in the wing root and visible in the crew compartment. The fuel level could not be read while flying from the front seat. Only total fuel was indicated by the fuel tank markings, and hence, no usable fuel indications were present nor was the usable fuel level placarded.

Airplane Flight Manual

As described in the flight test results presented earlier, the AFM was inadequate in several areas. The AFM was subsequently revised and found satisfactory.

Conclusions

The Quicksilver GT 500 design was awarded a provisional-type certificate based on review of engineering data and results of flight tests. The limitations of the provisional-type certificate were removed when all discrepancies identified during data review and flight test were corrected. The Sportplane Design Standard was found to be a satisfactory certification tool for aircraft certified in the primary category. Each new aircraft design must, however, be individually evaluated to determine what additional testing should be done to ensure the type design exhibits no unsafe characteristics.

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