U.S. Department
of Transportation

**Federal Aviation
Administration**

Memorandum

Subject: ACTION: Equivalent Level of Safety, Pilatus PC-12; Finding No. ACE-94-8

Date:

From: Manager, Brussels Aircraft Certification Office, AEU-100

Reply to Attn. of: L. Foster
ACE-112
(816) 426-5688

To: Manager, Small Airplane Directorate, ACE-100

This memorandum requests your office to review and provide concurrence with the proposed finding of equivalent level of safety to the spin requirements of § 23.221 of 14 CFR Part 23.

BACKGROUND:

The Pilatus PC-12 is a single-engine turboprop airplane with a gross weight in excess of 8,000 pounds, which exhibits stall characteristics under some conditions that do not meet the requirements of the Federal Aviation Regulations (FAR). The manufacturer has installed a stall warning/stick-shaker system and a stick-pusher system where the latter will define the stall. Pilatus has elected to show the airplane has the same safety level as that intended in § 23.221(a)(2). This action will require an equivalent level of safety finding to be made by the FAA since such a method of compliance is not currently addressed by FAA requirements and, thus, not considered in accordance with the provisions of the existing U.S. - Switzerland Bilateral Airworthiness Agreement.

APPLICABLE REGULATIONS:

Section 23.221 requires that single-engine, normal category airplanes must demonstrate compliance with either the one-turn spin or the spin-resistant requirements. The airplane must recover from a one-turn spin or a three-second spin, whichever takes longer, in not more than one additional turn after the controls have been applied for recovery. This should be demonstrated for all configurations.

APPLICANT POSITION:

The stall characteristics on the PC-12 do not comply with the FAR regulations and can be classed as hazardous in some configuration with high power applied. To protect the aircraft, a stick-shaker and a stick-pusher stall barrier system are installed. The architecture and reliability satisfy the FAA requirements for the PC-12 to prevent entry into a stall and for inadvertent operation.

The stall testing of the PC-12 not only included all the FAR required demonstration points but also a sufficiently complete matrix of configurations to totally assess the capability of the stick pusher to protect against the stall under each condition and the respective safety margins.

It is widely accepted that if an aircraft is protected against stalling it is also protected from inadvertently entering a spin. Pilatus proposed to investigate further abused control inputs during and after the (artificially produced) stall and, thereby, demonstrate that no spin was possible. As the FAR were not written with a stick pusher equipped single-engine aircraft in mind (artificial stall barrier), it was necessary to apply for an equivalent level of safety. Having decided to comply with Amendment 42, it was determined that § 23.331 (a)(2) addressing "spin resistant" most closely represented the PC-12's situation and should, therefore, be used as the basis for the equivalent safety finding.

An examination of § 23.221 will show that the basic requirement is to demonstrate a one-turn spin. Both the spin resistant, § 23.331(a)(2), and the incapable of spinning, § 23.221(d), requirements are, in effect, equivalent safety findings built into the regulation (both written specifically for particular aircraft produced by the U.S. aviation industry). Neither of these requirements provide a very satisfactory solution, nor has the concept been accepted or adopted in the JAR 23. An equivalent safety finding has been issued on § 23.221(d) for an aircraft equipped with a stick pusher. In reality, this equivalent safety is applied to § 23.221, spinning, and not to § 23.221(d). The method of demonstration, however, has been agreed to in accordance with § 23.221(d). Pilatus is also requesting an equivalent safety finding for § 23.221 on the PC 12, using criteria adapted from § 23.221(a)(2). They believe that the criteria set out in § 23.221(a)(2)(iii), demonstration with the airplane in uncoordinated flight, is a much more representative test for an aircraft equipped with a stick pusher than any of the other tests outlined in § 23.221, paragraphs (a) or (d).

FAA POSITION:

The Pilatus PC-12 has stall characteristics that do not meet the requirements of 14 CFR Part 23 and they have elected to install a stick pusher as an alternative. This is not a unique solution. Numerous airplanes (e.g., Lear 23, Fairchild Metro, etc.) have been certified with stick pushers to solve stall characteristic problems. Pilatus also intends to use the stick pusher to provide relief from the spin requirements in § 23.221 on the basis that the system provides a stall barrier. This is analogous to current airplanes using the stick pusher to prevent entry into a deep stall, a post stall flight condition that may be

unrecoverable. Field experience has justified that stick pushers provide at least the level of safety that the stall requirements provide. Pilatus chose to use § 23.221(a)(2), "spin resistant," as the requirement to show equal safety. The FAA does not believe that this is the best solution. As Pilatus argued, both § 23.221(a)(2), spin resistant, and § 23.221(d), incapable of spinning, are, in effect, equivalent safety findings built into the regulation. In fact, both paragraphs were essentially written for specific aircraft. The older of the two requirements is § 23.221(d), "Characteristically incapable of spinning," was a derivative of the design that is generally accepted as the only spin-proof airplane to receive FAA certification. This airplane utilized only two pilot controls, aileron and elevator. The rudders were interconnected to the ailerons for turn coordination and the elevator was mechanically limited. "Spin resistant" is a recent requirement derived from NASA research, which focused on aerodynamic treatments to the wing leading edge and, to some degree, the empennage. In summary, the concept of "spin resistant" is to:

a. Protect against the abused stall -- the precipice from which a spin begins.
b. Retain roll damping and aileron control at and after the point at which inboard wing buffeting and nose down pitch occurs, as in a traditional stall.
c. Provide roll power sufficient to overcome yaw rates well into the traditional stall indications.
d. Improve basic stall qualities to prevent unwanted roll-off due to uncoordinated flight at or near the stall.
e. Provide post-stall control that follows the same [logic] of control movements that the pilot has been using. There should be no need for specified anti-spin training and trying to recall a procedure that is never practiced.
f. The spin resistant criteria should provide equal or better opportunity to regain control of an abused stall than does the present one-turn criteria.
g. The spin resistant airplane is not a "spin-proof" airplane. When aft c.g. loadings are abused, or when high pitch-rate (zoom) stalls are performed, current test data indicated a 5% probability of a spin.
h. Provide these qualities with a minimum drag penalty.[1]

Both requirements were based on the use of aerodynamic solutions, as noted in items b, d, and e. The FAA cannot find that there was ever an intent for a stick pusher system to be used to meet either the spin resistant or the characteristically incapable of spinning requirements. However, the FAA accepts Pilatus' rationale that the basic requirement of § 23.221 is for a one-turn spin recovery and that any safety equivalent should ultimately reference this requirement.

From 1945 to 1962, all normal category airplanes under 4,000 pounds had to meet the one-turn spin test. Prior to 1945, the requirement was a six-turn spin with recovery in no more than one and one-half additional turns with controls neutral and power off. Amendment 3-7 of CAR 3 in 1962 clarified the intent of the one-turn spin test. The amendment eliminated the 4,000 pound

[1] From a paper presented at the SAE "AEROTECH 87" conference by Charles E. Arnold, Flight Characteristics Section, Small Airplane Certification Directorate, Federal Aviation Administration, Kansas City, MO 64106

limit and deleted the requirement for twins. The preamble material to Amendment 3-7 clearly indicates the objective was spin prevention rather than spin recovery by citing the test as ". . . an investigation of the airplane's characteristics in a delayed stall. . . ." The rationale for deleting the twin requirements was again that spin prevention will contribute more toward reducing stall-spin accidents than spin recovery; therefore, the engine-inoperative stall requirements were revised to preclude inadvertent spin tests.

Supporting the rationale that the intent of the spin requirement was spin prevention (stall qualities) rather than spin recovery, statistics clearly show that spins and spin recoveries are not significant issues, but post stall characteristics are. A review of the AOPA Air Safety Foundation's General Aviation Accident Analysis Book reveals that 99.75% of the inadvertent stall accidents (1544 out of 1548, based on 209,302,000 flight hours) occurred at or below pattern altitude, presenting no chance of spin entry and recovery. The FAA agrees with Pilatus' argument that an equal level of safety is achieved if an airplane is prohibited from entering a stall (ideal stall characteristics) and, thus, a spin.

In supporting Pilatus' request, the FAA must consider the experience level of the pilots who could, according to the operating rules, fly this airplane. Part 25 (14 CFR Part 25), for example, has a provision in their certification of system reliability that allows manufacturers installing a stick pusher credit for the probability of entering a stall. In considering single-engine 14 CFR Part 23 airplane operation, it is reasonable to assume the pilot has a higher probability of entering the stall; therefore, it is appropriate to conservatively modify this probability factor for 14 CFR Part 23 airplanes.

Also, stick pusher systems vary from airplane to airplane. The multiple factors that make up the pusher system work in conjunction with the airplane's natural aerodynamics. The only way to actually evaluate the stick pusher's effectiveness is to fly the airplane. The FAA would expect that any stick pusher installation would be evaluated by a test pilot for normal conditions, abused conditions, and conditions where the system might not operate during expected flight operations. The stick pusher actuation must be quick enough that it could not be confused with any other force that might feed back through the stick. The flight test should evaluate the stick pusher force and onset rate to determine if a pilot could mistake the stick pusher for an aerodynamic force and, consequently, fly below the pusher activation airspeed.

The FAA's final consideration for stick pusher installations is the airspeed margin. The safety that the stick pusher offers is related to the margin it provides between the pusher airspeed and the natural stall speed. For a slow entry with wings level, the margins don't need to be as large as for an accelerated stall condition in a turn. The recommended margins are covered in AC 23-8A and have proven to be adequate from service history.

RECOMMENDATION:

The stick-shaker/stick-pusher installation on the PC-12 provides an equivalent level of safety to § 23.221, subject to the following conditions:

1. Compliance with § 23.201, wings level stall, and § 23.203, turning flight and accelerated stalls, must be demonstrated with the airplane in uncoordinated flight, corresponding to one ball width displacement on a slip-skid indicator. If one ball width displacement cannot be obtained with full rudder, the demonstration must be with full rudder applied.

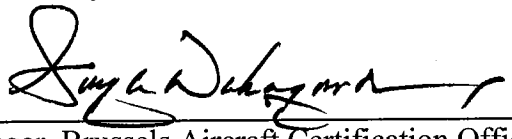
2. Evaluate the airspeed margin between unsatisfactory stall characteristics and the minimum stick pusher actuation speed for identical flight conditions. For unsatisfactory, hazardous or unrecoverable aerodynamic stall characteristics, the minimum speed margin between aerodynamic stall and minimum stick pusher system action speed should not be less than five knots. For non-hazardous aerodynamic stall characteristics, the speed margin may be reduced to not less than two knots. For the purposes of this test, hazardous is defined as a roll to more than 60 degrees from the horizontal for normal (coordinated) stalls.

3. The system reliability must compensate for the lower pilot experience level allowed in 14 CFR Part 23 airplanes.

4. A pilot evaluation of the stick pusher system onset rate and force must be accomplished. The pusher must operate fast enough and strong enough that the possibility of a pilot inadvertently holding the controls against the pusher is unlikely.

5. Establish an in-service stall warning/stick pusher system reliability program to report failure cases to the FOCA and FAA for a period of two years to determine that the in-service reliability meets the predicted certification requirements.

Concurred by:

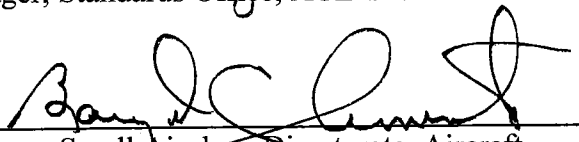


JUNE 16TH 1994

Manager, Brussels Aircraft Certification Office
AEU-100 — Date

6/6/94

Manager, Standards Office, ACE-110 — Date



6/21/94

Manager, Small Airplane Directorate, Aircraft
Certification Service, ACE-100 — Date