U.S. Department of Transportation
Federal Aviation Administration

Memorandum

Subject: ACTION: Equivalent Level of Safety of Grob G520T EGRETT, Accelerated Stall, Stall Warning, and Spinning; Finding No. ACE-94-10

Date:

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

Reply to Attn. of:

To: Manager, Small Airplane Directorate, Aircraft Certification Service, ACE-100

Background:

Burkhart Grob, Luft-und Raumfahrt, GmbH & Co. KG, manufacturer of the EGRETT Model G520T airplane petitioned for exemption to § 23.203(a)(2) above 35,000 feet, § 23.207(c) only for accelerated stalls, and § 23.221 spins.

The G520T is a dual seat version of the G520, a high aspect ratio, high altitude, pressurized, mid-wing monoplane with tricycle landing gear, which is unique to .14 CFR Part 23 airplanes in that normal operational altitudes extend up to 50,000 feet. The G520T utilizes composite materials for its structure and is powered by a turbopropeller engine. The maximum gross weight is 10,362 pounds. The airplane has two emergency exits and canopy breaker hammers.

Applicable Regulations:

The applicable Federal Aviation Regulations (FAR) state in brief:

Section 23.203, Turning Flight and Accelerated Stalls must be demonstrated in flight tests with a 30 degree bank by reducing the speed by steadily and progressively tightening the turn with the elevator until the airframe is stalled or until the elevator has reached its stop. The rate of speed reduction must be constant and must be 3 to 5 knots per second for accelerated stalls with steadily increasing normal acceleration.

Section 23.207, Stall Warning, requires that there must be a clear and distinctive stall warning, with the flaps and landing gear in any normal position, in straight and turning flight. The stall warning may be furnished either through the inherent aerodynamic qualities of the airplane or by a device that will give clearly distinguishable indication under expected conditions of flight. The stall warning must begin at a speed exceeding the

stall speed by a margin of not less than 5 knots, by not more than the greater of 10 knots or 15 percent of the stalling speed, and must continue until the stall occurs.

Section 23.221 of Part 23 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's Position:

No exemption or rule change is required or requested for straight stalls, including turning stalls, since compliance with the existing rules throughout Amendment 23-34 has been shown. The flight test reports show benign stall characteristics at all altitudes up to 50,000 feet. The stall margin for accelerated stalls decreases to 3 knots at 50,000 feet in lieu of the 5 knot minimum specified by§ 23.207. Note:§ 23.207(a) requires the 5 knot margin for straight and turning flights only. The following analysis is based on the assumption that this margin is also applicable for accelerated stalls.

For accelerated stalls, all requirements of § 23.203 are met up to 35,000 feet. Above this altitude, the 3 to 5 knots/sec. required reduction can no longer by met, the maximum value is 2 knots/sec. The accelerated stall maneuvers were performed with rapid aft stick motion using both arms (physical limit of the pilot) to attain a decreasing airspeed change as high as possible to the required 3 to 5 knots/sec. regulatory value. The aircraft was completely controllable during all Part 23 stall tests and immediate and prompt recovery was easily achieved. No tendency toward incipient spin was observed.

A carefully performed rational analysis showed that at FL 500 the operating limits will be exceeded during recovery of a spin. The Luftfahrt-Bundesamt (LBA) proposed to install a stick shaker/pusher system in lieu of the required spin tests. The system is designed in such a way that a stall, and consequently the entry into a spin, is safely prevented at all attitudes and altitudes. LBA required a margin between aerodynamic stall and stick pusher onset of at least 2 knots.

The airplane meets all regulatory requirements with the stick pusher/shaker installed including stalls in straight and turning flight at all altitudes. As of 35,000 feet the noncompliance with § 23.203(a)(2) is also applicable. Furthermore, the margin between stick pusher onset and stall warning decreases to approximately 0. However, the margin between aerodynamic stall and pusher onset (or respectively stick shaker onset) is still greater than at least 3 knots at all altitudes.

Whether the 5 knot margin between stall warning and stall speed required by § 23.207(c) can be met for accelerated stall maneuvers is very much dependent on the interpretation of "steadily increasing normal acceleration". A clear definition of this phrase in not given in the rule.

As already mentioned, for the G520T we [Grob] were forced by § 23.203(a)(2) to give abrupt elevator inputs (high pitch rate) in order to comply with the required reduction in speed. This resulted in a relatively high increase of the normal acceleration. But, the higher the g-load increase rate, the lower the probability to meet the 5 knot margin. The reason is as follows:

A stall of an airplane is not directly related to an airspeed, it is related to the maximum lift coefficient of the wing-fuselage-empenage combination, the resulting stall speed is determined with this maximum lift coefficient coupled with the airplane mass and the load factor.

If a stall maneuver is flown with steadily increasing normal acceleration, and the stall is reached at a higher load factor than the flight condition of the stall warning , it is obvious that the difference between stall speed and stall warning speed is strongly related to the change in the normal acceleration load factor during the maneuver.

Example:

Turning flight with 30° bank;

Stall warning:	80 kts at a load factor of 1.15g
Stall speed:	75 kts if load factor stays at 1.15g
Stall speed at:	80 kts if load factor is increased to 1.31g (no margin!)
Stall speed at:	85 kts if load factor is increased to 1.48g (negative margin!)

The above results are based on the following formula:

$$V = \sqrt{\frac{2 * n * m * g}{\rho * S * C_L}}$$

Where -

- n = load factor
- m = mass of the airplane
- g = acceleration due to gravity
- ρ = air density
- S = wing area
- C_L = lift coefficient
- V = stall speed

The above example demonstrates the enormous impact of increase of normal acceleration to the stall speed.

Result: If accelerated stall maneuvers are performed with a high increase of normal acceleration, the 5 knot rule can never be met. This is true for all aircraft with or without a stick pusher. Therefore, to comply with this requirement, the increase of the load factor during the maneuver must be very gentle. In the case of the G520T , however, this would lead to a noncompliance with§ 23.203(a)(2) at all altitudes.

For the G520T, with its special design optimized for high altitude operation, compliance with one of the two paragraphs (§§ 23.203(a)(2) and 23.207(c)) excludes the compliance with the other one.

Taking into account that § 23.207 has no specific accept/reject criteria for accelerated stalls, Grob proposes to use the Military Specification MIL-F-8785C as a guideline. This U.S. Government MIL-Spec has a requirement for the 1g stall similar to the definitions given in Part 23.

For the accelerated stalls, the MIL-Spec requires warning ranges in $\%C_L$ rather than in knots.

The GROB flight test results show that for the G520T the stall warning (stick shaker) onsets are between 81% and 89.8% C_L pusher (since the pusher onset speed is per definition the new stall speed, C_L pusher = C_L stall). Therefore, the G520T meets the warning range requirements defined in the above Mil-Spec for accelerated stalls.

The MIL-Spec is an approved document for the certification of military aircraft and could be introduced into the certification basis of the G520T by our request for an exemption.

Justification:

Granting this exemption is in the public interest since many of the flight profiles shown are not only of importance but several are aimed directly at assisting in the current environmental problems the world is undergoing.

The chemical reactions of all trace gases produced by human activities also affect other materials contained in the Earth's atmosphere. No one can say with any accuracy at this present time which gases react against another or at which heights and with what results. Present scientific knowledge must, therefore, be considerably extended. Only with high altitude research aircraft, as proposed by the G520T, can a clear picture of these complex interrelationships be formed.

Previously unattainable mission profiles and many hours of sample measurements make these high altitude aircraft the indispensable tools of modern research.

The facility to make both on board analysis during flight and also bring various samples taken from a wide area back for further tests merely goes to show how valuable an asset

this aircraft could be in helping to give more understanding to the effects our expanding industrialization is having on our daily lives.

The earth can be compared to a spaceship with its life support system breaking down. The ability to live on this planet depends on whether we succeed in analyzing precisely the disturbances in the ecology of the atmosphere and whether we initiate the necessary countermeasures as soon as possible.

In cases of natural disaster, such as earthquakes or floods, the G520T is quickly able to be deployed to overfly the whole area of devastation -- coordinating the rescue operation and directing the relief forces to the points of greatest need. The ability to remain "on station" for several hours could well make a life saving difference. It is also worth noting that the G520T is, in relative terms, an inexpensive option for such surveillance reconnaissance activities and, therefore, affordable to developing countries often in the forefront of need.

Summary:

It is the intent of the Federal Aviation Regulations that only safe aircraft are type certificated. Although the G520T does not meet all the regulatory requirements, it was demonstrated by flight tests and a rational analysis that the aircraft is safe and reliable.

The G520T does not meet§ 23.203(a)(2) as of an altitude of 35,000 feet. The required speed decrease of 3 to 5 knots per second decreases to a maximum of 2 knots per second. The design of the aircraft prevents the pilot from moving the stick more rapidly (pilot limit). This is not a safety critical item.

The G520T does not meet § 23.207(c). Without stick pusher, the margin between aerodynamic stall and stall warning during accelerated stall maneuvers is at least 2 knots in lieu of the required 5 knots. With the stick pusher, the speed margin between stall warning and stick pusher onset is approximately 0. This noncompliance also has no impact on the safety of the aircraft since,

> the respective requirements of Military Specification MIL-F-8785C are met, the existing § 23.207(a) requires the 5 knot margin for straight and turning stalls only.

The G520T does not meet § 23.221. In lieu of the requirements of § 23.221, the G520T is equipped with a stick shaker/pusher system. The system is designed in such a way that a stall, and consequently the entry into a spin, is safely prevented at all attitudes and altitudes. The stick shaker/pusher system offers the following compensating features:

1. Two AOA computers will be provided working in fail-safe mode.

2. The AOA system will provide a failure monitoring output to a warning light if discrepancies in the following circuits exist:

   AOA potentiometer
   AOA heater
   Flap position switch
   Stick pusher
   Power input

3. The AOA system is designed in such a way that a single failure would not result in an unwanted operation of the stick pusher.

4. The reliability [FAA note: this is referring to the probability of failure] of the complete AOA system is > 10^{-7} (as per NPA 25B-154). A fault tree safety analysis was performed to show compliance with this paragraph. The results of this analysis are contained in the GROB report FA12, "Failure Analysis Stick Pusher System", dated 11 Sept. 1991.

5. A stall warning light and horn is provided.

6. In addition a stick shaker will announce the possibility of a stall.

7. A press to test button is provided for both AOA computers. This device activates the stick shaker, the stall warning light and horn when the aircraft is on the ground or in the air and the stick pusher when on the ground only.

8. All warning indications are routed to the aircraft battery bus. This will ensure operation of the stick shaker/pusher system in the event of complete AC/DC loss.

Furthermore,

9) The G520 Pilot's Operating Handbook will give the pilot information about the system and what actions to perform in case of failure indication.

10) The stick pusher system will meet the requirements of DO-160C (refer to report No. SSC-520/91/1).

    The G520T high altitude research airplane may only be flown by qualified and trained pilots having a type rating for this aircraft. The training will include a detailed introduction to the stick shaker/pusher system.

    The stick pusher force was adjusted according to NPA 25B-154 to 50-60 pounds.

FAA's Position:

The G520T stick shaker/pusher installation is unique because it is not compensating for poor stall characteristics. The G520T met all stall characteristic requirements without the stick shaker/pusher system except for accelerated stalls, which cannot be achieved above 35,000 feet. Typically, stick shaker/pusher systems are installed in airplanes to prevent the pilot from reaching the stall because, in one or more configurations, the airplanes exhibit characteristics that either do not meet the Part 23 requirements or that are considered hazardous because the stall may be unrecoverable. Grob chose to use a stick shaker/pusher system only because analysis showed that a spin at altitudes approaching 50,000 feet would result in exceeding structural limits during recovery.

Grob requests relief from the accelerated stall and stall warning requirements in § 23.203 and § 23.207. Above 35,000 feet, the G520T does not have the excess energy needed to accomplish an accelerated stall with a 3 to 5 knots/sec. deceleration rate. The maximum deceleration rate achieved was 2 knots/sec. The intent of the stall requirements is to evaluate stall characteristics and recovery. Since the G520T does reach a deceleration rate greater than 1 knot/sec. above 35,000 feet, but is controllable during the these stall tests with no tendency toward incipient spin, it meets the intent of § 23.203(a)(2). The stall warning, however, is intended to provide the pilot enough time in advance of the stall to react and prevent the stall from happening. The G520T does not meet this intent. The stall warning issue is addressed in the following paragraphs.

Below 35,000 feet, however, the G520T has the energy to stall in an accelerated condition. The accelerated stall characteristics are the same as for normal stalls, benign. The G520T stall warning system uses an AOA sensor but does not have AOA rate information. The result is that the warning may occur at the same time that the stick pusher fires. The LBA made the determination that this situation is acceptable because the airplane met the handling requirements with the natural stall, and there is an airspeed margin between the stick pusher and natural stall. However, FAA policy states that with a stick pusher installed, the stall is defined at the stick pusher speed and not at the natural stall. This policy is based on airplanes installing stick shaker/pusher systems because the airplane exhibits poor handling qualities in one or more types of stalls.

Grob states that the existing § 23.207(a) requires the 5 knot margin for straight and turning stalls only. They bring up an interesting point that resulted in the FAA researching the history and implementation of that section. The "Flight Test Guide for Certification of Part 23 Airplanes, AC 23-8A," offers guidance for accelerated stall warning margins by addressing acceptable stall warning margins at greater deceleration rates than 1 kts/sec. Aircraft certification offices have required stall warning margins for the accelerated stall case, but have allowed lesser margins than in AC 23-8A if the warning was sufficiently ahead of the stall that the pilot could take corrective action. Conversely, the latest policy memo from the Small Airplane Directorate (1985) states:

> Therefore, it is concluded that stall demonstrations for showing compliance with § 23.207 should be accomplished under the conditions set forth in § 23.201(f) during straight and turning flight at stall entry rates of one knot per second. Any warnings that occur during other stall demonstrations do not constitute noncompliance with § 23.207, but should be evaluated for compliance with § 21.21.

Section 21.21, 14 CFR Part 21, allows the certification office the flexibility needed in unusual cases where an airplane complies with the rule but the FAA believes there is a safety issue. It authorizes the FAA to require additional conditions such that " no feature or characteristic makes it unsafe for the category in which certification is requested." A legal review by the Central Region Chief Counsel Office, ACE-7, found that Part 23, § 23.207 does not require a stall warning for accelerated stalls. The titles of § 23.201 and § 23.203 clearly refer to the stalls as wings level and as turning and accelerated. So, when § 23.207 refers to the stalls as straight and turning, only the two stalls are addressed, wings level and turning flight.

Even though policy and legal review of a requirement for a stall warning for accelerated stalls concluded that Part 23 does not require them, a study of Part 23 preamble material indicates the intent to ensure that the stall warning operates during the accelerated stall. In Amendment 23-45, the confusion is corrected with the addition of paragraph (d) to § 23.207, which reads:

> For all other stall tests, the stall warning must begin at not less than 5 knots above the stall speed and be sufficiently in advance of the stall for the stall to be averted by action after the stall warning first occurs. In addition, when following the procedures of § 23.1585, the stall warning must not operate during a normal takeoff, a takeoff continued with one engine inoperative or approach to landing.

The Grob G520T certification basis is prior to Amendment 23-45; therefore, Grob is correct in stating that there is not a stall warning requirement for accelerated stalls. This ruling does not relieve Grob or other manufacturers from accelerated stall warnings. The FAA feels justified, with regard to safety, to evaluate the stall warning margin in accelerated stall and may impose additional requirements if the evaluation results in a condition considered unsafe. However, for the G520T, the FAA agrees with the LBA and will consider the existing system performance equivalent in safety to the intent of the rule. This action will not reduce the level of safety, considering the special nature of the airplane and the pilot training requirements, and it will be in the best interest of the public.

The final issue to address is Grob's request to use the stick pusher to provide relief from the spin requirement 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. For

the G520T, the stick shaker/pusher system is not the only spin prevention measure available. If the system failed, the stall characteristics are benign and recoverable, which the FAA finds is a compensating feature.

Regulatory background for spins from 1945 to 1962 shows that all normal category airplanes under 4,000 pounds had to meet the one-turn spin test. Prior to 1945, the requirement was a 6-turn spin with recovery in no more than one and one-half additional turns with controls neutral and power off. The next change came in Amendment 3-7 of CAR 3 in 1962, which clarified the intent of the one-turn spin test. The amendment eliminated the 4000 pound 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 recovery are not a significant issue, but stall characteristics are significant. 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.

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 feedback 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.

A type rating will be required for the G520T. This requirement is based on the specialized training needed to fly the missions for which the G520T was designed. The airplane is essentially a high powered, heavy glider that is already unique for Part 23, but the high altitude capability adds training concerns/requirements that are best met with a type rating.

RECOMMENDATION:

We concur with Grob and LBA that the stick shaker/pusher system is acceptable for showing compliance with the accelerated stall and that a warning is not required by Part 23 amendments prior to Amendment 23-45. The FAA evaluated compensating features to conclude that the accelerated stall warning was acceptable with little or no stall warning margin and that no unsafe condition existed. Additionally, the stick shaker/pusher system will prevent the EGRETT airplane from entering a spin by preventing an inadvertent stall; therefore, the stick-shaker/stick-pusher installation on the G520T provides an equivalent level of safety to § 23.203 and § 23.221 subject to the following conditions. These conditions are in addition to compensating features 1-12 listed by Grob in this document.

1. Compliance with §§ 23.201 and 23.203, where possible, must be demonstrated with the airplane in uncoordinated flight, corresponding to one ball width displacement on a slip-skid indicator, unless one ball width displacement cannot be obtained with full rudder, in which case the demonstration must be with full rudder applied.

2. The airplane may only be flown by pilots type rated in the G520 series airplanes.

3. 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.

Concurred by:

July 11th 1994

Manager Brussels Aircraft Certification Office, AEU-100 — Date

Manager Standards Office, ACE-110 — Date

Barry Clements
Aircraft Certification Service,
Small Airplane Directorate — Date