Flight Testing of British Prototype Gliders

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Summary

This paper is intended to explain the philosophy behind the methods used in handling trials of British prototype gliders: that all the limitations stated on cockpit placards must depend on practice rather than theory. Some examples of the technique used in specific tests are given.

Introduction

In order to obtain a Certificate of Airworthiness, either from the British Ministry of Transport and Civil Aviation, or from the British Gliding Association, a glider prototype must be subjected to handling tests to the schedule laid down in British Civil Ajrworthiness Requirements, Section E. (There is also a BGA draft paper containing some proposed modifications to BCAR. This prescribes some additional tests which are also carried out at present.) These tests are designed to ensure that the glider is safe to fly, from the handling point of view, within suitable limits of weight, speed and centre of gravity position, during all conditions of flight likely to be encountered in service, including suitable aerobatic manœuvres. These tests are therefore quite separate from any performance testing which may be carried out, since the safety of the machine is not directly affected by the performance.

BCAR, Section E, was originally published in 1949, after consultation between the Air Registration Board and the Technical Committee of the BGA. Necessarily, much of the experience of those concerned with framing the requirements was pre-war, somewhat enhanced by war-time experience in testing aeroplanes and military gliders. Since then, effective airbrakes have become almost universal and gliders have become cleaner and faster, to mention only two trends. But the excellence of the 1949 issue of Section E is shown by the fact that only recently have the BGA suggested some amendments, and these mostly represent relatively minor additions and modifications to existing test procedure.

Purpose of Testing

BCAR, Section E, states requirements which must be met in various conditions of flight, e. g. during aero-tow, stalling, spinning, behaviour at maximum permissible speed, etc., and then describes the method of carrying out the appropriate test and the observations to be made.

The underlying assumption is that when machines of the type under consideration are eventually sold, their pilots must be confident that they are safe under all the permitted conditions of flight, and that the cockpit placards really mean what they say: that if, for example, the never-exceed speed is stated as 110 knots, then the prototype has been flown at this speed. (In fact, it would have been flown at 116 knots.)

It is also implied that a safe machine will be easy and pleasant to fly. In some respects, it is difficult to frame suitable requirements in quantitative terms: for example, there is not yet sufficient evidence to state requirements for longitudinal static stability in terms of c. g. margins. Under these circumstances, the test pilot is the only person who can decide whether or not the machine is acceptable and hence the more subtle characteristics will depend on the reliability of his judgment.

BGA Test Groups

Much of this flight testing is carried out by the Test Groups of the British Gliding Association, each of which is under the control of a BGA approved test pilot. The material of this paper is based largely on the experience of No. 1 Flight Test Group, Lasham, whose chief test pilot is Mr. Lorne Welch. In practice, the function of the Test Group, acting on behalf of the manufacturer, involves rather more than flying the machine to the schedule and writing a report. Few prototypes are entirely satisfactory in their initial form, and the preliminary tests will probably reveal some features which require modification. For example, one machine was found to suffer from lateral oscillations and corresponding movements of the stick in rough air, due to the effect of the inertia of the ailerons. The Test Group calculated a suitable mass balance, fitted it in consultation with the manufacturer, and found that it completely cured the trouble, incidentally improving the "feel" of the ailerons to a remarkable extent. This modification was subsequently incorporated in the production aircraft. To some extent, the Test Group tends to act as consultant to the manufacturer on matters affecting flying qualities.

Examples of Specific Tests

Whilst it can be said that all the tests are important, otherwise they would not have been included in BCAR, some are of fundamental significance. These are the tests which either (a) involve conditions close to the design limits or (b) conditions in which unsatisfactory behaviour would produce a dangerous situation. An example of (a) is the high-speed dive, where the machine is flown at 0.95 of the Design Diving Speed, and an example of (b) is the spin with an aft centre of gravity position.

Before any tests are carried out, however, it is most important to determine the pressure errors (or position errors) of the pitot/static system, so that the indicated and design speeds can be correlated. Significant speeds, such as the stalling speed and brakes-open terminal velocity can then be accurately determined.

Pressure Error Test

This is done by comparing the readings of two calibrated airspeed indicators, one connected to the normal pitot and static sources on the glider and the other to sources of known accuracy. An accurate static pressure is obtained by means of a suspended Static Head (or "Trailing Static"), hanging from a tube whose length should not be less than two wing spans. If the glider has a normal pitot-tube, this is usually assumed to be correct, but a nose can-type pitot may suffer from pitot pressure errors. In such a case, a separate pitot-tube must be fitted.

The glider is then flown at a series of steady speeds, from the stall upwards, and readings of both instruments are taken. At this stage in the tests, it is clearly inadvisable to fly at very high speeds, but it is usually quite legitimate to extrapolate the curve. Experience shows that the pressure error of a normal pitot/static installation mounted ahead of the cockpit cover on the front fuselage is of the order of 8 % to 10 % of the equivalent airspeed, whilst with a well-designed nose-pitot and fuselage static vent system, the error can be kept within 2 % of the EAS. The figures are usually presented as indicated airspeed plotted against equivalent airspeed, to avoid any confusion over the sign of the correction.

Following this test, it is possible to determine the stalling speed accurately *(Vs)* and to express certain speeds which are significant in later tests (such as 1.4 *Vs*) in terms of indicated airspeed. The Manufacturer's Design Diving Speed, V_D, will be known in terms of equivalent airspeed, and the significant quantities 0.9 V_D and 0.95 V_D can also be converted into indicated airspeeds.

Longitudinal Static Stability

As mentioned previously, there is no quantitative requirement as yet, the statement in BCAR being as follows:

"The glider shall have positive static longitudinal stability over the speed range. As the speed increases, or decreases, a corresponding increasing forward or backward movement and force shall be necessary on the control column."

In practice, there is some evidence to suggest that, provided the damping in pitch is adequate, a glider may be acceptable with zero stick-fixed stability (i. e. zero stick movement to change speed), provided that the stick-free stability is still positive (i. e. the stick forces remain the correct sense). Such a condition may well determine the aftmost acceptable centre of gravity position, provided that the spin recovery is satisfactory.

The test consists of flying at a series of steady speeds, and measuring the stick position and stick force at each speed. Strictly, one should measure elevator angle, but it is usually sufficient, and easier, to apply a scale to the top of the stick. At present, a hand-held balance is used to measure the stick force, but this is somewhat unsatisfactory and a dial-reading instrument fixed to the stick is now under consideration. Some recent tests have shown aero-elastic effects, leading to a decrease in stability at high speeds. This implies that trim curves cannot be extrapolated much with any degree of certainty, and the test must be carried out at quite high speeds, which usually introduces some difficulty in keeping the speed really steady if the stability is low.

BCAR only require this test to be carried out at one centre of gravity position, known as the "extended aft centre of gravity position", 1 % of the mean chord aft of the aft limit which will eventually be stated on the Certificate of Airworthiness. It will obviously be more useful to measure the stabilities with at least one other centre of gravity position, so that estimates of the neutral point positions can be made. In any case, it is desirable to conduct a number of tests, moving the c. of g. progressively further aft, until the pilot considers that the least acceptable stability has been achieved. Subject to satisfactory spinning characteristics, the corresponding c. of g. position will represent the extended aft limit.

As the above implies, this extended aft limit depends very largely on the opinion of the test pilots concerned, partly because there is no quantitative requirement and partly because the "feel" of the glider in pitch depends on other factors in addition to the static stability. In the course of these tests, it may be found necessary to modify the characteristics of the glider by adjusting the elevator weight hinge moment, by inserting springs in the elevator circuit, or even by alterations to the shape of the tailplane and elevator.

As yet, no test is called for to assess the stick-force per "g", partly, again, because opinions vary widely on what constitutes a satisfactory figure. There has been a tendency for the stick force per "g" to be rather high on some British designs, due to excessive elevator weight moments, but this has been remedied on the latest types.

The static longitudinal stabilities must also be measured brakes open. It is usually very difficult to do so at high speeds, since the rate of descent is very great and there is often insufficient height for the speed to stabilise and the pilot to take readings. However, the conventional DFS-type brakes usually improve the longitudinal stability when opened, and a qualitative check at high speeds is usually sufficient. If, however, they have any appreciable effect on the stability, this implies that they will produce an appreciable change of trim when opened, particularly at high speeds. Such effects are clearly undesirable for cloud-flying, and must be carefully investigated.

Spinning

The behaviour of a typical conventional glider in the spin is as follows:

(a) At a forward centre of gravity position, it will not perform a steady spin. After a conventional entry, a spiral dive develops, in which the wing is partially or completely unstalled. The speed, normal acceleration and rate of turn all increase fairly rapidly, and recovery action must be taken promptly to avoid excessive loads.

(b) At an aft of c. of g. position, the glider will perform a steady spin. Commonly, the indicated airspeed would be about 1.4 *Vs*, the normal acceleration about 2 g, and the height lost per turn about 250 to 300 feet. Recovery is straightforward and rapid.

(c) As the c. of g. is moved further aft, the spin tends to become flatter and may also become oscillatory. Recovery may tend to become more sluggish. This condition is obviously tending to become possibly dangerous.

Whilst the above represents a typical behaviour, any particular machine may have considerably different characteristics, and spinning tests must be approached with caution. It is usual to perform a few brief spins at a forward c. of g. position, and then to move the c. of g. progressively further aft until either the extended aft limit, as established by longitudinal stability measurements, is reached or the characteristics start to show unpleasant symptoms. At the c. of g. position which is finally to be taken as "extended aft", five-turn spins must be carried out, air brakes shut and open. Briefer spins, about two turns each, must also be carried out with the ailerons deflected in either direction. Broadly speaking, aileron deflections seem to have little influence on the spin itself, but inwards aileron (i. e. stick to the left in a spin to the left) produces a rather spectacular angle of roll at entry and outwards aileron produces a rather sluggish entry.

During the spin, the pilot notes the indicated airspeed, normal acceleration, any tendency for control forces to reverse, and any buffet. In practice, either the aileron or the rudder force may reverse, and opening the brakes may produce appreciable tail buffet. The use of fuselage static vents and nose pitots has produced one effect which could mislead the unobservant, in that the airspeed indicator may give a negative reading which, on certain instruments, could be mistaken for a very high positive reading.

These spins must also be carried out with the c. of g. at the forward limit, but it will rarely be possible to prolong them for five turns. The usual spiral dive is such that recovery must be made after less than two turns if the speed or "g" is not to become excessive.

All the above relates to the behaviour of fairly conventional gliders, but the test pilot must naturally be prepared for almost any manœuvre: the machine may tend to spin in an unexpected direction; it may suddenly recover by itself; or it may make a determined effort to pitch nose-down beyond the vertical. All of these things have happened, and it is unwise for the pilot to assume that they are unlikely to happen to him, particularly if the machine has any unorthodox features.

Behaviour at High Speeds

The placarded "never exceed" speed will normally be 95 % of the demonstrated diving speed, but not more than 90 % of the Design Diving Speed. For convenience, it is usual to fly the machine at a demonstrated diving speed of 95 % of the Design Diving Speed. Brakes shut, this is normally quite straightforward, although it is clearly prudent to approach this speed in a series of progressive steps. This test must be carried out at two loadings: with the c. g. at the extended aft limit and at an all-up weight not less than 90 % of the maximum permitted.

The pilot observes that the controls and stability are normal, that there is no undesirable buffet and attempts to assess the wing deflection and aileron upfloat, if these are visible from the cockpit. It is not uncommon for the dive-brakes to show a tendency to suck-out slightly, due to insufficiently rigid locks and, apart from spoiling the performance at higher speeds, this may lead to some buffeting.

Having established satisfactory behaviour brakes shut, it becomes necessary to investigate the behaviour, brakes open, at high speed. The practical effect of British Requirements is that the terminal velocity, brakes open, should be 90 % of the Design Diving Speed, and the brakes should be opened in flight at 95 % of the Design Diving Speed. Again, these tests are carried out at the two loadings.

In practice, the terminal velocity test consumes several thousand feet before the speed becomes steady. It is usual to open the brakes, get the machine in a more or less vertical dive (usually via a "peeling-off" manœuvre), and then to adjust the angle of dive as necessary. If the speed seems to be increasing rapidly towards the final figure, there is time to reduce the angle of dive. Clearly, this procedure is only suitable for machines whose airbrakes are obviously quite powerful: a more gentle approach would be more suitable if it was felt that the brakes were likely to prove very inadequate. And again, this dive should be preceded by some brief tests at lower speeds. If the dive can be made truly vertical, it is usually rather difficult to assess this condition, since angles of dive tend to feel steeper than they really are.

In opening the brakes at higher speeds, the object is to assess the force required to operate them, whether they produce excessive changes of trim or excessive buffeting and whether there is any difficulty encountered. With brakes of the DFS "scissors" type, there is usually a sucking-out tendency, and once unlocked, they tend to open by themselves. The sucking-out force may be so large that they cannot be closed at high speeds, and if unlocked under these circumstances the pilot cannot prevent their coming fully open with great violence. This characteristic is undesirable, and the more modern British designs use brakes which are very thin in the wing-chordwise sense, to reduce the total sucking-out load.

In carrying out these tests, the brakes are opened at progressively higher speeds up to 95 % of the Design Diving Speed. From the pilot's point of view, the effect of terminal-velocity brakes at this speed is quite spectacular, since the deceleration is of the order of 1 g.

Concluding Remarks

The examples of tests given above only relate to those which are likely to prove critical in practice. No great attempt has been made to describe the requirements, since these can be found in the references mentioned and the object here is to explain the usual behaviour of gliders and to mention common difficulties encountered.

In order to establish satisfactory handling qualities, all the prescribed tests must be carried out in considerable detail and with great care. This involves an appreciable amount of flying, but it is felt to be well worthwhile, in that future operators of the type in question are assured that its handling qualities have been proved to be satisfactory.

Flugprüfung für Prototypen britischer Segelflugzeuge

Zusammenfassung

Die Abhandlung versucht, die Grundgedanken darzulegen, welche für die Flugprüfungsmethoden bei Prototypen britischer Segelflugzeuge maßgebend sind.

Es wird eine kurze Schilderung der Entwicklung der heutigen britischen Bauvorschriften und der Arbeit der Flugprüfungsgruppen in der British Gliding Association gegeben.

Die Prüfungsmethoden werden durch entsprechende Beispiele veranschaulicht: Druckirrtumsbestimmung, Längsstabilität, Trudeln und Verhalten bei Schnellflügen.

Epreuves de vol des prototypes de planeurs britanniques

Résumé

Cet exposé se propose d'expliquer les idées sur lesquelles se basent les méthodes employées pendant les essais en vol des planeurs britanniques.

L'auteur donne un bref aperçu de l'évolution des prescriptions valables pour les constructions britanniques d'aujourd'hui et du travail des groupes chargés des épreuves de vol de la British Gliding Association.

Les méthodes des épreuves sont illustrées par quelques exemples d'essais typiques: Détermination de l'erreur de pression, stabilité longitudinale, vrille et conduite pendant le vol à haute vitesse.

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