New British Airworthiness Requirements for Diving Speed and for the Rough-Gust Case

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Introduction

A complete revision of the British airworthiness requirements for private gliders is being undertaken, to incorporate the lessons learned during the post-war period (the present regulations were issued in 1948) and to bring them up to date generally and into line with current thought.

This paper presents a *résumé* of the revised requirements as regards diving speeds and the rough-gust case.

Diving Speeds

The existing BCAR [1] specify the design diving speed V_D as a multiple of the stalling speed, the constant of proportionality depending on the glider category. The actual requirements are:

Normal category	$3.0\ V_s$
Semi-aerobatic category . . .	$4.5\ V_s$
Aerobatic category	$5.5\ V_s$

where V_s is the stalling speed at the maximum all up weight.

It is now thought that stalling speed is not suitable as a basis for determining V_D, partly because it is difficult to predict it with great accuracy in the design stage, and partly because there is only a very limited relationship, if any at all, between stalling speed and the maximum speed required operationally, since the latter has little to do with $C_{L\,max}$.

Secondly, the existing requirements give quite high speeds for semi-aerobatic and aerobatic gliders, and this results in the need for unduly great torsional stiffness in order to meet aero-elastic requirements, leading in turn to disproportionately high structure weight and cost.

Now for semi-aerobatic gliders and those which cloud-fly, the highest speeds are used only in aerobatics or "beat-ups". As regards the usual run of aerobatics, i. e. loops, stall turns, chandelles and spins, these can all be normally accomplished within quite moderate speeds, even by pilots of only moderate skill, particularly in view of the now virtually universal use of speed-limiting brakes. More advanced manoeuvres, such as half loops and rolls-out, half rolls and dives-out, and full rolls, admittedly require appreciably greater speeds than the simpler ones; it is felt however, that the savings in weight and cost, in which the avoidance of such extreme speeds results, outweigh by far the loss of usefulness entailed by the prohibition of such advanced manoeuvres, as far as the vast majority of operations is concerned. As regards "beat-ups", these are usually done at the maximum permissible (placard) speed simply because it *is* the maximum permissible speed, and this can as well be a moderately high one as a very high one.

[1] British Civil Airworthiness Requirements

These considerations head to the idea of a slight modification in the arrangement of the categories. This is to replace the existing semi-aerobatic category by one having the same load factors, which is basically cloud-flying, which has mandatorily to perform only spins and tight turns up to $3^1/_2$ g, and which in addition performs such aerobatics as the designer chooses to specify, subject to it being demonstrated that they can be carried out while keeping inside the design speed and normal acceleration by a suitable margin. Within this latter proviso, the designer has complete freedom to specify what manoeuvres he likes, and he can increase his speed and/or load factor to allow for any of the more advanced manoeuvres if he wishes. The speed requirement for this modified category as such is then determined simply from considerations of cloud-flying.

The exact form which the requirement should take is open to endless argument. That finally adopted is based on the general considerations of a fairly severe nose-down pitch occurring while the glider is being flown at a high cruising speed; this leads to a requirement of the form

$$V_D = A \times \sqrt{\text{wing loading}} + B$$

where A and B are constants. Wing loading is not strictly the only parameter involved, but is certainly the main one; the drag properties are obviously also concerned, but investigation showed that their effect was small relative to that of wing loading.

Since the range of wing loading now used, and at least for some considerable time likely to be used, for private gliders is comparatively narrow, the requirements can be simplified to the linear form.

$$V_D = (A \times \text{wing loading}) + B$$

without significant effect and this is the form currently agreed.

In the case of normal (or non-aerobatic, or non-cloud-flying) category gliders, the speed requirement can be much lower, and has been decided from considerations of recovery from incipient spins. The form of the requirement is the same as that for the cloud-flying category, but one of the constants is lower.

The new requirements actually adopted are as follows:

Normal category $V_D = 8.7\,w + 52$ knots
Cloud-flying category $V_D = 8.7\,w + 80$ knots

where w = wing loading (lb./sq.ft.).

For the (fully) aerobatic category, no numerical requirement is specified; the designer most choose a value which is adequate for the manoeuvres he declares, and it is later demonstrated by flight test that it is in fact adequate. If the test shows that the design speed is insufficient for any particular manoeuvres, then these manoeuvres are prohibited.

It may be argued that "beat-ups" are useful for demonstrations and that very high speeds enable them to be more effectively performed. This may well be so, but BGA [2] opinion specify that the small operational advantage thereby gained is completely overshadowed by the price that has to be paid in additional weight and cost.

It is the practice in some countries to provide for a very high diving speed allied to zero normal acceleration. Such conditions can represent only a vertical dive with no pull-out capability and would therefore seem to have no practical use.

The comparison between the existing and modified requirements, for a $C_{L\,max}$ of 1.4 and three wing loadings, is illustrated in the following table.

Category		Normal or Noncloud flying		Cloud-flying (Semi-aerobatic)	
Requirements		Existing	Modified	Existing	Modified
Wing loading	3 lb./sq.ft.	75 kts.	78 kts.	113 kts.	106 kts.
	4 lb./sq.ft.	87 kts.	87 kts.	130 kts.	115 kts.
	5 lb./sq.ft.	97 kts.	96 kts.	146 kts.	124 kts.

Rough-Gust Case

The existing BCAR rough-gust case specifies a 66 f./s. EAS gust at speed of 2.5 times stalling speed. This is equivalent, in typical cases, to a normal acceleration requirement of about 6 g (exclusive of safety factor) and thus about 20 % more severe than the semi-aerobatic manoeuvring requirement of 5 g.

Operational experience suggests that gliders built to the latter requirement are quite suitable for flight in turbulent conditions such as occur, for example, in cumulo-nimbus clouds, provided that they are flown reasonably and that they are fitted with efficient airbrakes and with suitable instruments. The additional weight and cost resulting from designing to a factor of about 6 do not appear, therefore, to be justified, and it is considered that this should be reflected in the requirements.

In terms of flight conditions, the above implies either that the speeds at which the most severe gusts are encountered do not exceed $V_s \sqrt{5}$, i. e. 2.24 V_s (where V_s = stalling speed) since at speeds equal to or lower than this, the wing can only reach 5 g before stalling, or that the semi-aerobatic gliders in question are, in fact, stronger than they are calculated to be, or perhaps both.

One approach to the rough-gust problem is, therefore, to declare some critical speed, which is not to be intentionally exceeded while conditions remain turbulent, such that normal accelerations of 5 g will not be exceeded. The critical speed is in fact 2.24 V_s, and for this approach to be legitimate it must be established that the speed at which the most severe gusts are met is, or can be, less than this critical speed.

Direct evidence of the accelerations achieved in gusts from V-g records is not available, and recourse was, therefore, made to experienced pilot opinion. A survey was conducted in which eleven pilots, all having considerable cloud-flying experience, made statements, either in general terms or for specific instances, concerning

(A) The speeds, having regard to circumstances, at which they were aiming;

(B) the upper limit speeds within which they managed to keep most of the time;

(C) the maximum speeds reached after the worst bumps;

(D) the turbulence associated with A, B and C, in terms of a rough scale "slight, moderate, severe or extreme".

Only the broad conclusions of this survey will be given here; these were as follows:

[2] British Gliding Association

(1) The highest value for speed B was 65 m/h IAS or about 2.1 V_s.

(2) The highest value for speed C was 90 m/h IAS or about 2.8 V_s.

(3) There was a definite tendency to use brakes more frequently at the higher turbulence levels.

(4) There was no correlation between speed B and turbulence level, but there was a distinct tendency for speed C to increase with turbulence level.

(5) Speed A, which is the "cruising" speed in cloud, varied from 1.25 V_s to 1.75 V_s the mean being 1.45 V_s or around 45 to 50 m/h IAS.

In examining the meaning of the three speeds A, B and C in relation to gust strength, it can be shown that, for safety, it is necessary to design to the rough gust at speed B. The full argument leading to this conclusion is somewhat complex and is not given here; broadly it is based on the idea that a severe gust is encountered while cruising at A, which causes the speed to increase to B, that before recovery is effected a second severe gust is encountered, resulting in a further speed increase to C, and that any third gust which might then occur would only be moderate since it follows two successive severe ones, one of which is assumed to be the most severe ever likely to be encountered.

As stated above, the maximum value of speed B found in the survey was 2.1 V_s. Since the experience on which this figure is based is only a sample albeit quite a large one in relation to the total available at the time (most British pilots having appreciable experience of storm clouds were included) some small increase in the speed is necessary for design purposes. In the absence of statistical analysis, for which the sample is not large enough, it would appear that 2.24 V_s is a reasonable value, and hence the critical speed approach is feasible.

The revised requirement, therefore, is that the rough-gust stressing speed is 2.24 V_s. This will, as indicated above, mean in practically all cases that the normal acceleration will not exceed 5 g.

Though this requirement has been derived entirely from experience in which the choice of speed was left to the pilot, it is considered that some sort of speed warning should be provided, particularly for the benefit of pilots having little or no cloud-flying experience. In the new requirements this takes the form of a cockpit notice stating the critical rough-air speed. It is then up to the pilot to *aim* to fly at a speed sufficiently below it to ensure that he will not exceed it after any but the very worst gusts.

The survey did not indicate that speed increases due to turbulence were any greater when brakes were not used than when they were, and it might be inferred from this that brakes are not really essential. This is a comforting thought in view of the possibility that they might become iced up. Nevertheless, brakes clearly do confer additional safety, and they are virtually a necessity on high-performance machines for landing; the present requirement that their fitment to cloud-flying gliders is mandatory is, therefore, retained.

It should perhaps be pointed out that the objection to the use of stalling speed as a basis for determining design diving speed does not apply in the case of the rough-gust speed, since the new requirement for the latter depends directly on the idea that the wing will stall before the limit load can be exceeded. For the same reason, it is, of course, essential that the rough-air speed placarded in the cockpit is based on the measured stalling speed and that the pressure error is properly allowed for.

It is also necessary that, where low speed (landing) flaps are fitted, flight in turbulent conditions with flaps down is prohibited, since the load factors for the flaps down case do not cover such conditions.