Comparison of Various National Airworthiness Requirements for Sailplanes

By Cedric Vernon

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1. Introduction

The material in this paper was prepared in 1959 for the British Gliding Association, to which body my thanks are due for permission to publish it. The material is mainly a collection of data; where opinions are expressed, however, they are those of the author.

The requirements examined are the following:

British A.R.B. Paper 315[1] (B.G.A. requirements), 1959;
French Standard AIR 2104, 1951;
German Bauvorschriften für Segelflugzeuge, 1951;
Dutch Official Publication No. L1/13523 d/d, 1953;
Polish Article in Swiss Aero Review, Oct. 1958, and OSTIV Publication V[2];
U.S.A. C.A.R. Part 05, 1940–1947.

This comparison is confined to the principal strength cases and essential related data; in particular it covers the following:

Categories and classes
Diving speed
Symmetric manoeuvres } en-route
Gust cases } cases only
Ground loads
Safety factors

In many instances direct comparison of the requirements as set out in the various documents is misleading owing to the different ways in which they are expressed. The comparison was therefore made in terms of gliders having typical characteristics; in choosing these the tendency towards higher wing loading was borne in mind. Numerical values refer to two general classes of gliders, designated here as "normal" and "high performance".

The actual characteristics assumed were:

Class	Wing Loading lb/ft²	Wing Loading kg/m²	Stalling Speed Knots	Stalling Speed km/h	C_{D_0}
Normal	4	19,5	30	55,5	0,020
High performance	4	19,5	30	55,5	0,016
	5	24,4	33,5	62	0,016
	6	29,2	37	68,5	0,016

The value of $dC_L/d\alpha$ used in evaluating the gust cases was 0.09 per degree, which is appropriate to all aspect ratios between 15 and 20 with sufficient accuracy for the present purpose.

2. Categories and Groups

The categories and groups, which signify different performance/strength levels, are defined in different terms in the various requirements. Table 1 shows the divisions, designated as short titles based on the original wording. In some cases these divisions do not correspond precisely between the different requirements, there being a certain amount of overlapping. This is indicated roughly by the vertical overlap of the boxes in the table.

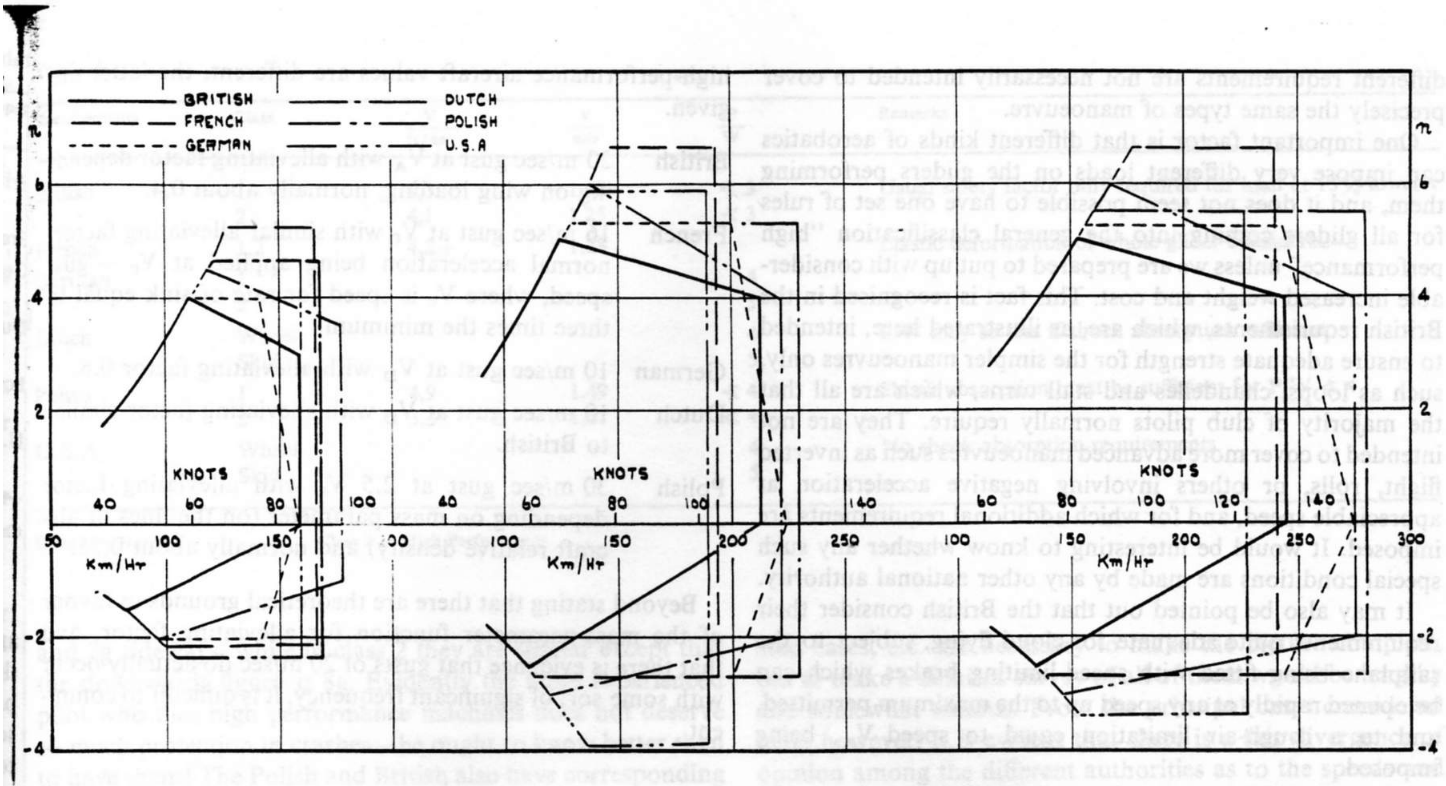
[1] Now published in slightly amended form, as BCAR Section E Issue 2

[2] Principes généraux polonais de résistance et de construction des planeurs comparés aux principes étrangers, par Mg. inž. Irena Kaniewska

Table 1 Categories and Groups

British	*French*	*German*	*Dutch*	*Polish*	*U.S.A.*
Non—cloud—flying	I Normal II Training	1. Low performance, training	I Training	1. Lightly loaded I School II Training III Performance	II Utility, primary C } Sub-division B } as for cat. I A. } below
Cloud flying, some aerobatics, aerotowing	III Performance cloud flying	2. High performance, advanced training, aerotowing	II Advanced * training, aerotowing	2. Medium loaded IV High performance some aerobatics	I High performance C Cantilever wings B Single Strut wings A Double strut wings, open cockpit
Aerobatic, aerotowing	IV Aerobatic cloud flying	3. Very high performance, aerobatics, aerotowing	III Cloud flying, * aerobatics, aerotowing	3. Highly loaded V Aerobatics	
Special	—	4. Special	IV Special	4. VI Special	—

* The Dutch categories II and III are each sub-divided into three groups similar to the U.S.A., C, B & A for diving speed purposes, but the number of struts in case A is not specified



(a) NORMAL - 19·5 Kg/M² (b) HIGH PERFORMANCE - 19·5 Kg/M² (c) HIGH PERFORMANCE - 29·2 Kg/M²

FIG. 1. SYMMETRIC MANOEUVRES - TYPICAL EXAMPLES

The British, French, and Polish grouping is generally similar in three categories, but the French and Polish subdivide the first group. The German and Dutch grouping is again in three categories, but the demarcations appear to be at slightly lower levels. The American grouping is in two categories only, the higher one embracing both middle and higher levels of the other nations; both divisions are subdivided according to aerodynamic cleanness. The latter applies also to the two higher Dutch categories.

The remainder of this comparison was made on the following basis of equivalence for the two classes stated in 1) above:

British	Non cloud flying	Cloud flying
French	II	III
German	1	2
Dutch	IIA	IIIC
Polish	III	2 IV
U.S.A.	IIB	1 A

3. Design Diving Speed

The values in knots E.A.S. are given in Table 2. The normal category value for French requirements may be unduly high; it depends on a knowledge of the performance curve, and I have little performance data for this type of glider. The Dutch figure is for an open cockpit; with a closed cockpit it would be 100 knots (185 km/h).

In general, the Dutch and Polish requirements are greater than the others, and the American a little lower. Although the German figures appear similar to the Polish, they are for zero normal acceleration only—values for appreciable acceleration are 10% lower. The British value varies less rapidly with wing loading than the remainder; this is because it was designed to approximate to the form V_A + constant.

4. Symmetric Manoeuvres

The normal accelerations are given in Fig. 1 (a), (b) and (c) in the usual flight envelope form. The stalling lines are calculated for lift coefficients of +1,3 and —0,8. The German values have been multiplied by 2/1,5 to convert them to safety factor 1,5 and so become consistent with the other values. In the French normal category envelope, the diving speed has been drawn arbitrarily at a mean value of 90 knots (166 km/h).

Considerable disparity is seen to exist between the envelopes for the various nations. At first sight it might be inferred that Dutch and Polish pilots, and perhaps Germans too, are especially fond of dives and beat-ups, that Frenchmen are more given to screaming round tight turns, that U.S.A. pilots like to do their flying upside down, while the British, true to one of their national characteristics, just like to float calmly along in the afternoon sunshine! While this is obviously not so, there may well be a hint of truth in the picture, since the

Table 2

Design Diving Speeds in Knots (EAS) and km/h

Category	Normal				Cloud Flying			
Wing loading lb/ft² kg/m²	4 19,5		4 19,5		5 24,4		6 29,2	
	knots	km/h	knots	km/h	knots	km/h	knots	km/h
British	87	161	115	213	123,5	228	132	244
French	95	175	105	194	117,5	217	129	238
German	77	142	121	224	135	250	148	274
Dutch	91	168	124	230	139	257	152	281
Polish	96	177	120	222	134	248	148	274
U.S.A.	87	161	102	189	112	207	123	228

different requirements are not necessarily intended to cover precisely the same types of manoeuvre.

One important factor is that different kinds of aerobatics can impose very different loads on the gliders performing them, and it does not seem possible to have one set of rules for all gliders coming into the general classification "high performance" unless we are prepared to put up with considerable increased weight and cost. This fact is recognised in the British requirements, which are, as illustrated here, intended to ensure adequate strength for the simpler manoeuvres only, such as loops, chandelles and stall turns, which are all that the majority of club pilots normally require. They are not intended to cover more advanced manoeuvres such as inverted flight, rolls, or others involving negative acceleration at appreciable speed, and for which additional requirements are imposed. It would be interesting to know whether any such special conditions are made by any other national authority.

It may also be pointed out that the British consider their requirements quite adequate for cloud flying, subject to the sailplane being fitted with speed-limiting brakes which can be opened rapidly at any speed up to the maximum permitted, and to a rough-air limitation equal to speed V_A, being imposed.

These arguments can hardly apply to the normal or training category, yet the comparison is much the same as for the high performance class. If the argument for such generous accelerations is that the pilots who fly these machines are relatively inexperienced and hence ham-fisted, it would seem that perhaps there is a case for better training methods—on looking at some of the values one is tempted to say that if the pilote are *that* ham-fisted they should be back on the two-seater!

5. Gust Cases

Gust cases are often presented in envelope form but for present purposes it will suffice to tabulate the maximum accelerations and the speeds at which they apply (see Table 3).

Normal acceleration is limited by maximum lift coefficient (taken as +1,3 and —0,8) in two cases. In the British case, the CL_{max} is applied at flight speed using the ordinary lift equation; in the Polish case, a factor of 1,25 is applied as well.

Numerically, the German and Polish values seem high, particularly the latter at the higher wing loading. One wonders how many sailplanes have actually been designed to this sort of figure. There are no gust cases in the U.S.A. document.

The actual methods of defining the gust case are so varied that they are worth enumerating; in cases where normal and high-performance aircraft values are different, the latter are given.

British	20 m/sec gust at V_A with alleviating factor depending on wing loading, normally about 0,4.
French	16 m/sec gust at V_c with similar alleviating factor, normal acceleration being applied at V_c + gust speed, where V_c is speed for rate of sink equal to three times the minimum.
German	10 m/sec gust at V_D with alleviating factor 0,6.
Dutch	10 m/sec gust at V_D with alleviating factor similar to British.
Polish	30 m/sec gust at 2,5 V_s with alleviating factor depending on mass parameter (on the lines of aircraft relative density) and normally about 0,25.

Beyond stating that there are theoretical grounds in favour of the mass-parameter function for alleviating factor, and that there is evidence that gusts of 20 m/sec do actually occur with some sort of significant frequency, it is difficult to comment.

6. Ground Loads

These are specified in many different ways. Here, the vertical velocity of descent for shock absorption, v, and the vertical load factor, P/W, in the principal landing case, are considered in Table 4.

Regarding velocity of descent, the British requirements are the most severe of those quoted, but it may be remarked that the values given are somewhat lower than were originally proposed. However, no safety factor need be applied to the loads associated with these velocities; the velocities for the main strength case, for which the usual safety factor 1.5 applies, are 15% lower. This method is adopted to prevent greatly increased loads occurring when the normal limiting velocity is exceeded just slightly.

It is interesting that some nations appear to be satisfied not to specify any shock absorption requirements at all.

Many other landing conditions are specified, e.g. nose-down cases, tail-down cases, some with side and drag loads, some with these applied separately, but the variations are too wide to enable any further simple comparison to be made. It is worth noting, however, that the Dutch specify a number of crash-landing cases in which damage is permitted, but serious injury to the occupants is to be avoided; in Class 1, the requirements are 12g downwards, 4g upwards, 9g forwards

Table 3

Category	NORMAL				HIGH PERFORMANCE							
Wing Loading	4 lb/sq. ft (19,5 kg/m²)				4 lb/sq. ft (19,5 kg/m²)				6 lb/sq. ft (29,2 kg/m²)			
	EAS knots	km/h	+ n	— n	EAS knots	km/h	+ n	— n	EAS knots	km/h	+ n	— n
British	60	111	4,0	2,0	67	124	5,0*	3,1*	83	153	4,9	2.9
French	86	159	4.3	2,3	96,5	178	4.3	2,3	111	205	3.9	1.9
German	77	142	4,6	2,6	121	224	6,7	4,7	148	274	5,7	3.7
Dutch	91	168	3,9	1,9	124	229	5,0	3,0	152	281	4,6	2.6
Polish	69	127	4,7	2,7	86,5	160	5,6	3.6	106	196	7,8*	4.8*
U.S.A.			—	—			—	—			—	—

* Limited by maximum lift coefficient

Table 4

Requirements	Class	V ft/sec	V m/s	P/W	Remarks
British	1	5,3	1,62	≮ 3	Usual safety factor only required for load at 15% lower v
	2	4,1	1,25	≮ 3	
French	1,2	4,2+	1,28		Elastic deformation of whole glider considered
German	1			4	
	2			3	
Dutch	Wheel			4	P/W may be less if shock absorption sufficient
	Skid			5	
Polish	1	4,9	1,49	≮ 4	Shock absorption must be sufficient for P/W ≮ 4
	2	3,3	1,01	≮ 4	
U.S.A.	Wheel			4	No shock absorption requirements
	Skid			5	

Class 1 = Normal Class 2 = High Performance

and 2g sideways, while in class 2 they are similar except that the downwards figure is 8g. Evidently the more experienced pilot who flies high performance machines does not deserve so much protection in crashes—he ought to know better than to have them! The Polish and British also have corresponding cases or the equivalent but for safety harness only. Both Dutch and Americans have in addition a 4g (ultimate) case applied to the nose of the glider.

7. Safety Factor

Generally speaking the safety factor applied to limit loads is 1,5, except in the case of Germany which specifies 2,0. As far as normal acceleration is concerned, however, the values appear to have been adjusted to give about the same ultimate loads (see para. 4).

Several countries however, specify additional factors for particular items, as in Table 5.

The British castings factor can be reduced if strenght tests are made.

8. General Remarks

The above comparisons give only a general idea of the overall levels of strength required by the various national authorities; many other factors, such as launching cases, controls-operated cases, etc. are necessary to make the picture complete, but to make a detailed survey of all of them would be lengthy and somewhat tedious. From the principal cases considered here, however, it is evident that there is a fair divergence of opinion among the different authorities as to the speeds and factors to which gliders should be designed.

To the British observer, some of the flight cases seem needlessly severe for the ordinary sailplane which is perfectly capable of putting up good cross-country performance, and cloud-flying safety, but which does not need to do the more intricate aerobatic manoeuvres, while on the other hand many of the landing cases seem noticeably deficient as to shock absorption.

Table 5

	British	French	Dutch	Polish	U.S.A.
Castings	2,0	1,25	2,0	1,3	2,0
Joints and fittings		1,08	1,2		1,2
Transport joints		1,15	2,0		
Multiple cables		1,25			1,05
Control cables			2,0–3,33		3,33
Bracing wires			2,0		
Control surface hinges			6,67		6,67
Torque tube hinges					1,5
Lift struts and wires					1,2
Wood construction				1,15	