Sailplane Weighing

By C. O. Vernon

Introduction

In conversation with gliding people the author has noticed that a number of them have some difficulty both in weighing their sailplanes, when this becomes necessary, and in turning the results into cockpit load limitations. The subject has been fully written up in Ref. 1, and no doubt elsewhere, and this brief article is intended only to act as a general guide – there is nothing very profound in it but one or two of the practical points do not appear to be well known and it is hoped that it may help those not fully conversant with the subject.

The reason for weighing a sailplane is mainly as hinted above, to determine the cockpit load limits, that is the maximum and minimum cockpit loads. Another reason is that the sailplane weight affects its performance, sizable changes in load having an appreciable effect on optimum speed etc. in most conditions. We are concerned here with the former reason.

If the sailplane is flown with too big a load, so that the maximum certificated weight is exceeded, the loads arising in manoeuvres may exceed the design values so that the safety factors are reduced. This can affect the lives of components subject to fatigue and in extreme cases could lead to structural failure either because of fatigue or statically.

If the cockpit load is such that total weight is within the permitted value but the C. G. of the sailplane is ahead of the permitted forward limit, the strength of the tailplane and rear fuselage may again be affected, though usually only slightly. Also, however, the sailplane may be impossible to trim at low speed, particularly in circling flight and so be tiring to fly, and it may be more difficult to attain the proper landing attitude. If the cockpit load is below the minimum so that the C. G. is behind the permitted aft limit, the longitudinal stability will be reduced and the stalling and spinning characteristics will be affected and spin recovery may be more difficult; the sailplane will be less easy to fly and in extreme cases could be dangerous.

Note that I have said «cockpit load» and not «pilot weight». The cockpit load includes all the things that are not part of the sailplane, that is parachute, food and all loose equipment, in addition to the pilot. If a particular piece of equipment, for example the barograph, is *always* carried it may be considered part of the empty sailplane if desired, but if so this should be made clear in the paper-work.

The Weighing

The sailplane is supported at two points, one in front of the C. G. and one behind ist, the sum of the two reactions giving the weight and the individual reactions in conjunction with the distance between them yielding the C. G. position. This brings us to the first practical point, which is that one of the supports should be as near the C. G. itself as possible and the other one a good distance away from it. With the normal methods of slinging, the former will be the forward support. The moment of the reaction of the other (normally rear) support, and hence the C. G. position, can then be determined with the maximum accuracy. This is simply because the distance of the C. G. from the (normally) front support is directly proportional to the said moment, so that a given percentage error in the latter results in the same percentage error in the distance, and the smaller that distance is the

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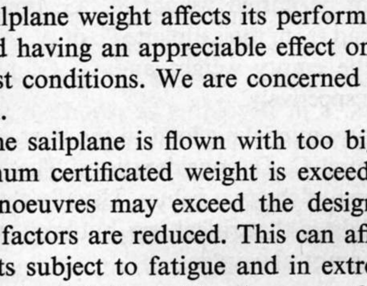
EMPTY WEIGHT & C.G. POSITION



EMPTY WEIGHT

FRONT SUPPORT:-			REAR SUPPORT:-		
READING	F_1	163·5 KG	READING	R_1	41·4 KG
ZERO	F_2	2 KG	ZERO	R_2	1·2 KG
$F = F_1 - F_2$		161·5 KG	$R = R_1 - R_2$		40·2 KG

EMPTY WEIGHT $E = F + R = 161{\cdot}5 + 40{\cdot}2 = 202$ KG

EMPTY C.G. POSITION

FRONT SLING AHEAD OF DATUM a 1·2 CM
FRONT SLING TO REAR SLING l 342 CM

EMPTY C.G. $x_e = \left(l \times \frac{R}{E}\right) - a = 342 \times \frac{40{\cdot}2}{202} - 1{\cdot}2$
$= 68{\cdot}1 - 1{\cdot}2 = 66{\cdot}9$ CM AFT OF DATUM

MAXIMUM & MINIMUM COCKPIT LOAD

MAXIMUM PERMITTED WEIGHT *	W	300 KG	
EMPTY WEIGHT	E	202 KG	
FORWARD C.G. LIMIT *	x_f	31 CM	(+VE AFT)
AFT. C.G. LIMIT *	x_a	44 CM	(+VE AFT)
COCKPIT LOAD C.G. *	x_p	30 CM	(+VE FOR'D)
EMPTY C.G.	x_e	66·9 CM	(+VE AFT)

MAXIMUM COCKPIT LOAD

BY WEIGHT $P = W - E = 300 - 202 = 98$ KG (1)

BY C.G. $P = E\,\frac{(x_e - x_f)}{(x_p + x_f)} = 202 \times \frac{(66{\cdot}9 - 31)}{(30 + 31)}$

$= 202 \times \frac{35{\cdot}9}{61} = 119$ KG (2)

MAX. LOAD = LOWER OF (1) & (2) $= 98$ KG

MINIMUM COCKPIT LOAD

BY C.G. $P = E\,\frac{(x_e - x_a)}{(x_p + x_a)} = 202 \times \frac{(66{\cdot}9 - 44)}{(30 + 44)}$

$= 202 \times \frac{22{\cdot}9}{74} = 62{\cdot}5$ KG

* FROM C OF A OR AIRCRAFT HANDBOOK

WEIGHING RECORD'	SINGLE SEATER OR SIDE BY SIDE TWO ST'R	GLIDER TYPE NEMO SERIAL Nº 1234	SIGNATURE V.O.C DATE 1.4.68.

smaller therefore is the actual error. If the front support is a rope sling round the forward part of the fuselage, it should therefore be placed as close to the wing leading edge as possible – the author aims to have it touching.

Two more points now arise. It is better to take each side of the sling to a roof support separately, and to have a spring balance in each, than to loop them together and then use a single spring balance hung from the roof. This is because the former method gives rolling stability whereas the latter does not; the latter method, unless you are lucky, requires a wing-tip holder and this may introduce errors.

The next point is that the slings must be truly vertical, and this should be checked by sighting the sling with the smaller load against a suitable vertical surface or plumb line. It is then not necessary to look at the other one, since if one sling is vertical the other one must be also. This is because if one sling is not vertical, the horizontal component of its load must be balanced by an equal and opposite component of the load in the other.

It may be preferred to use a platform scale under the wheel of the sailplane in place of the rope sling and spring balance. With this method of support, if the rear support provides fore and aft constraint (e. g. it is another platform scale and the sailplane has a tailskid rather than a tailwheel, so that friction can be exerted) and there is a wheel-brake, the latter must be off and free, or an error may be introduced.

When the sailplane is on its supports it should be at about the correct attitude as specified by the manufacturers. The operative word is «about» – this attitude is one of the few things which does not usually need to be accurate. This is simply because the vertical position of the C. G. is not usually far from the datum point, which is generally the wing leading edge, so that any error in attitude only affects the horizontal C. G. very slightly. If some point well above or below the C. G. were used as a datum – the axle centre line, for example – the above would not be true and it would then be important to set the attitude more accurately.

The last practical point to be mentioned here concerns the accuracy of the readings. The loads should be accurate to 0.5 kg, and the smaller one to 0.2 kg if possible. Corrections should of course be made for the zeros, i. e. the weights of the slings including any spreader-bars etc. The distance between the support nearest the C. G. (the one having the larger load) and the datum point of the sailplane should be measured as accurately as possible, certainly to 2 mm and preferably to 1 mm. On the other hand, the distance between the two supports, or between the datum point and the support furthest from the C. G. (the one having the smaller load) need be known only to the nearest 0.5 cm in the usual case. This is because the former distance affects the C. G. position directly, i. e. each mm error in the distance is a mm error in the C. G. position, whereas the latter distance only affects the C. G. position in the proportion which the smaller load bears to the weight. These remarks on distances apply particularly when, as recommended above, one support is close to the C. G. and the other one well away from it. If, however, it is found in a particular case that it is impossible to avoid having the two supports at not very dissimilar distances from the C. G. – in practical terms if the ratio of the loads at the two supports, which is of course the inverse of the ratio of the distances, is less than say 2½ to 3 – then the distance between the two supports should also be measured as accurately as possible.

The Cockpit Load Limitations

These are calculared from the weighing figures by simple moment sums. Rather than give the derivation of these, I have drawn out a pro-forma on which the whole calculation, for a single-seat sailplane or side-by-side two-seater, and be made by entering the support loads and distance measurements, and doing some simple arithmetic. This pro-forma, with a sample set of results, is shown in Fig. 1.

In using the pro-forma, proceed as follows:

(1) Enter the support loads in the Empty Weight section and calculate the empty weight.

(2) Enter the distance measurements in the Empty C. G. Position section and calculate the empty C. G. position.

(3) Enter the Maximum and Minimum Cockpit Load section with the maximum permitted weight, C. G. limits and C. G. of cockpit load from the sailplane C. of A. or handbook, and with the empty weight and C. G. position from (1) and (2) respectively.

(4) Calculate the maximum cockpit load in the next section, both from weight and C. G. considerations. The load to be taken is the lower of the two values. Usually the value determined by weight is the critical one, but both must be calculated as this is not always so.

(5) Calculate the minimum cockpit load in the last section.

All quantities are fully defined on the pro-forma and the whole calculation should take only a few minutes.

Ref: Standard Repairs to Gliders, published by the British Gliding Association.

Zusammenfassung

Es wird begründet, weshalb Gewicht und Schwerpunk eines Segelflugzeuges wichtig sind. Wenn die Zuladung im Cockpit zu gross ist (der Schwerpunkt demnach zu weit vorn liegt), werden die Sicherheitsfaktoren verkleinert; das Segelflugzeug ist vielleicht ermüdend zu fliegen und schwierig zu landen. Ist die Zuladung aber zu klein (der Schwerpunkt zu weit hinten), so vermindert sich die Längsstabilität; überzogener Flugzustand und Trudeln können gefährlicher werden.

Es werden eine Anzahl praktischer Erfahrungen über das Wägen von Segelflugzeugen gegeben, deren Kenntnis nicht sehr verbreitet scheint. So kann zum Beispiel die Genauigkeit erhöht werden, wenn sich eine der beiden Stützen wesentlich näher am Schwerpunkt befindet als die andere; bei der Verwendung von Aufhängungsstützen genügt es, wenn geprüft wird, dass die weniger beanspruchte Stütze senkrecht ist; der Winkel, unter welchem das Segelflugzeug gestützt wird, muss nur annähernd genau sein.

In der Zeichnung ist anhand eines Beispiels schematisch dargestellt, wie aus der Belastung der Stützen und den genauen Messungen das Leergewicht und die Schwerpunktlage des Segelflugzeuges errechnet werden können, ferner wie aus diesen Daten die Höchst- und Mindestzuladung im Cockpit abgeleitet werden kann.

Swiss Aero-Revue 7/1968