Understanding weight and balance sheets

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To the average glider pilot "Ballast" is a part of the pre-flight check passed over without a lot of thought. Some competition pilots may put a little more emphasis on it. However despite its lack of glory it is very important.

I would certainly recommend that before you buy a glider you evaluate the information given in the weight and balance section of the C of A document.

To gain a greater understanding of your weight and balance record please read on.

Martin Carolan

Some Definitions

Before delving into the guts of a weight and balance report let's just define a few things

- **The Datum: A point in space from which we make all the measurements. It is usually, but not always, defined as the leading edge. Some gliders use the nose, or a frame forward of the leading edge.**

- **Centre of Gravity: This is the point from which if you suspended it the glider would balance. If you can imagine a balance point somewhere towards the middle to rear of the wing then you won't go far wrong.**
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- **The C of G range: The limits on the position of the C of G between which the glider can be safely flown. *They are not open to negotiation.* Flight outside these limits would be foolhardy and will invalidate your insurance.**
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- **Aft Centre of Gravity: This is the rearward limit for safe flight. It is usually achieved by either a lightweight pilot or by putting ballast towards the rear of the glider.**
  Ballasting to the aft limit reduces the download on the tailplane and thereby reduces drag.
  Many competition pilots will ballast the glider to give a value of about 40mm forward of the aft limit. This is determined by weighing the glider and pilot together and calculating the optimum load at the tail.
  Exceeding this limit will result in stability problems - Try throwing a dart the wrong way round & see what happens.
  In an extreme case the glider will fail to pitch nose down after stalling & be unable to recover
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- **Forward Centre of Gravity: This is the opposite extent to which you can load the glider. It may be reached by heavy pilots or if ballast has been added for a lightweight pilot. It is very rare to be limited by this value while still staying within the limits for All Up Weight (AUW).**
  As this limit is approached the download on the tailplane increases, especially at high speed & during winch launches. *Exceeding this limit could result in structural failure of the tailplane or fuselage*
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- **Pilot's Centre of Gravity: This is the approximate position for your average pilot's C of G. A short pilot will sit further forward in the seat but may weigh less, a tall pilot sits further back but will be heavier. The best way to determine in-flight C of G is to weigh the pilot in the glider.**
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- **All Up Weight: This is the maximum weight for the glider and is usually expressed as two values. 1) Max AUW DRY and 2) Max AUW WET. Both are self explanatory and should be adhered to.**
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- **Maximum weight of non-lifting parts: These are the fuselage and tailplane. The manufacturer requires that these be weighed separately to determine their value. Unless you have carried out major repairs or refinishing you are unlikely to exceed this value. For the standard 5 year re-weigh it is not necessary to re establish this figure since it won't change dramatically without radical alterations.**

The values for your glider

The best place to start looking is within the manufacturer's pilot's notes, or on the "BGA Certificate of

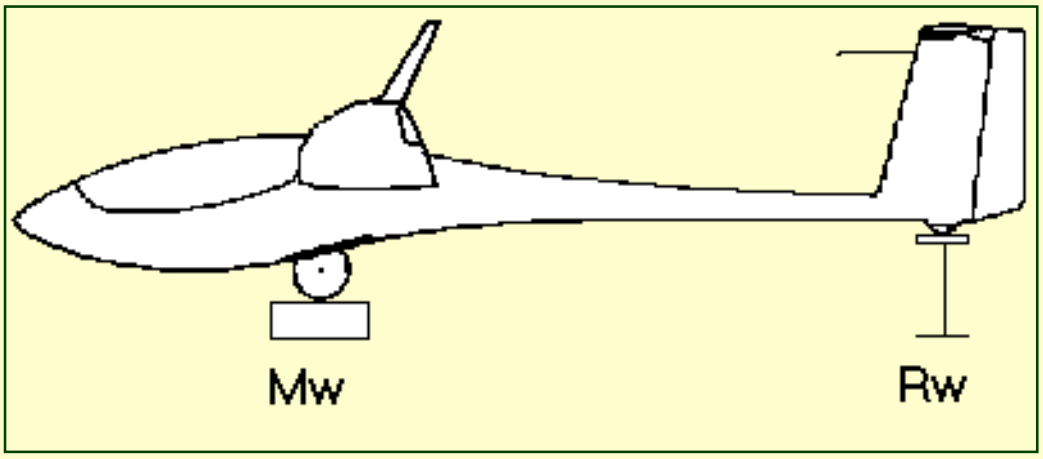
Airworthiness". If that fails to get you the answer try the agent or another owner. The BGA has now set up a set of Type Data sheets on its web site so you may well find the information there.

The Forward & Aft limits for the C of G are determined by the designer of your Glider.

A typical single seater will be likely to have limits of the order of 200mm (Forward Limit) to 500mm (Aft Limit) measured back from the leading edge.

Weighing the Glider

The glider is rigged and placed on two scales. Normally with the tail raised to a position specified by the manufacturer



The readings from both scales are recorded. The empty weight of the glider is then determined by adding the two figures.

Next the distances from the datum to each of the weighing points are measured

All the values for weight and distance are substituted into a formula and the Centre of Gravity position is calculated.

It is then possible using the forward and aft C of G limits to determine the maximum and minimum cockpit loads.

What to look for on a weight and balance sheet

The details recorded on the C of A document issued by the BGA are **"Empty Weight" "Max Cockpit**

Load" "Min Cockpit Load" and **"Date Weighed"**

Empty Weight:

This value should be checked for variations over the life of the glider. A few Kgs or Lbs here or there may be due to differences in weighing equipment. With wooden gliders a slight increase can be expected during damp winters due to water absorption.

Most changes will be due to:

Refinishing work

Over many years most gliders deteriorate and require refinishing. If performed badly this can add considerably to the weight of the glider. This is more apparent on fabric covered gliders where stripping back paint can reveal 4 or more colour changes.

Repair work.

It would be nice to think that a correctly executed repair will add nothing to the empty weight. Unfortunately most major repairs do result in an increase. Check for an aftward change in C of G position as this can result in a high value for cockpit minimum.

Instrumentation

Modern electronics weigh very little, but this has not always been the case. The addition or removal of a 1950's Horizon can make a 2 - 3 kg change in the empty weight and a considerable change to the cockpit loads. Oxygen is usually placed at or near the C of G and so should only affect the empty weight.

Max Cockpit Load:

The usual value is around 110 kg and you are unlikely to find a value greater than 220kg on any glider This value is the design limit for the seat and should not be exceeded. The reasons for lower values could be:

High empty weight:

To keep within the Max All Up Weight ss the empty weight increases the reserve available for seat load is reduced.

Forward C of G limitation:

This is vary rare, in most cases the value determined by the manufacture has adequate range. If this ***is*** a problem look for repairs forward of the Datum or large amounts of lead in the nose from a previous lightweight pilot.

Min Cockpit Load:

A new glider delivered from a German factory today is likely to have a minimum cockpit load of around 65 kg or more. This figure is a value given in the pilots notes and is a safe value. It will be a standard value for that type and avoids the manufacturers having to calculate the exact value for each individual glider

It is wise however to find the true value by calculating it from the figures given on the weight and balance sheet. Under BGA rules a value lower than that in the pilot's manual may be calculated using the aft C of G

limit

Reasons for a **high** minimum cockpit load are:
Repairs
Repairs to the rear fuselage or tailplane will move the C of G aftwards.

Tail Ballast
Maybe a previous owner was heavy or competition orientated. Removal of the ballast should return the value to normal.

Date weighed:

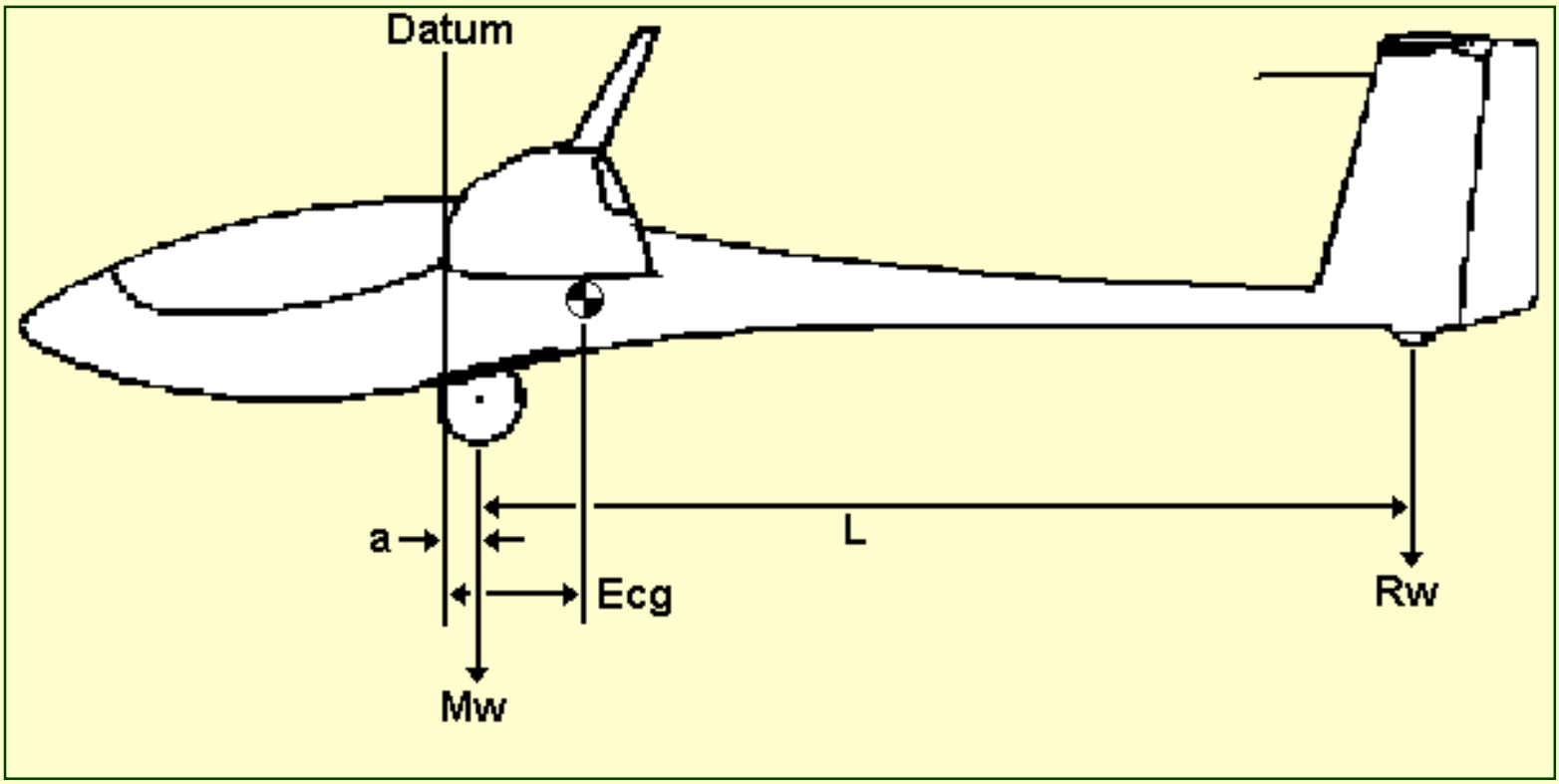
Under BGA rules a glider must be re-weighed every 8 years or whenever the weight and balance may have been affected.

A re-weigh may be required after :

- New instruments
- Repairs or Refinishing
- Ballast being added or removed

It is therefore worth looking to see when & why the glider was last weighed.

Formulae



Empty Weight

$$Ew = Mw + Rw$$

Where :
Ew = Empty Weight
Mw = Weight at Main Wheel
Rw = Weight at Tailwheel (Or Skid)

Empty C of G position

$$Ecg = L \times (Rw/Ew) + a$$

Where :
Ecg = Empty Cof G position, Relative to Datum
L = Distance from Main Wheel to Tailwheel
a = Distance from Datum to Main Wheel

Min Cockpit load

$$P_{min} = E_w \left((E_{cg} - \text{Aft cg}) / (\text{Pilot cg} + \text{Aft cg}) \right)$$

Where :
Pmin is the minimum cockpit load

Max Cockpit Load

$$P_{max} = E_w \left((E_{cg} - \text{Fwd cg}) / (\text{Pilot cg} + \text{Fwd cg}) \right)$$

Where :
Pmax is the minimum cockpit load

Note: Pmax is likely to be limited by AUW or seat structural limits

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More detailed information may be found in:-

"Standard repairs to gliders" available from the British Gliding Association