



BMAA TECHNICAL INFORMATION LEAFLET (TIL)

TIL 012 ISSUE 6

WEIGHT, BALANCE AND WEIGHING

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1. Introduction

This leaflet describes and discusses the BMAA weight and balance policy.

The primary purpose of the BMAA's weight and balance policy is to ensure that the empty weight and balance of every BMAA aircraft is sufficiently accurately known to allow pilots to load their aircraft safely.

1.1. Basic and Actual empty weight

Unfortunately the definition of empty weight is not as simple as one might hope!

The complicating factor is that there is an empty weight limit for each aircraft type. The intention of this weight limit is sensible: to ensure that an aircraft sold as a two seat aircraft is indeed a reasonably practical two seat aircraft, not a one plus one that actually can't be flown by two average adults without exceeding the aircraft's maximum weight.

The problem is that many BMAA aircraft are manufactured very close to (or even at) their empty weight limit. Many owners - perfectly reasonably - want to fly with additional (optional) equipment fitted, at the expense of two-seat practicality.

This results in two empty weights for the aircraft:

- Its **Basic empty weight**, without optional equipment fitted, and
- Its **Actual empty weight**, with optional equipment fitted.

The aircraft's Basic empty weight must not exceed the empty weight limit for the type when the aircraft is brand new. The Basic empty weight must also be considered if the aircraft is fundamentally modified in service: to ensure that it is not being modified from a two seater into a one plus one. Other than in these specific cases, the Basic empty weight can largely be ignored. The important thing - from a flight safety perspective - is that the pilot knows what the aircraft's Actual empty weight is, so that the aircraft can be loaded within its safe limits.

1.2. Changes to the BMAA weight and balance policy - 2015

Prior to 2015 BMAA aircraft had to be weighed every 5 years irrespective of whether anything significant on the aircraft had changed or not. And the primary purpose of the weighing appeared to become to ensure that the aircraft did not exceed the empty weight limit. The most important thing - ensuring that the pilot knows what the aircraft's actual empty weight is - seemed to be forgotten.

Therefore, the BMAA has undertaken a review of its weight and balance policy, and has agreed with the CAA:

- That aircraft on the BMAA fleet no longer need to be routinely re-weighed. Before 2015 UK Microlight aeroplanes had to be re-weighed every 5 years. This does not mean that aircraft should not be reweighed occasionally to ensure the Actual empty weight is known. This is discussed in Section 3.3.3.
- That an aircraft whose Basic empty weight drifts over the Basic empty weight limit for the type can continue to fly legally. Therefore, once an aircraft is in service, the Basic empty weight need only be considered if the aircraft is modified or repaired. This is discussed in Section 3.2.
- Some exceptions to having to comply with the Basic empty weight limit should an aircraft need to be modified or repaired in service. All exceptions to compliance with the Basic empty weight limit following modification must be agreed by the Technical Office. This is discussed in Section 3.2.1.
- Aircraft must have a valid weight report using form AW028 Issue 09 (or later) to determine the actual empty weight.

2. Important definitions

2.1. Actual empty weight

The Actual empty weight of the aircraft is the empty weight of the aircraft in its current state. The Actual empty weight includes any Optional equipment currently fitted.

The placarded empty weight of the aircraft must be the Actual empty weight. Also the empty weight and CG position used to check the balance of a 3-axis control aircraft must be the Actual empty weight.

The Actual empty weight is the weight used by the pilot to ensure that he doesn't overload his aircraft with occupants, fuel and baggage.

2.2. Basic empty weight

The Basic empty weight of an aircraft is the empty weight of the aircraft with:

- Required equipment fitted;
- Unusable fuel only;
- Full engine oil, engine coolant, and hydraulic fluid;
- Fixed ballast.

The weight of non-required, or optional, equipment may be excluded from the Basic empty weight of an aircraft. The distinction between Required and Optional equipment is clarified below.

The CAA specifies an upper limit on the Basic empty weight of regulated (two-seat) Microlights, which, when new, they must not exceed in order to qualify for a UK Permit to Fly. Similarly if the aircraft is fundamentally modified in service the Basic weight of the modified aircraft must not exceed this upper weight limit. This is clarified below.

2.2.1. Basic empty weight limit / Maximum Zero Fuel Weight

The Basic empty weight limit for a particular type is normally specified on the TADS / HADS for the type as the 'Maximum Zero Fuel Weight (ZFW) at Initial Permit Issue'.

2.3. Required and Optional equipment

Optional equipment is equipment that can be physically removed and whose removal does not make the aircraft un-airworthy. To be airworthy the aircraft must be in an approved design configuration and able to be safely flown with the equipment removed.

Equipment that can be removed but must be replaced with something else for the aircraft to remain airworthy is not normally considered optional equipment.

Examples:

- Altimeter. The altimeter is one of the required instruments for the type (see the TADS / HADS). Therefore although it can be removed, the aircraft is not approved for flight without it. Therefore the altimeter is required equipment.
- GPS. A GPS is not one of the required instruments for the type (see the TADS / HADS). Assuming it can be removed the GPS is, therefore, optional equipment.

- Doors and spats. Doors and spats are usually able to be removed. However not all aircraft are approved for flight without them fitted (normally for aerodynamic reasons). Doors and spats are only optional equipment if the aircraft is approved for flight without them fitted.
- Lightweight equipment options. Some types have lightweight equipment options such as a lightweight battery, lightweight tyre, or lightweight wheel. An aircraft's Basic weight is the Basic weight of the aircraft with the actual equipment fitted, not the Basic weight it could be with lightweight replacements.

3. BMAA weight and balance policy

3.1. New aircraft

All brand new aircraft must be accurately weighed. The purpose of the weighing is twofold:

- To confirm that the aircraft's Basic empty weight does not exceed the Basic empty weight limit for the type;
- To determine the Actual empty weight, and, for 3-axis control aircraft, ensure the balance is satisfactory.

For BMAA amateur-built aircraft this weighing is overseen by the build Inspector and the Technical Office. For factory-built aircraft this weighing is the responsibility of the manufacturer.

3.2. Modifications and repairs

A modification or repair almost always affects the empty weight of the aircraft. Unless the change is simply the addition of Optional equipment, the Basic empty weight of the aircraft will also be affected. If the Basic empty weight is affected, it must normally remain within the Basic empty weight limit for the aircraft type.

3.2.1. Exceptions to compliance with the Basic empty weight

The BMAA has agreed with the CAA some exceptions to having to comply with the Basic empty weight limit. All exceptions to compliance with the Basic empty weight limit following modification must be agreed by the Technical Office.

An existing aircraft undergoing incorporation of a change that affects the Basic empty weight that is found to be overweight prior to the change may still have the change incorporated if:

- The change does not significantly increase the weight, or
- The change is required to keep the aircraft airworthy (and there is no reasonable, lighter alternative).

An existing aircraft undergoing incorporation of a change that affects the Basic empty weight where the change will make the aircraft overweight may still have the change incorporated if:

- The change is required to keep the aircraft airworthy (and there is no reasonable, lighter alternative).

3.2.2. BMAA Modifications and Repairs

For modifications and repairs approved by the Technical Office, the effect on weight and balance is considered as part of the approval.

3.2.3. Fitment of pre-approved changes

This Section should be read in conjunction with the flowchart in Appendix 2.

Pre-approved changes are usually listed on the TADS / HADS as Approved Optional Modifications or as alternative power-plant configurations. These are already approved and therefore do not require further approval before they can be fitted. They are required to be inspected and signed-off by a BMAA Inspector.

Unless the change is simply the addition of Optional equipment, the Basic empty weight of the aircraft will be affected, and the Technical Office must be consulted.

3.3. In-service tracking of weight and balance

Even if an aircraft is not modified, its weight can drift in service. It is important to keep track of this weight drift so that the pilot can continue to load his aircraft safely (within the maximum take-off weight limit, and remaining within balance). This weight drift can affect the Basic empty weight as well as the Actual empty weight.

The BMAA has agreed with the CAA that an aircraft whose Basic empty weight drifts over the Basic empty weight limit for the type can continue to fly legally. Therefore, once an aircraft is in service, the Basic empty weight need only be considered if the aircraft is modified or repaired. This is discussed in Section 3.2.

The main reason for weight drift in service is the direct replacement of parts during maintenance with essentially identical parts that are, in reality, of a different weight to the originals. See section 3.3.2. A secondary reason is the absorption of moisture. This particularly affects composite and wooden airframes.

3.3.1. Annual weight review

As part of the annual inspection (to revalidate the Permit to Fly) the BMAA Inspector performs a weight review. The reason for the weight review is to ensure that the Actual empty weight of the aircraft is known and correct.

If the Actual empty weight has changed, the following also need to be done:

- Check the aircraft is in balance (3-axis control aircraft only).
- Amend the aircraft's placards (empty weight, occupant / fuel trade-off, etc.).
- Send the new or amended weight and balance reports to the Technical Office.

See the flowchart in Appendix 1.

3.3.2. Maintenance and replacement of parts

The weight of replacement parts should be checked to ensure that they weigh the same as those they replace. This is particularly important for heavy items, such as engines and large airframe components, where a small percentage change in weight can be significant in terms of kilograms. It is also particularly important for commercial items, such as batteries and tyres, where differences in weight are more likely.

If there is a significant difference in weight the advice of a BMAA Inspector or the Technical Office should be obtained before further flight. Note that, for 3-axis control aircraft, balance can be adversely affected.

The difference in weight between replacement parts and those they replace should be recorded in the aircraft logbook. If there is no difference in weight this fact should be recorded too. A carefully completed logbook will make the Inspector's life easier at the annual inspection, and might avoid the Inspector having to insist that the aircraft be reweighed.

3.3.3. Routine weighing

The BMAA has agreed with the CAA that aircraft on the BMAA fleet need not be routinely re-weighed. Before 2015 UK Microlight aeroplanes had to be re-weighed every 5 years.

However competently empty weight is monitored in service, as time passes the risk that the placarded empty weight is in error increases. This may be due to the accumulation of undocumented small weight changes, human error/oversight, environmental effects etc. It is therefore recommended that the Actual empty weight and balance is still checked occasionally by re-weighing. The frequency of re-weighing depends very much on individual circumstances, and in particular the amount of work that could have affected the weight that has been performed since the last weighing.

It is good practice for an aircraft with a metal airframe be weighed at least every 10 years. This should only be exceeded in exceptional circumstances. An example would be an airframe, which - since the last weighing - has a well-documented (and reliable) maintenance history that does not include any major repair/maintenance work.

It is good practice for an aircraft with a composite (or wooden) airframe be weighed every 5 years. This shorter time period is because the airframe weight can drift even if untouched by human hand.

Remember: a routine weighing is only used to check the aircraft's Actual empty weight and balance for safety reasons; an aircraft cannot 'fail' a routine weighing for being too heavy.

4. Weighing an aircraft

4.1. General weighing guidelines

The aircraft must be dry and reasonably clean (in particular no large build-ups of mud on the underside and in spats), and drained of all but unusable fuel. Weighing an aircraft with fuel on board is unacceptable because the weight of fuel on board cannot be determined accurately enough. Equipment and baggage not intended to be weighed must be removed. Optional equipment left in place must be included in the 'equipment inventory' on the weight report - see Section 5.1.1. For example: flying kit, charts, helmets and headsets would not normally be weighed; GPS, radios, spats and seat cushions would be weighed (if normally fitted).

The aircraft should be weighed on a hard, level surface in an enclosed (draft free) building. Weighing outside is discussed in Section 4.1.2.

When on the scales the aircraft must be at the weighing attitude specified on the TADS / HADS (3-axis control aircraft only). A small error in this attitude can result in a large error in the calculated location of the centre-of-gravity. A spirit level, plumb bob, or similar, should be used to get the weighing attitude right. If blocks are placed on the scales to achieve the weighing attitude, ensure that their weight is not erroneously added to the aircraft's weight.

The preferred option is to roll the aircraft onto the scales. If the aircraft has to be lifted onto the scales this results in the mainwheels exerting a large side load on the scales as the undercarriage compresses. Many scales give erroneous readings under side loads. The side loads can be minimised by lifting the aircraft by its wheels or axles so that the undercarriage is fully compressed as it is lowered onto the scales. Rolling the aircraft back and fore on the scales can help in removing any residual side loads.

A single weighing is never sufficient. The aircraft must be loaded and unloaded from the scales until confidence is gained that the wheel weights obtained are reliable. Ensure that the scales return to zero after the aircraft has been removed.

4.1.1. Safety precautions

Weighing an aircraft is potentially hazardous. There are risks involved with draining the aircraft of fuel and lifting the aircraft onto the scales. Ensure that these risks are properly assessed and mitigated. Ensure that aircraft are not damaged while being manhandled.

4.1.2. Weighing an aircraft outside

Weighing an aircraft outside is very unreliable because any wind will affect the results. Even a 4 mph draft can affect the measured weight of a Microlight by around 5kg, and have an even more significant effect on balance. If there is no enclosed building available the aircraft must be weighed in still - nil wind and thermal free - conditions. If weighed outside, the aircraft should be weighed a number of times pointing in different directions until confident that air movement is not affecting results. In case of difficulty contact the Technical Office as it may be possible to authorise a ferry flight to a more suitable location.

4.1.3. Using a single scale – NOT ALLOWABLE

BMAA no longer allows this method as the results are not reliable enough.

~~It is possible to weigh with a single scale, rotating the scale between the three wheels to get a total weight for the aircraft. However to do this accurately and reliably is much more difficult than using a full set of scales—for the reasons outlined below—so it is not recommended.~~

~~When the scale is under one particular wheel, dummy scales of exactly the same height as the actual scale must be placed under the other wheels to compensate. If this is not done the aircraft is weighed in three different attitudes and the result will be wildly incorrect (too low).~~

~~Any residual side load on the main wheels will result in the main undercarriage being unnaturally deflected. This can result in the aircraft tipping slightly to one side or the other, which will affect how the weight is distributed between the main wheels. This doesn't matter if the weights on the main wheels are measured at the same time, but does matter if a single scale is used. Therefore, if a single scale is used, be particularly careful to ensure that there is no residual side load – see Section 4.1. Also, each wheel must be weighed multiple times, loading and unloading between each weighing, until entirely confident that the correct wheel weight is being measured.~~

4.2. Weighing to determine Actual empty weight

Remember: an aircraft's Actual empty weight is its empty weight with normally fitted, optional equipment installed.

The BMAA's procedures require that Actual empty weight is determined to an accuracy of better than 0.5kg.

To achieve this accuracy the scales used must:

- Be of a type appropriate for weighing aircraft reliably and reasonably accurately.
- Have a resolution of at least 0.1kg (i.e. 0.1kg or lower e.g. 0.05, 0.01kg).
- Have been checked for accuracy within the last 12 months.

4.2.1. Bathroom scales – NOT RECOMMENDED

Note BMAA advises against the use of bathrooms scales as the results are not as accurate or reliable as load cells.

Bathroom scales are often unsatisfactory for weighing aircraft, especially fixed wing. The same may be true of other scales not primarily intended for weighing aircraft or other vehicles.

Bathroom scales are often intolerant to being used on a less than perfectly flat surface. This can be improved by manufacturing a rigid base for each scale from thick plywood. The plywood needs to be around 1" thick to be rigid enough. Bathroom scales are also often intolerant to a single point load from an aircraft wheel, preferring the distributed load from a pair of feet. Again this can be improved by manufacturing a top for each scale from a piece of plywood. This plywood doesn't usually need to be as rigid, and therefore thick, as the plywood for the base.

When weighing an aircraft it is often difficult to get the wheel right in the middle of the scale, and even more difficult to ensure the wheel is not applying any side load to the scale. Bathroom scales may be wildly inaccurate under offset loads and side loads. The only way to assess this is by test. A test side-load can be easily applied by trapping a chord underneath the test weight sat on the scale. If this chord is pulled perfectly horizontally it applies a pure side load, with no vertical component. This can be used to see if a side load affects the measured weight of the test weight.

4.2.2 Load cells – HIGHLY RECOMMENDED

Note BMAA highly recommends using digital load cell (based) scales due to their superior accuracy and reliability.

Many types of load cell are available. Here is a basic list, starting with the most affordable through to more expensive options;

- Heavy duty postal load cells
- Go-kart racing load cells
- Veterinary load cells
- Car racing load cells

- Aircraft load cells

BMAA does have its own set of load cells, maximum rating of 200kg per load cell. These are available for a small hire charge, or alternatively for use to compare with other scales/load cells.

4.2.3. Checking for accuracy

Prior to any weighing being performed, each load cell to be used **MUST** be checked for accuracy within 3%. The method involves standing on platform #1, recording the figure, then moving to scale #2 and finally #3. The maximum difference between all platforms **MUST** be no more than 3%. NOTE: outlier cells (one showing the least accuracy) should always be using for mainwheels, not nose or tailwheels.

BMAA highly recommends that platforms and weighing systems be checked for accuracy using either:

- known weights;
- using a professional company;
- against a calibrated set of scales (i.e. BMAA scales or those used by a CAA approved company such as an A8-1 Microlight manufacturer).

The scales should be checked over a number of different weights representative of the anticipated wheel weights. Checking at 50kg and 100kg is satisfactory for many 450kg aircraft. Some aircraft, particularly tail-wheel aircraft and the CFM Shadow require one scale that is accurate at a much lower weight.

4.3. Weighing to determine Basic empty weight

Remember: an aircraft's Basic empty weight is its empty weight without optional (non-required) equipment.

The BMAA's procedures require that Basic empty weight is determined to an accuracy of better than 0.5kg.

To achieve this accuracy the following are required of the scales used must:

- Be of a type appropriate for weighing aircraft reliably and accurately. Typically, industrial scales or racing car scales are suitable; bathroom scales are totally unacceptable (in this case).
- Have a resolution of at least 0.1kg (i.e. not greater than 0.1kg).
- **MUST** have been checked for maximum 3% error across all platforms.
- **SHOULD** have been calibrated (normally not more than 12 months old), traceable back to national standards.

The weighing of an aircraft to determine its Basic empty weight is always performed in conjunction with the Technical Office, who will require details of the scales used and how they were error checked (or calibrated if conducted). The Technical Office may wish to see a copy of the calibration certificate.

4.3.1. Calibration

The Technical Office maintains a set of calibrated industrial scales (traceable back to national standards) that can be used to calibrate other scales for the purposes of determining the Basic empty weight of BMAA aircraft. These BMAA scales can be hired for short periods of time.

Alternatively, by using a CAA approved company such as an A8-1 Microlight manufacturer is always an acceptable and recommended method.

5. Forms and Spreadsheets

The spreadsheets are written using MS Excel. There are two versions of each spreadsheet available: one .xls version for old versions of MS Excel; one .xlsx version for newer versions of MS Excel. The spreadsheets are written to be able to run on Apple devices as well as PCs. However, they will only work properly on MS Excel, not on other spreadsheet software.

| Aircraft must have a valid weight report using form AW028 Issue 09 (or later) to determine the actual empty weight.

5.1. The BMAA Weight Report spreadsheet

The weight report is suitable for 3-axis control aircraft - where the location of the centre-of-gravity must be calculated - as well as for weight-shift control aircraft (and powered parachutes) - where the centre-of-gravity location is not normally checked. The spreadsheet permits centre-of-gravity calculation to be turned on or off as required.

Any new or amended report must be signed-off by a BMAA Inspector and forwarded to the Technical Office.

5.1.1. Equipment inventory

The weight report includes an 'equipment inventory' section. This is a free text section that is used to record the state of the aircraft when it was weighed. The intention of this section is to assist the owner and Inspector in future determine exactly what was, and what was not, fitted to the aircraft when it was weighed.

| The Equipment Inventory MUST be completed and reflect the condition of the aircraft at the time of weighing.

5.1.2. Subsequent changes

The weight report includes a 'subsequent changes' section. This section allows post-weighing changes to be recorded, and the new weight and balance calculated.

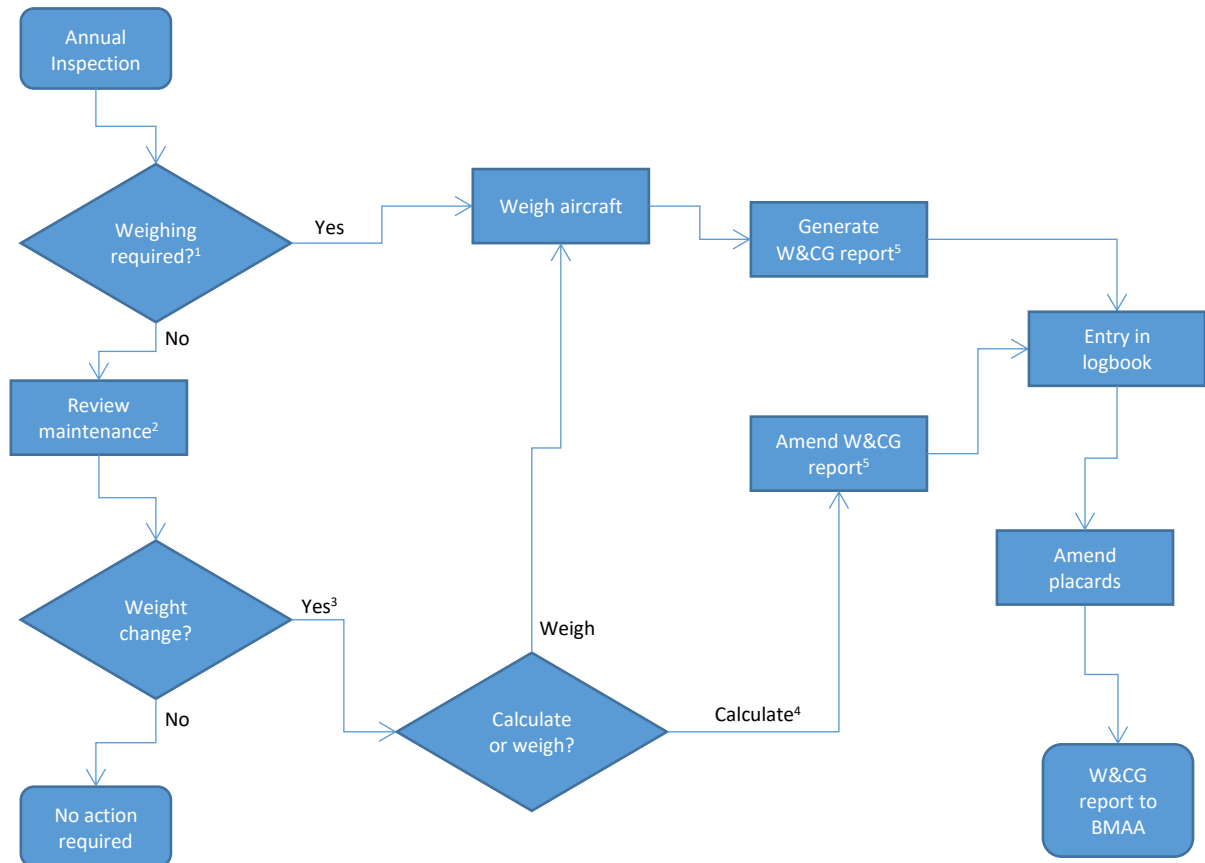
For 3-axis control aircraft - where the location of the centre-of-gravity must be calculated - this section can only be used for the addition or removal of 'lumped mass' items whose location from the datum is known or can be measured. It can't be used for 'distributed mass' changes where the location from the datum can't be accurately determined. Examples of 'lumped mass' items are a radio or a replacement propeller. Examples of 'distributed mass' items are fuel hose, wiring looms or aircraft covers.

| BMAA MUST be informed of any such changes, mass added or subtracted.

5.2. The BMAA Balance Check spreadsheet

The balance check is for 3-axis control aircraft only, and checks that the aircraft can't normally be loaded outside of its approved CG range. The empty weight and details of how the aircraft can be loaded - occupants, fuel and baggage - are entered into the spreadsheet. The spreadsheet then calculates the most forward and most aft locations of the centre-of-gravity possible, and checks these against the CG limits.

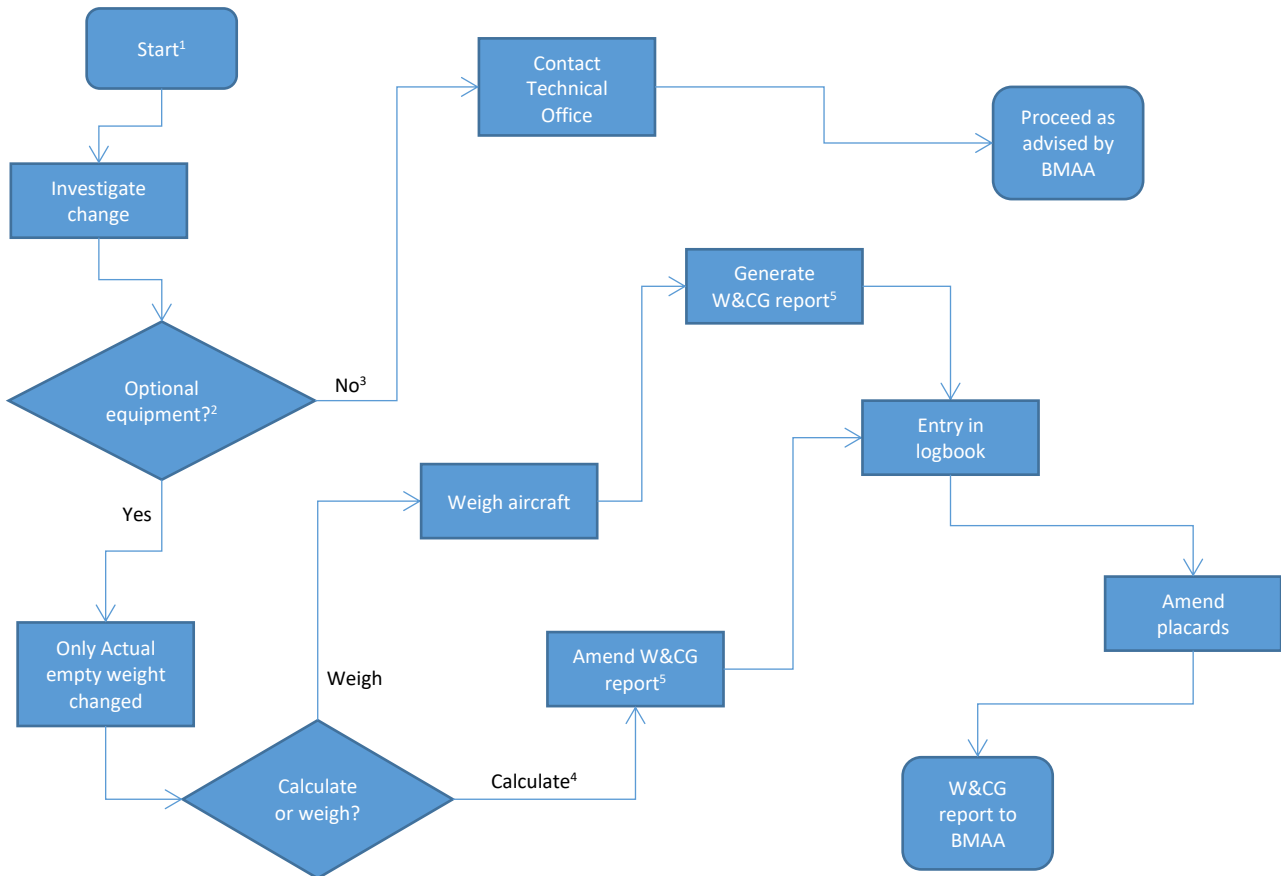
Appendix 1 - annual weight review procedure



The following notes relate to the numbered points in the flowchart above.

1. The Inspector must insist on a weighing if not convinced the current weight report is accurate. An occasional re-weigh is still also considered good practice - see Section 3.3.3.
2. Review maintenance and part replacement since last weight review.
3. Or if not entirely sure.
4. A calculation is only possible if the weight change is accurately known, and, for a 3-axis control aircraft, the weight change(s) are individual items whose position relative to datum is known, or can be measured.
5. And check balance if applicable (3-axis control aircraft).

Appendix 2 - fitment of pre-approved changes



The following notes relate to the numbered points in the flowchart above.

1. A BMAA Inspector is required to sign-off fitment of a pre-approved change.
2. To be Optional Equipment it must be able to be removed, is not required to make the aircraft airworthy, and does not need to be replaced with something else.
3. Or if not entirely sure.
4. A calculation is only possible if the weight change is accurately known, and, for a 3-axis control aircraft, the weight change(s) are individual items whose position relative to datum is known, or can be measured.
5. And check balance if applicable (3-axis control aircraft).