WEIGHT CONTROL OF AIRCRAFT

DEPARTMENT OF TRANSPORT

1975

FOREWORD

This Publication has been prepared as a guide for persons who are engaged in some or all of the activities associated with the weight control of aircraft. The objective has been to provide a basic source of material to give information on aircraft weighing procedures and the determination of empty weight and empty weight centre of gravity position, on the need for weight control and on the compilation of loading data. In this regard the Publication has been prepared to reflect the Department of Transport's policies and recommendations concerning the weight and balance of aircraft, and due reference is given in the text to pertinent Air Navigation Regulations and Orders. The reader should be aware that these requirements are subject to amendment, and any query regarding the currency of Regulations and Orders should be referred to the appropriate Regional Office of the Department of Transport.

CONTENTS

INTRODUCTION

The Australian Air Navigation Regulations require that aircraft be operated within the weight and centre of gravity limitations specified in the certificate of airworthiness or approved flight manual. Ultimately it is the responsibility of the pilot in command to ensure that his aircraft is correctly loaded before flight, and for this purpose information in the form of loading data and instructions are made available for his use. Such information normally contains details of the aircraft empty weight and empty weight centre of gravity position, together with suitable instructions as to the means by which the aircraft can be loaded within safe limits. The information made available to the pilot represents the end result of a number of steps made by persons whose task it is to provide accurate and precise loading data. Correct loading is essential for the safe operation of an aircraft and it is the responsibility of a weight control officer to ensure that the information he approves is not only correct but is also presented in a clear and unambiguous manner.

All civil aircraft, whether they be of a fixed or rotary wing type, large or small, have been certificated against a comprehensive set of airworthiness standards for a clearly defined range of weights and centres of gravity. The manufacturer of an aircraft must demonstrate to the responsible certification authority that his product can meet the stringent safety standards laid down by that authority. These standards take into consideration, among other things, not only the structural strength of the aircraft but also performance and flight handling characteristics, and the weight and centre of gravity limitations that result can be dictated by any one of these parameters. An aircraft flown outside approved limits is being operated in an area where compliance with the required levels of airworthiness may not have been demonstrated, and any pilot who flies his aircraft incorrectly loaded could well be taking on the duties of an experimental test pilot.

Maximum take-off and landing weights are in most cases determined by structural considerations, and operation in excess of these weights could downgrade the strength of the aircraft to unacceptable levels. Continued overweight operation could also accelerate the onset of metal fatigue induced structural failure. In addition excessive weight reduces the flying ability of an aircraft in almost every respect, the most significant deficiencies of an overweight aircraft being :

Longer take-off distance

Reduced rate of climb

Shorter range

Reduced cruising speed

Higher stalling speed

Longer landing distance.

The balance of an aircraft on the other hand refers to the position of the centre of gravity, and is of primary importance in relation to flight handling characteristics. Adverse balance situations can cause marked deterioration in stability and control to thepoint where an aircraft may become uncontrollable. For example, a pilot may have difficulty, if his aeroplane is loaded too far forward, in raising the nose during take-off, or in being able to flare the aircraft into the correct landing attitude at the completion of the flight. Conversely, if the aeroplane is loaded too far aft the longitudinal stability may be seriously impaired, stalling characteristics adversely affected and, if the aircraft is of a type approved for spinning, spin recovery difficult or even impossible.

The prime concern of aircraft balancing is along the longitudinal axis, that is, the fore and aft location of the centre of gravity. The design of aircraft is such that lateral symmetry is usually assumed to exist, and for each item of weight to the left of the aircraft centre line there is an equal weight to the right existing at a corresponding location. Lateral imbalance however can occur in aeroplanes with unevenly distributed fuel loads, and in helicopters, where a litter may be loaded on one side but not on the other. With the exception of rotorcraft, where lateral centre of gravity limits are usually specified, lateral imbalance is normally relatively easy to control, the longitudinal balance being much more critical. As this is the case, further reference to centre of gravity in this Publication will mean the longitudinal location of the point of balance.

The need to operate within approved limits is a matter of serious concern, not only to the pilot but also to those ground personnel whose responsibilities encompass the preparation of an aircraft for flight. Weight and balance control begins with the initial determination of the aircraft empty weight and empty weight centre of gravity position. Subsequent changes as a result of repair or modification are accounted for either by adherence to a suitable weight and balance change record system or by reweighing the aircraft. Loading information in the form of, for example, baggage compartment and fuel tank placards, together with pertinent loading rules and systems are made available to the pilot for his ready guidance and use to ensure safe loading. All of these activities can be grouped under the one general heading, that is, the weight control of aircraft.

1 - DEFINITIONS

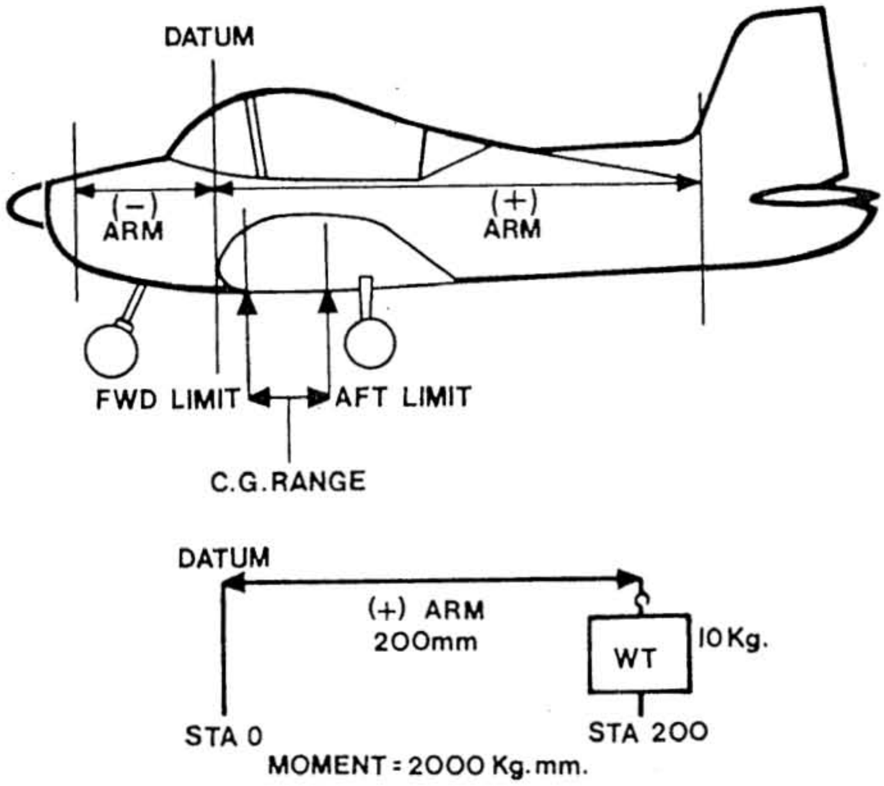


Figure 1. Definitions

The various terms commonly used in weight control have the following meanings.

1. ARM (moment arm) - is the horizontal distance in millimetres from the reference datum to the centre of gravity of the item. The algebraic sign is plus (+) if measured aft of the datum and minus (-) if measured forward of the datum.

2. CENTRE OF GRAVITY (c. g.) - is the point about which the aircraft would balance if it were possible to suspend it at that point. The weight of an aircraft may be assumed to be concentrated at its centre of gravity.

3. CENTRE OF GRAVITY DATUM (reference datum) - is an imaginary plane from which all measurements of arm are taken. For most aircraft the datum is established by the manufacturer and in some cases its horizontal location is marked on the aircraft. Once selected all moment arms must be taken with reference to the datum. The datum is specified in the certificate of airworthiness or approved flight manual.

4. CENTRE OF GRAVITY LIMITS - are the most forward and most rearward centre of gravity positions at which an aircraft may be operated in accordance with the airworthiness certification standards of the Department of Transport. Centre of gravity limits are normally expressed in millimetres forward or aft of the datum but for a fixed wing aircraft may be stated as a percentage of the mean aerodynamic chord (M. A. C.) of the wing. The centre of gravity limits are specified in the certificate of airworthiness or approved flight manual.

5. CENTRE OF GRAVITY RANGE - is the distance between the forward and aft centre of gravity limits.

6. LOAD DATA SHEET - is a document prepared in respect of an individual aircraft to provide weight and centre of gravity information for use in the loading system.

7. LOADING SYSTEM - is a system for ensuring that an aircraft is loaded within approved gross weight and centre of gravity limits at all times during flight.

8. MEAN AERODYNAMIC CHORD (M. A. C.) - is the average chord of an imaginary wing having the same aerodynamic characteristics as the actual wing.

9. MOMENT - is the product of a weight multiplied by its arm. The moment of an item about the datum is obtained by multiplying the weight of the item by its horizontal distance from the datum. The total moment of an aircraft about the datum

is the weight of the aircraft multiplied by the horizontal distance from the centre of gravity of the aircraft to the datum. Moments are usually expressed in terms of kilogram - millimetre. (kg. mm.).

10. MOMENT INDEX (or index) - is a moment divided by a constant such as 1,000, 10,000 or 100,000. The constant is arbitrarily selected to reduce the number of significant figures in moment values to easily handled proportions but which will yet give the desired accuracy. An index is considered to conist of so many index units.

11. REMOVABLE EQUIPMENT - is equipment carried on some or all operations but which is not included in the empty weight.

12. SECRETARY - is the Secretary to the Department of Transport or any person to whom he has delegated his authority in the manner concerned.

13. STATION - is a location in the aircraft which is identified by a number designating its distance from the datum. The datum therefore is station zero. Station and arm are usually identical.

14. WEIGHT CONTROL OFFICER - is a person holding a weight control authority issued under Air Navigation Orders Section 100.28.

15. WEIGHT, EMPTY - is the measured or calculated weight of an aircraft including all items of fixed equipment and other equipment that is mandatory for all operations, fixed ballast, unusable fuel, undrainable oil, total quantity of hydraulic fluid, but excluding all other items of disposable load.

16. WEIGHT, MAXIMUM LANDING - is the maximum weight, according to the certificate of airworthiness or approved flight manual, at which the aircraft may usually be landed.

17. WEIGHT, MAXIMUM TAKE-OFF - is the maximum weight, according to the certificate of airworthiness or approved flight manual, at which the aircraft is permitted to take-off.

18. WEIGHT, MAXIMUM ZERO FUEL - is the maximum weight approved for the aircraft not including fuel load.

19. WEIGHT, OPERATING - is, in relation to a particular type of operation, the empty weight of the aircraft plus those items of removable equipment and disposable load that remain constant for the type of operation being conducted.

20. WEIGHT, RAMP - is the allowable weight for take-off plus the fuel burned during taxi and run-up.

2 - WEIGHING OF AIRCRAFT

Air Navigation Orders Section 100. 7 requires that the empty weight and empty weight centre of gravity position be determined for all aircraft prior to the initial issue of a certificate of airworthiness. These determinations can be made either by weighing the aircraft or, as an alternative in the case of a newly manufactured small aircraft, by suitable computations made by the manufacturer. The empty weight details for an imported aircraft can be established prior to arrival in Australia; however if reasonable doubt exists as to the validity of the weighing data the Secretary may require the aircraft to be weighed in Australia before a certificate of airworthiness is issued.

Over extended periods, unaccountable weight changes and other factors can render the initial weighing details inappropriate, and because of this the Department of Transport requires periodic weighings to be carried out for certain classes of aircraft subsequent to the initial weighing or weight determination. The intervals between these periodic weighings have been made as long as possible consistent with the probable effect of weight and centre of gravity changes on the airworthiness of the aircraft. Aircraft must also be weighed when, as the result of modification or repair, the empty weight or empty weight centre of gravity position has varied by more than a specified amount. The intervals between weighings, and the tolerances allowed on empty weight and empty weight centre of gravity, are given in Air Navigation Orders Section 100. 7. An operator may however reweigh an aircraft at any time he so desires.

WEIGHING EQUIPMENT

The equipment used to weight an aircraft must be of a type approved by the Department as complying with the accuracy and repeatability standards specified in Air Navigation Orders Section 100. 7. Intending purchasers of scales should contact their local Department of Transport Regional Office to ascertain if the proposed equipment is of an approved type, or if not, and approval is sought, to provide such substantiating data as is necessary. Each scale unit used to weigh an aircraft must have been calibrated either by the manufacturer or by a State Weights and Measures Authority within a period of one year prior to the weighing of an aircraft. The Department can however reduce this period if it considers it to be necessary, or increase it if the owner of the scales can justify a longer calibration period.

The type of equipment used will vary with the aircraft size. Light aircraft may be weighed on platform type scales whereas large aircraft will usually need an electronic weighing kit. In any case the equipment must have a capacity suitable to the size of the aircraft. For example, three scales with a 2000 kg. capacity each would be required for an aircraft with an empty weight of approximately 4000 kg., while an electronic weighing kit with cells of 30,000 kg. capacity would be needed for a 60,000 kg. empty weight aircraft.

WEIGHING PROCEDURES

Aircraft weighings should be conducted inside closed hangars to avoid the possibility of air currents affecting the accuracy of the weighings. The floor surface should be level, particularly where the weighing kits or jacks are placed, and suitable for marking with chalk or pencil. In preparing an aircraft for weighing the following general procedures should be observed;

(a) The aircraft should be cleaned inside and out,

(b) The aircraft must be dry before weighing. An aircraft should not be weighed immediately after it has been washed.

(c) Seat backs should be placed in the upright position.

(d) Wing flaps must be retracted and all other control surfaces secured in the neutral position.

(e) The equipment state of the aircraft must be checked, and all items that are to be included in the empty weight placed in their appropriate positions. An aircraft equipment list must be raised, or if one is already in force must be amended, to reflect the configuration of the aircraft at the time of weighing. All items not included as fixed equipment should be removed, or if this is inconvenient such equipment may remain in the aircraft provided that the appropriate deductions are subsequently made.

(f) Fuel tanks should be drained in accordance with the manufacturers' instructions. In some cases it may not be feasible to drain the tanks, and if this is so, they should then be filled to capacity and the aircraft weighed in this configuration. The weight of fuel in the tanks should then be calculated and later subtracted from the total weight to obtain the empty weight. If the total quantity of fuel in all tanks is 700 litres or less a specific gravity for aviation gasoline of 0.71 for 100/130 grade and 0.72 for all lower grades, or in the case of aviation kerosene a specific gravity of 0.79, may be assumed in calculating the weight. If the total fuel quantity is in excess of 700 litres the actual specific gravity must be determined and used for weight calculations. Where a weighing has been carried out with drained tanks, the weight of the unusable fuel quantity should be established and the appropriate change made to the weighing details when determining the empty weight and empty weight centre of gravity position.

(g) Unless otherwise specified by the aircraft manufacturer the oil system should be completely drained through the normal drain ports. Under these conditions the amount of oil remaining in the tanks, lines and engines is termed "undrainable oil" and must be included in the empty weight. When the aircraft is weighed without draining the oil the tanks should be filled to capacity. The oil weight can then be calculated and the appropriate deduction made. The specific gravity of oil may be assumed to be 0.90 for mineral base oil and 0.96 for synthetic base oil.

(h) Reservoirs and tanks containing hydraulic fluid, anti-icing fluid and other liquids that are to be considered as part of the empty weight should be filled to capacity.

(i) If the main wheels are to be used as reaction points the brakes should not be set. Resultant horizontal loads on the weighing equipment may cause erroneous readings.

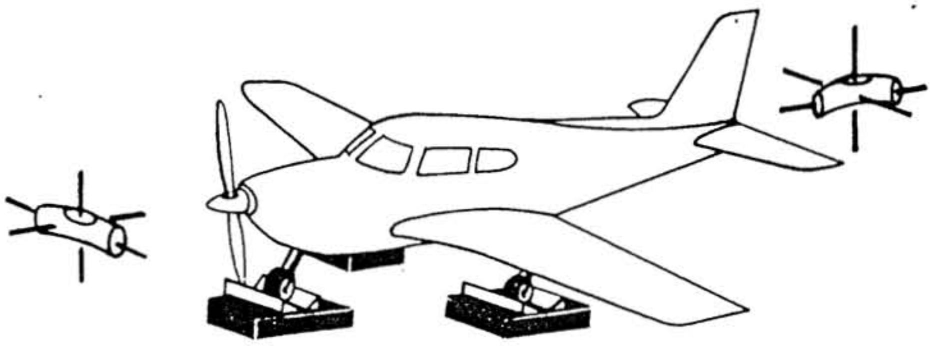


Figure 2. Weighing on platform scales

Aircraft should be weighed in a level position, that is with the longitudinal and lateral axes horizontal. On most aircraft, levelling devices such as lugs, pins or plates have been accurately installed by the manufacturer. The methods used to level aircraft vary with the type of aircraft, and reference must be made to the manufacturer's instructions. The following general procedures should however be followed;

(a) Jacks used for levelling should never be employed other than at the specified jack points.

(b) During the levelling procedure extreme care should be taken to prevent side loads developing which may cause an aircraft to slip off the jacks. When raising an aircraft with two wing or main undercarriage jacks they should be actuated simultaneously in order to maintain the aircraft in a laterally level position.

(c) Nose wheel oleo struts or tyres may be inflated or deflated to level the aircraft.

(d) Rotary wing aircraft fitted with undercarriage oleo struts may be placed in the level position by inflating or deflating the struts.

(e) A hoist or jack should be used to level tailwheel aircraft if the tail is too heavy to be raised manually.

(f) Ballast may be placed to correct any instability of the aircraft. However if this is done the weight and position of the ballast should be accurately determined so that the appropriate deductions may be subsequently made.

When the aircraft is in a level position it may be necessary to measure and record relevant dimensions so that the empty weight centre of gravity position may be calculated. The horizontal distances that need to be measured for this purpose are those establishing the position of the reaction points in relation to some fixed datum. As an example, when an aircraft is weighed using the landing gear wheels as weighing (reaction) points the following three dimensions must be determined;

(a) The horizontal distance from the reference datum to some known jig point. This dimension for small aircraft is usually zero, because the reference datum is an easily identified location such as the firewall or wing root leading edge. However for certain aircraft the datum may be located ahead of the nose, and in these cases it is necessary to use some convenient jig point on the aircraft.

(b) The distance from the jig point to a lateral line passing through the main gear reaction points. This measurement should be made along a line which is parallel to the longitudinal axis of the aircraft, and

(c) The distance from the jig point to the forward or aft reaction point for nose and tail wheel aircraft respectively.

The required points can be projected to the hangar floor by means of a plumb bob, after which it is a simple matter to measure the necessary dimensions. When an aircraft is weighed using the wheels as reaction points it is important to measure the relevant distances, and not rely on published dimensions. Variations in oleo strut extensions can vary the position of the reaction points to a significant degree.

When fuselage and wing jack points are used as reaction points it is unnecessary to measure dimensions as these points remain fixed, and their moment arms may be found in the aircraft records. It is important however to use the fixed reaction points indicated in the basic aircraft records for the particular aircraft, because manufacturing tolerances and other factors can cause variations in these dimensions between aircraft of the same type or model.

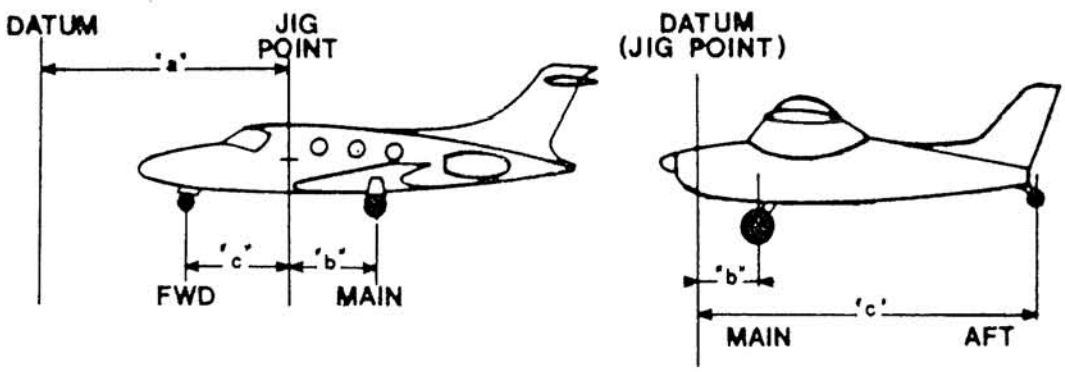


Figure 3. Necessary weighing dimensions

The empty weight can be determined from the results of two consecutive and independent weighings, the load being removed from the scales between each recording. Weighings must be repeated if necessary until the differences between two consecutive measurements agree within the tolerances specified in Air Navigation Orders Section 100. 7.

3 - EMPTY WEIGHT AND EMPTY WEIGHT CENTRE OF GRAVITY

When all the required dimensions and weights have been established they must be entered into an Aircraft Weighing Summary Form CA. 65 or an approved equivalent, and the empty weight and empty weight centre of gravity position determined. The empty weight is the average total of the scale readings from which the weights of appropriate deductible items such as ballast, wheel chocks and fuel have been removed. The scale readings must of course be corrected as necessary for equipment calibration errors. (Figure 4).

The centre of gravity of an aircraft is that point at which all the weights of the aircraft can be considered to be concentrated, in other words if the aircraft could be suspended from that point it would neither pitch nose up or nose down. The position of the centre of gravity can be obtained by dividing the total moment of the aircraft about the datum by the total weight.

Consider as an example the following weighing details;

	Weight (kg.)	Arm (mm.)	Moment (kg. mm.)
Right wheel	223	80	17840
Left wheel	221	80	17680
Tail wheel	30	5250	157500
Total	474	*	193020

The centre of gravity position from the datum can then be calculated by dividing the total moment, (193020), by the total weight, (474), as follows;

$$\text{C of G} = \frac{193020}{474} = 407 \text{ mm.} \ *$$

DETERMINATION OF EMPTY WEIGHT

NOTE 1: The difference between the two gross weights must not exceed 0.2% or 10kg (whichever is the greater) otherwise further weighings must be carried out until two consecutive weighings agree within this tolerance

NOTE 2: Readings should be made to the nearest 1 kg

Jack point	Cell colour	Scale reading	Zero set	Correction	Actual weight	Jack point	Cell colour	Scale reading	Zero set	Correction	Actual weight
PORT	–	759	0	+7	766	PORT	–	760	0	+7	767
STBD	–	763	-2	0	761	STBD	–	768	-2	0	766
TAIL						TAIL					
NOSE	–	321	0	-3	318	NOSE	–	319	0	-3	316

FIRST WEIGHING – Gross total 1845 kg

SECOND WEIGHING – Gross total 1849 kg

AVERAGE – Both weighings 1847 kg

DEDUCTIONS					
Fuel, oil and other fluids	MAIN tanks	450 l at	·71 kg/l	320 kg	
	tanks	l at	kg/l	kg	
	AUX tanks	82 l at	·71 kg/l	58 kg	
	tanks	l at	kg/l	kg	
	OIL tanks	6 l at	·90 kg/l	5 kg	
Removable equipment		Moment arm ±		kg	
	SEAT (ROW 5)		+3010	7 kg	
				kg	
				kg	
Weighing gear	NIL	Moment arm ±	–	– kg	
				kg	
				TOTAL DEDUCTIONS	390 kg
ADDITIONS		Moment arm ±		kg	
	BULKHEAD		+3110	5 kg	
				kg	
				TOTAL ADDITIONS	5 kg

GROSS TOTAL (average of both weighings) 1847 kg

NET ADJUSTMENT (±) -385 kg

EMPTY WEIGHT OF AIRCRAFT 1462 kg

Configuration at time of weighing (refer also to equipment list) FLOOR PLAN AT /102 (6 SEAT)

REMARKS EMPTY WEIGHT INCLUDES UNUSABLE FUEL & UNDRAINABLE OIL

Supervised by M. J. Jones
Weight Control Officer

1 / 11 / 75

Figure 4. Weighing details and empty weight determination

As the determination of the centre of gravity involves the addition and subtraction of moments (weights multiplied by arms), care should be exercised to ensure retention of the correct algebraic signs (+ or –) throughout all balance calculations. For the sake of convention the aircraft should always be visualized with the nose to the left. In this position any arm to the left (forward) of the datum is minus, and any arm to the right (aft) of the datum is plus. Any item of weight added to the aircraft, either forward or aft of the datum is a plus weight, and conversely any weight removed is a minus weight. When multiplying weights by arms to obtain moments the answer is positive if the signs are like, and negative if the signs are unlike, the following combinations being possible;

(a) items added forward of the datum :
(+) weight x (–) arm = (–) moment

(b) items added aft of the datum :
(+) weight x (+) arm = (+) moment

(c) items removed forward of the datum :
(–) weight x (–) arm = (+) moment

(d) items removed aft of the datum :
(–) weight x (+) arm = (–) moment.

It can be seen that a moment acting in a clockwise manner, tending to pitch the nose up, is positive, whereas a moment acting in an anticlockwise manner, pitching the nose down, is considered negative.

The calculation of the empty weight centre of gravity position therefore becomes no more than the summation, about a datum, of a number of moments, which are then divided by the empty weight of the aircraft. Weights may be added or subtracted, in turn giving rise to positive or negative moments. As noted above, although a weight may be removed from an aircraft its very removal will create a moment change affecting the position of the centre of gravity. Similarly, the addition of a weight will also give rise to a moment shifting the point of balance. It should however be noted that if weights are added to or subtracted from the centre of gravity position the only change will be to the gross weight of the aircraft, the centre of gravity in this instance remaining constant.

The basic formula used to calculate the centre of gravity distance from the datum may therefore be written;

$$X = \frac{\text{total moment}}{\text{weight}} = \frac{M}{W}$$

The example given at figure 5 illustrates how the empty weight centre of gravity position may be calculated for a typical nose wheel aircraft.

In balance calculations therefore, the important things to remember are;

(a) All moments are calculated about a given fixed point called the datum, the position of which is specified by the manufacturer.

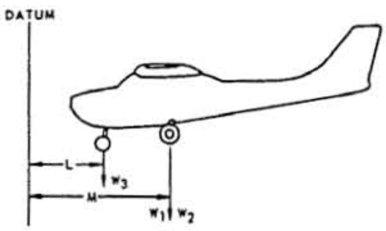
(b) Moments must be clearly identified as positive or negative. The question should be asked, will the effect of this weight, or the lack of it, cause the nose of the aircraft to pitch up or pitch down when using the datum point as the moment centre? With the nose of the aircraft to the left pitch up is positive, pitch down is negative.

(c) When all the relevant moments have been calculated, the major ones being those determined from the weights on the reaction points (e.g. main wheels and nose or tail wheel), they are added and subtracted as necessary to obtain the total moment. This is then divided by the empty weight of the aircraft to obtain the distance of the centre of gravity from the datum.

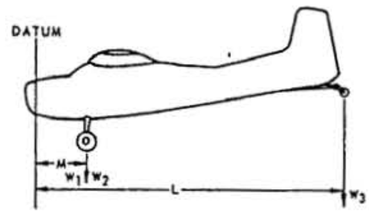
MOMENT INDEX

Because weights are measured in kilograms and arms in millimetres the moments calculated can be very large numerically, for example, a weight of 1000 kg. at an arm of 1000 mm. has a moment of 1,000,000 kg. mm. Such large numbers are unwieldy, and because of this it is easy to introduce mistakes. Therefore, in order to simplify the handling of balance calculations, moments are usually divided by a constant "C" called an index constant. This constant is

NOSEWHEEL AIRCRAFT



TAILWHEEL AIRCRAFT



	FIRST WEIGHING	SECOND WEIGHING	AVERAGE
Horizontal distance from datum to main jack point (M)	+ 2980 mm	+ 2984 mm	+ 2982 mm
Horizontal distance from datum to nose or tail jack point (L)	- 1218 mm	- 1220 mm	- 1219 mm

NOTE: Distances measured aft of the datum are positive (+). Distances measured forward of the datum are negative (-)

W1 - kg	W2 - kg	W3 - kg
766·5	763·5	317

NOTE: W1, W2 and W3 are the average values of the reaction point weights for the two weighings recorded on page 2

ITEM	WEIGHT kg		MOMENT ARM	INDEX $\left(\frac{\text{MOMENT (kg-mm)}}{C}\right)$ $(C = 10^4)$	
	+	−	± mm	+	−
W_1	766·5		(M) +2982	228·57	
W_2	763·5		(M) +2982	227·68	
W_3	317		(L) - 1219		38·64
FUEL (MAIN)	–	320	+2800		89·60
FUEL (AUX.)	–	58	+2740		15·89
OIL	–	5	-1138	0·57	
SEAT	–	7	+3010		2.11
BULKHEAD	5		+3110	1·56	

ADDITIONS AND DEDUCTIONS (Refer page 2)

MOMENT TOTALS 458·38 ① 146·24 ②

AIRCRAFT EMPTY MOMENT INDEX 312·14 (①-②)

AIRCRAFT EMPTY WEIGHT (from page 2) 1462 kg

AIRCRAFT EMPTY WEIGHT C of G $\left(\frac{\text{empty moment index} \times C}{\text{empty weight}}\right)$ + 2135 mm ~~fwd~~/aft of datum

LOAD DATA SHEET DETAILS

Issue No 1 Date of expiry 31-10-78

Empty weight 1462 kg Arm + 2135 mm

Index units 312·14

Prepared by R.W. Smith 1 / 11 / 75

Supervised by H.J. Jones 1 / 11 / 75

Weight Control Officer

Figure 5. Empty weight centre of gravity

arbitrarily selected depending on the magnitude of the moments handled, and can vary from 1000 to 100, 000 or even larger, but once selected for a particular aircraft remains unchanged for that aircraft. A moment divided by an index constant is called an index;

Example :

A moment of 1, 000, 000 kg. mm. divided by an index constant of 10, 000 has an index of $\frac{1,000,000}{10,000}$,

or 100.

In the above example the moment has an index of 100, or alternatively it may be said to be composed of 100 index units. Whenever index units are used the index constant should always be clearly specified.

Obviously, the index number system can be applied to total aircraft moments as readily as to individual load items. An aircraft with an empty weight of 474 kg. and an empty weight centre of gravity position 407 mm. aft of the datum has a total moment of 193, 020 kg. mm., or if an index constant of 1000 is used, a total index of 193. 02.

MEAN AERODYNAMIC CHORD

Expressing the centre of gravity relative to the mean aerodynamic chord (MAC) is common practice with fixed wing aircraft, both the centre of gravity position and the centre of gravity limits being given as a percentage of the MAC. Relating the centre of gravity location to the chord of the wing is convenient from an aerodynamic design viewpoint, and normally an aircraft will have acceptable flight characteristics if the centre of gravity is located over a range of some 15 to 30 percent of the MAC. The allowable range will however vary from aircraft type to aircraft type.

The MAC is calculated by the manufacturer and may be defined as the chord of an imaginary wing having the same aerodynamic characteristics as the actual wing. The MAC can be quite complicated to determine, particularly if the wing is tapered or swept, and the manufacturer is normally the only reliable source of information for this parameter. Where the MAC is used for weight and balance purposes its location relative to the aircraft's datum must also be specified.

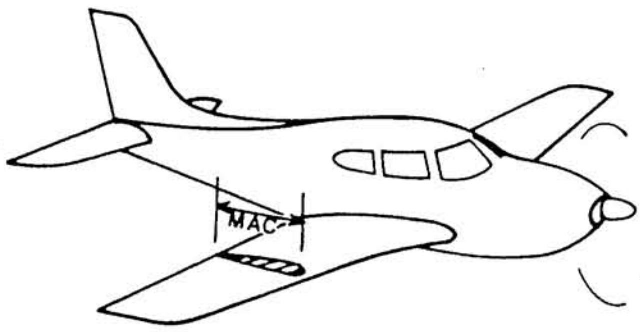


Figure 6. Mean aerodynamic chord

To convert a centre of gravity position in terms of distance from the datum to a percentage of the MAC the calculation steps as shown in the following example are made;

Given : (i) MAC = 2010 mm.

(ii) position of the leading edge of the MAC from the datum = +500 mm.

(iii) empty weight centre of gravity position from the datum = +915 mm.

Therefore the distance of the centre of gravity from the leading edge of the MAC = (915-500) = 415 mm., and the percentage MAC is;

$$\frac{415}{2010} \times \frac{100}{1} = 20.65.$$

Consequently the empty weight centre of gravity position is at 20.65 percent of the MAC.

Conversely, if it is desired to convert a centre of gravity position in terms of percentage MAC to a distance relative to the datum the above procedure is reversed.

LOAD DATA SHEET

On completion of the weighing the empty weight and empty weight centre of gravity position must be entered onto a load data sheet. This document, of which figure 7 is a typical example, is the formal expression of the weight and centre of gravity information for the aircraft, and in many cases can be used directly by the operating crew. It can also include a description of the aircraft configuration to which the weight and balance details refer, together with an expiry date. If the operator wishes to use an operating weight in lieu of an empty weight then the appropriate operating weight and operating weight centre of gravity position must also be included on the load data sheet, together with the relevant configuration details. Whenever an operating weight is used an operating weight equipment list, readily available to the crew, must also be provided. The completed load data sheet must be approved by a weight control officer who has the relevant authority to make such an approval.

AUSTRALIA

DEPARTMENT OF TRANSPORT

LOAD DATA SHEET

....
(Name of Organisation)

Aircraft Type ....Aircraft Reg. VH – ....

Approved Loading System ....

AUTHORISED	DATE	DATE OF EXPIRY	ISSUE

APPROVAL STAMP

AIRCRAFT WEIGHT AND CENTRE OF GRAVITY DATA

ITEM	WEIGHT	ARM	INDEX UNITS	CONFIGURATION
EMPTY WEIGHT				
OPERATING WEIGHT				
DATUM				

Figure 7.

4 - LOADING SYSTEMS

The determination of the empty weight and empty weight centre of gravity is just the first step in making sure that an aircraft is safely loaded for flight. It is still necessary to devise some means whereby the pilot can control the loading of his aircraft so as to maintain the weight and centre of gravity within approved limits. This is usually done by the provision of a suitable loading system, which may take the form of a cockpit placard or a combination of placards, load chart, load and trim sheet or loading computer. For small and relatively simple aircraft a formal loading system may not be required as an extreme conditions check may show that, for all possible loading combinations, it is impossible to exceed either weight or centre of gravity limits.

A certificate of type approval will be issued to the manufacturer of an aircraft only after he has shown that the type can comply with the relevant certification requirements appropriate to its design. Compliance with these requirements, or safety standards, is demonstrated for particular ranges of weights and centres of gravity, and these ranges can in turn be declared as airworthiness limitations and specified as such in the certification approval of the type. Each production aircraft must then be operated in accordance with these approved limits, and to do otherwise is not only illegal, but also potentially dangerous.

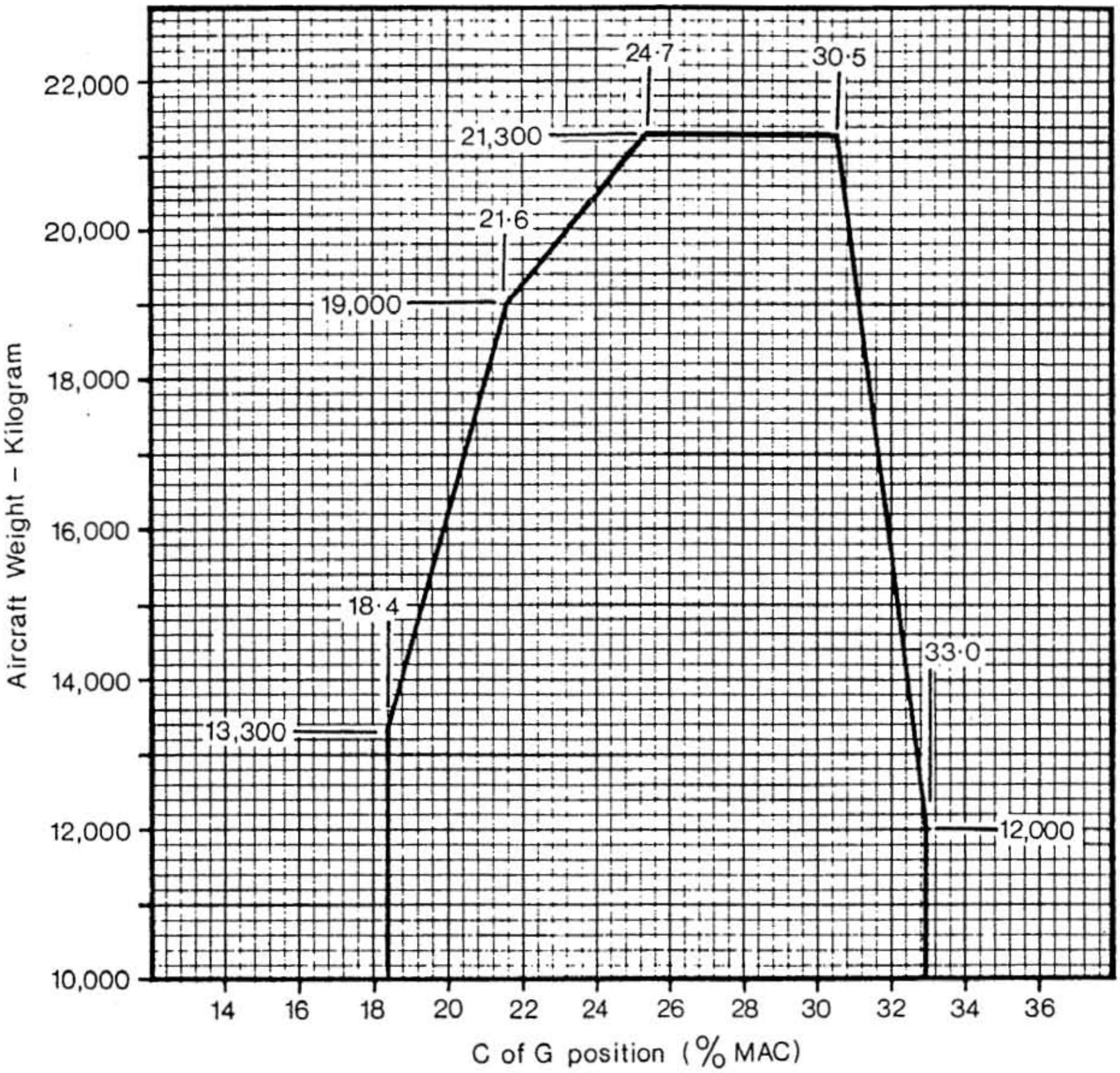
For an Australian registered aircraft the pertinent weight and balance limitations must be included in the approved flight manual or certificate of airworthiness for that aircraft. Reference can also be made to the type certificate data sheet (figure 8). However, if the aircraft is of an imported type due care should be exercised as local changes may result in variations to the limitations given in that document. Many aircraft are designed with centre of gravity limits that vary with changes in weight, and a typical graphical representation of these limits is shown at figure 9.

The loading system must provide methods or instructions to ensure-that an aircraft may be conveniently and correctly loaded within the approved weight and balance limits. Even in its most complex form a loading system is no more than a way of adding up all the weights comprising the loaded aircraft (empty aircraft, fuel, oïl, passengers and baggage), together with their moments, and using these to calculate a gross weight and centre of gravity position, which items are then compared to the allowable weight and balance envelope.

1. Model Civil-1, (Normal and Utility Category)

Engine	Lycoming O-320-E2D
Fuel	80/87 minimum grade aviation gasoline
Engine limits	All operations, 2700 rpm (150 hp)
Propeller and propeller limits	McCauley IC172/TM. Diameter : not over 2320 mm., not under 2200 mm. Static rpm at maximum permissible throttle setting; not over 2360, not under 2260.
Airspeed limits (CAS)	Never exceed 154 knots Maximum structural cruising 117 knots Manoeuvring 95 knots Flaps extended 20° - 95 knots 35° - 80 knots
C. G. range	Normal category - (+220 mm.) to (+549 mm.) at 850 kg. or less. (+333 mm.) to (+549 mm.) at 1050 kg. Utility category - (+220 mm.) to (+530 mm.) at 850 kg. or less. (+310 mm.) to (+530 mm.) at 1000 kg. Linear variation between points given.
Empty weight C. G. range	None.
Maximum weight	Normal category - 1050 kg. Utility category - 1000 kg.
Number of seats	4 (2 at +413 mm., 2 at +1220 mm.).
Maximum baggage	65 kg. (+1900 mm.).
Fuel capacity	165 litres (160 usable) at +630 mm.
Oil capacity	9 litres (-1248 mm.).
Control surface movements	Wing flaps Down $35^\circ \pm 2^\circ$ Aileron Up $22^\circ \pm 2^\circ$ Down $20^\circ \pm 2^\circ$ Elevator Up $20^\circ \pm 1^\circ$ Down $7^\circ \pm 1^\circ$ Elevator tab Up $25^\circ \pm 2^\circ$ Down $25^\circ \pm 2^\circ$ Rudder Left $30^\circ \pm 1^\circ$ Right $25^\circ \pm 1^\circ$
Serial numbers eligible	001 through 00139 except 005.

Figure 8. Type certificate data sheet



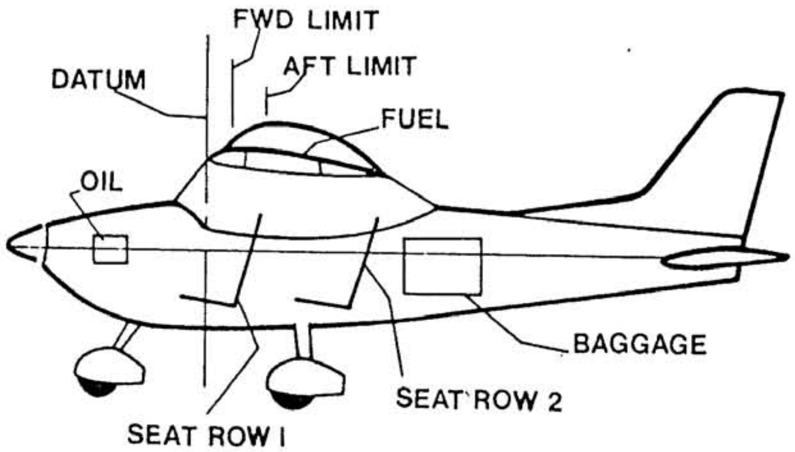
C.G. range (% MAC) (gear extended)	Fwd:	18·4 at 13,300 Kg and below
		21·6 at 19,000 Kg
		24·7 at 21,300 Kg
	Aft:	33·0 at 12,000 Kg and below
		30·5 at 21,300 Kg

Linear variation between points given.

Figure 9. Centre of gravity limits

However, before embarking on the task of preparing a loading system it is just as well to establish whether one is required or not. Although any aircraft with a reasonable disposable load, either passengers or baggage, will probably require a loading system of one sort or another, there are a good many small aircraft which, without exceeding permissible compartment loadings and seating capacities, cannot be loaded outside their weight and balance limits. Therefore, in order to establish that a loading system is not required, it is necessary to carry out weight and balance extreme conditions checks. The following example shows how these checks can be made :

NOTE : The standard crew and passenger weight of 77 kg. per person must be used when carrying out extreme condition weight and balance checks except where a particular seat installation has been approved for a lesser weight. In this case the maximum placarded passenger weight for that seat must be used instead.



Given :

Empty weight of the aircraft	530 kg.
Empty weight centre of gravity position ..	+250 mm.
Maximum take-off weight	1020 kg.
Forward centre of gravity limit	+220 mm.
Aft centre of gravity limit..	+549 mm.

Oil (capacity 9 litres at an arm of
-1248 mm.) .. .. 8.1 kg.

Fuel (capacity 160 litres at an arm of
+630 mm.) .. .. 114 kg.

First row of seats .. .. 2 @ +413 mm.

Second row of seats .. .. .. 2 @ +1220 mm.

Baggage arm (45 kg. maximum) .. +1900 mm.

(a) Forward weight and balance extreme condition.

For this case it is necessary to load the aircraft so as to achieve the most forward centre of gravity position possible. All items located ahead of the forward centre of gravity limit must be included, full fuel being used if the tank is in front of this limit, and zero fuel if it is located behind.

Item	Weight (kg.)	Arm (mm.)	Index units (C=1000)
Empty weight	530	+250	+132.50
Oil	8.1	-1248	-10.11
Pilot	77	+413	+31.80
Total	615.1	*	+154.19

The most forward centre of gravity position possible is then;

$$\frac{+154.19 \times 1000}{615.1} = +251 \text{ mm.}^{*}$$

Since the most forward centre of gravity limit (+220 mm.) and the maximum take-off weight (1020 kg.) are not exceeded, the forward weight and balance extreme condition is satisfactory.

(b) Rear weight and balance extreme condition.

For this case the aircraft must be loaded in such a manner as to achieve the most rearward centre of gravity position possible. All items located behind the aft centre of gravity limit must be included and only those essential items forward of this limit may be used. Full oil however should be assumed in every case, together with zero fuel if the fuel tanks are ahead of the aft limit.

Item	Weight (kg.)	Arm (mm.)	Index units (C=1000)
Empty weight	530	+250	+132.50
Oil	8.1	-1248	-10.11
Pilot	77	+413	+31.80
Passenger (2)	154	+1220	+187.88
Fuel (full)	114	+630	+71.82
Baggage	45	+1900	+85.50
Total	928.1	*	+499.39

The most rearward centre of gravity position possible is then;

$$\frac{+499.39 \times 1000}{928.1} = 538 \text{ mm.}^{*}$$

Since the most rearward centre of gravity limit (+549 mm.) and the maximum take-off weight (1020 kg.) are not exceeded, the rear weight and balance extreme condition is satisfactory.

(c) Maximum weight extreme condition.

There is one further check to be carried out, and that is to ensure that the maximum take-off weight cannot be exceeded when the aircraft is fully loaded.

Item	Weight (kg.)	Arm (mm.)	Index units (C=1000)
Empty weight	530	+250	+132.50
Oil	8.1	-1248	-10.11
Pilot	77	+413	+31.8
Passenger (row 1)	77	+413	+31.8
Passenger (row 2)	154	+1220	+187.88
Fuel (full)	114	+630	+71.82
Baggage	45	+1900	+85.50
Total	1005.1	528	+531.19

Since the maximum take-off weight (1020 kg.) is not exceeded and the resulting centre of gravity position is within permissible limits (+220 mm. to +549 mm.) the maximum weight extreme condition is satisfactory.

In the above example it has been shown that the subject aircraft cannot be loaded (while observing all compartment and seating limitations) outside permissible weight and centre of gravity limits. Consequently, a loading system would not be required in this case.

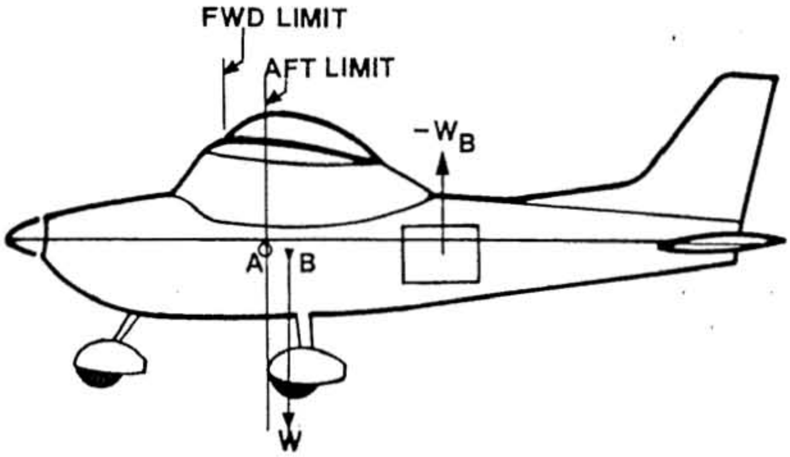
The aircraft used in this example has forward and aft centre of gravity limits that do not change with weight. Where sloping forward or aft centre of gravity limits apply, many checks may be necessary to ensure safe loading within the complete weight and centre of gravity envelope.

A decision to carry out weight and balance extreme conditions checks, rather than specify at the outset some, perhaps rather complex, loading system, must however be made in the first instance. As a general rule it can be assumed that most single engine fixed wing aircraft with up to four seats may not need a loading system, and that the time taken to carry out the relevant checks may be well spent. It is important to realise that extreme condition checks are only a means to establish that a loading system for a particular aircraft is unnecessary for that aircraft, and that, if preferred, a loading system could still be used.

If, as a result of making a weight and balance extreme conditions check, it is found that a weight or centre of gravity limit is exceeded then it may still be possible to establish a suitable loading limitation in lieu of a more formal loading system. Given that the maximum placarded baggage compartment loading for the aircraft used in the previous example is 60 kg. instead of 45 kg., but that in ail other respects the aircraft are identical, the rear centre of gravity extreme condition check will take the following form.

Item	Weight (kg.)	Arm (mm.)	Index units (C=1000)
Empty weight	530	+250	+132.50
Oil	8.1	-1248	-10.11
Pilot	77	+413	+31.80
Passengers (row 2)	154	+1220	+187.88
Fuel	114	+630	+71.82
Baggage	60	+1900	+114.00
Total	943.1	560	+527.9

Although the maximum take-off weight is still within limits, the calculated centre of gravity position of +560 mm. is outside the permitted rear limit and is therefore unsatsifactory. The most obvious, and easiest, solution to this problem is to provide a particular limitation on the baggage compartment restricting the load that may be carried to some value less than the maximum for which it is designed. This may be accomplished as follows;



The aircraft is balanced at "B" (+560 mm.), but is required to be balanced at "A" the aft limit (+549 mm.). Removal of some baggage from the locker moves the centre of gravity forward, and the weight to be removed (W_B) to reach the rear limit must be calculated. This is done by balancing the moments of W and W_B about the rear limit "A".

$$- W_B\ (1900-549) = 943\ (560-549)$$

$$\text{or } W_B = \frac{-943 \times 11}{1351}$$

$$= -8 \text{ kg.}$$

Thus 8 kg. must be removed from the rear compartment to restore the centre of gravity to the rear limit, and the locker subsequently placarded limiting the maximum load to 52 kg.

This solution, although perfectly adequate, is not the optimum answer to the loading of the above aircraft, as the maximum permissible carrying capacity could not be realised. To overcome this problem a loading system would be required, and in this instance need be no more than a simple cockpit placard instructing the pilot as to the correct procedures to be used when loading his aircraft.

The rear extreme condition check was based on a loading configuration of two passengers in row two, and one occupant, the pilot, in row one. A check of the centre of gravity position with a loading condition of filling the first row of seats before the second needs to be made. A weight and balance calculation made with two persons in row one, one person in row two, full fuel and full baggage (60 kg.), shows that the gross weight is 943 kg. with a centre of gravity position of +494 mm. With the remaining passenger included at row 2 the gross weight is increased to 1020 kg., and the centre of gravity position moves aft to +549 mm., both of which however are still within the allowable limits.

In this case therefore a cockpit placard, mounted so as to be clearly visible to the pilot, can be provided stating;

> <u>LOADING LIMITATION</u>
>
> BOTH FRONT SEATS TO BE OCCUPIED BEFORE REAR SEATS.

Or Alternatively

> <u>LOADING LIMITATION</u>
>
> WHEN LOAD IN BAGGAGE LOCKER EXCEEDS 52 Kg BOTH FRONT SEATS TO BE OCCUPIED BEFORE REAR SEATS.

Cockpit placards must be both durable and securely located so that there is no possibility of their becoming illegible or detached. To this end placards made from pressure sensitive tape with an adhesive backing are considered unsuitable.

The placard form of loading system may be extended in scope considerably from the simple examples given above, to a somewhat more extensive loading rule such as the example shown at figure 10. The method of construction of loading placards however remains the same, to establish a set of particular loading cases, and to specify limitations on the method of loading or on the various items of disposable load, in order to ensure that the weight and centre of gravity is always within approved limits.

No. of Occupants		Maximum Fuel Permitted (Capacity 300 L)	Maximum Baggage Permitted (Max Comp Load 80Kg)
Front Seats	Rear Seats		
ONE	–	280	80
TWO	–	235	80
ONE	ONE	300	65
TWO	TWO	300	22
ONE	TWO	Operation Not Permitted	
TWO	ONE	300	80

Figure 10. Loading placard

For larger and heavier aircraft, or when, for some reason or another, the use of placards is no longer practical or desirable, a more precise loading system is necessary. As the loading system provides a means of adding moments and weights the choice of how this may be done is to some extent governed by the size and complexity of the aircraft concerned. For most aircraft however moment information can be provided either graphically or in tabular form, separately prescribed for each load item. Typical graphical and tabular presentations of moment information are shown at figure 11.

The chart or tabulation is entered with the weight of the item concerned and the relevant moment (or index) established. The table at figure 11 provides the same data as shown on the graph for the relevant loading item, additional tabulations (not shown) being required for the oil, fuel and baggage moments. The tabular form of loading system is normally bulkier than the graphical one, however the choice of presentation is at the discretion of the person preparing the system, and there is little reason to prefer one method to the other. The graph or tabulation is easily established, for each appropriate location, the moments for the range of weights likely at that location are calculated, and then plotted or tabled as the

OCCUPANTS			
Weight	Seat 1&2	Seat 3&4	Seat 5
40	72	100	128
50	90	125	160
60	108	150	192
70	126	175	224
$\boxed{80}$	$\boxed{144}$	200	256
90	162	225	288
100	180	250	-
110	198	275	-
120	216	300	-
130	234	325	-
140	252	350	-
150	270	375	-
160	288	400	-
170	306	425	-
180	324	450	-

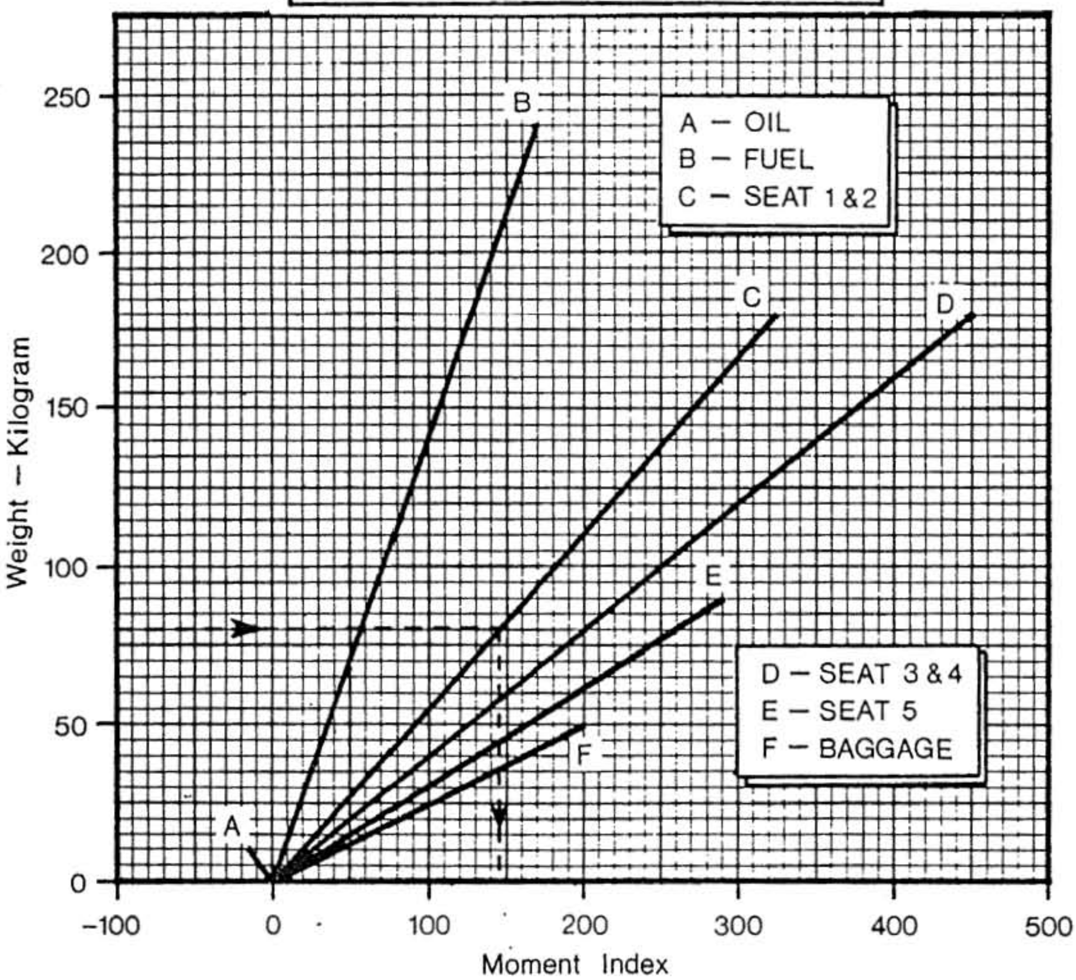


Figure 11. Loading chart and tabulation

case may be. Unless the moment arm varies as the weight is changed, as may be the case with some fuel system or baggage compartment designs, the moment-weight variation is linear, and therefore only the extreme points need to be calculated when preparing a loading graph. Of course if a tabular presentation is preferred each individual moment must be calculated for the required weight intervals.

The weight ranges covered will be determined by such parameters as tank capacities and baggage compartment structural limitations. Although standard crew and passenger weights are specified in Air Navigation Orders Section 20.16, an operator may elect to use actual occupant weights. Consequently, when presenting passenger weight moment data, it is desirable to provide for more than the maximum standard passenger weight of 77 kg., and a weight of 90 kg. per seat position is suggested.

Having determined both the gross weight and moment for the loaded aircraft a simple calculation can be made to find the centre of gravity position. This final step however can be eliminated by providing a moment-weight envelope. In this case, the gross weight and moment can be used directly to determine whether the aircraft is safely loaded, instead of going through the additional step of calculating the actual centre of gravity position. (Figure 12).

A diagram such as that shown at figure 12 can be prepared from the standard weight-centre of gravity envelope by multiplying each weight by its arm and plotting the resultant graph. Alternatively, if a moment table type of presentation is being used, a table of gross weight-moment limits may be provided, in which case maximum and minimum allowable moments can be calculated for the full range of gross weights. In addition to the above the loading system should provide a floor plan showing the location of the various items together with their moment arms.

A complete loading system, therefore, contains a loading graph or table for all the items of disposable load, an allowable weight-moment or weight-centre of gravity graph or table, and a floor plan, together with any other items or instructions as are necessary. A typical loading system of the graphical sort is shown at figure 13.

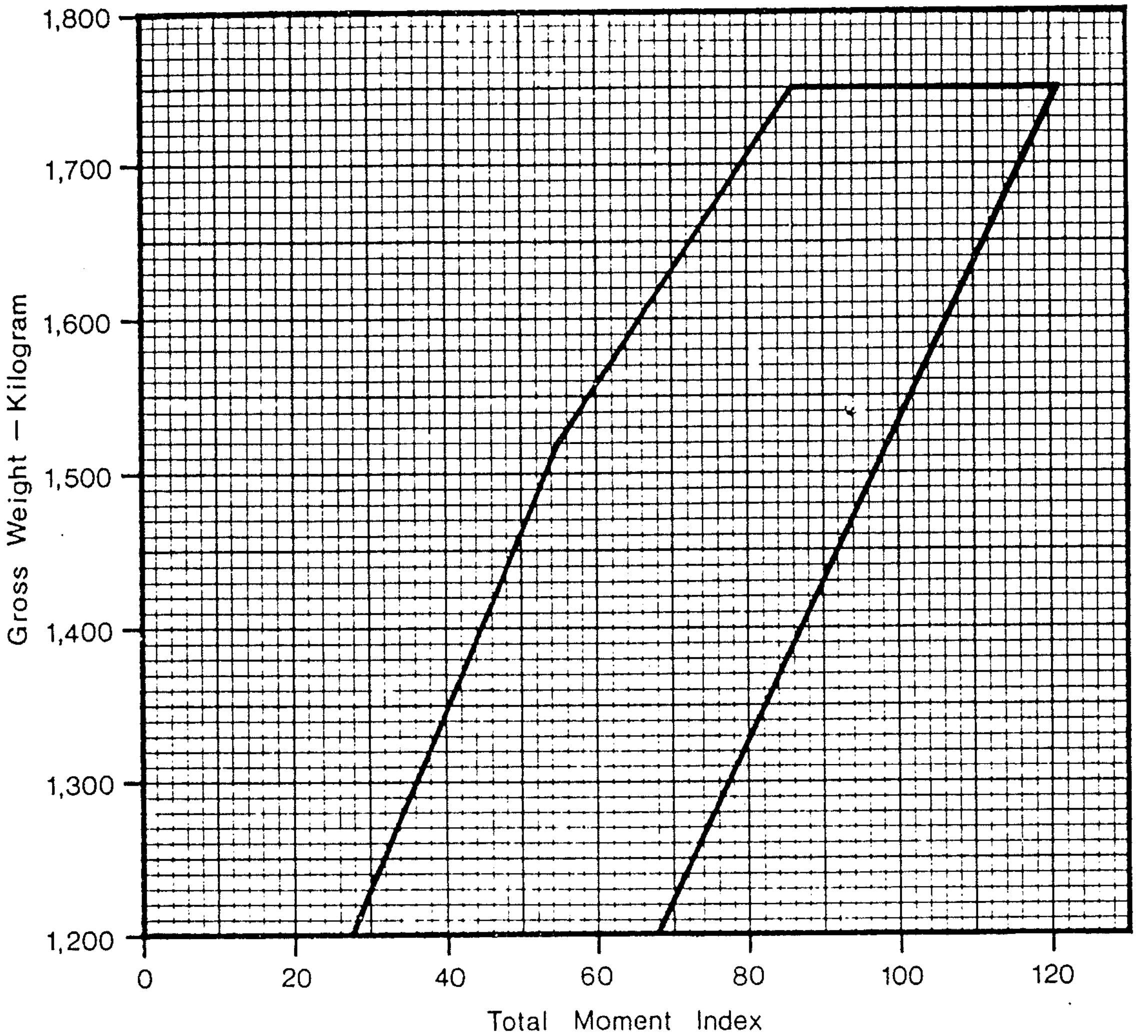


Figure 12. Moment-weight envelope

Where weights and/or centres of gravity fall outside allowable limits the loading of the aircraft must be changed, load being removed, added or re-distributed as necessary.

Some loading systems are prepared in the form of a special weight and balance plotter. The typical plotter is made of plastic and usually consists of a transparent sliding cursor moving over a fixed backing plate on which a weight-moment envelope is inscribed. The cursor has provision to plot on the fixed plate, weight and moment changes for the various items of disposable load. Such a device is in effect no more than a model of the loading graph described above, with the advantage that weights and moments are directly and progressively plotted rather than added separately. (Figure 14).

LOADING SYSTEM : CIVIL MK.1

FORM CV12 ISSUE 2

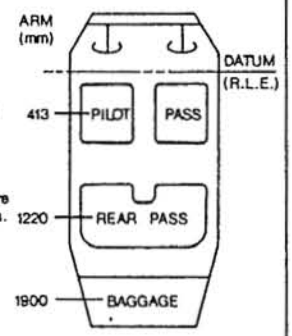
AIRCRAFT REGISTRATION **VH -**

Approved ..../../...

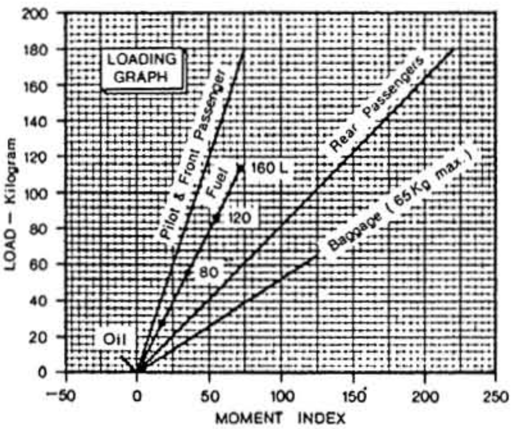
Loading Calculation	Weight Kg	Moment Index
1. Aircraft empty weight and moment index. (Refer approved load data sheet.)	....	....
2. Oil (9 litre at 0·9 Kg per litre)	....	....
3. Usable fuel (160 litre max. at 0·71 Kg per litre)	....	....
4. Pilot and front passenger	....	....
5. Rear passengers	....	....
6. Baggage (65Kg max.)	....	....
Gross weight & total moment index	- - - - -	- - - - -
Locate the gross weight and total moment index on the moment weight envelope. If this point falls within the envelope the loading is acceptable.		

FLOOR PLAN

NOTES:
1. Pilot and passenger moment arms are given for seats in mid-travel position.
2. Baggage arm measured from centre of compartment area.



NOTES
1. The datum for the calculation of index units is the root leading edge of the wing.
2. Index constant is 1000.
3. Maximum permissable floor loading intensity in the baggage compartment is 980 Kg/m².
4. The location of the centre of gravity must be checked under conditions of:
   (a) Actual fuel at departure, and
   (b) Zero fuel.



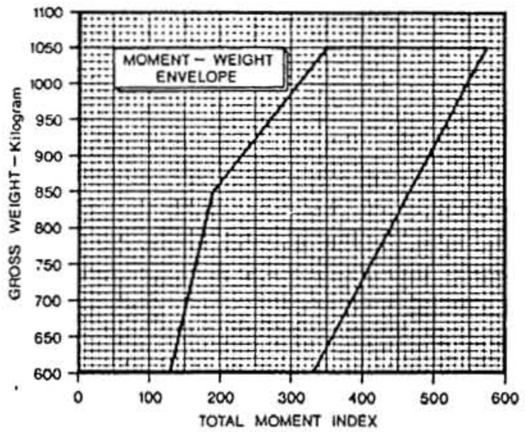
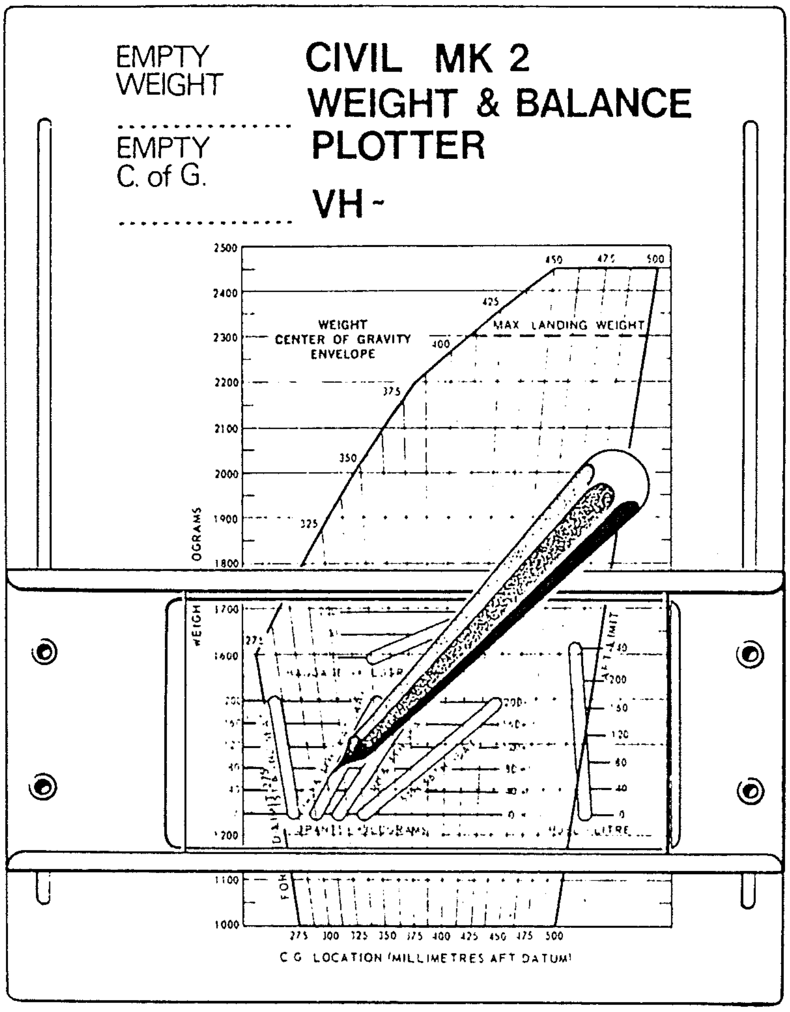


Figure 13. Loading systems



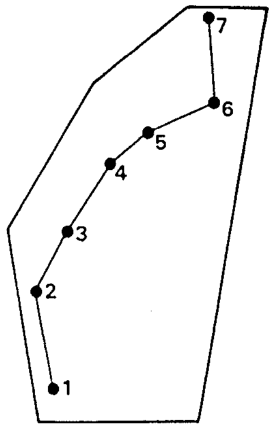


Figure 14. Weight and balance plotter

In the case of large transport category aircraft the loading system is generally prepared either in the form of a load and trim sheet (figure 15), or as a loading slide rule. These forms are similar in concept to the loading systems described above, with the exception that where passenger or crew movement can occur in flight, due allowance should be made for this movement by restricting the centre of gravity envelope. To simplify loading calculations the passenger cabins are usually divided into zones, and a random loading of persons assumed within each zone.

It is the responsibility of the operator to provide a loading system. He may do this either by preparing it himself or by adopting one already available from the aircraft manufacturer. Most manufacturers of general aviation aircraft produce suitable loading systems for their products, and these suffice in the majority of cases. However, whether prepared by the manufacturer or by the operator, the loading system must be approved by a weight control officer who has the authority to make such an approval.

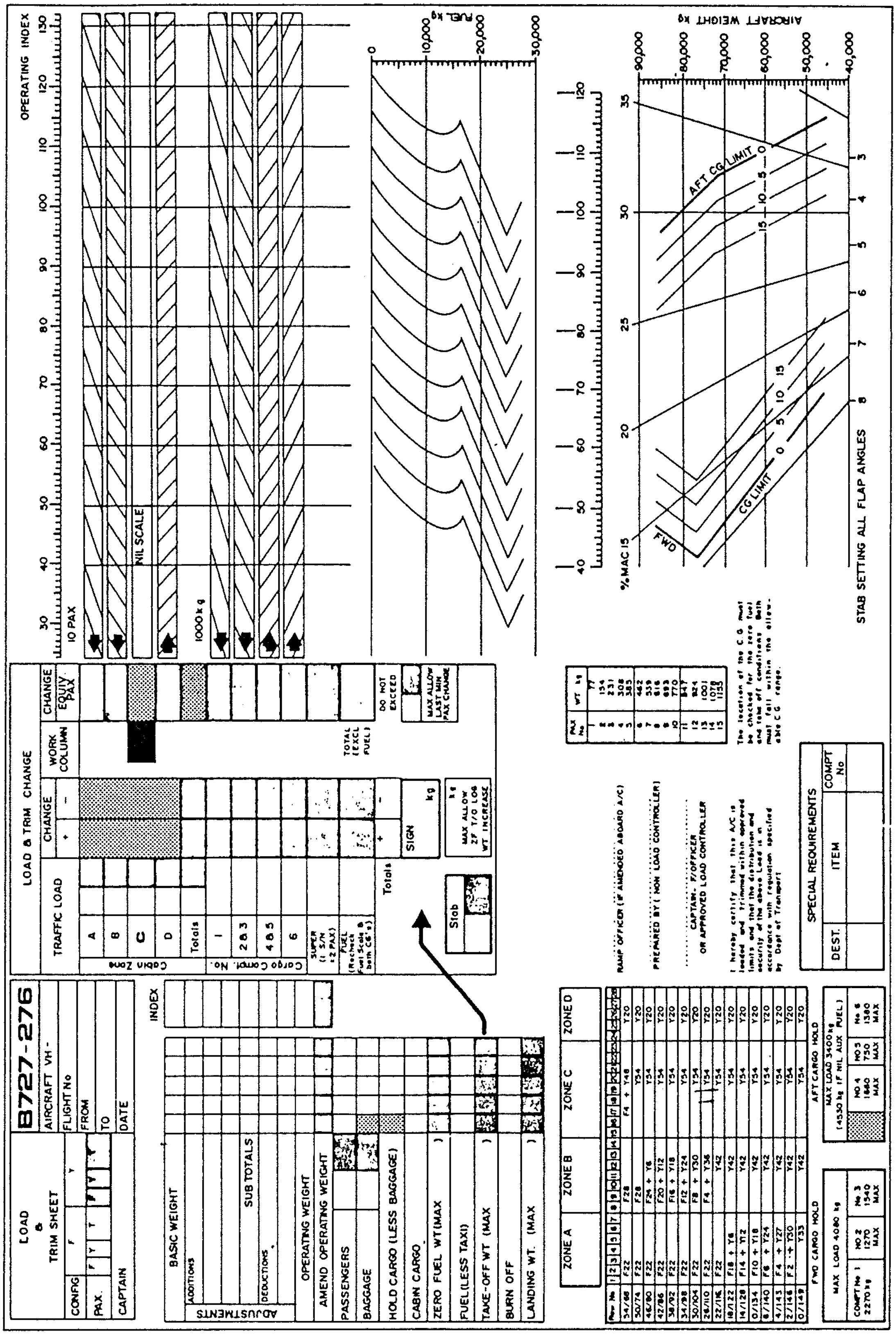


Figure 15. Load and trim sheet

5 - WEIGHT AND BALANCE DOCUMENTATION

WEIGHT AND BALANCE REPORT

Air Navigation Orders require that a weight and balance report for each aircraft be submitted to the Department, as part of the certification documentation for that aircraft, prior to the initial issue of an Australian certificate of airworthiness. The weight and balance report must contain at least the following;

(a) A list of the various weight limits such as maximum take-off, landing, zero fuel and ramp weights.

(b) The approved centre of gravity range.

(c) Weighing details including all relevant calculations made to establish the empty weight and empty weight centre of gravity positions.

(d) Equipment list.

(e) Load data sheet.

(f) Loading system. If a loading system is not required the justification as to why it is not required must be provided.

(g) Such other instructions are as considered necessary for the safe loading of the aircraft.

Each weight and balance report submitted to the Department will be retained by the Department for record purposes.

LOADING DATA

Weight and balance data necessary to ensure that an aircraft can be correctly and safely loaded for flight must be contained in the flight manual. In lieu of the flight manual, Regulation 113(3) of Air Navigation Regulations permits carriage in the aircraft of operations manuals, placards or other documents, provided that they supply the pilot in command with all the relevant data contained or referened in the flight manual. The pilot needs to know the empty weight and empty weight centre of gravity position, operating weight and operating weight centre of gravity position if appropriate, and details of the aircraft configuration to which these apply, together with the appropriate loading instructions.

This means that a load data sheet, equipment list and loading system must be provided for the direct use of the pilot, either in the flight manual or in some other recognised form, or in a combinations of these two methods. If specific loading documents or instructions are not contained within the flight manual document, then the flight manual must provide sufficient information for all the pertinent weight and balance data to be clearly identified, at any time, as being applicable to the particular aircraft. The flight manual is at all times the master document, and the information contained therein should be recognised as the official definition of the applicable loading data. Data not contained or referenced in the flight manual may not have any legal validity, and it is therefore important that any changes to load data sheets, equipment lists or loading systems be immediately identified by an appropriate flight manual amendment.

6 - WEIGHT ALTERATIONS

The addition or subtraction of equipment, the effect of various structural repairs, and the general accumulation of dirt and other items all cause the empty weight and empty weight centre of gravity position to change during the service life of an aircraft. In order to minimise the effect of these changes on airworthiness it is necessary to maintain a record of accountable weight changes in order that, within permissible tolerances, the empty weight and empty weight centre of gravity position for an aircraft may be correctly stated on the load data sheet. Periodic reweighings are carried out when considered necessary to cater for the effect of the unaccountable weight items. It is not necessary however for a record of weight alterations to be maintained for a glider.

Whenever a change is made to the equipment status of an aircraft, or whenever a significant structural modification or repair has been carried out, the weight change involved, together with the relevant moment arm from the aircraft datum, must be determined and entered onto a suitable record of weight alterations form. Department of Transport Form CA. 792 (figure 16), or for small aircraft the appropriate page in the Light Aircraft Log Book (Form CA. 9A), are acceptable documents for this purpose. When the changes to the aircraft are such that they are not amenable to calculation, or when in the opinion of the Department of Transport, inadequate weight control has been exercised, the aircraft must be reweighed.

A running total of weight and centre of gravity changes must be kept and the load data sheet revised, that is, a new empty weight and empty weight centre of gravity position declared, when changes exceed;

(a) for aeroplanes,

(i) the empty weight has changed by more than one half of one percent of the maximum take-off weight, or

(ii) the empty weight centre of gravity position has changed by more than one half of one percent of the mean aerodynamic chord,

DEPARTMENT OF TRANSPORT RECORD OF WEIGHT ALTERATIONS			NO.
NAME OF ORGANISATION	AIRCRAFT VH –	TYPE	DATUM

REWEIGH AIRCRAFT ON OR BEFORE ....

LIMIT DATA

AEROPLANES	ROTORCRAFT
MAXIMUM TAKE-OFF WEIGHT...kg	MAXIMUM TAKE-OFF WEIGHT...kg
1% MAX. TAKE-OFF WEIGHT...kg	1% MAX. TAKE-OFF WEIGHT...kg
MEAN AERODYNAMIC CHORD...mm	MAXIMUM CENTRE OF GRAVITY RANGE.................................mm
1% MEAN AERODYNAMIC CHORD...mm	10% MAX. C.G. RANGE OR 10 mm (whichever is the lesser) ....mm

REVISE LOADING SYSTEM

EMPTY WEIGHT LESS THAN ....kg

EMPTY WEIGHT GREATER THAN...kg

EMPTY C.G. POSITION FORWARD OF...mm forward/aft OF DATUM

EMPTY C.G. POSITION AFT OF..mm forward/aft OF DATUM

DATE	DESCRIPTION OF ALTERATION	MOMENT ARM FROM DATUM mm	WEIGHT AND BALANCE CHANGE				RUNNING TOTAL EMPTY AIRCRAFT		
			Added (+)		Removed (–)				
			Weight kg	Index	Weight kg	Index	Weight kg	Arm mm	Index

Figure 16. Record of weight alterations form

(b) for rotorcraft,

(i) the empty weight has changed by more than one percent of the maximum take-off weight, or

(ii) the empty weight centre of gravity position has changed by more than 10 mm. or 10 percent of the maximum permissible centre of gravity range whichever is the less.

As previously shown, the addition or subtraction of weight items will give rise to moments affecting the balance of the aircraft. The following example illustrates how equipment changes alter the weight and balance of a typical fixed wing aircraft;

Aircraft empty weight .. .. 2217 kg.

Aircraft empty weight centre of gravity .. .. +973 mm.

Aircraft mean aerodynamic chord .. .. 2300 mm.

It is required to remove a seat (7 kg.) from station +2930 mm. and add an item of radio equipment (10 kg.) at station +5138 mm.

Item	Weight	Arm	Moment (C=1000)
Aircraft empty	2217	973	2157.14
Seat (remove)	-7	2930	-20.51
Radio (add)	10	5138	51.38
Total	2220	985.60	2188.01

Thus the empty weight has changed by only 3 kg. but the empty weight centre of gravity position has been moved further aft by 12.6 mm. (985.6-973), that is 0.55 percent of the mean aerodynamic chord. In this case therefore, as the change to the empty weight centre of gravity position is in excess of the allowable 0.5 percent of the MAC, the load data sheet must be revised and raised in issue.

Whenever a load data sheet is renewed, the need for either the introduction of a loading system or for the revision of an existing one must be determined. This step must be made in all those cases where it has previously been established that a loading system was not necessary, or where the loading system has taken the form of a loading instruction or placard. In these instances additional extreme conditions checks must be made, as described in Section 4 of this Publication, and the required changes made.

The loading system review is not normally required however where the loading system is a load chart, load and trim sheet, or other such standard form where the particular empty weight and empty weight centre of gravity position are only used as input conditions.

CONCLUSION

The foregoing has been prepared in an attempt to provide some basic information in relation to the weight control of Australian aircraft, for those persons who are likely to be involved in such activities. This Publication is by no means an exhaustive treatment of the subject, and the reader who may require further information is recommended to contact the Regional office of the Department of Transport in the State in which he lives.