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AUS OPERATIONS, FLIGHT PLANNING AND PERFORMANCE

CHAPTER 9
ECHO-MAKING C of G ADJUSTMENTS

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ECHO - MAKING C OF G ADJUSTMENTS

INTRODUCTION

Consider the situation where the C of G is found to be out of limits.

The C of G can be changed by moving the payload or ballast to different positions or by adding or removing payload or ballast.

Ballast is extra dead weight carried to keep the C of G within limits. Ballast is not useful cargo. Therefore it is desirable to carry the minimum possible amount of ballast.

To move the C of G forward, the ballast needs to be situated as far forward as possible. If the C of G needs to be moved rearward, the ballast needs to be placed as far rearward as possible. When adding ballast, always check that the MZFW has not been exceeded.

When payload or ballast is moved to a new position, it needs to be moved the greatest distance possible to minimise the amount that needs to be moved. To move the C of G forward, payload would be moved from the most rearward position to the most forward position possible. At all times check that limits for the compartment and floor loads are not being exceeded.

USING THE 'BALLAST TO ADD OR REMOVE' FORMULA.

Carrying ballast increases the aircraft's gross weight and negatively effects the speed and fuel consumption. This makes this option the least attractive from the economical viewpoint.

The 'Ballast To add or remove' Formula is as follows:

$$\text{BALLAST/WEIGHT NEEDED} = \frac{\text{ORIGINAL WEIGHT x DISTANCE TO MOVE C of G}}{\text{BALLAST STATION - REQUIRED C of G POSITION}}$$

Note: This formula cannot be used to move the C of G to the forward limit, because when the weight changes, the forward limit also changes. Using the formula would result in moving the C of G to the forward limit for the *original* weight.

Example 1 – Applying the 'Ballast to add or remove' formula

Consider the Echo Mk IV aircraft to illustrate the ballast solution.

ZFW: 2,400 kg total

Moment: 6,456,000 kgmm

- Calculate the C of G position in mm aft of the datum:

6,456,000 kgmm / 2,400 kg = 2,690 mm aft of datum

- Check the C of G limits. The AFT limit is at 2,680 mm aft of datum at EVERY WEIGHT. This means that the C of G is BEHIND the AFT limit. An adjustment must be made to shift it forward:

2,690 mm - 2,680 mm = 10 mm.

To add minimum ballast it must be placed as far forward as possible which indicates to place ballast into the front locker which has a station 500 mm aft of the datum.

- Apply the ballast formula:

Ballast needed = 0riginal weight x Distance to move C of G

Ballast station - C of G position needed

= 2,400 kg x 10 mm

500 mm - 2,680 mm

= 24,000 kg.mm = 11.09Kg

2,180

Answer: **11.09 kg** needs to be placed in the FWD locker.

Example 2

An Echo Mk IV having no weight limitations imposed by performance criteria, is loaded and has a ZFW of 2,450 kg and a ZFW moment of 6,595,400 kgmm. The FWD locker is empty.

Problem:

All cargo must be carried, if possible, and no cargo may be shifted. Find the amount of ballast required and its station.

- Calculate the C of G position in mm aft of the datum:

6,595,400 kgmm / 2,450 kg = 2,692 mm

The C of G is too far AFT - ballast needs to be placed into the FWD locker.

- The station of the FWD locker is 500 mm aft of datum.
- Find the distance to move the C of G:

2,692 mm - 2,680 mm = 12 mm

- Insert data into formula:

Ballast needed = 2,450 kg x 12 mm

500 - 2,680 mm

Ballast needed = 29,400

2,180

Answer: Ballast needed = 13.486 = **13.49 kg in FWD locker**

It is seldom necessary to put ballast into the AFT locker. If the C of G is too far forward, cargo can be moved from the front locker into the aft locker.

A problem could arise when carrying passengers who wish to have in-flight access to their luggage. Luggage placed in the forward compartment would be inaccessible.

MOVING WEIGHT

After loading an aircraft and finding that the C of G is outside permissible limits, the C of G position can be changed by moving payload forward or aft. The load moved may consist of passengers and cargo. Cargo may be shifted to a different locker if space is available.

When changing the position of payload, it is not necessary to add ballast. For example, you can move the C of G forward by moving cargo from the AFT locker to the FWD locker. The advantage of doing this is that is that the aircraft's gross weight is not changed.

Applying the 'Weight to move' formula

The weight which must be moved depends on both the :

DIFFERENCE IN MOMENTS *and ……*

DIFFERENCE IN ARMS.

The difference in moment is the product of :

WEIGHT X DISTANCE TO MOVE C of G

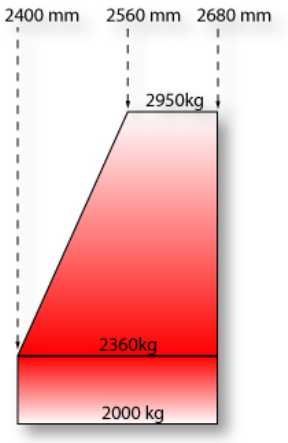
The difference in arm is :

THE DISTANCE NEW STATION TO OLD STATION.

The formula is :

$$\text{Weight to move} = \frac{\text{Weight x Distance to move C of G}}{\text{Distance Old to New Station}}$$

Example 1



The load sheet shows: ZFW 2,400 kg MOMENT 6,456,000 kgmm.

The AFT locker is loaded with 70 parcels weighing 2 kg each. The front locker is empty.

- Find the C of G position:

  6,456,000 kgmm / 2,400 kg = 2,690 mm (This is too far aft).

- Find the distance the C of G must move to get it to the AFT limit (when fuel is burned, the C of G in the Echo Mk IV moves AFT. It follows that the C of G is in the most AFT position at ZFW).

  C of G position 2,690 mm - AFT limit 2,680 mm = C of G to move 10 mm.

- Find the difference in mm between the position where the parcels are to be moved to (FWD locker 500 mm aft of the datum) and where the parcels are now (AFT locker 5,000 mm aft of the datum).

  New Station 500 mm - Old station 5,000 mm = Arm Change 4,500 mm

Applying the formula:

$$\text{Weight to move} = \frac{\text{Weight x Dist. to move C of G}}{\text{New station - old station}}$$

$$\text{Weight to move} = \frac{\text{2,400 kg x 10 mm}}{\text{500 mm - 5,000 mm}}$$

$$\text{Weight to move} = \frac{\text{24,000 kgmm}}{\text{- 4,500mm}}$$

Weight to move = 5.333 kg

Take note that each parcel has a weight of 2 kg and the weight to shift result is the minimum. This requires that 6kg (3 parcels) be moved as this would move the C of G inside the aft limit. To move exactly 5.333kg moves the C of G onto the aft limit.

Example 2

An ECHO Mk IV is loaded in the following manner:

ZFW:	2,350 kg
ZFW Moment:	6,335,600 kgmm
Cabin:	no load to be moved
FWD Locker:	2 parcels 2 kg each
AFT Locker:	50 parcels 3 kg each

Problem:

How much cargo would have to be moved to move the C of G to the AFT limit?

- Find the C of G position in mm AFT OF DATUM (AoD)

6,335,600 kgmm / 2,350 kg = 2.696 mm (AoD)

- Find the distance to move the C of G:

2,696 mm - 2,680 mm = 16 mm

- Now apply the formula:

$$\text{Weight to move} = \frac{2{,}350 \text{ kg} \times 16 \text{ mm}}{500 \text{ mm} - 5{,}000 \text{ mm}}$$

$$\text{Weight to move} = \frac{37{,}600 \text{ kgmm}}{4{,}500 \text{mm}}$$

The weight to move = 8.356 kg

Answer - Each parcel weighs 3 kg. It is necessary to move **9 kg (3 parcels).**

Example 3

An ECHO Mk IV is loaded in the following manner :

ZFW	2,400 kg
Take-off Weight	2,700 kg
ZFW Moment	6,408,000 kgmm
Take-off Moment	6,712,220
FWD Locker	55 kg
AFT Locker	20 kg

No load to is to be moved in cabin (3 px)

- Find the C of G position at ZFW:

  6,408,000 kgmm / 2,400 kg = 2,670 mm (it is within limits)

- Find the C of G position at take-off weight:

  6,712,220 kgmm / 2,700 kg = 2,486 mm

- Find FWD C of G limit at 2,700 kg gross weight:

  2,700kg - 2,360kg = 340kg x 0.271 = 92 mm

  2,400 mm + 92 mm = 2,492 mm aft of the datum.

- Check if the C of G at take-off is within limits :

  The FWD limit is 2,492 mm. The actual is 2,486 mm. Therefore the C of G is too far forward) The C of G must be moved aft at the TAKE-OFF WEIGHT.

- Find the distance to move C of G:

  2,492 mm - 2,486 mm = 6 mm

- Apply the formula:

$$\text{Weight to move} = \frac{2{,}700 \text{ kg} \times 6 \text{ mm}}{5{,}000 \text{ mm} - 500 \text{ mm}}$$

$$\text{Weight to move} = \frac{16{,}200 \text{ kgmm}}{4{,}500 \text{ mm}}$$

Answer: The weight to move = **3.6 kg rearward** to AFT locker.

REMOVING WEIGHT

If the aircraft is fully loaded and it is not possible to add ballast or move payload from one compartment to another, the C of G may be moved back within limits by removing payload.

In order to remove the least payload, it should be removed from a station which presents the longest arm in relation to the desired C of G position.

Applying the 'Weight to remove' formula:

$$\textbf{WEIGHT TO BE REMOVED} = \frac{\textbf{GROSS WEIGHT x DISTANCE TO MOVE C of G}}{\textbf{DISTANCE BETWEEN STATION AND DESIRED C of G}}$$

Example 1

An ECHO Mk IV is loaded in the following manner:

ZFW 2,900 kg

ZFW Moment 7,801,000 kgmm

The payload consists of passengers and 2 kg parcels. All lockers are full.

Problem: How much weight needs to be removed from the aircraft?

- Find the ZFW C of G position in mm AoD (Aft of the Datum)

  7,801,000 kg/mm / 2,900 kg = 2,690 mm AoD.

  The AFT limit is at 2,680m AoD; the C of G is too far back.

  Calculate the distance the C of G must move forward:

  2,690 mm - 2,680 mm = 10 mm

- To move the C of G forward by removing the minimum load, remove cargo from the AFT locker as that locker is the greatest distance away from the desired C of G.

  We want to move the C of G forward to 2,680 mm AoD which is the aft limit.

- Apply the formula:

$$\textbf{Weight to be removed} = \frac{\textbf{2,900 kg x 10 mm}}{\textbf{5,000 mm - 2,680 mm}}$$

$$\textbf{Weight to be removed} = \frac{\textbf{29,000 kgmm}}{\textbf{2,320 mm}}$$

Weight to be removed = 12.5 kg

Answer - As the load consists of parcels 2 kg each we must remove:

7 parcels = 14 kg.

Example 2

An ECHO Mk IV is loaded in the following manner:

ZFW 2,700 kg

ZFW Moment 7,276,500 kgmm

Problem - What is the minimum weight that must be removed from the AFT locker?

- Find the C of G position in mm AoD

  7,276,500 kgmm / 2,700 kg = 2,695 mm AoD

- Identify which way to move the C of G

  The C of G AFT limit is 2,680mm AOD. The C of G is too far back and must be moved forward. To achieve this, cargo must be removed from the AFT locker.

  The LEAST weight is to be removed, so move the C of G the least distance. Required C of G position is at AFT limit 2,680 mm AoD.

- Find the distance to move the C of G:

  2,695 mm - 2,680 mm = 15 mm FWD

- Apply the formula:

$$\text{Weight to be removed} = \frac{2{,}700 \text{ kg} \times 15 \text{ mm}}{5{,}000 \text{ mm} - 2{,}680 \text{ mm}}$$

$$\text{Weight to be removed} = \frac{40{,}500 \text{ kgmm}}{2{,}320 \text{ mm}}$$

$$\text{Weight to be removed} = 17.456 = 17.46 \text{ kg}$$

Answer - 17.46 kg needs to be removed from the AFT locker. It is impractical in real life to remove 17.46kg so a weight more than this would be removed. 18 kg or the number of parcels that equals the minimum weight above 17.46 kg needs to be removed.

ADDING CARGO

A formula can be used to calculate the amount of additional cargo that can be carried.

The Load and Trim Sheet shows:

AFT cargo compartment	empty
Cabin	5 pax
FWD compartment	10kg
Wing lockers	full
ZFW	2,400 kg
C of G	2,660 mm AoD
Take-off Weight	2,700 kg
C of G	2,495 mm AoD

There is no performance limit on your MTOW.

Before departure 200 parcels each with a weight of 5 kg have been delivered. There is a requirement to load as many of them as possible.

Check the MTOW and MZFW to determine the maximum extra payload can be carried without exceeding the structural limits.

MTOW 2,950 kg - 2,700 kg = 250 kg. Extra payload

MZFW 2,630 kg - 2,400 = 230 kg. Extra payload

The aircraft is ZFW limited.

Extra payload is 230 kg.

There is 155kg of space in the rear compartment and 45kg available in the forward compartment. The maximum extra is now 200kg.

Problem - Calculate how much extra payload may be carried.

Check the C of G for ZFW.

	WEIGHT	**ARM**	**MOMENT (IU)**
	2,400 kg	2,660 mm	638.4
Front compartment	55 kg	500 mm	2.8
Rear compartment	155 kg	5,000 mm	77.5
ZFW	**2,600 kg**	**2,764 mm**	**718.7**

As 2,680 mm is the most rearward limit, the C of G must be moved forward 84 mm. The C of G will move forward during the flight as fuel is burnt off.

- Apply the WEIGHT TO REMOVE FORMULA to the NEW ZFW:

Weight to remove = $\frac{\text{2,600 kg x 84 mm}}{\text{2,680 mm-5,000 mm}}$

Weight to remove = $\frac{\text{218,400kgmm}}{\text{2,320 mm}}$

Weight to remove = 94.1 kg

Each parcel weighs 5 kg and the amount that must be removed is 95 kg. This leaves 60 kg in the rear compartment.

The total extra payload that can be carried is 45 kg in the front compartment and 60 kg in the rear compartment.

Answer - The total extra weight which may be carried is **105 kg.**

- Check the weight and balance of the aircraft.
-

	WEIGHT	**ARM**	**MOMENT (IU)**
	2,400 kg	2,660 mm	638.4
Front compartment	45 kg	500 mm	2.3
Rear compartment	60 kg	5,000 mm	30.0
ZFW	**2,505 kg**	**2,677 mm**	**670.7**