CHAPTER 6
MASS AND BALANCE

6.1 INTRODUCTION

In order to achieve the performance and flight characteristics described in this Airplane Flight Manual and for safe flight operation, the airplane must be operated within the permissible mass and balance envelope.

The pilot is responsible for adhering to the permissible values for loading and center of gravity (CG). In this, he should note the movement of the CG due to fuel consumption. The permissible CG range during flight is given in Chapter 2.

The procedure for determining the flight mass CG position at any point in time is described in this Chapter. Over and above this there is a comprehensive list of the equipment approved for this airplane (Equipment List), as also a list of that equipment installed when the airplane was weighed (Equipment Inventory).

Before the airplane is delivered the empty mass and the corresponding CG position are determined, and entered in Section 6.3 MASS AND BALANCE REPORT.

NOTE

Following equipment changes the new empty mass and the corresponding CG position must be determined by calculation or by weighing.

Following repairs or repainting the new empty mass and the corresponding CG position must be determined by weighing.

Empty mass, empty mass CG position, and the empty mass moment must be certified in the Mass and Balance Report by an authorized person.

NOTE

Refer to Section 1.6 UNITS OF MEASUREMENT for conversion of SI units to US units and vice versa.

6.2 DATUM PLANE

The Datum Plane (DP) is a plane which is normal to the airplane's longitudinal axis and in front of the airplane as seen from the direction of flight. The airplane's longitudinal axis is parallel with the upper surface of a 600:31 wedge which is placed on top of the rear fuselage in front of the vertical stabilizer. When the upper surface of the wedge is aligned horizontally, the Datum Plane is vertical. The Datum Plane is located 2.194 meters (86.38 in) forward of the most forward point of the root rib on the stub wing.

6.3 MASS AND BALANCE REPORT

The empty mass and the corresponding CG position established before delivery are the first entries in the Mass and Balance Report. Every change in permanently installed equipment, and every repair to the airplane which affects the empty mass or the empty mass CG must be recorded in the Mass and Balance Report.

For the calculation of flight mass and corresponding CG position (or moment), the *current* empty mass and the corresponding CG position (or moment) in accordance with the Mass and Balance Report must always be used.

Condition of the airplane for establishing the empty mass:

- Equipment as per Equipment Inventory (see Section 6.5)
- Including brake fluid, lubricant (7.6 liters = 8 qts), plus unusable fuel (4 liters = approx. 1 US gal).

MASS AND BALANCE REPORT

(Continuous report on structural or equipment changes)

DA 40				Serial No.: 40,972			Registration: N194TS			Page: 1		
	Entry No.			Changes in mass						Current Empty Mass		
				Addition (+)			Subtraction (-)					
				Mass	Moment Arm	Moment	Mass	Moment Arm	Moment	Mass	Moment Arm	Moment
Date	IN	OUT	Description of Part or Modification	[kg] [lb]	[m] [in]	[kg m] [in lb]	[kg] [lb]	[m] [in]	[kg m] [in lb]	[kg] [lb]	[m] [in]	[kg m] [in lb]
July 1, 2008	1		Upon delivery							835.00	2.49	2079.15

6.4 FLIGHT MASS AND CENTER OF GRAVITY

The following information enables you to operate your DA 40 within the permissible mass and balance limits. For the calculation of the flight mass and the corresponding CG position the following tables and diagrams are required:

6.4.1 MOMENT ARMS
6.4.2 LOADING DIAGRAM
6.4.3 CALCULATION OF LOADING CONDITION
6.4.4 PERMISSIBLE CENTER OF GRAVITY RANGE
6.4.5 PERMISSIBLE MOMENT RANGE

The diagrams should be used as follows, taking the fuel tank size into account:

Empty mass

Take the empty mass and the empty mass moment of your airplane from the Mass and Balance Report, and enter the figures in the appropriate boxes under the column marked 'Your DA 40' in Table 6.4.3 - 'CALCULATION OF LOADING CONDITION'.

Oil

The difference between the actual amount of oil in the engine (check with dipstick) and the maximum oil quantity is called 'Oil not added'; this mass and its related moment are counted as negative. The empty mass of the airplane is established with the maximum amount of oil in the engine, thus the 'missing' oil must be subtracted. If the airplane is flown with maximum oil, the 'Oil not added' entry should be zero.

In our example 6.0 qts have been measured on the dip-stick. We are thus 2.0 qts short of the maximum, which equates to 1.9 liters. Multiplying this quantity by the mass density of 0.89 kilograms per liter gives a mass of 'Oil not added' of 1.7 kg. (in US units: 2.0 qts multiplied by the mass density of 1.86 lb/qts gives a mass of 3.7 lb).

Baggage

The DA 40 may be equipped with one of the following baggage compartment variants:

(a) Standard baggage compartment

(b) Standard baggage compartment with 'baggage tube'

(c) Extended baggage compartment (OÄM 40-163). It consists of a forward and an aft part.

Depending on the baggage compartment variant installed in your DA 40 the following calculations must be done in Table 6.4.3 'CALCULATION OF LOADING CONDITION':

For variants (a) and (b) . . . . . use row 5 of the table; row 6 is filled with '0'

For variant (c) . . . . . use row 6 of the table; row 5 is filled with '0'

Fuel

a) Standard tank:

The fuel quantity can be read on the fuel indicators.

NOTE

Depending on the type of fuel probes installed, the indicator can read a maximum of 15 US gal or 17 US gal (refer to Section 7.10 for details). When the fuel quantity indicator reads the maximum amount of fuel detectable, a fuel quantity up to 20 US gal can be in the fuel tank. In this case the fuel quantity must be measured with the fuel quantity measuring device (see Section 7.10 FUEL SYSTEM).

b) Long range tank:

Read the fuel quantity indicated on the fuel quantity indicators.

NOTE

At an indication of 16 US gal the amount of auxiliary fuel can be determined by switching the AUX FUEL QTY switch to the respective position (LH or RH). The indicated auxiliary fuel quantity is added to the 16 US gal.

An auxiliary fuel quantity of less than 3 US gal cannot be indicated by the system. In this case the quantity must be determined by means of the fuel quantity measuring device (see Section 7.10 FUEL SYSTEM).

CAUTION

The correct indication of the fuel quantity takes 2 minutes after actuation of the switch.

Moments

Multiply the individual masses by the moment arms quoted to obtain the moment for every item of loading, and enter these moments in the appropriate boxes in Table 6.4.3 - 'CALCULATION OF LOADING CONDITION'.

Total mass and CG

Add up the masses and moments in the respective columns. The CG position is calculated by dividing the total moment by the total mass (using row 7 for the condition with empty fuel tanks, and row 9 for the pre take-off condition). The resulting CG position must be within the limits.

CAUTION

For airplanes equipped with the optional Long Range Tank, a restricted range of permitted CG positions applies.

As an illustration the total mass and the CG position are entered on Diagram 6.4.4 'PERMISSIBLE CENTER OF GRAVITY RANGE'. This checks graphically that the current configuration of the airplane is within the permissible range.

Graphical method

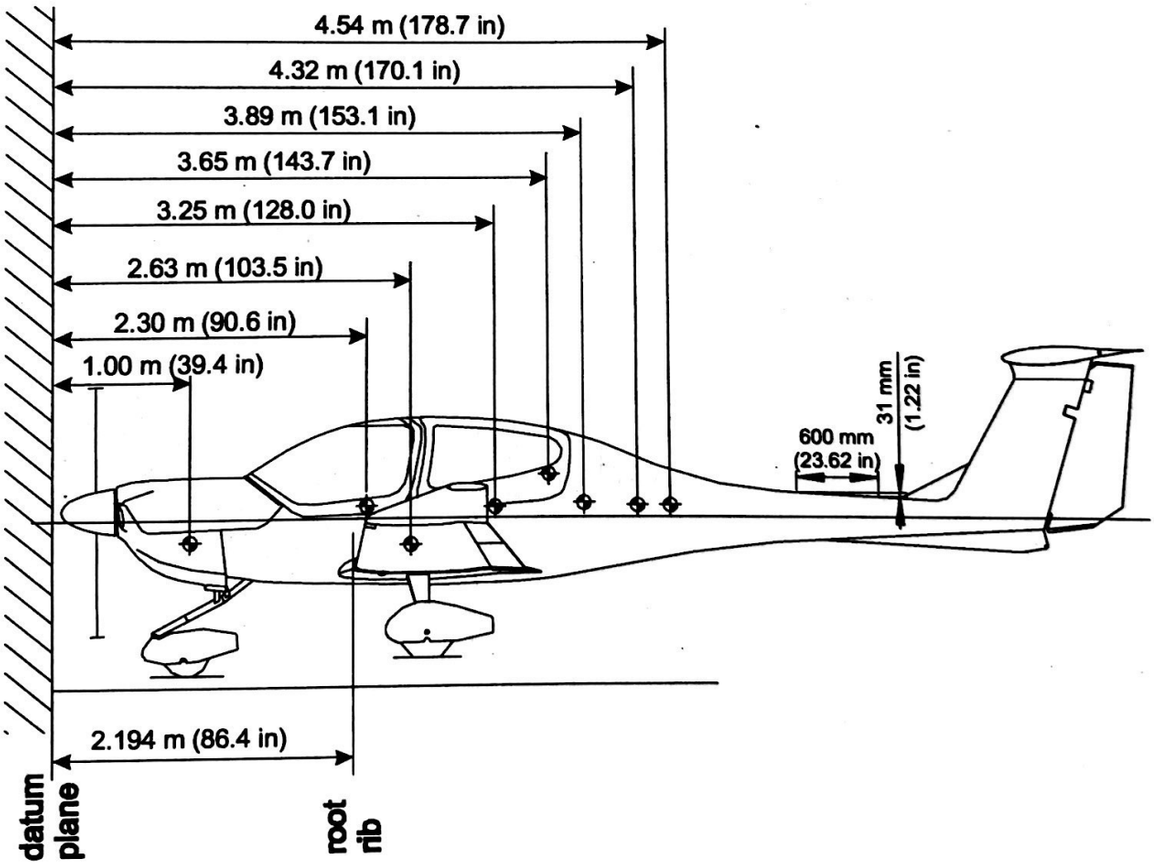
Diagram 6.4.2 'LOADING DIAGRAM' is used to determine the moments. The masses and moments for the individual items of loading are added. Then Diagram 6.4.5 'PERMISSIBLE MOMENT RANGE' is used to check whether the total moment associated with the total mass is in the admissible range.

The result found with the graphical method is however inaccurate. In doubtful cases the result must be verified using the exact method given above.

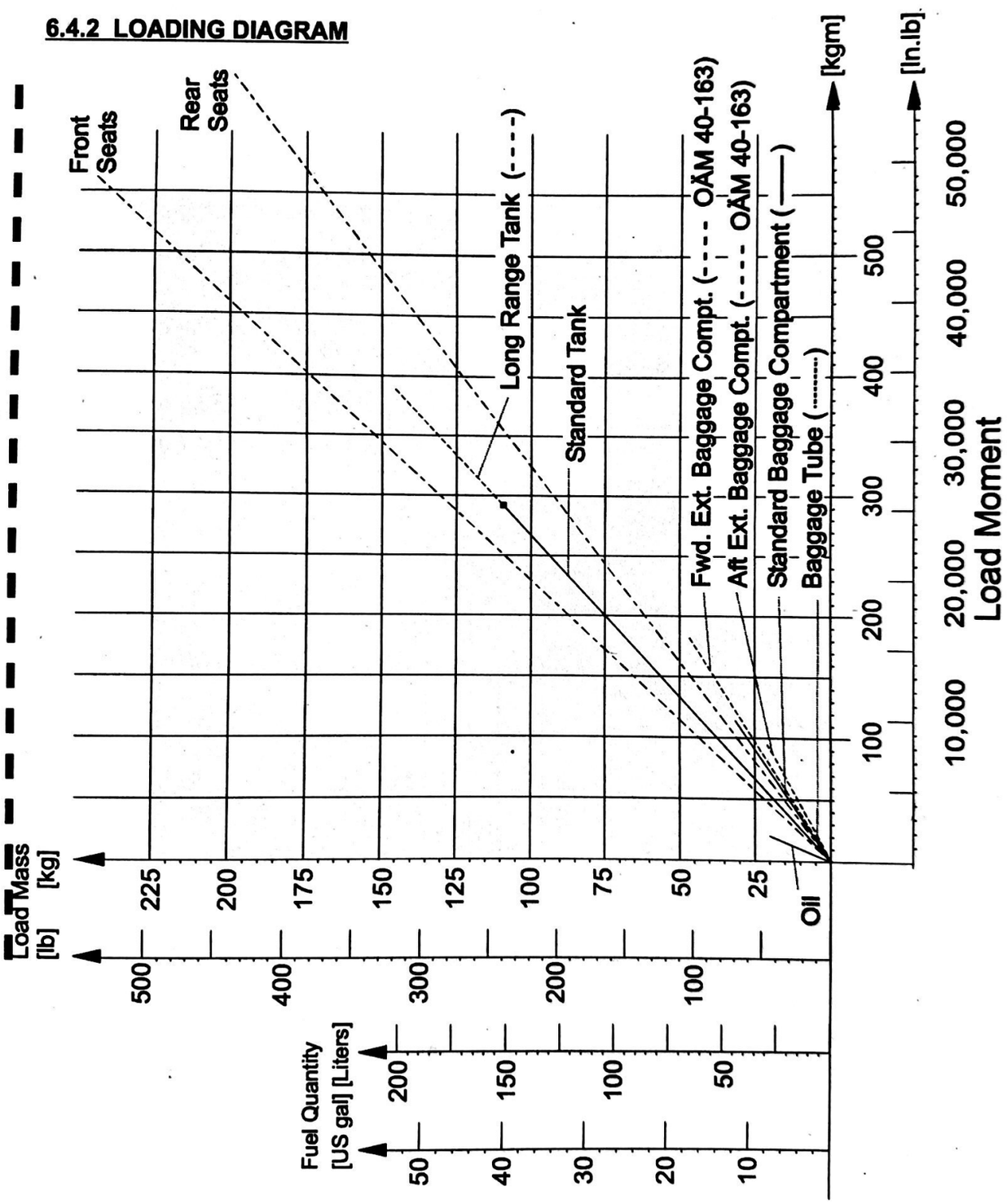
6.4.1 MOMENT ARMS

The most important lever arms aft of the Datum Plane:

- Oil	:	1.00 m	39.4 in
- Front seats	:	2.30 m	90.6 in
- Rear seats	:	3.25 m	128.0 in
- Wing tanks (Standard & Long Range)	:	2.63 m	103.5 in
- Baggage in standard baggage compartment	:	3.65 m	143.7 in
baggage in baggage tube	:	4.32 m	170.1 in
- Baggage in extended baggage compartment			
forward part	:	3.89 m	153.1 in
aft part	:	4.54 m	178.7 in



6.4.2 LOADING DIAGRAM



6.4.3 CALCULATION OF LOADING CONDITION

CAUTION

For airplanes equipped with the optional Long Range Tank, a restricted range of permitted CG positions applies.

NOTE

For the mass (weight) of the fuel, a density of 0.72 kg/liter (6.01 lb/US gal) is assumed. For the mass (weight) of the engine oil, a density of 0.89 kg/liter (1.86 lb/US qt, 0.84 kg/US qt) is assumed.

NOTE

In the following example it is assumed that the fuel tank is not full at take-off.

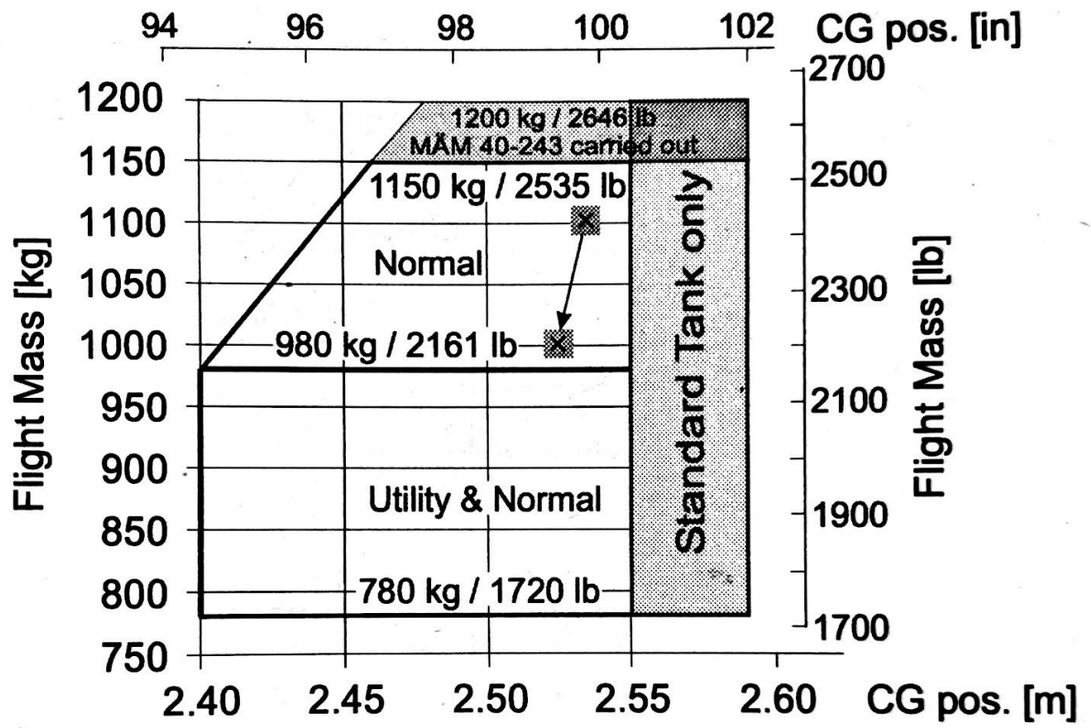
		DA 40 (Example)		Your DA 40	
		Mass [kg] *[lb]*	Moment [kg m] *[in lb]*	Mass [kg] *[lb]*	Moment [kg m] *[in lb]*
1	Empty mass (from Mass and Balance Report)	735 *1620*	1760 *152,762*		
2	Oil not added Lever arm: 1.00 m *(39.4 in)*	-1.7 *-4*	-1.7 *-158*		
3	Front seats Lever arm: 2.30 m *(90.6 in)*	150 *331*	345 *29,989*		
4	Rear seats Lever arm: 3.25 m *(128.0 in)*	75 *165*	243.8 *21,120*		
5	Standard baggage compt. Lever arm: 3.65 m *(143.7 in)*	0 *0*	0 *0*		
	Baggage Tube Lever arm: 4.32 m *(170.1 in)*	0 *0*	0 *0*		
6	Fwd. extended baggage compartment Lever arm: 3.89 m *(153.1 in)*	27 *60*	105 *9,186*		
	Aft extended baggage compartment Lever arm: 4.54 m *(178.7 in)*	18 *40*	81.7 *7,148*		
7	Total mass & total moment with empty fuel tanks (Total of 1.-6.)	1003.3 *2212*	2533.8 *220,047*		
8	Usable fuel Lever arm: 2.63 m *(103.5 in)*	99.4 *219*	261.4 *22,667*		
9	Total mass & total moment including fuel (7. plus 8.)	1102.7 *2431*	2795.2 *242,714*		

10 The total moments from rows 7 and 9 (2533.8 and 2795.2 kgm) *(220,047 and 242,714 in.lb)* must be divided by the related total mass (1003.3 and 1102.7 kg respectively) *(2212 and 2431 lb)* and then located in Diagram 6.4.4 'PERMISSIBLE CENTER OF GRAVITY RANGE'.

As in our example CG positions (2.525 m and 2.535 m respectively) *(99.48 and 99.84 in)* and masses fall into the permitted area, this loading condition is allowable.

6.4.4 PERMISSIBLE CENTER OF GRAVITY RANGE

The diagram is replaced by the following:



Forward flight CG limit:

The paragraph is amended to read:

2.40 m (94.5 in) aft of DP from 780 kg to 980 kg (1720 lb to 2161 lb)

2.46 m (96.9 in) aft of DP at 1150 kg (2535 lb)

linear variation between these values

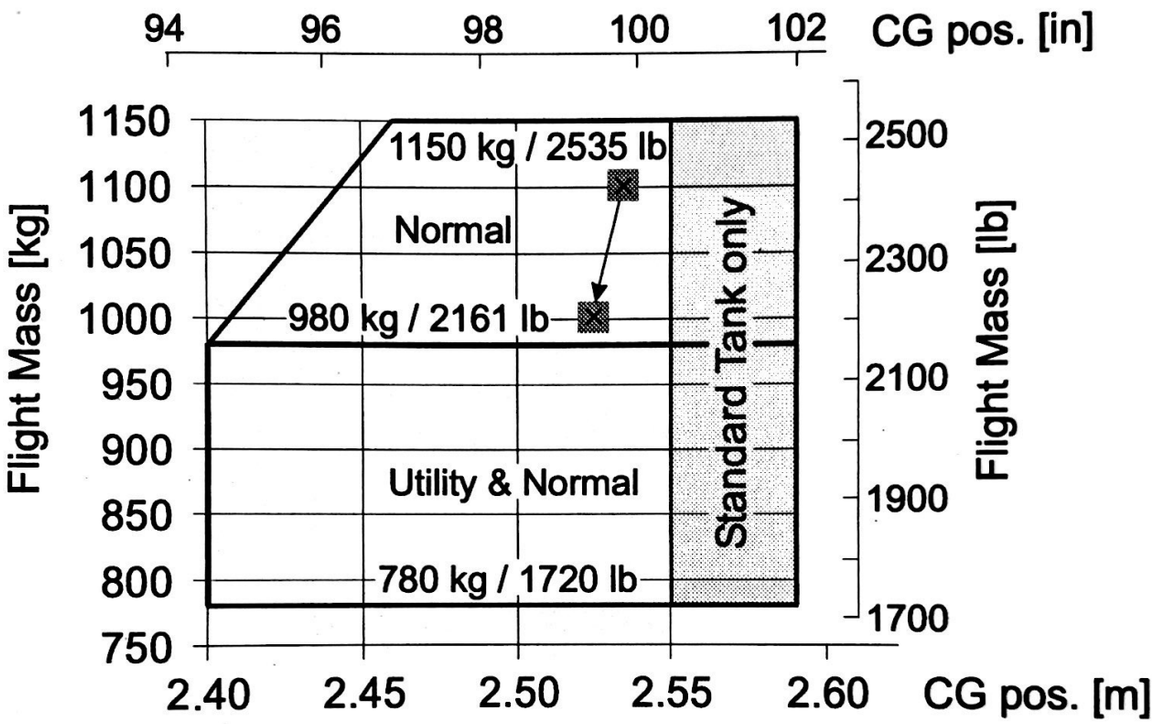
If MÄM 40-227 is carried out:

2.40 m (94.5 in) aft of DP from 780 kg to 980 kg (1720 lb to 2161 lb)

2.48 m (97.6 in) aft of DP at 1200 kg (2646 lb)

linear variation between these values

6.4.4 PERMISSIBLE CENTER OF GRAVITY RANGE



The CG´s shown in the diagram are those that from the example in Table 6.4.3 'CALCULATION OF LOADING CONDITION'.

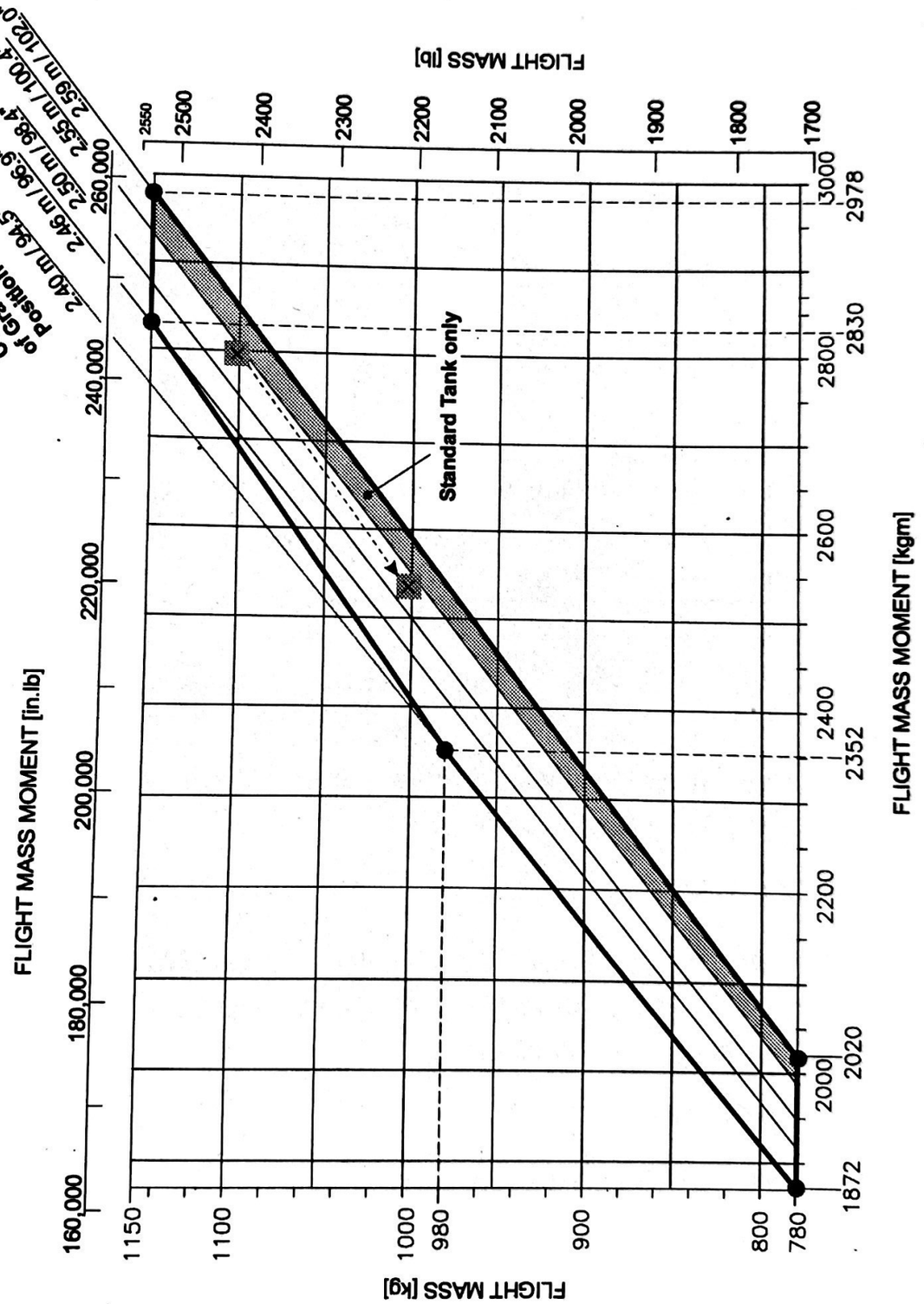
Forward flight CG limit:

2.40 m (94.5 in) aft of Datum Plane at 780 to 980 kg (1720 to 2161 lb)
2.46 m (96.9 in) aft of Datum Plane at 1150 kg (2535 lb)
linear variation between these values

Rearward flight CG limit:

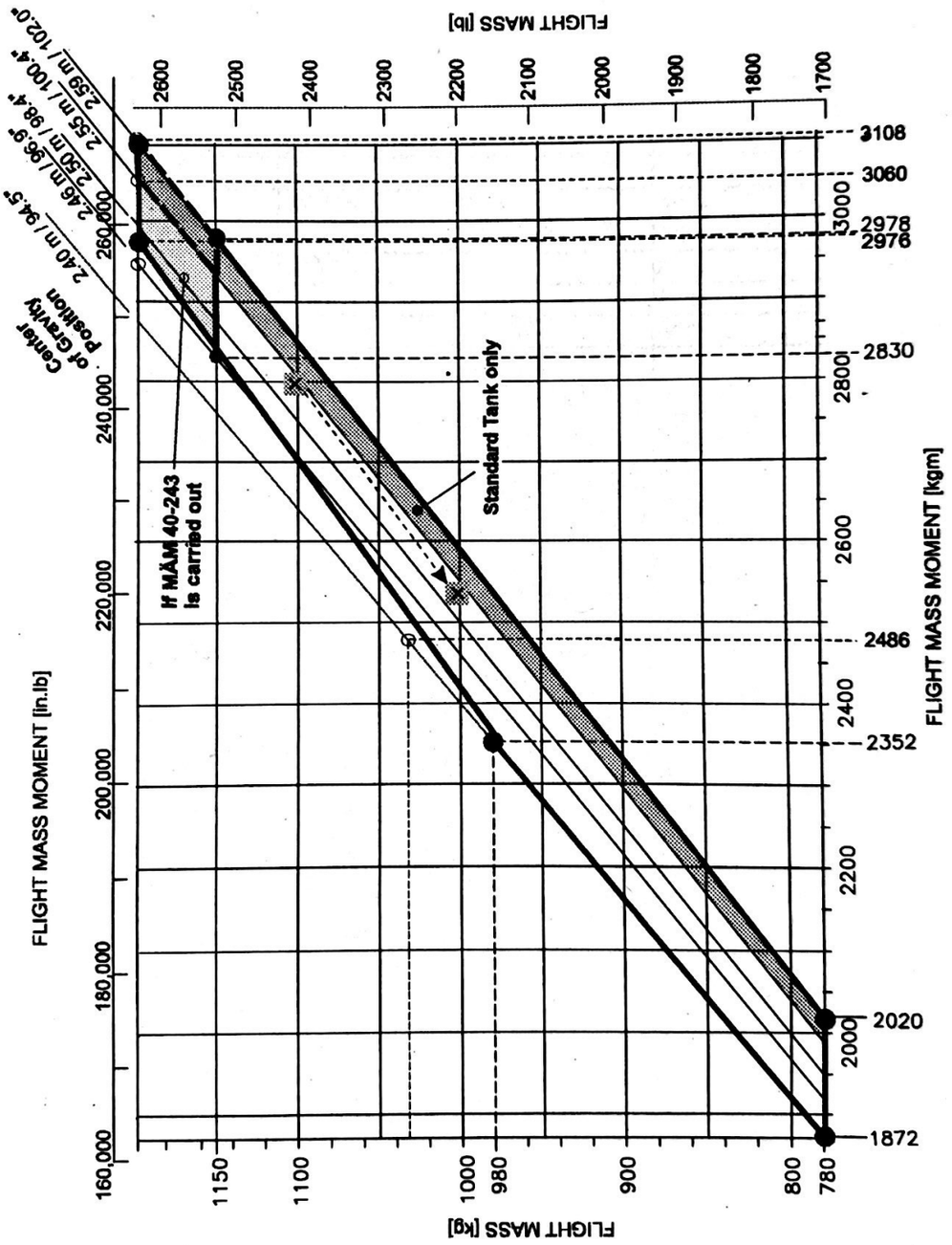
2.59 m (102.0 in) aft of Datum Plane (Standard Tank)
2.55 m (100.4 in) aft of Datum Plane (with Long Range Tank installed)

6.4.5 PERMISSIBLE MOMENT RANGE



6.4.5 PERMISSIBLE MOMENT RANGE

The diagram is replaced by the following:



Model: DA 40

Diamond

Aircraft Serial Number	40.972
Registration	N194TS
Issue Date	July 1.2008

Aircraft Specific Weighting Report

Data with reference to the Type Certificate Data Sheet and the Flight Manual
Reference Plane: Vertical plane 2194mm (86.38 in) in front of wing leading edge at root rib
Horizontal reference plane: Wedge 600:31 (2.96°), 2910mm (114.57 in) aft of step in the cockpit rim.

Equipment list dated: July 1.2008

Cause for weighing: ORIGINAL

Weight and Balace Calculations

Weight Condition:
Include brake fluid, engine oil and unusable fuel (2 liters/0.5 US gallons on each side).

Empty Weight

Support	Gross kg	Gross lbs	Tare kg	Tare lbs	Net Weight kg	Net Weight lbs
Front, G_2	118.40	261.00	0.00	0.00	118.40	261.00
Main, G_{1LH}	357.40	788.00	0.00	0.00	357.40	788.00
Main, G_{1RH}	359.20	792.00	0.00	0.00	359.20	792.00
EMPTY WEIGHT, G					835.00	1841.00

	Lever Arm mm	Lever Arm in.
X_2	978.00	38.50
X_{1LH}	2739.50	107.85
X_{1RH}	2739.50	107.85

Empty Weight Centre of Gravity, (X_{CG}):

Empty Weight CG Formula

$$X_{CG} = \frac{((G_{1LH}+G_{1RH})*X_1) + (G_2*X_2)}{G_2 + G_{1LH} + G_{1RH}} = \frac{2.49 \text{ m}}{98.02 \text{ in.}}$$

Empty Weight Moment, (M):

Empty Weight Moment Formula

$$M = G \times X_{CG} = \frac{2079.15 \text{ kg-m}}{180454.82 \text{ in-lbs}}$$

Maximum Permitted Useful Load:

Maximum Take-off Weight	1200.00	kg	2646.00	lbs
Empty Weight	835.00	kg	1841.00	lbs
Maximum Useful Load	365.00	kg	805.00	lbs

Data to be entered into the Flight Manual:

Empty Weight, G:	Empty Weight Moment, M:
835.00 kg 1841.00 lbs	2079.15 kg-m 180454.82 in-lbs

Place: D.A.I.C - CYXU Date: July 1.2008	Authorizing Stamp	DA Q 20	Authorizing Signature