CHAPTER 6

WEIGHT AND CENTRE OF GRAVITY POSITION

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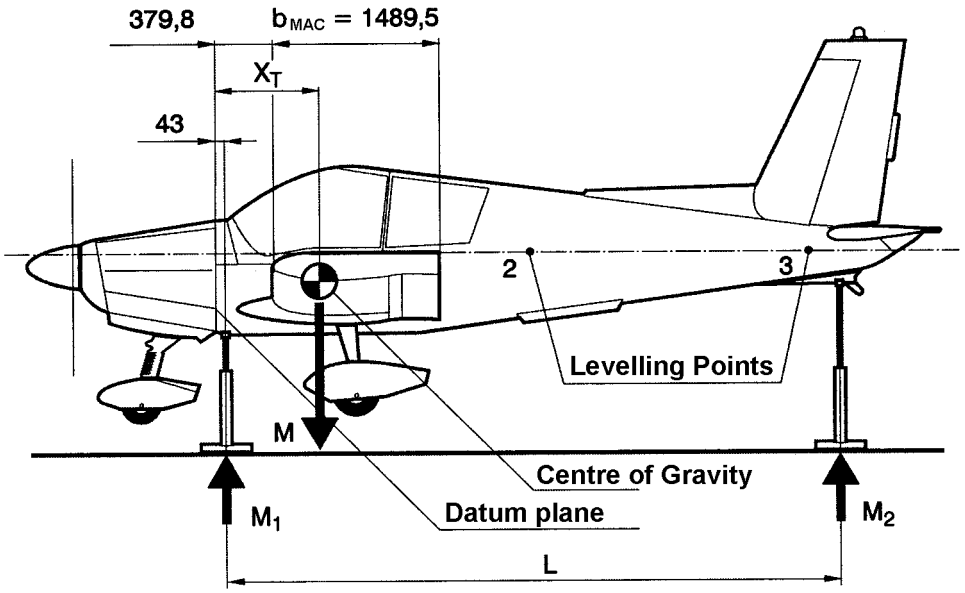
6. WEIGHT AND CENTRE OF GRAVITY POSITION

6.1. GENERAL

6.1.1. Definitions, Symbols and Units



NOTE

Measures in figure are in millimetres.

M_1	:	Front scale (including jack) reading	kg, (lb)
M_2	:	Rear scale (including jack) reading	kg, (lb)
M_3	:	Total **$M_1 + M_2$**	kg, (lb)
M_4	:	Front jack weight	kg, (lb)
M_5	:	Rear jack weight	kg, (lb)
M_6	:	Total **$M_4 + M_5$**	kg, (lb)
M	:	Empty weight **$M_3 - M_6$**	kg, (lb)
L	:	Distance between jacking points	m, (in)
S	:	Static moment **$S = M \cdot X_T$**	kgm, (lb.in)
b_{MAC}	:	Mean aerodynamic chord length = 1,4895 m (58,642 in)	
X_T	:	Centre of gravity arm (measured from datum)	(m),(in)
X_T	:	Centre of gravity position	(% b_{MAC})

Weighing of the aircraft - is carried out in order to determine the aircraft weight, centre of gravity and static moment. The aircraft shall be weighed in levelled position. It is supported by adjustable jacks at the first fuselage bulkhead and tail skid spar jacking points.

Position of the aircraft - as determined by the levelling points No. Nib 2 - Nib 3 located on the rear part of the fuselage.

6.1.2. Calculation Formulas

1) Standard Empty Weight:

$M = M_3 - M_6$ *kg, (lb)*

2) Centre of Gravity Arm (measured from datum):

$X_T = L \cdot \frac{M_2 - M_5}{M} + 0.43$ (m)

$X_T = L \cdot \frac{M_2 - M_5}{M} + 1{,}693$ (in)

3) Static Moment:

$S = M \cdot X_T$ *kgm, (lb.in)*

4) Centre of Gravity position:

Units	Calculation formula	Result
metric	$\overline{X_T} = \frac{(X_T - 0{,}3798)}{1{,}4895} 100$	% b_{SAT}
imperial	$\overline{X_T} = \frac{(X_T - 14{,}953)}{58{,}642} 100$	

CAUTION

THE WEIGHT AND CENTRE OF GRAVITY POSITION CHECK MAY BE CARRIED OUT IN THE ONLY ONE SINGLE SYSTEM (METRIC OR IMPERIAL).

6.2. BASIC EMPTY WEIGHT (TRUE)

At the time of licensing the manufacturer provides each aircraft with the basic empty weight and Centre of gravity position data. This information is entered in the Basic Empty Weight and balance record at the first row.

NOTE

The tabled values correspond to the following aircraft conditions:

- Actual aircraft status
- The aircraft system contain
  - unusable fuel
  - maximum oil quantity
- Brake system
  - filled with hydraulic fluid
- Position of seats
  - extreme front
- Canopy
  - closed

CAUTION

WHENEVER NEW EQUIPMENT IS ADDED OR ANY ALTERNATIONS IS PERFORMED, THE RESPONSIBLE PERSON MUST RECALCULATE OR REPEAT THE WEIGHING OF THE AIRCRAFT BASIC EMPTY WEIGHT DEPENDING ON THE NATURE OF CHANGE.

HISTORY OF CHANGES IN THE AIRCRAFT EQUIPMENT LEADING TO CHANGES OF THE WEIGHT AND THE STATIC MOMENT IS TO BE ENTERED INTO THE “BASIC EMPTY WEIGHT AND BALANCE RECORD”.

THE LIST OF WEIGHTS AND CORRESPONDING ARMS OF THE PARTS OF EQUIPMENT IS IN SECTION 9 “EQUIPMENT LIST”.

Basic Empty Weight and Balance Record

Date	Description of the change in equipment or modification	Change								Basic empty weight					Signature
		Added (+)			Removed (-)					Weight		Moment			
		Weight	Arm	Moment	Weight	Arm	Moment			kg	lb	kgm	lbinch		
		kg (lb)	m (in)	kgm (lbinch)	kg (lb)	m (inch)	kgm (lbinch)								
	ON DELIVERY														

The arms and moments of the items installed in front of the datum, bear negative sign and their moments must be subtracted.

6.3. STATIC MOMENT OF VARIABLE LOAD

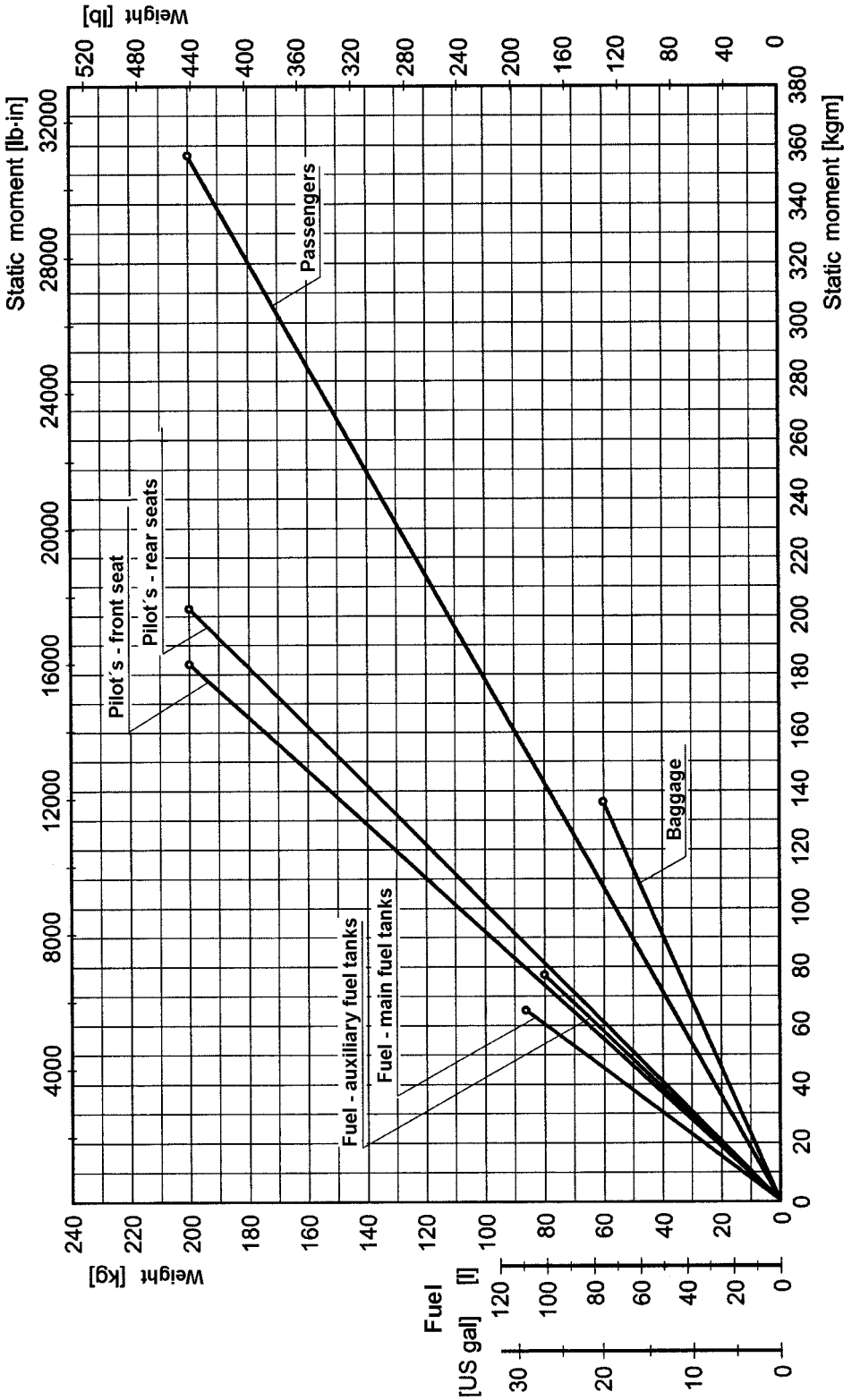
The variable load arms for the calculation of static moments are as follows.

Variable Load	Specification		Arm	
			m	in
Pilot and passengers	Position of seats	front	0,917	36,10
		middle	0,962	37,87
		rear	1,007	39,65
Passengers	Rear seats		1,784	70,24
Fuel	Main tanks		0,750	29,53
	Auxiliary tanks		0,948	37,32
Baggage			2,266	89,21

The static moments of the particular variable loads are calculated:

- as the product of the particular arm and the variable load weight
- from the following graph of static moments

Static Moments of Variable Load



6.4. WEIGHT AND BALANCE CHECK PROCEDURE

CAUTION

THE PILOT IS OBLIGED TO CHECK THE TAKE-OFF WEIGHT, THE VARIABLE LOAD AND THE CENTRE OF GRAVITY POSITION BEFORE EACH FLIGHT.

The calculation shall be carried out on the “Weight and Balance Record”.

Calculating procedure:

1) The Basic empty weight and Static moment are determined in Section 6.2.
2) The procedure for calculating the static moments of variable loads is described in Section 6.3.
3) Sum up the Weights and the static moments in the “Weight and balance record” columns.
4) The loading of the aircraft is ACCEPTABLE if the intersection of the “static moment” and “total weight” lines lay within the loading envelope in appropriate category in the “Centre of gravity position check graph” - Section 6.6.

Weight and Balance Record

No.	Date:	Type: ***Z 143 LSi***	Identification Mark:			
	Description	Maximum permissible variable load	Weight		Static moment	
			kg	lb	kgm	lb.in
1.	Basic Empty Weight (true)	-				
2.	Seats left	max. 100 kg 220 lb				
	Seats right	max. 100 kg 220 lb				
3.	Main tanks …….. litres …….. US gal					
4.	Rear seats	Max. 2 x 100 kg 2 x 220 lb				
5.	Auxiliary tanks …….. litres …….. US gal					
6.	Baggage total max. 60 kg (132 lb)	Upper shelf max. 20 kg 44 lb				
		Compartment max. 2 x 30 kg 2 x 66 lb				
7.	**Σ**					
8.	Check centre of gravity position: C.G. position $\overline{X_T}$ = % b_{SAT}					

NOTE

Conversion coefficients of fuel volume units to weight:

1 litre = 0,720 kg = 1,587 lb

1 US.gal. = 2,722 kg = 6,000 lb

6.5. SAMPLE PROBLEM

6.5.1. Task

Check the take-off weight and the centre of gravity position for the following flight conditions:

Basic empty weight	860 kg
Static moment	580,5 kgm
Left pilot	73 kg (front position of seat)
Right pilot	96 kg (rear position seat)
One passenger	82 kg
Fuel in the main tanks	2 x 60 litres
Fuel in the auxiliary tanks	2 x 20 litres
Total weight of baggage	22 kg

6.5.2. Calculation

NOTE

Sample problem calculation is carried out in metric system.

1) Enter the basic empty weight/moment values into “Weight and balance record” line 1. - are described in Sect. 6.2. For this sample was used values according to the task.
2) Determine the values of static moments for the left and right pilots according to Sect. 6.3:
   a) Left pilot 73 x 0,917 = 66,9 kgm
   b) Right pilot 96 x 1,007 = 96,7 kgm

   Enter the weights and static moments of the pilot into line 2. of the record.

CAUTION

FOR DETERMINING THE STATIC MOMENTS OF THE PILOTS, THE POSITION OF THE SEAT MUST BE OBSERVED.

3) Calculate the fuel weight in the main tanks.
   Conversion coefficient is 0,720 kg = 1 litres of fuel
   Fuel weight = 120 x 0,72 = 86,4 kg

   According to Sect. 6.3. determine the fuel static moment in the main tanks = 86,4 x 0,750 = 64,8 kgm.

   The weight and the fuel static moment in the main tanks are entered on line 3. of the record.

4) According to Section 6.3, determine the static moment of the passengers
Static Moment = 82 x 1,784 = 146,3 kgm

   The weight and the static moment of the passengers are entered on line 4. of the record.

5) Calculate the fuel weight in the auxiliary tanks.
Conversion coefficient is 0,720 kg = 1 litres of fuel
Fuel weight = 40 x 0,720 = 28,8 kg

   According to Sect. 6.3. determine the fuel static moment in the auxiliary tanks =
28,8 x 0,948 = 27,3 kgm

   The weight and the fuel static moment in the auxiliary tanks are entered on line 5. of the record.

6) According to Sect. 6.3. determine the value of static moment of the baggage =
22 x 2,266 = 49,8 kgm

   Enter the weight and the static moment of the baggage on line 6. of the record.

7) Calculate sums of the weights and of the static moments and enter them on line 7. of record

Σ of weights	= 1248,2 kg	(point 1 - graph)
Σ of static moments	= 1032,3kgm	(point 2 - graph)

8) The check of the centre of gravity position shows the compliance with the limitation envelope in the “C.G. position check” graph.
The resulting centre of gravity position is **30.0 % b_{MAC}**.

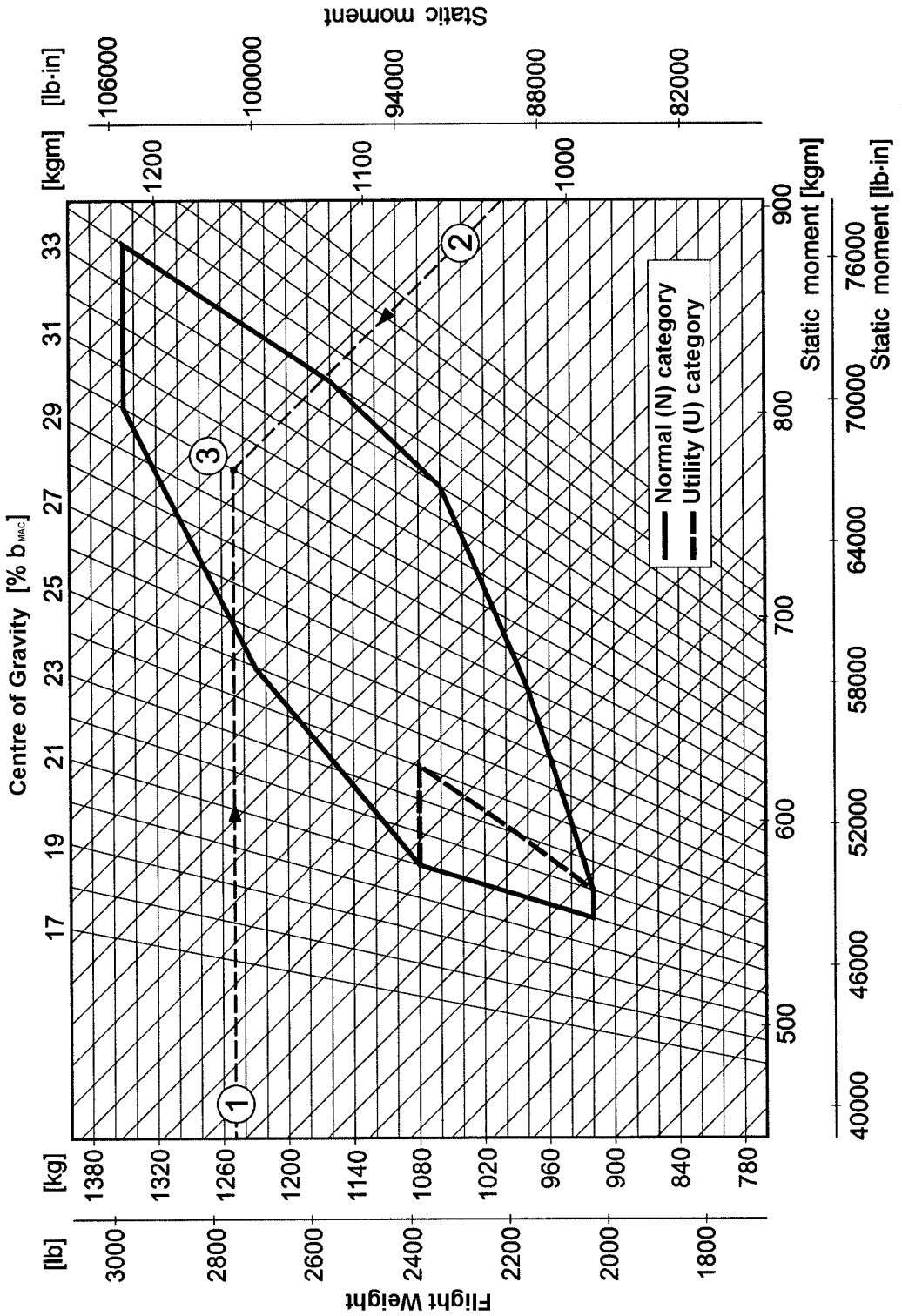
The form for weight and centre of gravity check completed according to the example

No.	Date:	Type: ***Z 143LSi***	Identification Mark:			
	Description	Maximum permissible variable load	Weight		Static moment	
			kg	lb	kgm	lb.in
1.	Basic Empty Weight	-	***860***		***580,5***	
2.	Seats left	max. 100 kg 220 lb	***73***		***66,9***	
	Seats right	max. 100 kg 220 lb	***96***		***96,7***	
3.	Main tanks	…..*120*…. litres …….. US gal	***86,4***		***64,8***	
4.	Rear seats	Max. 2 x 100 kg 2 x 220 lb	***82***		***146,3***	
5.	Auxiliary tanks	…..*40*….. litres …….. US gal	***28,8***		***27,3***	
6.	Baggage total max. 60 kg (132 lb)	Upper shelf max. 20 kg 44 lb Compartment max. 2 x 30 kg 2 x 66 lb	***22***		***49,8***	
7.	**Σ**		***1248,2***		***1032,3***	
8.	Check centre of gravity position:		C.G. position $\overline{X_T}$ = ***30.0*** % b_{MAC}			

6.5.3. Conclusion

The point 3 is situated in diagram the permissible centre of gravity and NORMAL category weight limit range. With regard to weight and centre of gravity the flight may be executed.

6.6. CENTRE OF GRAVITY POSITION CHECK DIAGRAM



6.7. EQUIPMENT LIST

The “Equipment List“ is described in Chapter 9.

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