Weight and Balance

Objective

Understand the concept of weight and balance, the relationship of center of gravity on aircraft performance and limitations, and how to compute a weight and balance problem.

Motivation

The effect of weight and CG location is critical to the safety of flight and an essential part of cross-country flight planning. Pilots should have a clear understand of the limits of their airplane with regards to weight and balance.

Overview

- Weight and balance concepts
 - \circ Torque
 - Moments
- Terms and Definitions
- Sample weight and balance problem
- Weight and balance and performance

Torque: See-Saw, Moments

Terms



- Datum: Fixed reference point to measure from
- Station: Area where item can be loaded
- Arm: Distance from datum to the item
- Moment: Item arm * item weight
- Center of Gravity:
 - Point at which weight appears to be concentrated
 - Location of C.G. = Total moments / total weights
- Loading Envelope: Graph of acceptable weight and CG ranges

Stations

LOADING ARRANGEMENTS

*Pilot or passenger center of gravity on adjustable seats positioned for average occupant. Numbers in parentheses indicate forward and aft limits of occupant center of gravity range.

**Arms measured to the center of the areas shown.

- NOTES: 1. The usable fuel C.G. arm is located at station 46.5.
 - 2. The aft baggage wall (approximate station 134) can be used as a convenient interior reference point for determining the location of baggage area fuselage stations.



Weights

- Standard empty weight: From the factory with standard equipment
 - Includes oil, fuel, and unusable fuel
- Basic empty weight
 - Standard empty weight, plus optional equipment
 - What we'll start with for W&B calculations
- Licensed empty weight:
 - Older term, does not include full engine oil
- Max ramp weight (MRW): The maximum weight for ground operations (no flight)
- Max takeoff weight (MTOW): Maximum weight for takeoff
- Max landing weight (MLW): Max weight for landing
- Fuel: 100LL is 6 lbs / gal.



WEIGHT & BALANCE AND EQUIPMENT LIST AMENDMENT

DATE INO "				
DATE WO# OW	NER REG. #	MAKE & MODEL	SERIAL #	
4/1/2024 4626 Plan	e Fun N2017E	Cessna T182	18268183	

ITEM		WEIGHT	ARM	MOMENT
Previous empty weight as of 4/10/2020		1911.0		69891.300
Remove Noso Wheel Devi				
Romove Nose Wheel Pant:		-3.9	-6.00	23.400
				0.000
				0.000
			,	0.000
				0.000
				0.000
				0.000
				0.000
Totals		1907.1	36.66	69914.700
NEW EMPTY WEIGHT	1907 1			
E.W.C.G.	36.66			
MOMENT	69914.700		× 8	
MAX TAKE-OFF WEIGHT	3100			
USEFUL LOAD	1192.9			
Robert Freinecke				
Robert L Reinecke AP3455579IA				

W&B Sheet

- Required to be in the airplane
- Changes whenever work is done that changes the W&B

Sample Problem

W&B Problem

- Fuel: 50 gallons of 100LL
 - @ 6lbs / gallon
- Pilot: 160lbs
- Co-pilot: 180lbs
- Rear passenger: 120lbs
- Expected fuel burn during the flight: 40 gallons



SAMPLE LOADING PROBLEM		SAMPLE AIRPLANE		YOUR AIRPLANE	
		Moment (Ibins. /1000)	Weight (Ibs.)	- Moment (Ibins. /1000)	
 Basic Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel and full oil) 	1815	64.0			
2. Usable Fuel (At 6 Lbs./Gal) Standard Tanks (88 Gal. Maximum)	528	24.6			
Reduced Fuel (65 Gal.)					
3. Pilot and Front Passenger (Station 32 to 50)	340	12.6		-	
4. Second Row Passengers	340	25.2			
Cargo Replacing Second Row Seats (Sta. 65 to 82)					
5. *Baggage (Area "A") or Passenger on Child's Seat (Sta. 82 to 109) 120 Lbs. Maximum	70	6.8			
6. *Baggage (Area ''B'') (Sta. 109 to 124) 80 Lbs. Maximum	19	2.2			
7. *Baggage (Area ''C'') (Sta. 124 to 134) 80 Lbs. Maximum					
8. RAMP WEIGHT AND MOMENT	3112	135.4			
9. Fuel allowance for engine start, taxi and runup.	- 12	6			
10. TAKEOFF WEIGHT AND MOMENT (Subtract step 9 from step 8)	3100	134.8			
11. Locate this point (3100 at 134.8) on the Center of Gravity Moment Envelope, and since					

 Locate this point (3100 at 134.8) on the Center of Gravity Moment Envelope, and since this point falls within the envelope, the loading is acceptable, provided that flight time is allowed for fuel burn-off to a maximum of 2950 pounds before landing.

*The maximum allowable combined weight capacity for baggage in areas A, B, and C is 200 pounds.

*The maximum allowable combined weight capacity for baggage in areas 8 and C is 80 pounds.



SAMPLE		SAMPLE AIRPLANE		YOUR AIRPLANE	
LOADING PROBLEM	Weight (Ibs.)	Moment (Ibins. /1000)	Weight (Ibs.)	- Moment (Ibins. /1000)	
 Basic Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel and full oil) 	1815	64.0	1907	69.91	
2. Usable Fuel (At 6 Lbs./Gal) Standard Tanks (88 Gal. Maximum)	528	24.6	300	14	
Reduced Fuel (65 Gal.)					
3. Pilot and Front Passenger (Station 32 to 50)	340	12.6	340	12.6	
4. Second Row Passengers	340	25.2	120	8.8	
Cargo Replacing Second Row Seats (Sta. 65 to 82)					
5. *Baggage (Area "A") or Passenger on Child's Seat (Sta. 82 to 109) 120 Lbs. Maximum	70	6.8			
6. *Baggage (Area ''B'') (Sta. 109 to 124) 80 Lbs. Maximum	19	2.2			
7. *Baggage (Area ''C'') (Sta. 124 to 134) 80 Lbs. Maximum					
8. RAMP WEIGHT AND MOMENT	3112	135.4	2667	105.3	
9. Fuel allowance for engine start, taxi and runup.	- 12	6	-12	-0.6	
10. TAKEOFF WEIGHT AND MOMENT (Subtract step 9 from step 8)	3100	134.8	2655	104.7	
11 Locate this point (3100 at 134.8) on the Center of	Gravity A	Noment Fi	nvelone a	nd since	

 Locate this point (3100 at 134.8) on the Center of Gravity Moment Envelope, and since this point fails within the envelope, the loading is acceptable, provided that flight time is allowed for fuel burn-off to a maximum of 2950 pounds before landing.

*The maximum allowable combined weight capacity for baggage in areas A, B, and C is 200 pounds.

*The maximum allowable combined weight capacity for baggage in areas 8 and C is 80 pounds.

Alternate Method: Weight * Arm = Moment

Station	Weight	Arm	Moment	Moment / 1000
Basic Empty Weight	1907	36.68	69,910	69.91
Usable Fuel	300	46.66	14,000	14
Pilot and Front Passenger	340	37	12,600	12.6
Second Row Passenger	120	74	8,880	8.8
Ramp Weight	2667	39.51	105,390	105.39

CG Moment Envelope



CG Location Envelope



What is our landing weight?

What is our landing weight and moment?

- 2655 40 gal * 6 lbs/gal = 2415 lbs
- 104700 46.66 * 40 gal * 6 lbs/gal = 93501 in-lbs

What happens if we move our 180 passenger to the rear seats?

What happens if we move our 180 passenger to the rear seats?

- Weight doesn't change = 2655 lbs
- 104700 180 lbs * 37 in + 180 lbs * 74 in = 111360 in-lbs

What happens if we add a forth passenger to the copilot seat who weighs 200?

What happens if we add a forth passenger to the copilot seat who weighs 200?

- 2655 + 200 = 2855
- 111360 + 200 lbs * 37 in = 118760 in-lbs

How W&B Affects Performance

Overweight



CG and Cruise Performance: Elevator Downwash



CG Aft of Limits



CG Forward of Limits



Summary

- Weight and balance concepts
 - \circ Torque
 - Moments
- Terms and Definitions
- Sample weight and balance problem
- Weight and balance and performance

Knowledge Check

You show up to the plane, ready to take three friends flying. The last pilot topped off the airplane with 88 gallons, which will put you over gross weight.

How would you deal with the situation?

Knowledge Check

You're planning a cross-country with a passenger who's new to flying. He brings 100lbs of baggage and want to put it in the back, which will put you aft of your CG limits. He says "there's plenty of room!"

How would you respond?