

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

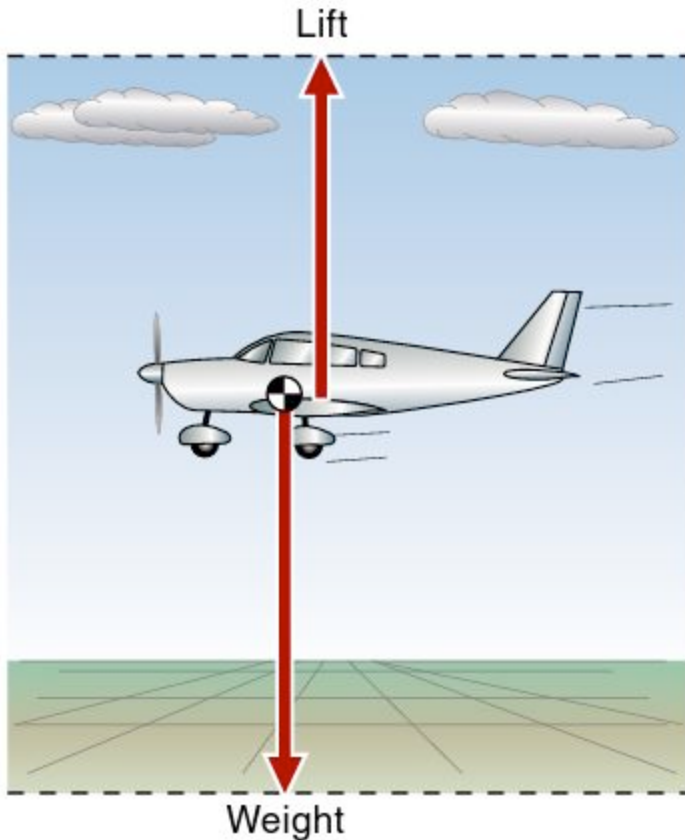
The effect of weight and CG location is critical to the safety of flight and an essential part of cross-country flight planning. Pilots should have a clear understand of the limits of their airplane with regards to weight and balance.

Instruction: Known to unknown, simple to complex

Overview

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

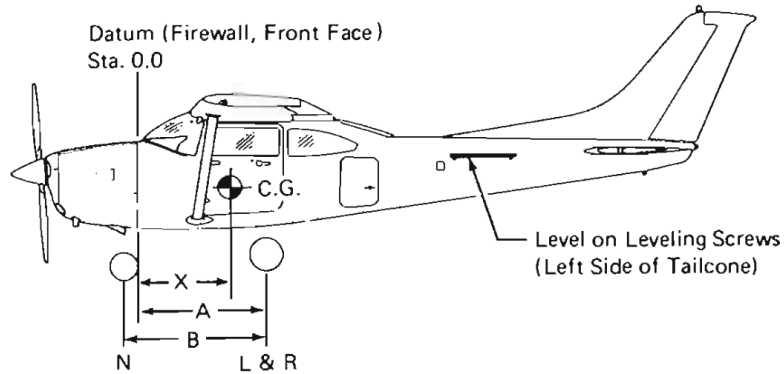
Airplane Weight



- The greater the weight, the greater the lift provided
- The greater the lift, more induced drag
- Thus more **weight = less airplane performance**
 - Slower cruise speed
 - Higher takeoff speed, longer takeoff roll
 - Slower climb performance
 - Higher landing speed, longer landing roll

Torque: See-Saw, Moments, Datum, CG

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

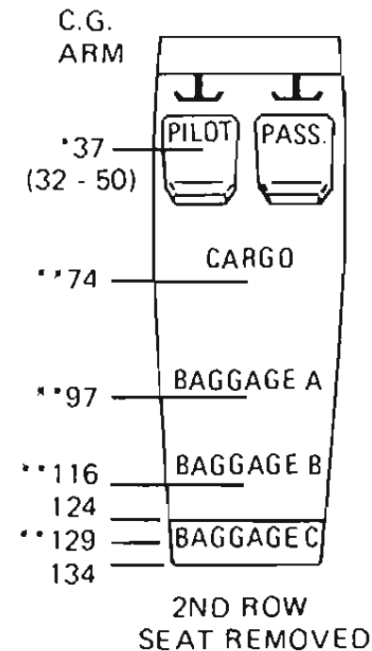
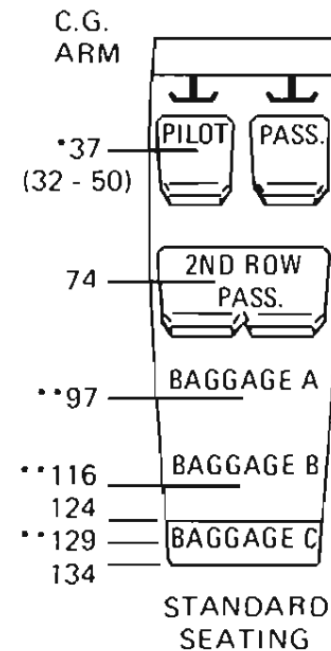
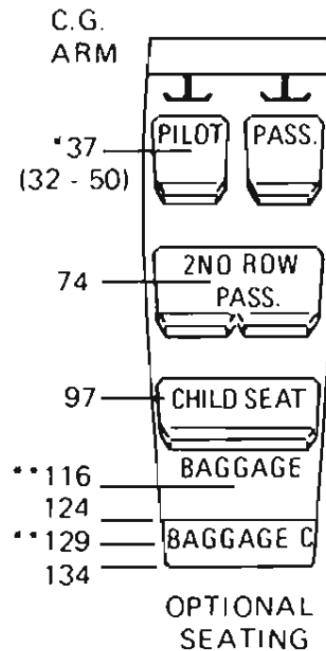
Stations

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 (3112 lbs)
- **Max takeoff weight (MTOW):** Maximum weight for takeoff (3100 lbs)
- **Max landing weight (MLW):** Max weight for landing (2950 lbs)
- **Useful load:** Max ramp weight - Basic empty weight



NORTHWEST AIRTECH




WEIGHT & BALANCE AND EQUIPMENT LIST AMENDMENT

DATE	WO #	OWNER	REG. #	MAKE & MODEL	SERIAL #
4/1/2024	4626	Plane Fun	N2017E	Cessna T182	18268183

W&B Sheet

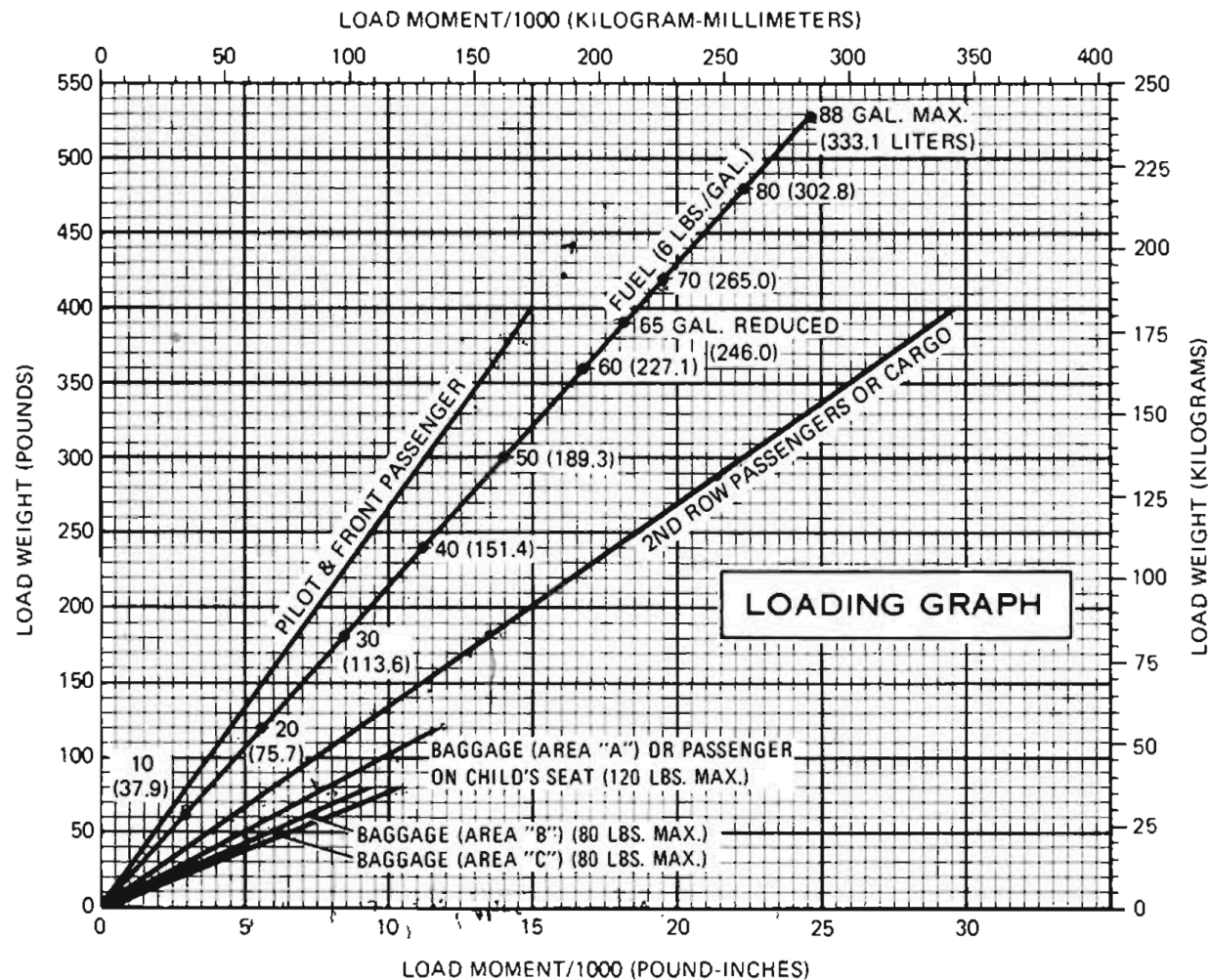
- Required to be in the airplane
- Changes whenever work is done that changes the W&B

ITEM	WEIGHT	ARM	MOMENT
Previous empty weight as of 4/10/2020	1911.0		69891.300
Remove 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
MAX TAKE-OFF WEIGHT	3100		
USEFUL LOAD	1192.9		
			
Robert L Reinecke AP3455579IA			

Sample Problem

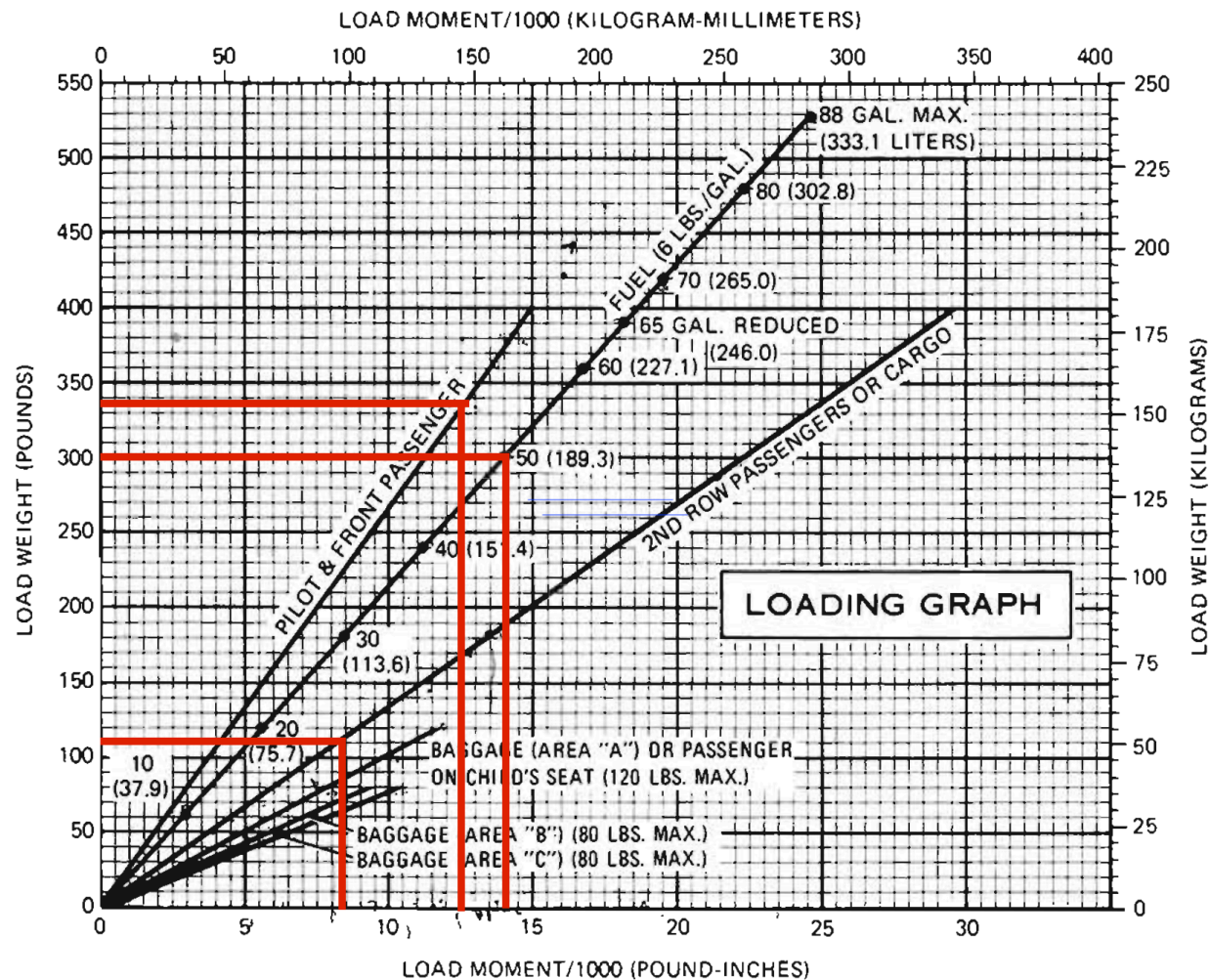
W&B Problem

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



SAMPLE LOADING PROBLEM

	SAMPLE AIRPLANE		YOUR AIRPLANE	
	Weight (lbs.)	Moment (lb.-ins. /1000)	Weight (lbs.)	Moment (lb.-ins. /1000)
1. 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 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 B and C is 80 pounds.				

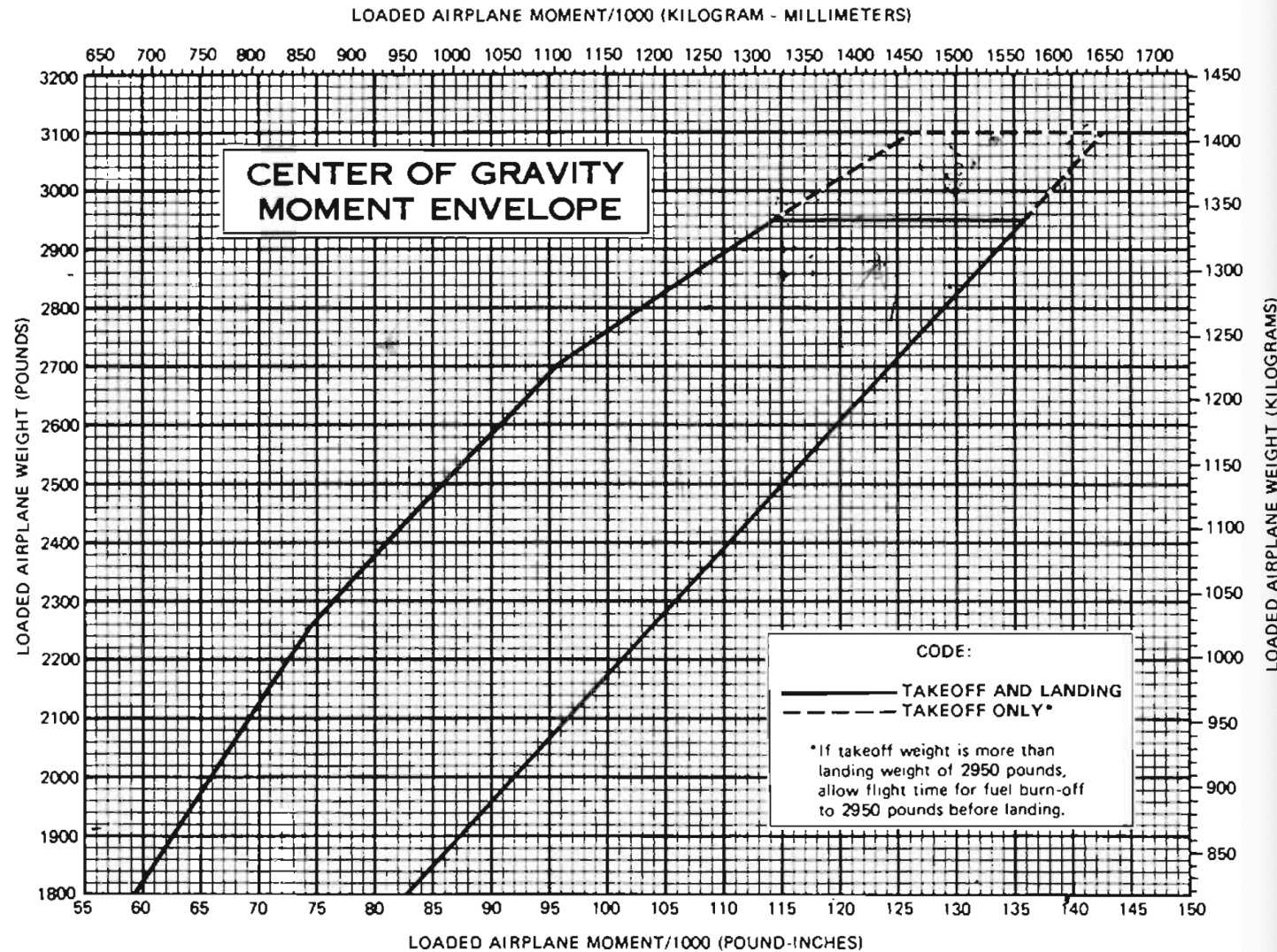


SAMPLE LOADING PROBLEM	SAMPLE AIRPLANE		YOUR AIRPLANE	
	Weight (lbs.)	Moment (lb.-ins. /1000)	Weight (lbs.)	Moment (lb.-ins. /1000)
1. Basic Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel and full oil)	1815	64.0	1907	69.91
2. Usable Fuel (At 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 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 B and C is 80 pounds.				

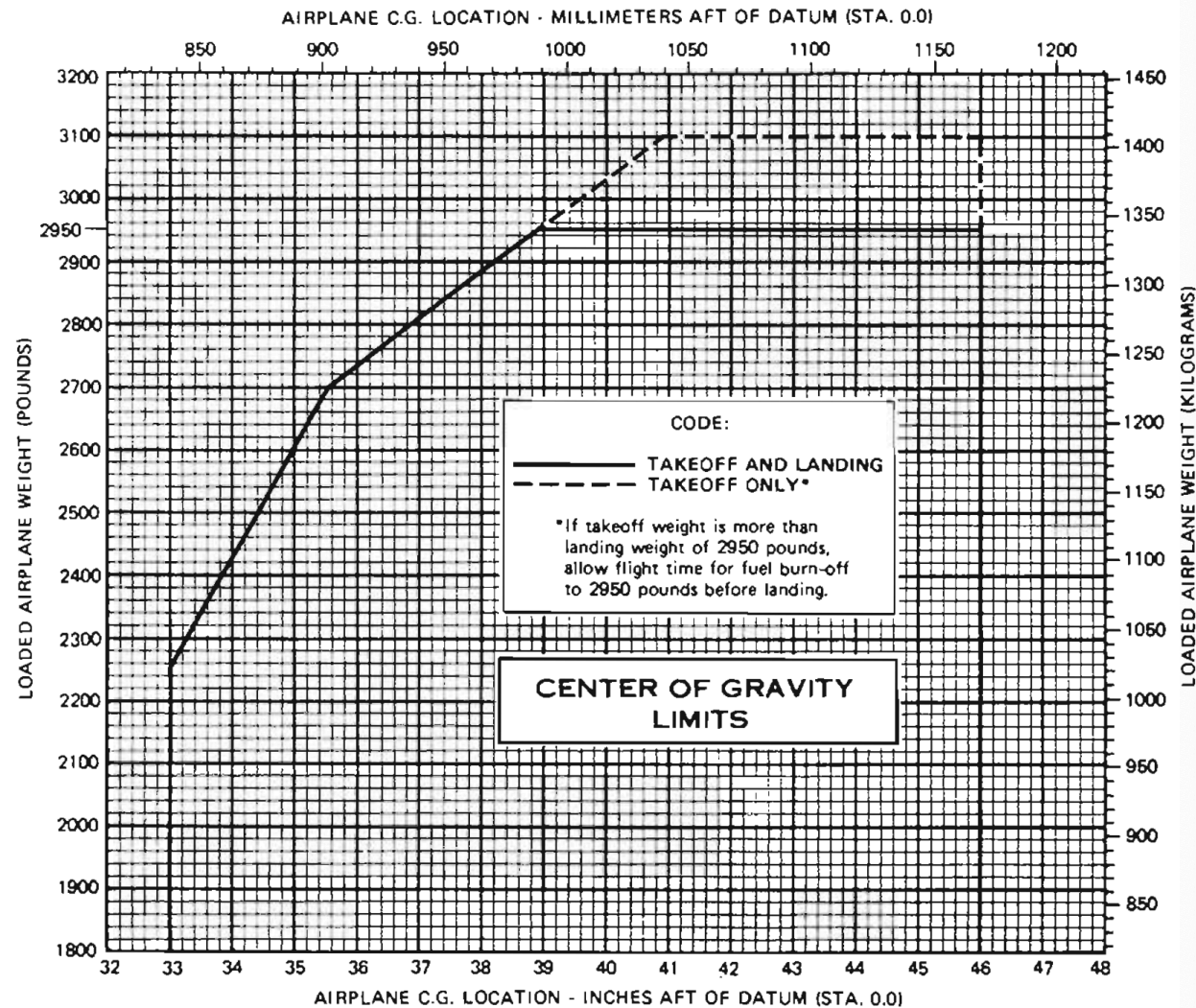
Alternate Method: Weight * Arm = Moment

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?

2655 lbs, 104.7 in-lbs / 1000, 40 gallon fuel burn, fuel arm 46.66

What is our landing weight and moment?

- $2655 - 40 \text{ gal} * 6 \text{ lbs/gal} = 2415 \text{ lbs}$
- $104700 - 46.66 * 40 \text{ gal} * 6 \text{ lbs/gal} = 93501 \text{ in-lbs}$

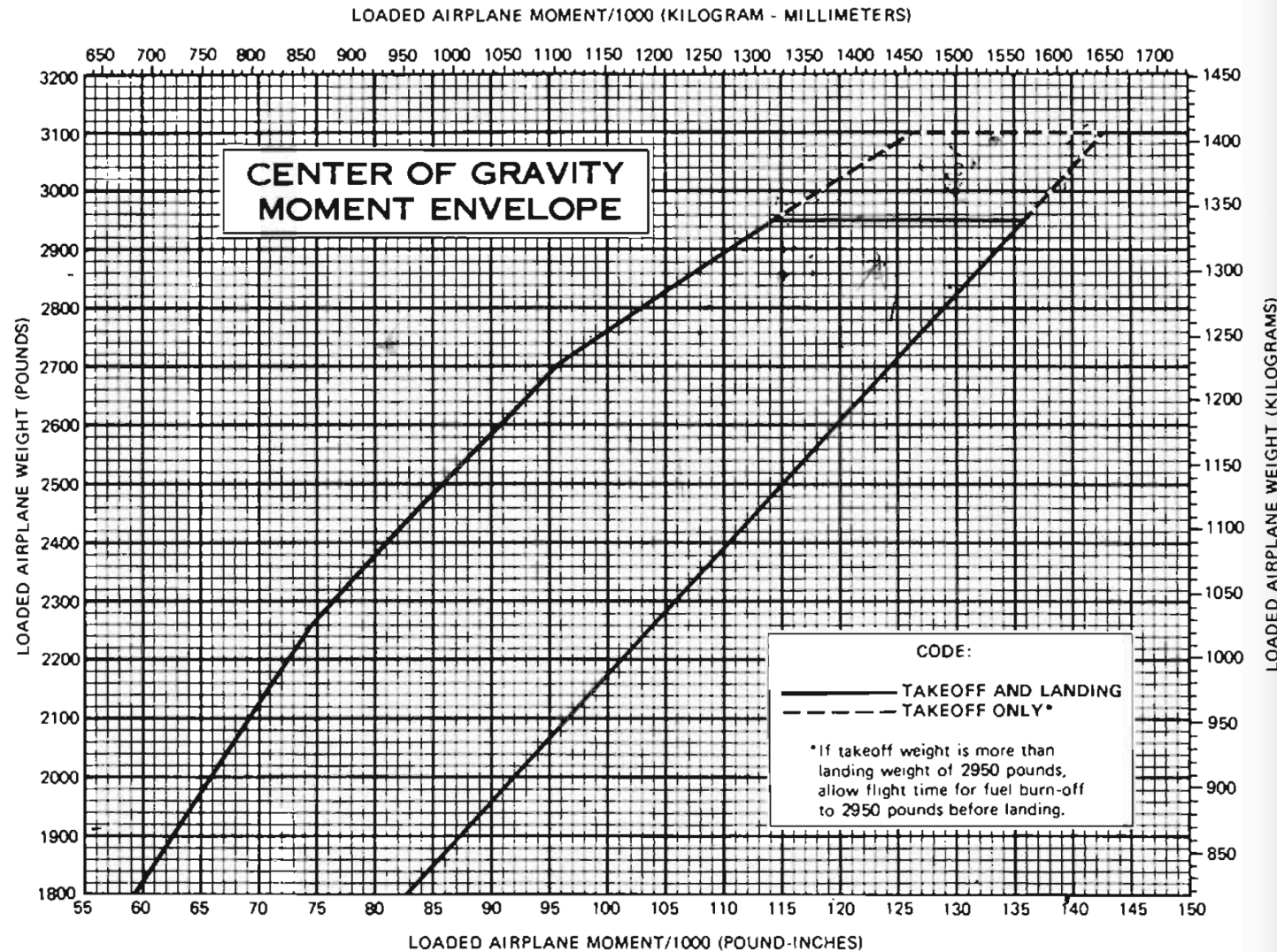
What happens if we move our 180 passenger to the rear seats?

2655 lbs, 104.7 in-lbs / 1000, front seat arm 37, rear seat arm 74

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

- Weight doesn't change = 2655 lbs
- $104700 - 180 \text{ lbs} * 37 \text{ in} + 180 \text{ lbs} * 74 \text{ in} = 111360 \text{ in-lbs}$

CG Moment Envelope



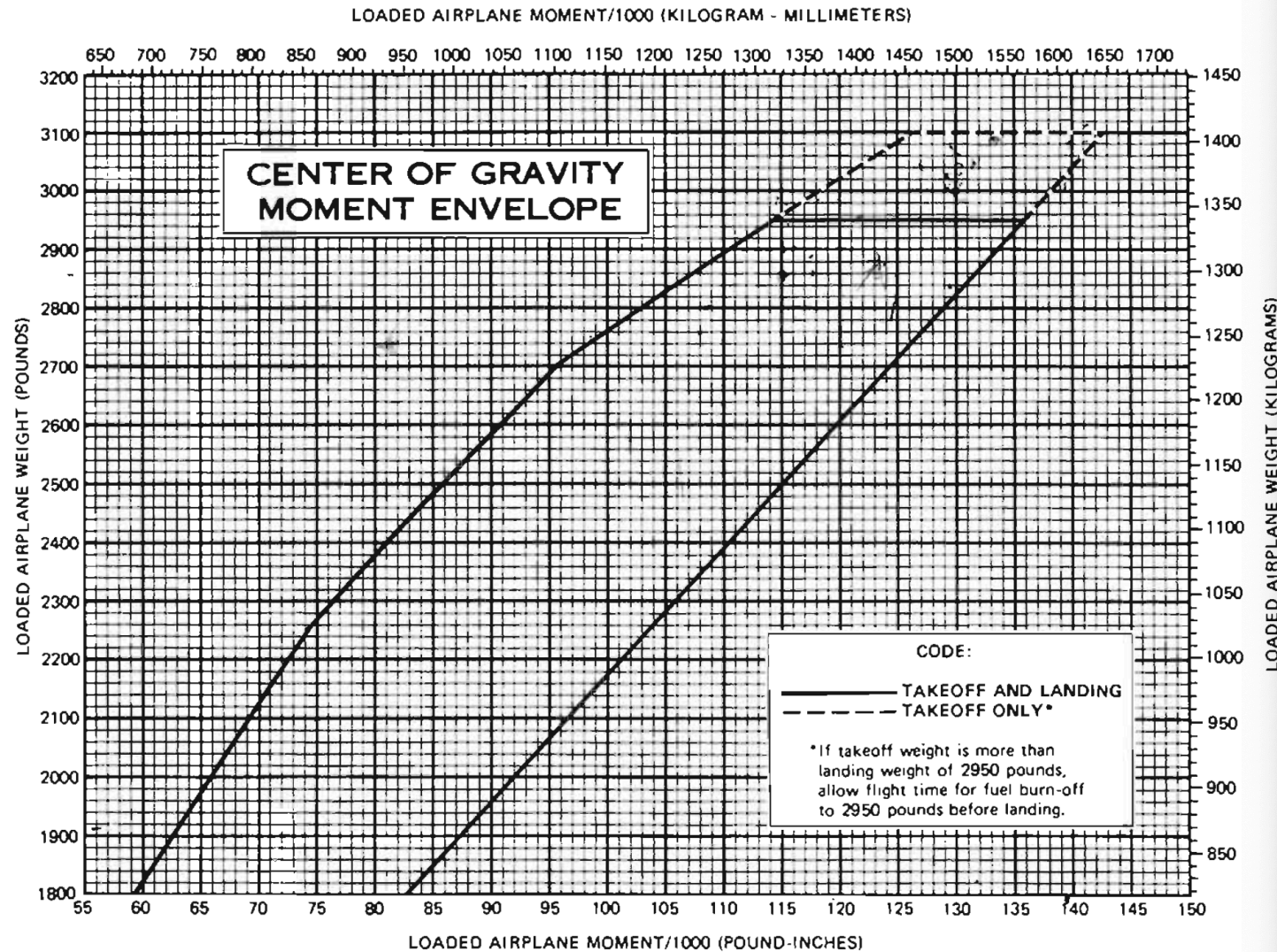
What happens if we add a forth passenger to the copilot seat who weighs 200, and we fill the fuel tanks?

2655 lbs, 111.36 in-lbs / 1000, front seat arm 37, fuel arm 46.66

What happens if we add a forth passenger to the copilot seat who weighs 200, and we fill the fuel tanks?

- $2655 + 200 + 38 * 6 = 3083$
- $111360 + 200 \text{ lbs} * 37 \text{ in} + 38 * 6 * 46.66 \text{ in} = 129398 \text{ in-lbs}$

CG Moment Envelope



Other Limitations

MAXIMUM CERTIFICATED WEIGHTS

Ramp: 3112 lbs.

Takeoff: 3100 lbs.

Landing: 2950 lbs.

Weight in Baggage Compartment:

Baggage Area "A" (or passenger on child's seat) - Station 82 to 109: 120 lbs. See note below.

Baggage Area "B" - Station 109 to 124: 80 lbs. See note below.

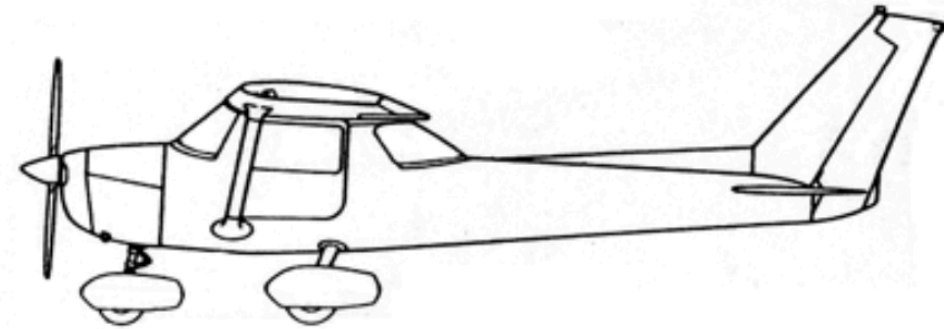
Baggage Area "C" - Station 124 to 134: 80 lbs. See note below.

NOTE

The maximum allowable combined weight capacity for baggage in areas A, B and C is 200 lbs. The maximum allowable weight capacity for baggage in areas B and C is 80 lbs.

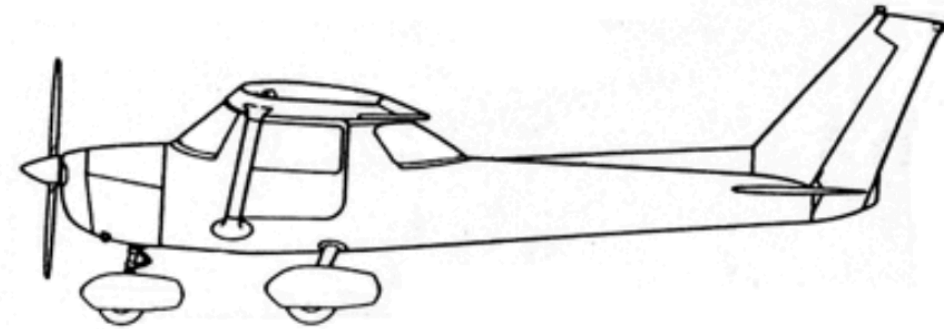
How W&B Affects Performance

Overweight



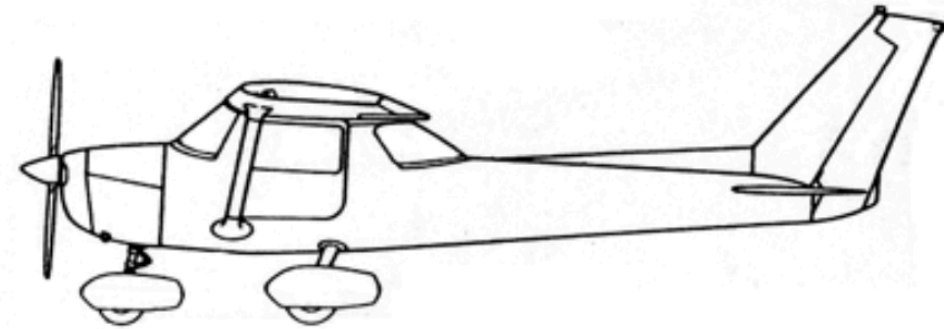
Reduced climb performance, longer takeoff/landing roll, slower cruise speed

CG and Cruise Performance: Rearward CG



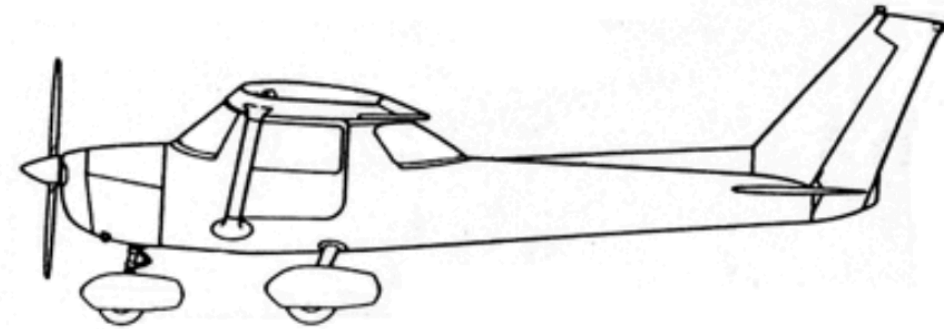
Less drag, faster cruise speed, sensitive controls, less stable

CG Aft of Limits



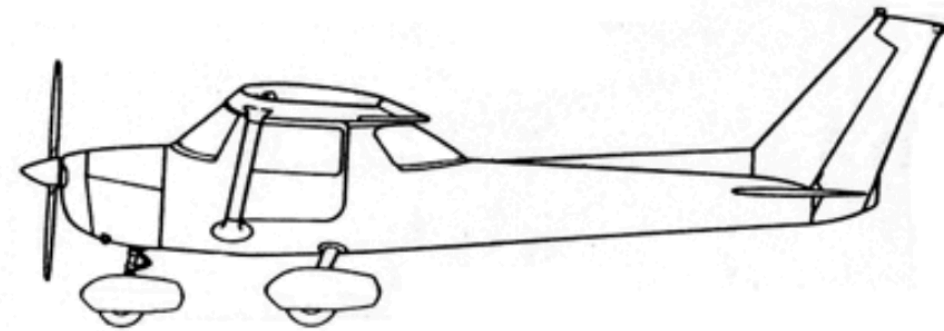
Stall recovery may be inhibited

CG and Cruise Performance: Forward CG



Slower cruise speed, less sensitive controls, more stable

CG Forward of Limits



Summary

- Weight and balance concepts
 - 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?

Knowledge Check

You depart in a T182 a gross weight of 3010 pounds with several passengers. One of you passengers immediately starts feeling ill and asks if you can turn back.

What would you say?