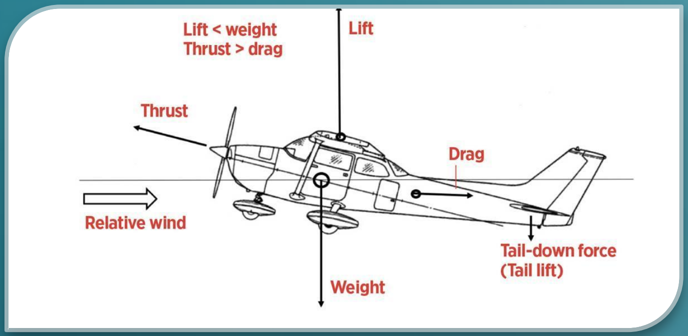
WEIGHT AND BALANCE

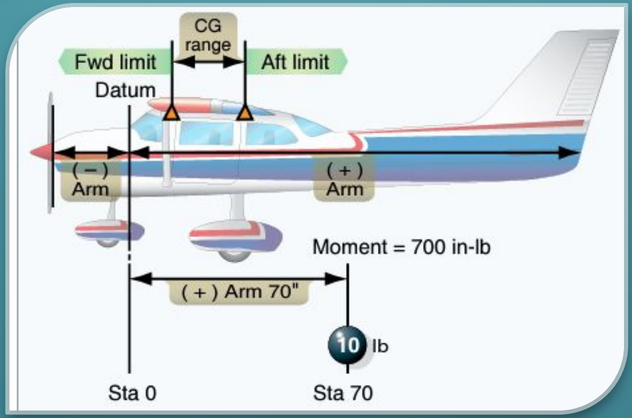
KATHERINE WILCOXSON

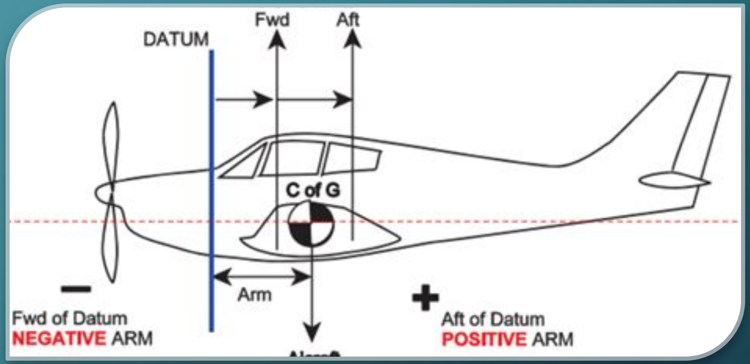
WHY IT'S IMPORTANT

- Critical to flight safety
- Operating above the maximum weight limits compromises structural integrity and affects performance
- Operation with the Center of Gravity outside of approved limits can be very dangerous, adversely affecting flight performance and capabilities

TERMINOLOGY







CG

The point about which an aircraft would balance if it were possible to suspend it at that point (think pendulum). It may be expressed in inches from the reference datum or in percent of MAC.

ARM (MOMENT ARM)

Horizontal distance in inches from the reference datum line to the CG of an item. The algebraic sign is plus (+) if measured aft of the datum and minus (–) if measured forward of the datum.

MOMENT

The product of the weight of an item multiplied by its arm. Moments are expressed in pound-inches (in-lb). Total moment is the weight of the airplane multiplied by the distance between the datum and the CG.

TERMINOLOGY

REFERENCE DATUM

An imaginary vertical plane or line from which all measurements of arm are taken. The datum is established by the manufacturer. Once the datum has been selected, all moment arms and the location of CG range are measured from this point.

CG LIMITS

The specified forward and aft points within which the CG must be located during flight. These limits are indicated on pertinent aircraft specifications.

CG RANGE

The distance between the forward and aft CG limits indicated on pertinent aircraft specifications.

MAXIMUM TAKEOFF WEIGHT

The maximum allowable weight for takeoff per manufacturer limitations (POH).

MAXIMUM LANDING WEIGHT

The greatest weight that an aircraft is normally allowed to have at landing

MAXIMUM RAMP WEIGHT

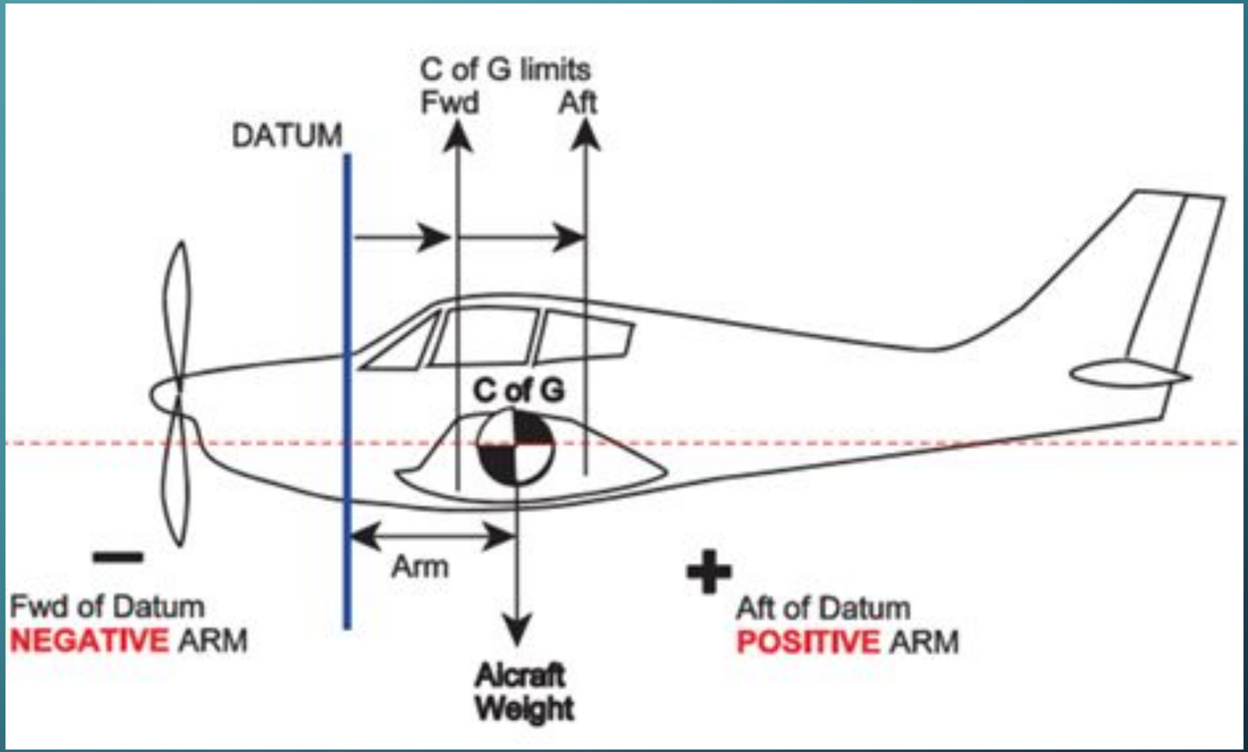
The total weight of a loaded aircraft including all fuel. It is greater than the takeoff weight due to the fuel that will be burned during the taxi and run-up operations. Ramp weight may also be referred to as taxi weight.

REFERENCE DATUM

A vertical plane or line from which all measurements of arm are taken. The datum is established by the manufacturer. Once the datum has been selected, all moment arms and the location of CG range are measured from this point.

The datum point represents the 0 point. Everything is measured away from this point. Positive numbers for being aft (behind) the 0 point and negative numbers for being forward (in front of) the 0 point.

It is important to note that the CG and reference datum are not the same thing. The reference datum provides a fixed reference point for measurements, the center of gravity is a dynamic (moving) point that can change depending on the distribution of weight within the aircraft.



TERMINOLOGY

FUEL LOAD

The expendable part of the load of the aircraft. It includes only usable fuel, not fuel required to fill the lines or that which remains trapped in the tank sumps.

BASIC EMPTY WEIGHT

Standard empty weight plus the weight of optional and special equipment that have been installed. This includes unusable fuel, and operational fluids

FLOOR LOAD LIMIT

The maximum weight the floor can sustain per square inch/foot as provided by the manufacturer.

DELTA

a Greek letter expressed by the symbol Δ to indicate a change of values. As an example, Δ indicates a change (or movement) of the CG.

MAXIMUM ZERO FUEL WEIGHT

the maximum weight, excluding usable fuel.

MEAN AERODYNAMIC CHORD

The average distance from the leading edge to the trailing edge of the wing.

TERMINOLOGY

USEFUL LOAD

The weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil. It is the basic empty weight subtracted from the maximum allowable gross weight. This term applies to general aviation (GA) aircraft only.

STATION

A location in the aircraft that is identified by a number designating its distance in inches from the datum. The datum is, therefore, identified as station zero. An item located at station +50 would have an arm of 50 inches.

LICENSED EMPTY WEIGHT

The empty weight that consists of the airframe, engine(s), unusable fuel, and undrainable oil plus standard and optional equipment as specified in the equipment list. Some manufacturers used this term prior to GAMA standardization.

MOMENT INDEX

a moment divided by a constant such as 100, 1,000, or 10,000. The purpose of using a moment index is to simplify weight and balance computations of aircraft where heavy items and long arms result in large, unmanageable numbers.

PAYLOAD

The weight of occupants, cargo, and baggage.

STANDARD EMPTY WEIGHT

Aircraft weight that consists of the airframe, engines, and all items of operating equipment that have fixed locations and are permanently installed in the aircraft, including fixed ballast, hydraulic fluid, unusable fuel, and full engine oil.

GAMA - General Aviation Manufacturers Association. GAMA does not provide a specific certification for aircraft or equipment. However, they play a role in establishing industry standards and guidelines through their member companies and collaborate with regulatory authorities such as the Federal Aviation Administration (FAA) in the United States and the European Union Aviation Safety Agency (EASA) in Europe.

STANDARD WEIGHTS

100LL…..6LB/GAL

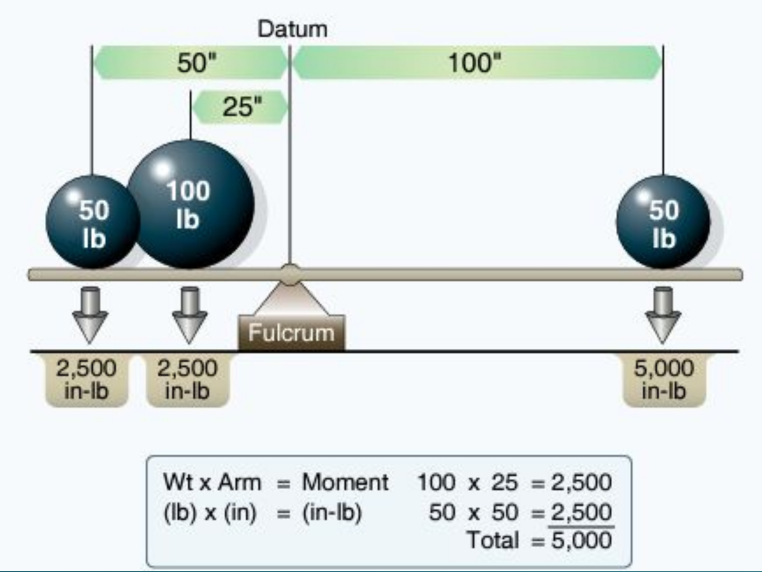
JET A, JET A-1…..6.8LB/GAL

JET B…..6.5LB/GAL

OIL…..7.5LB/GAL

WATER…..8.35LB/GAS

FULCRUM: A BALANCING ACT ON THE AIRPLANE



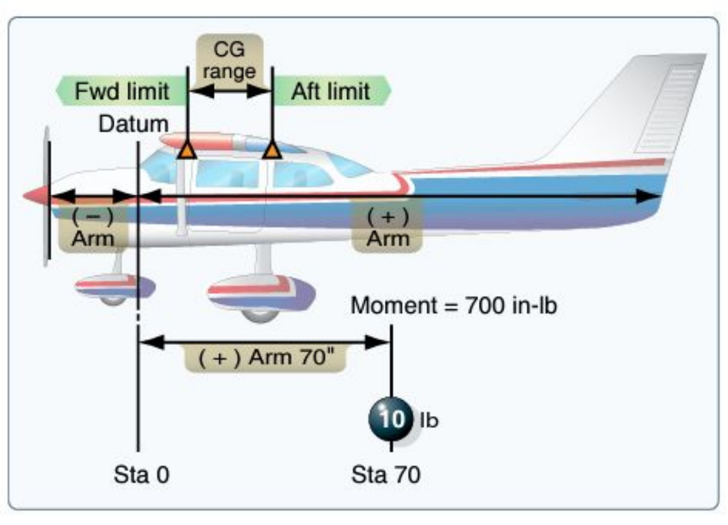


Figure 10-2. *Weight and balance.*

$$\text{Moment (lb-inch)} = \text{Weight (lb)} \times \text{Arm (inch)}$$

$$\text{Center of Gravity (inch)} = \frac{\text{Moment Total (lb-inch)}}{\text{Weight Total (lb)}}$$

FORWARD CG

A forward CG means the center of gravity is located closer to the aircraft's nose or forward of the reference datum

Stability:

- More longitudinally stable
- More controllable in a stall
- increases the aircraft's natural tendency to return to its trimmed or equilibrium state after a disturbance, such as a pitch-up or pitch-down motion
- The farther forward the CG moves from the center of lift, the greater the tail down force needs to become but the elevator becomes less effective. The farther forward the CG moves the more leverage there is on the nose compared to the tail and thus more AoA is needed and tail down force is needed to maintain level flight.

Control Forces:

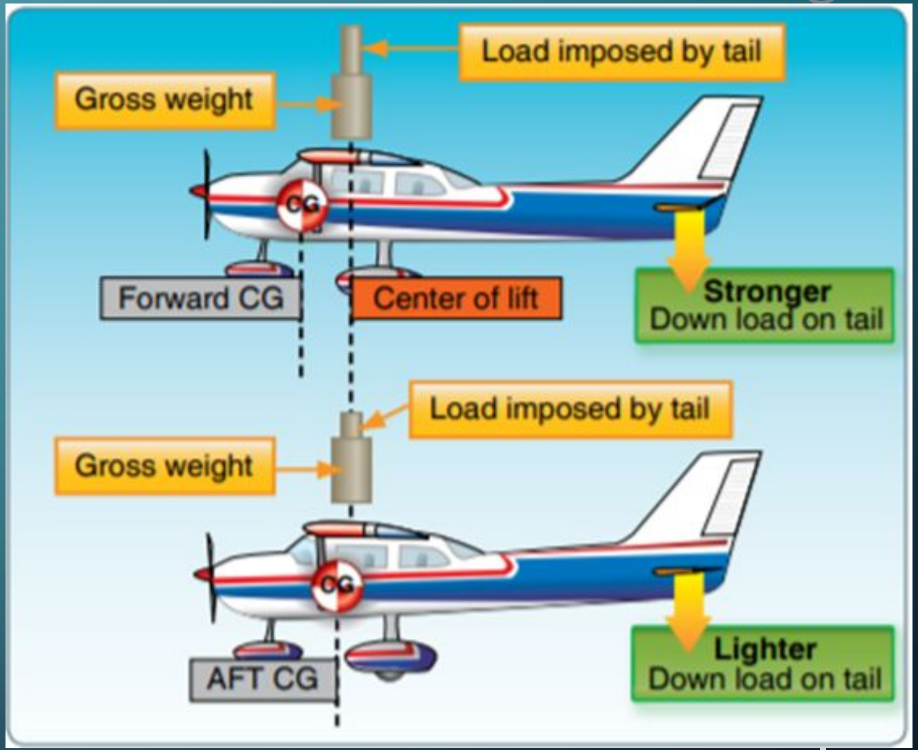
- Requires less control force to maintain the desired attitude or maneuver the aircraft.

Effects on Performance:

- Lower cruise speed – pulling the nose up to level flight requires a higher AoA to counteract the higher downward force by the tail
- More induced drag

Operational Considerations:

- Generally considered safer and is often within the normal operating range.
- May not be able to hold nose up at slow speeds / during landing / during takeoff



AFT CG

An aft CG refers to the center of gravity being positioned closer to the aircraft's tail or behind the reference datum

Stability:

- “Lighter” and therefore faster than a plane with a forward CG
- Lower AOA required to maintain altitude (lower stall speed)
- Less stable longitudinally. It reduces the aircraft's natural tendency to return to its trimmed state, making it more susceptible to pitch oscillations and potential loss of control = lower stall speed

Control Forces:

- If it is too near the center of lift; the airplane is unstable and difficult to recover from a stall. Shorter arm from the CG to the elevator
- Necessitates more control force to maintain the desired attitude or maneuver the aircraft. The elevators have reduced effectiveness, requiring more effort to control pitch movements.

Effects on Aircraft Performance:

- reduces stability and may result in reduced controllability, especially during certain phases of flight. It can also lead to a higher risk of stall or spin conditions, particularly during low-speed flight

Operational Considerations:

- Better cruise performance – less tail downforce = less drag
- Higher cruising speed

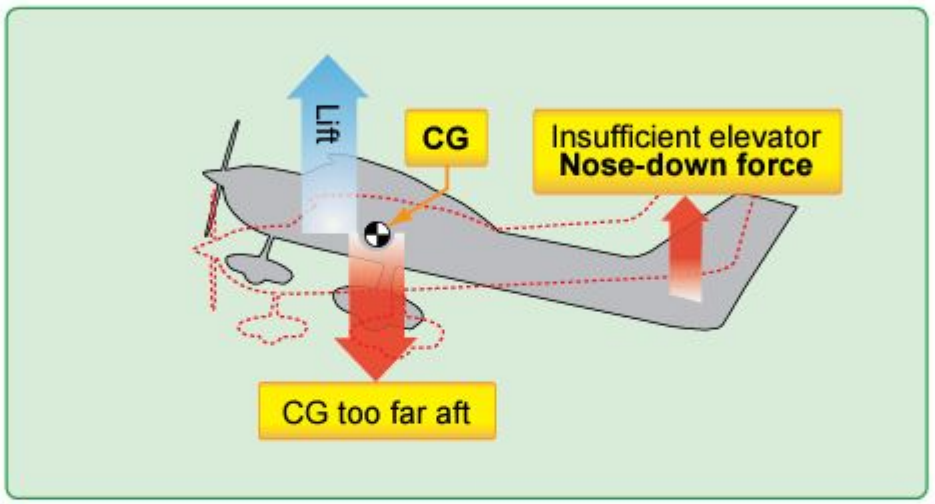


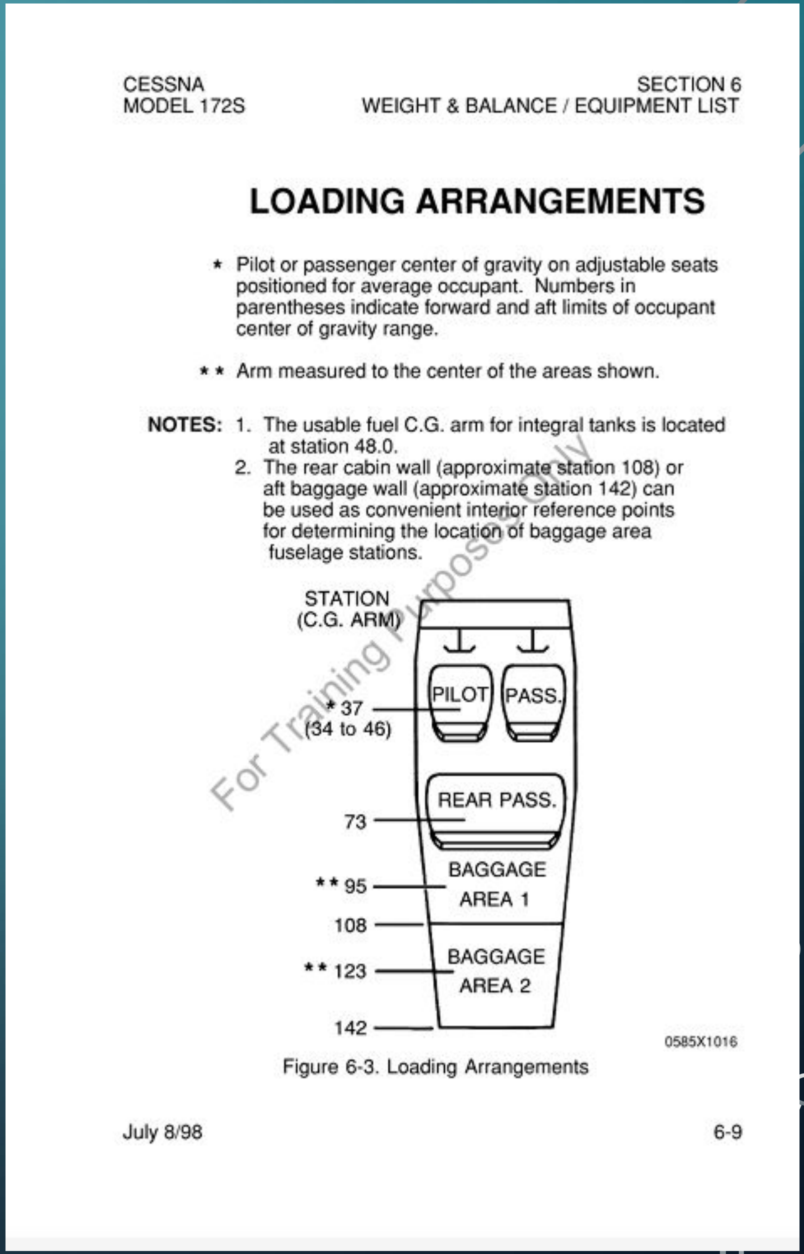
Figure 1-2. *If the CG is too far aft at the low stall airspeed, there might not be enough elevator nose-down authority to get the nose down for recovery.*

LETS WORK THROUGH ONE: C172S

GIVEN:

Lets find our Arms for the different stations

- Pilot 200lbs
- 1 Passenger 215lbs
- Rear Passenger 20lbs (Baggage at this location)
- Full tanks: Max Fuel load 53gal. (However 56 gallons total but 3 are not usable, and are included in the basic empty weight (total 28/ea tank, 1.5ea tank is unusable)
- Don't forget to convert gallons of fuel into pounds: 53 * 6 = 318 lbs
- Start Up and Taxi Fuel: 1 gall = 6lbs
- Flying about 2.5hrs
- Basic Empty Weight for this example will be in the sample POH and is 1642lbs @ 62.6 (lb-in/1000) moment


CESSNA
MODEL 172S

SECTION 6
WEIGHT & BALANCE / EQUIPMENT LIST

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.

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

NOTES: 1. The usable fuel C.G. arm for integral tanks is located at station 48.0.
2. The rear cabin wall (approximate station 108) or aft baggage wall (approximate station 142) can be used as convenient interior reference points for determining the location of baggage area fuselage stations.

Figure 6-3. Loading Arrangements

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LET'S FIND OUR BASIC EMPTY WEIGHT ARM

WE KNOW WEIGHT X ARM = MOMENT. HOWEVER, WE HAVE THE WEIGHT AND MOMENT. SO, LETS SOLVE FOR THE ARM:

- Our Equation looks like this: 1642 * X = 62.6 (lb-in/1000)
- X = arm
- First let's solve the moment first. The way it is written is known as the load index. When we see these in our POH, it doesn't mathematically make sense. But to solve is simple. We multiply the number 62.6 by 1000 to get 62,600.
- Rewrite the equation: 1642 * X = 62,600
- Now let's solve for X. To do this we need to put X on its own side. There are many ways to do this, so lets just keep it simple. We divide. So our equation would now look like this: 62,600 / 1642 = X
- Now divide and you get 38.124238….. Now we simplify = 38.12
- Our Arm is 38.12 for our basic empty weight. Let's put this weight & balance in our table.
- To check to see if we got it right, we can work the equation the first way we intended by putting 38.12 in place of X. We should get about the same number: 62,593.04.

SECTION 6
WEIGHT & BALANCE / EQUIPMENT LIST

CESSNA
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ITEM DESCRIPTION	WEIGHT AND MOMENT TABULATION			
	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)	1642	62.6		
2. Usable Fuel (At 6				

NOW LETS ADD WHAT WE KNOW

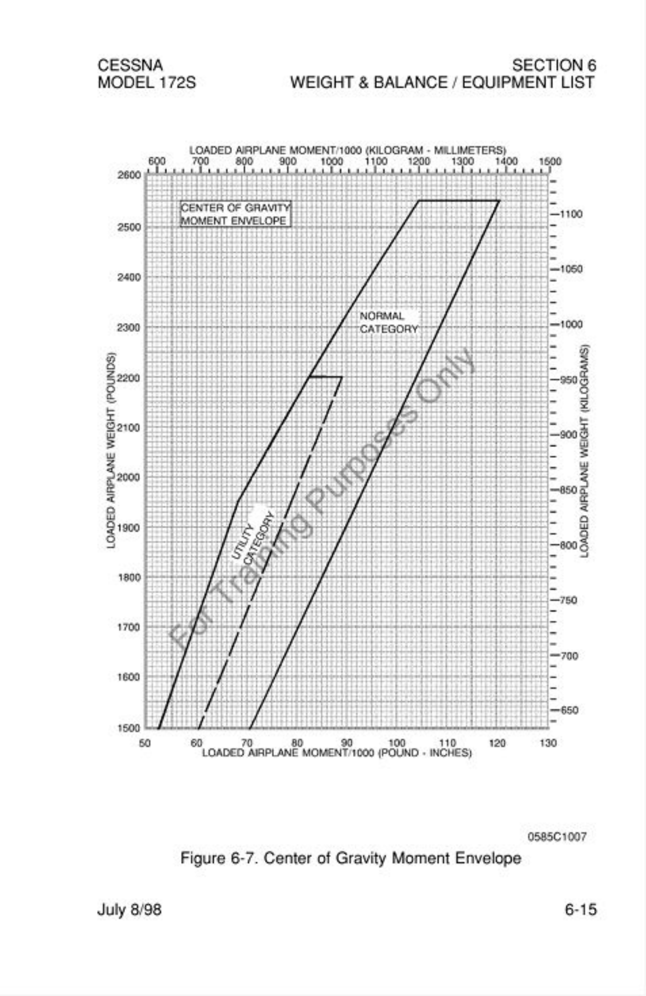
GIVEN:

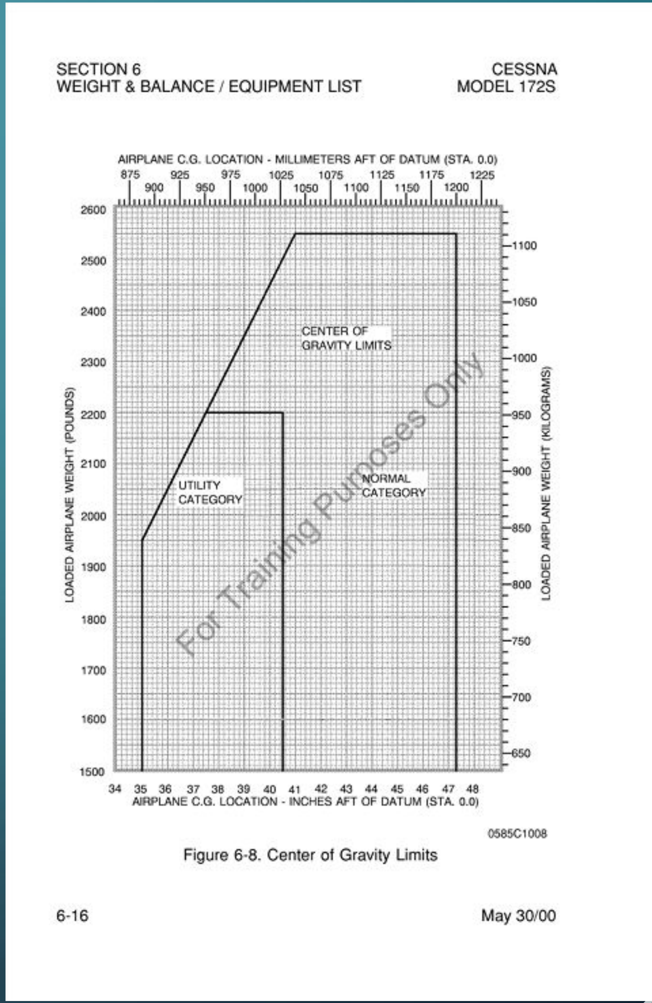
- Pilot 200lbs
- 1 Passenger 215lbs
- Rear Passenger 20lbs (Baggage at this location)
- Full tanks: Max Fuel load 53gal. (However, 56 gallons total but 3 are not usable and are included in the basic empty weight (total 28/ea tank, 1.5ea tank is unusable)
- Don't forget to convert gallons of fuel into pounds: 53 * 6 = 318 lbs
- Start Up and Taxi Fuel: 1 gall = 6lbs
- Flying about 2.5hrs = 25gallons = 150lbs
- Basic Empty Weight for this example will be in the sample POH and is 1642lbs @ 62.6 (lb-in/1000) moment

Weight and Balance			
Item	Weight (lbs)	Arm - CG (in)	Moment (lbs-in)
Basic Empty Weight	1642	38.12	62600
Pilot & Pax	415	37	15355
Rear Pax	20	73	1460
Baggage Area 1	0	95	0
Baggage Area 2	0	123	0
Zero Fuel Weight	2077	38.23	79415
Fuel	318	48	15264
Ramp Weight	2395	39.53	94679
Fuel Start, Taxi, and Run Up	-6	48	-288
Take Off Weight	2389	39.51	94391
Estimated Fuel Burn	-150	48	-7200
Estimated Landing Weight	2239	38.94	87191

IS OUR CG & WEIGHT WITHIN LIMITATIONS? WHAT CATEGORY ARE WE IN?

- Ramp Weight & CG
  - Moment: 94,679
  - CG: 39.53
  - Weight: 2,395
- Takeoff Weight & CG
  - Moment: 94,391
  - CG: 39.5
  - Weight: 2,389
- Landing Weight & CG
  - Moment: 87,191
  - CG: 38.94





Yes & Normal

WHY IS KNOWING OUR CATEGORY IMPORTANT?

Maneuver limitations due to overstressing the airplane

MANEUVER LIMITS

NORMAL CATEGORY

This airplane is certificated in both the normal and utility category. The normal category is applicable to aircraft intended for non aerobatic operations. These include any maneuvers incidental to normal flying, stalls (except whip stalls), lazy eights, chandelles, and turns in which the angle of bank is not more than 60°.

NORMAL CATEGORY MANEUVERS AND RECOMMENDED ENTRY SPEED*

Chandelles	105 Knots
Lazy Eights	105 Knots
Steep Turns	95 Knots
Stalls (Except Whip Stalls)	Slow Deceleration

*** Abrupt use of the controls is prohibited above 105 KIAS.**

UTILITY CATEGORY

This airplane is not designed for purely aerobatic flight. However, in the acquisition of various certificates such as commercial pilot and flight instructor, certain maneuvers are required by the FAA. All of these maneuvers are permitted in this airplane when operated in the utility category.

In the utility category, the rear seat must not be occupied and the baggage compartment must be empty .

UTILITY CATEGORY MANEUVERS AND RECOMMENDED ENTRY SPEED*

Chandelles	105 Knots
Lazy Eights	105 Knots
Steep Turns	95 Knots
Spins	Slow Deceleration
Stalls (Except Whip Stalls)	Slow Deceleration

*** Abrupt use of the controls is prohibited above 98 knots.**

Aerobatics that may impose high loads should not be attempted. The important thing to bear in mind in flight maneuvers is that the airplane is clean in aerodynamic design and will build up speed quickly with the nose down. Proper speed control is an essential requirement for execution of any maneuver, and care should always be exercised to avoid excessive speed which in turn can impose excessive loads. In the execution of all maneuvers, avoid abrupt use of controls.

AIRCRAFT CATEGORIES

Normal: -1.52 to 3.8 Gs
Utility: -1.76 to 4.4 Gs
Acrobatic: -3.0 to 6.0 Gs

SECTION 2
LIMITATIONS

CESSNA
MODEL 172S

UTILITY CATEGORY

Center of Gravity Range:

Forward: 35.0 inches aft of datum at 1950 lbs. or less, with straight line variation to 37.5 inches aft of datum at 2200 lbs.

Aft: 40.5 inches aft of datum at all weights.

Reference Datum: Lower portion of front face of firewall.

CESSNA
MODEL 172S

SECTION 2
LIMITATIONS

WEIGHT LIMITS

NORMAL CATEGORY

Maximum Ramp Weight: 2558 lbs.
Maximum Takeoff Weight: 2550 lbs.
Maximum Landing Weight: 2550 lbs.
Maximum Weight in Baggage Compartment:
Baggage Area 1 - Station 82 to 108: 120 lbs.
Baggage Area 2 - Station 108 to 142: 50 lbs.

NOTE

The maximum combined weight capacity for baggage areas 1 and 2 is 120 lbs.

UTILITY CATEGORY

Maximum Ramp Weight: 2208 lbs.
Maximum Takeoff Weight: 2200 lbs.
Maximum Landing Weight: 2200 lbs.
Maximum Weight in Baggage Compartment: In the utility category, the baggage compartment must be empty and rear seat must not be occupied.

CENTER OF GRAVITY LIMITS

NORMAL CATEGORY

Center of Gravity Range:

Forward: 35.0 inches aft of datum at 1950 lbs. or less, with straight line variation to 41.0 inches aft of datum at 2550 lbs.

Aft: 47.3 inches aft of datum at all weights.

Reference Datum: Lower portion of front face of firewall.

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WEIGHTS & LIMITATIONS

MAXIMUM CERTIFICATED WEIGHTS

Ramp Weight	Normal Category:	2558 lbs.
	Utility Category:	2208 lbs.
Takeoff Weight	Normal Category:	2550 lbs.
	Utility Category:	2200 lbs.
Landing Weight	Normal Category:	2550 lbs.
	Utility Category:	2200 lbs.

Weight in Baggage Compartment, Normal Category:

Baggage Area 1 (Station 82 to 108):	120 lbs. See note below.
Baggage Area 2 (Station 108 to 142):	50 lbs. See note below.

NOTE

The maximum combined weight capacity for Baggage Area 1 and Baggage Area 2 is 120 lbs.

Weight in Baggage Compartment, Utility Category:

In this category, the rear seat must not be occupied and the baggage compartment must be empty.

STANDARD AIRPLANE WEIGHTS

Standard Empty Weight:	1663 lbs.
Maximum Useful Load, Normal Category	895 lbs.
Maximum Useful Load, Utility Category:	545 lbs.

CABIN AND ENTRY DIMENSIONS

Detailed dimensions of the cabin interior and entry door openings are illustrated in Section 6.

BAGGAGE SPACE AND ENTRY DIMENSIONS

Dimensions of the baggage area and baggage door opening are illustrated in detail in Section 6.

SPECIFIC LOADINGS

Wing Loading:	14.7 lbs./sq. ft.
Power Loading:	14.2 lbs./hp.

GRAPHICAL COMPUTATION OF WEIGHT & BALANCE

- Start on the weight side of the graph
- Draw a line until it meets that weight for that station ie. 415lbs for pilot & front passenger.
- Then follow that point down to the moment.
- Add up all of your moments and weights and then divide to get the CG.
- Utilize the moment graph to determine if the flight will be within weight limitations and the category of the aircraft needed for that flight.

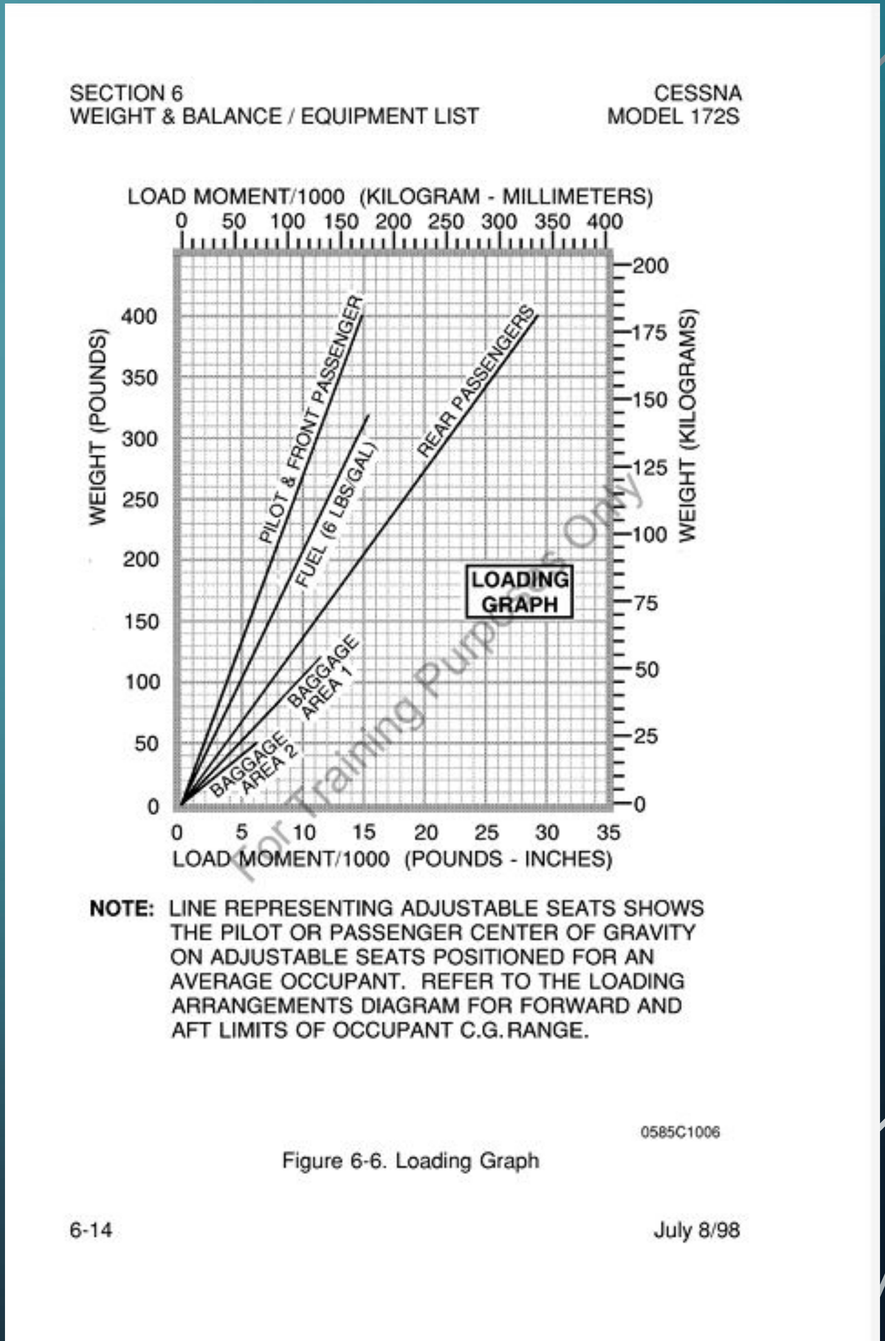
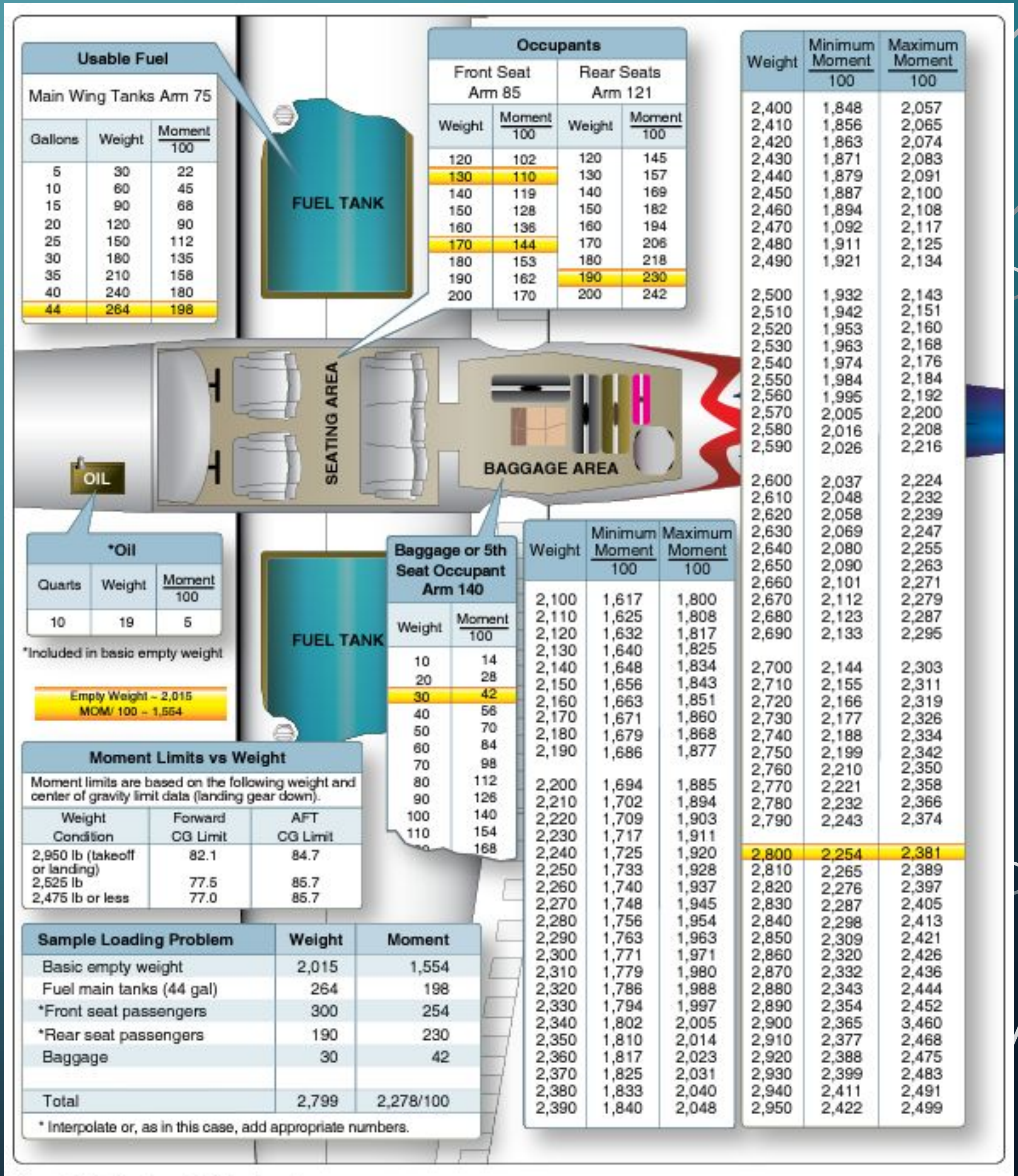


TABLE METHOD

The Table Method is seen on FAA written exams and POHs. Here is an example. Gather the information for all stations and the intended weights and then you can add them together in their respective columns to get the appropriate CG for the flight.



Usable Fuel

Main Wing Tanks Arm 75

Gallons	Weight	Moment/100
5	30	22
10	60	45
15	90	68
20	120	90
25	150	112
30	180	135
35	210	158
40	240	180
44	264	198

Occupants

Front Seat Arm 85		Rear Seats Arm 121	
Weight	Moment/100	Weight	Moment/100
120	102	120	145
130	110	130	157
140	119	140	169
150	128	150	182
160	136	160	194
170	144	170	206
180	153	180	218
190	162	190	230
200	170	200	242

***Oil**

Quarts	Weight	Moment/100
10	19	5

*Included in basic empty weight

Empty Weight ~ 2,015
MOM/ 100 ~ 1,554

Baggage or 5th Seat Occupant Arm 140

Weight	Moment/100
10	14
20	28
30	42
40	56
50	70
60	84
70	98
80	112
90	126
100	140
110	154
	168

Moment Limits vs Weight

Moment limits are based on the following weight and center of gravity limit data (landing gear down).

Weight Condition	Forward CG Limit	AFT CG Limit
2,950 lb (takeoff or landing)	82.1	84.7
2,525 lb	77.5	85.7
2,475 lb or less	77.0	85.7

Weight	Minimum Moment/100	Maximum Moment/100
2,100	1,617	1,800
2,110	1,625	1,808
2,120	1,632	1,817
2,130	1,640	1,825
2,140	1,648	1,834
2,150	1,656	1,843
2,160	1,663	1,851
2,170	1,671	1,860
2,180	1,679	1,868
2,190	1,686	1,877
2,200	1,694	1,885
2,210	1,702	1,894
2,220	1,709	1,903
2,230	1,717	1,911
2,240	1,725	1,920
2,250	1,733	1,928
2,260	1,740	1,937
2,270	1,748	1,945
2,280	1,756	1,954
2,290	1,763	1,963
2,300	1,771	1,971
2,310	1,779	1,980
2,320	1,786	1,988
2,330	1,794	1,997
2,340	1,802	2,005
2,350	1,810	2,014
2,360	1,817	2,023
2,370	1,825	2,031
2,380	1,833	2,040
2,390	1,840	2,048

Weight	Minimum Moment/100	Maximum Moment/100
2,400	1,848	2,057
2,410	1,856	2,065
2,420	1,863	2,074
2,430	1,871	2,083
2,440	1,879	2,091
2,450	1,887	2,100
2,460	1,894	2,108
2,470	1,092	2,117
2,480	1,911	2,125
2,490	1,921	2,134
2,500	1,932	2,143
2,510	1,942	2,151
2,520	1,953	2,160
2,530	1,963	2,168
2,540	1,974	2,176
2,550	1,984	2,184
2,560	1,995	2,192
2,570	2,005	2,200
2,580	2,016	2,208
2,590	2,026	2,216
2,600	2,037	2,224
2,610	2,048	2,232
2,620	2,058	2,239
2,630	2,069	2,247
2,640	2,080	2,255
2,650	2,090	2,263
2,660	2,101	2,271
2,670	2,112	2,279
2,680	2,123	2,287
2,690	2,133	2,295
2,700	2,144	2,303
2,710	2,155	2,311
2,720	2,166	2,319
2,730	2,177	2,326
2,740	2,188	2,334
2,750	2,199	2,342
2,760	2,210	2,350
2,770	2,221	2,358
2,780	2,232	2,366
2,790	2,243	2,374
2,800	2,254	2,381
2,810	2,265	2,389
2,820	2,276	2,397
2,830	2,287	2,405
2,840	2,298	2,413
2,850	2,309	2,421
2,860	2,320	2,426
2,870	2,332	2,436
2,880	2,343	2,444
2,890	2,354	2,452
2,900	2,365	3,460
2,910	2,377	2,468
2,920	2,388	2,475
2,930	2,399	2,483
2,940	2,411	2,491
2,950	2,422	2,499

Sample Loading Problem	Weight	Moment
Basic empty weight	2,015	1,554
Fuel main tanks (44 gal)	264	198
*Front seat passengers	300	254
*Rear seat passengers	190	230
Baggage	30	42
Total	2,799	2,278/100

* Interpolate or, as in this case, add appropriate numbers.

Figure 10-9. *Loading schedule placard.*

MEAN AERODYNAMIC CHORD (MAC)

Some aircraft POHs use a percentage of the length of MAC to determine CG limitations. The Mean Aerodynamic Chord is the average chord length of a tapered, swept wing.

The below formula is how the MAC is calculated. Where y is the coordinate along the wing span, S is the wing area, b is the span of the wing, and c is the chord at the coordinate y

$$\mathrm{MAC} = \frac{2}{S}\int_0^{\frac{b}{2}} c(y)^2\,dy,$$

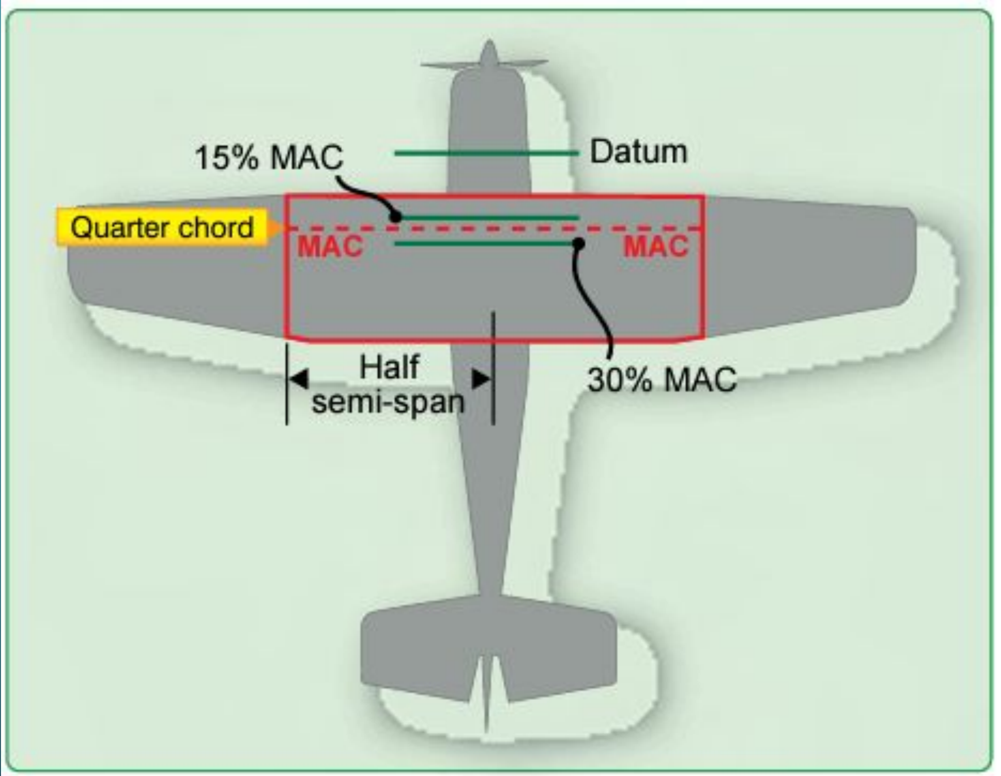


Figure 2-14. *Center of gravity expressed as percent mean aerodynamic chord.*

EMPTY WEIGHT CG (EWCG)

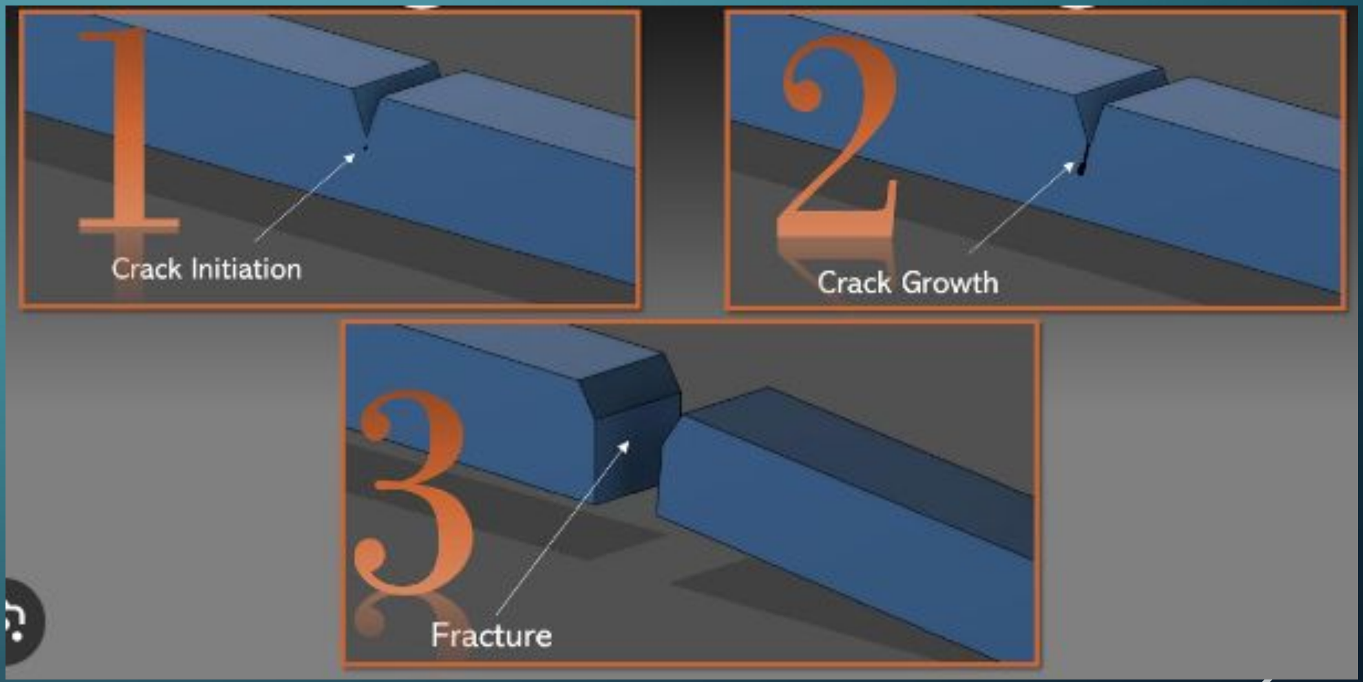
EWCG is the location of the aircraft's center of gravity when it is in an empty or non-operational state. Everything must be weighed accurately. If major repairs are made the FAA certified repairmen must re-weigh the aircraft.

Figure 3-2. *Ramp scales.*

WEIGHT & STRUCTURE

STRUCTURAL OVERSTRESSING

- Overloading causes undue stress on the airplane and can “add up” over time, in what is called Fatigue
  - Fatigue & cracking phases:
    - Crack Initiation
    - Crack Propagation (Growth)
    - Crack Fracture



BALANCE CONTROL

Balance control refers to the location of the CG of an aircraft.

- Longitudinal stability is maintained by ensuring the CG is slightly ahead of the center of lift. This gives us the nose-down force that doesn't rely on airspeed, which is balanced by a variable nose-up force produced by the horizontal stabilizer

Lateral balance can be upset by uneven fuel loading or burnoff. We don't normally calculate lateral CG for an airplane. Wing heaviness could occur. This can happen if you don't switch tanks often enough. So the remedy is to switch to the heavy tank and use a deflected aileron by trim if available until the imbalance is corrected.

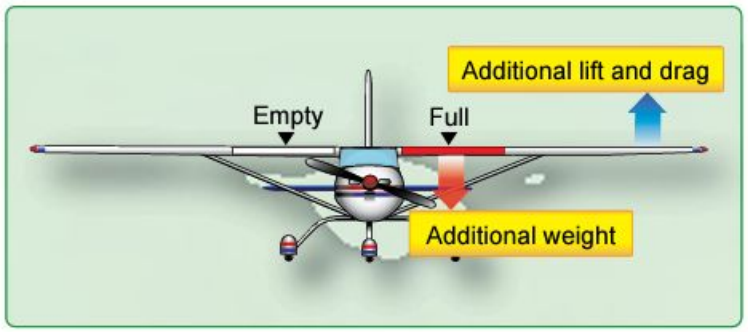


Figure 1-4. *Lateral imbalance causes wing heaviness, which may be corrected by deflecting the aileron. The additional lift causes additional drag, and the airplane flies inefficiently.*

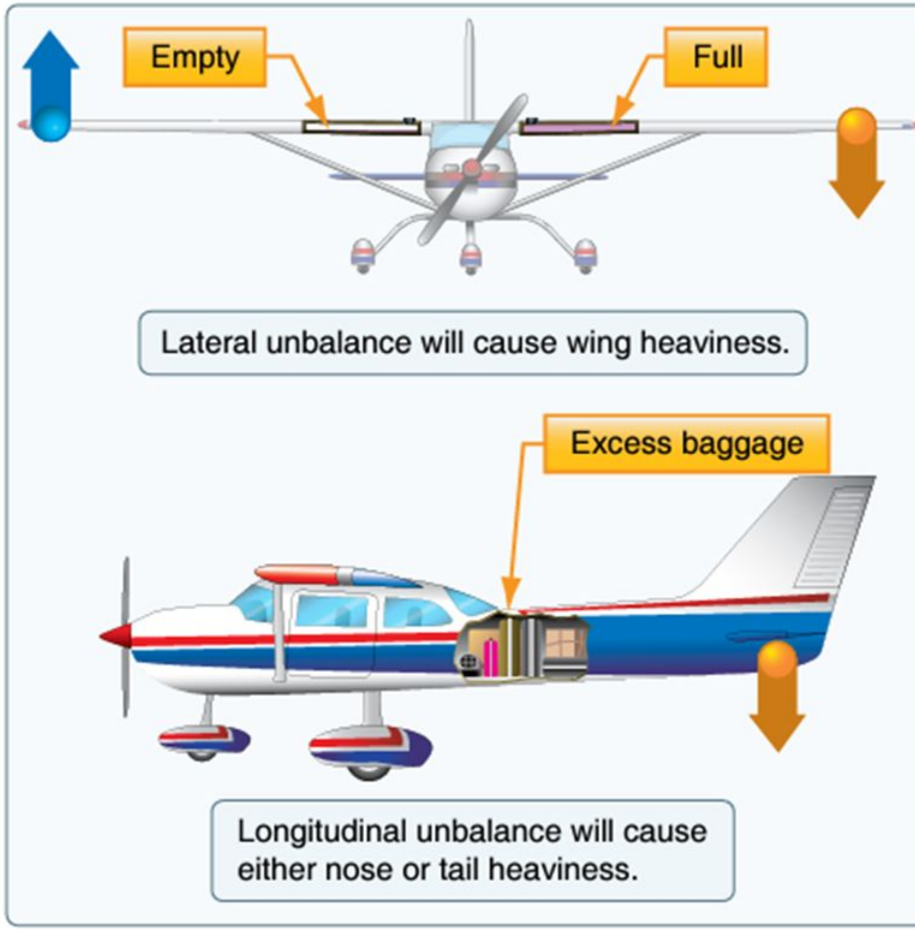


Figure 10-1. *Lateral and longitudinal unbalance.*

WEIGHT SHIFT CALCULATIONS

Operating above limitations comprises structural integrity and affects the performance of the airplane. So, ensuring the right weight is in the right place is critical to the safety of flight.

$$\frac{\text{Weight to be shifted}}{\text{Total weight}} = \frac{\Delta\ \text{CG}}{\text{Distance weight is shifted}}$$

$$\text{Total weight} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\Delta\ \text{CG}}$$

$$\text{Weight shifted} = \frac{\text{Total weight shifted} \times \Delta\ \text{CG}}{\text{Distance weight is shifted}}$$

$$\Delta\ \text{CG} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\text{Total weight}}$$

$$\text{Distance weight is shifted} = \frac{\text{Total weight} \times \Delta\ \text{CG}}{\text{Weight shifted}}$$

SHIFTING WEIGHT

The Problem:

You are flying a 2550lb aircraft loaded with 2 passengers and their baggage. Your boss wants you to load the aircraft at the most aft CG to save money on fuel during cruise. You complete the weight and balance with all baggage loaded in baggage area 1 and determine the CG is 1.75″ forward from the most rearward limit. Given baggage area 1 is 95″ and baggage area 2 is 123″, how much baggage should be transferred to baggage area 2?

Solution:

- First determine how far the weight must move. Here we see that the next location to place the weight is baggage 2 at 123". So, 123 – 95 = 28". Now we can plug in the values for the weight shift formula.
- Our equation looks like this: $\frac{x}{2550} = \frac{1.75}{28}$
- Then we multiply 2550 x 1.75 to get 4462.5
- Now we have 4462.5 = 28x
- Then we divide 4462.5 / 28 = 159.375
- So, 159.375 = x = weight that needs to be shifted to baggage area 2. So 160 lbs needs to be moved to bring he CG within range

ADDING WEIGHT

The Problem:

You calculated weight and balance only to find you are forward of the forward limit by 2". Your current calculated total weight is 2200lbs and your maximum allowable is 2550lbs. How much weight will you need to add to the baggage area 2 at 123" to bring CG within limits?

Solution:

- Our formula looks like this: $\frac{x}{2200} = \frac{2}{123}$
- Cross multiply 2200 x 2 = 4400
- 4400 = 123 X
- 123 / 4400 = 35.77
- ≈ 36lbs at baggage area 2 will need to be added to bring the CG within limitations.

ADDING WEIGHT CONT.

The Problem:

You preparing for a flight of 2 passengers and yourself. You calculate your weight and balance to see if you are within the limit. You determine that your total weight is 2400lbs and current CG is 44" Aft of the datum and the aft limit is 47". Your passengers show up with their child who is 100lbs and asks if they would be able to come as well. Will the flight remain within limits given an aft cabin moment arm of 73"?

Solution:

- Our equations looks like this: $\frac{100}{2500} = \frac{\Delta CG}{29}$
- Cross multiply 100 x 29 = 2900
- Now our equation looks like this: $2900 = 2500\,\Delta CG$
- 2900 / 2500 = 1.16 ΔCG add to the existing CG
- Add 1.16 to the existing CG: 1.16 +44 = 45.16
- Therefore, the new limit is 45.16, which is within limits to take the child

REMOVING WEIGHT

The Problem:

Your client and his passenger is staying at a golf resort and is bring 160lbs of cargo (including golf clubs) which are placed at station 123" (baggage area). You calculate the total flight weight to be 2600 and your limit is 2550. Your CG is within limits. You know that you must remove 50lbs of weight from station 150" to meet weight limitations. What will happen to CG?

Solution:

- Our equation looks like this: $\frac{50}{2550} = \frac{\Delta CG}{123}$
- Cross Multiply 50 x 123 = 6150
- $6150 = 2550\ \Delta CG$
-
- Now we divide: 6150 / 2550 = 2.41 ΔCG
- The CG will move 2.41" forward

REMOVING WEIGHT CONT.

If the client and his passenger state that they must take all the baggage what is the other course of action you can take? Remove fuel, if you still meet legal fuel requirements, personal minimums and flight route requirements, of course. What would the CG move look like then?

50lbs of weight still needs to be removed

So, 50/6 (weight of fuel) = 8.3. Because removing tenths of fuel is a tedious task we will remove 9 gallons of fuel (54lbs). The station for fuel is 48". Now we can fill in our formula

- Our Equation looks like this: $\frac{54}{2550} = \frac{\Delta CG}{48}$
- Cross multiply 54 x 48 = 2592
- $2592 = 2550\ \Delta CG$
- $2592/2550 = 1.016\ \Delta CG$
- $\approx$ 1"
- The CG is moved by an inch forward.

Comparing the previous move by removing 50lbs of baggage at station 123" gains 2.41" of forward CG and removing fuel of 54lbs gains us only 1" of forward CG, we must "weigh" the pros and cons of each solution to determine which would be best in flight and stays within limitations.

RESOURCES

https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/12_phak_ch10.pdf