



Commercial Pilot Ground School

Day 12

Controlling Weight and Balance, CG limitations, Weight and Balance Computations



Agenda

- Controlling Weight and Balance
- Weight and Balance Limitations
- Center of Gravity Limits
- Weight and Balance Documents
- Weight and Balance Computations
- Weight and Balance Condition Checks
- Computation Method
- Graph Method
- Table Method
- Weight Shift Computations

Controlling Weight and Balance

As a private pilot, you became aware of the importance of weight and balance control and learned how to determine the loading conditions of an airplane by using a variety of methods. While concepts and techniques for performing weight and balance computations are similar for commercial flights, there will be occasions when last minute load changes will require you to quickly amend your original loading computations.



Controlling Weight and Balance

In addition, you will probably fly airplanes that are larger and have a greater variety of loading options than the airplanes you have been flying. To conduct safe and efficient flights, you should thoroughly understand the effects of various weight and balance conditions, as well as the terminology and techniques that different manufacturers provide for weight and balance control.





Weight and Balance Limitations

The weight and distribution of items carried in an airplane has a tremendous effect on aerodynamic stability and control, as well as affecting overall performance. One of your responsibilities as pilot in command is to consider whether the loading conditions of your airplane are within allowable limits before beginning a flight. These limits are established by the aircraft manufacturer and have been demonstrated to the FAA to meet airworthiness certification standards.

EFFECTS OF EXCESSIVE AIRPLANE WEIGHT
— Higher takeoff speed and longer takeoff run.
— Reduced rate and angle of climb.
— Lower maximum altitude.
— Shorter range and endurance.
— Reduced cruising speed and maneuverability.
— Higher stalling speeds.
— Higher landing speed and longer landing roll.



Weight and Balance Limitations

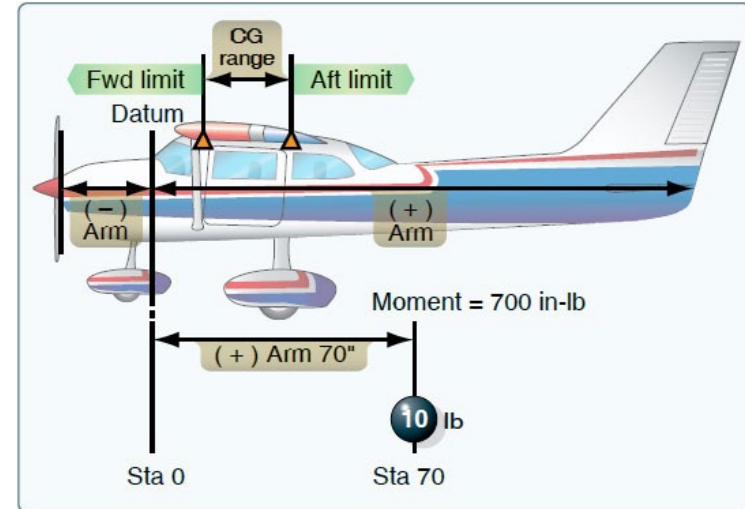
When loaded within these limits, and under normal operating conditions, the airplane will be stable and controllable throughout the flight envelope. In addition, the performance values obtained from the POH will allow you to plan your flight with sufficient accuracy to help ensure safety. On the other hand, if you fly an improperly loaded airplane, safety and performance will be compromised in many ways.

EFFECTS OF EXCESSIVE AIRPLANE WEIGHT
— Higher takeoff speed and longer takeoff run.
— Reduced rate and angle of climb.
— Lower maximum altitude.
— Shorter range and endurance.
— Reduced cruising speed and maneuverability.
— Higher stalling speeds.
— Higher landing speed and longer landing roll.

Center of Gravity Limits

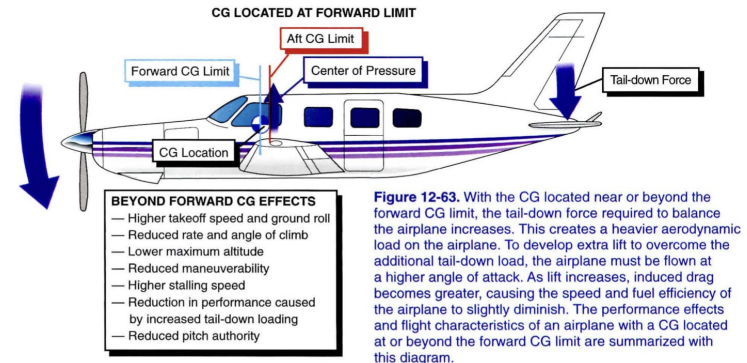
While it is important for you to maintain an airplane within allowable weight limits, you must also ensure that items loaded in your airplane do not cause the center of gravity to exceed the allowable range. The manufacturer establishes the CG range and designates it by the position of the forward and aft CG limit locations.

These limits are expressed as a distance measured in inches from the reference datum. The reference datum, as you recall, is an imaginary vertical plane established by the manufacturer from which longitudinal measurements are made. Provided you load your airplane within the CG range, and given normal flight conditions, longitudinal stability and control of the airplane will be satisfactory. However, if the load causes the CG to exceed allowable limits, airplane control, stability, and efficiency will be affected.



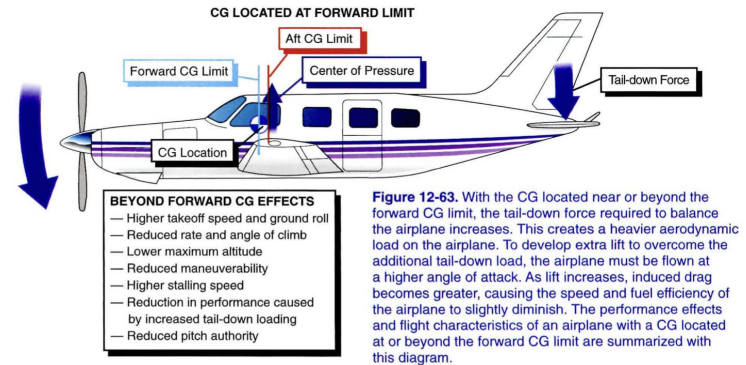
Forward CG Effects

When the CG is located near the forward limit, the airplane becomes more stable because of the equilibrium that is set up between the forward CG and the forces produced by the tail. For example, if the nose pitches downward, the angle of attack on the tail increases to create a greater tail-down force, which causes the nose to rise. On the other hand, if the nose pitches upward, the angle of attack on the tail decreases, resulting in a reduction in tail-down force, causing the nose to drop. Through a series of damping oscillations between nose-up and nose-down, the airplane eventually returns to a level flight attitude.



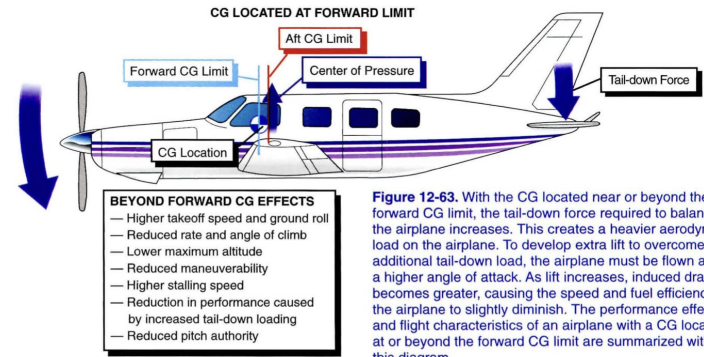
Forward CG Effects

However, as the airplane becomes more stable, its controllability decreases. This occurs because the tail must exert a greater force to counteract the stability of the airplane. As a result, the horizontal control surface must be deflected a greater amount to cause a pitch change. In fact, if the CG is located ahead of the forward CG limit, at slow airspeed it may be impossible for the control surface to exert enough force to sufficiently raise the nose.



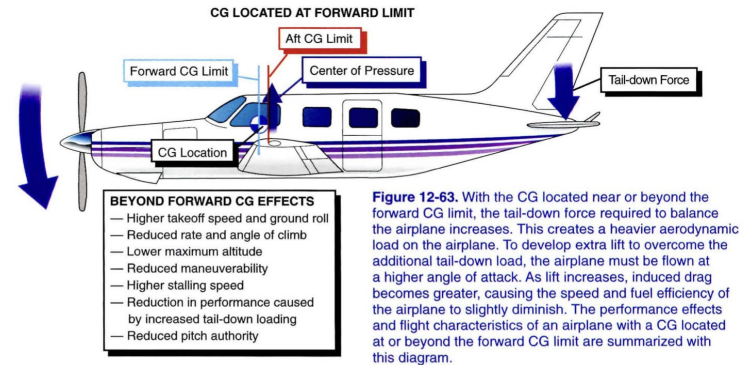
Aft CG Effects

When the CG of an airplane is located at the aft limit, the amount of tail-down force required to maintain a balanced condition decreases because the CG is located closer to the center of pressure. This causes the horizontal control surface to become more effective. However, with the increased control responsiveness, it may be possible for you to over-control the airplane. In addition, the airplane will have a tendency to pitch-up due to the aft CG position, which could cause an inadvertent stall.



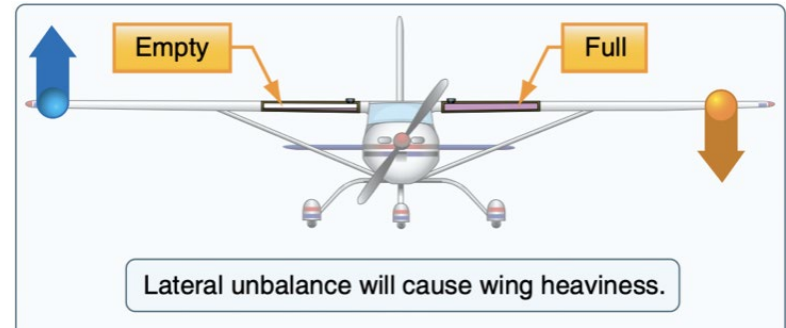
Aft CG Effects

As a further consideration, if the CG is located behind the aft limit, it may become difficult, or even impossible to recover from a stalled condition. Spins also are more critical with an aft CG, since the spin will tend to be flat, making recovery difficult or impossible. However, when the CG is located at the aft limit, there is a slight increase in TAS and fuel efficiency due to the reduction of the tail loading.



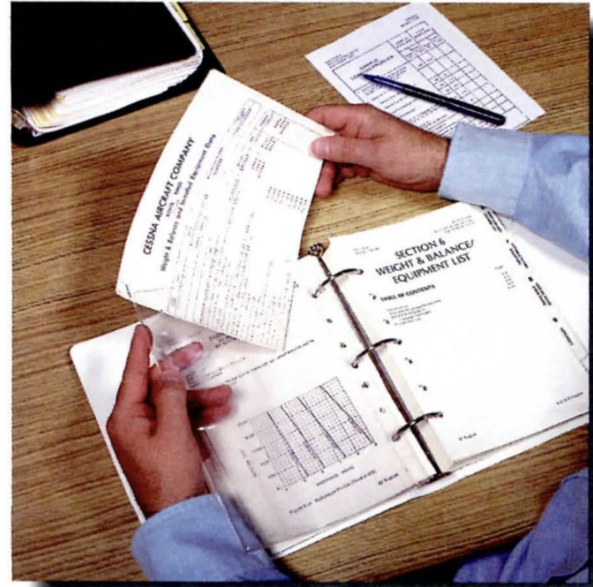
Lateral CG Effects

Lateral weight and balance control is not considered to be as critical as longitudinal control because of the symmetry that exists between the left and right side of the airplane. An exception occurs when fuel becomes unevenly distributed between left and right side fuel tanks which causes a lateral CG shift and wing heavy condition. In this condition, the ailerons can be positioned to offset the heavy wing. However, by deflecting the ailerons, drag increases, which causes a reduction in cruise speed, range, and endurance. To prevent the lateral imbalance, you should use fuel from left and right side fuel tanks simultaneously or alternate between the tanks at regular intervals.



Weight and Balance Documents

In order for you to determine the weight and balance limitations and loading conditions of an airplane, you need to be familiar with the information provided in various weight and balance documents. These documents primarily include the weight and balance report and equipment list. A weight and balance report is initially prepared by the manufacturer and is maintained by the aircraft owner or operator. In addition, the report must be carried in the airplane anytime it is flown, in order to meet standard airworthiness requirements. Equipment lists are generally considered to be part of a weight and balance report, and are used to inventory the weight and location of standard and optional equipment installed in the airplane.



Weight and Balance Report

A weight and balance report is required for all airplanes, and may be presented in a variety of formats. For airplanes that are required to have a POH, the report is retained in the handbook. For these airplanes, the POH contains charts, graphs, or tables for use in determining loading conditions. In addition, the POH includes sample problems to demonstrate methods for performing weight and balance computations. Remember that the sample problems provide weight and balance values for a hypothetical airplane. You should never use these values for performing actual load computations.



Weight and Balance Report

Information found in a weight and balance report includes the empty weight and empty weight center of gravity position of the airplane.

Depending on the certification requirements in effect when the airplane was manufactured, the empty weight may be referred to as a basic empty weight, or a licensed empty weight. Airplanes manufactured after March 1, 1979 use the term basic empty weight.



Weight and Balance Report

This weight includes the standard airplane, optional equipment, unusable fuel, and full operating fluids including full engine oil. For older airplanes, the term licensed empty weight is used, which is similar to basic empty weight, except that engine oil is not included. For these airplanes, you must remember to include the weight of the oil when you perform weight and balance computations. Engine oil weighs 7.5 pounds per gallon, or 1.875 pounds per quart.



Equipment List

The equipment list provides an inventory of the weight and location of standard and optional equipment installed in the airplane. When a POH is required, the equipment list will usually be inserted in the weight and balance section of the handbook. On airplanes not requiring a POH, the equipment list is included in the weight and balance report. The list includes permanently installed components such as radio equipment and flight instruments, as well as some removable items such as the POH, portable fire extinguishers, tow bars, and other similar items. If you are unsure if an item is part of the empty weight, you can refer to the equipment list to determine if it is included.



Equipment List

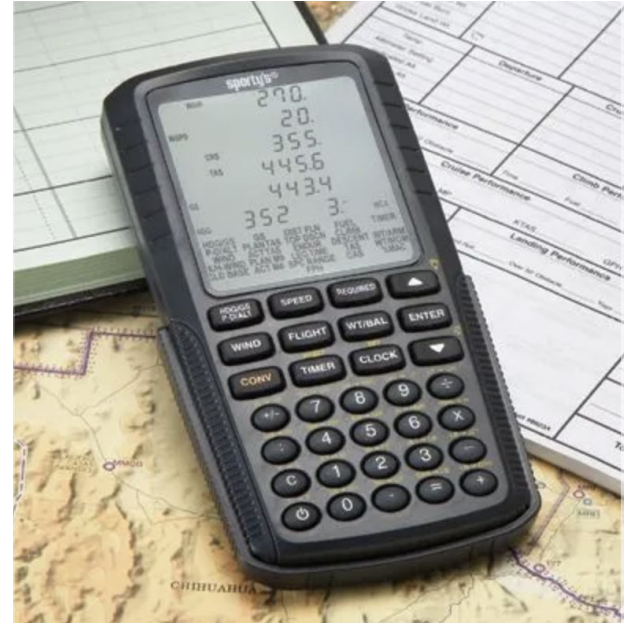
When the installation or removal of equipment alters an airplane, the technician or agency conducting the alteration must revise the equipment list to reflect the change. In addition, the weight and balance report also will be revised to reflect changes to the empty weight, empty weight CG and useful load. Remember, when equipment is added to an airplane, the empty weight increases, which causes a decrease in the useful load.



Weight and Balance Computations

To determine if an airplane is properly loaded, you must perform weight and balance computations to verify that both total weight and CG are within allowable limits.

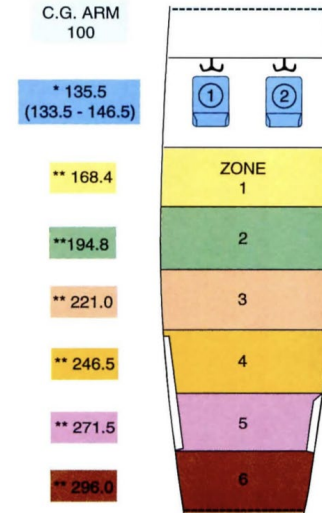
1. To compute total weight, you merely add the weight of useful load items to the empty weight. Although weight computations are reasonably easy to perform, balance computations require you to have an understanding of various terms and principles.
2. Once you understand these, balance computations are easy to perform.



Moment Computations

In order to determine the effects that useful load items have on balance conditions, you must calculate the moment that each item produces. A moment, as you recall, can be found by multiplying the weight of an item by its arm. For weight and balance purposes, an arm is the horizontal distance in inches that an item is located away from the reference datum. To designate the position of an item as being ahead of or behind the reference datum, the arms are assigned positive or negative values. Items located ahead of the reference datum have negative values, while items located aft have positive values. To alleviate computations with negative numbers, some manufacturers locate the reference datum on the nose or at some point ahead of the airplane. For these aircraft, items cannot be loaded ahead of the reference datum, so all arm values are positive.

SEATING AND LOADING ARRANGEMENTS



2-PLACE SEATING

* Pilot or front passenger center of gravity on adjustable seats positioned for an average occupant with the seat locking pin at station 145.0. Numbers in parentheses indicate forward and aft limits of occupant center of gravity range.

** Cargo or baggage area center of gravity in zones 0 thru 6.

Determining Center of Gravity Position

Once you have calculated the moment of each useful load item, you can locate the CG by determining the total weight of the items and the total of the moments. By dividing total moment by total weight, you can derive the CG position in inches from the datum.

Figure 12-70. To find the combined CG of various weights, perform the arithmetic operations as shown in this diagram. The combined CG of the given weights is located at 118.246 inches.

Given:

Weight A—175 pounds at 135 inches aft of datum
Weight B—135 pounds at 115 inches aft of datum
Weight C—75 pounds at 85 inches aft of datum

Find the CG location of the combined weights.

Solution:

Weight	X	Arm	=	Moment
175 pounds	→	135 inches	→	23,625 pound-inches
135 pounds	→	115 inches	→	15,525 pound-inches
75 pounds	→	85 inches	→	6,375 pound-inches
385 pounds				45,525 pound-inches

Multiply each weight by its arm to find the moment.

Add the weights and moments.

45,525 pound-inches

385 pounds

By dividing the moment by the weight you can find the CG of the combined weights.

118.246 inches

Weight and Balance Condition Checks

To verify that an airplane is loaded within acceptable weight and balance limits, manufacturers prescribe various methods for checking weight and balance conditions. Among these are the computation, table and graph methods for determining the total weight and CG location of the airplane. From your previous flying experience, you are probably familiar with each of these methods. However, as you progress into flying larger and more complex aircraft, you will likely encounter a greater number of loading considerations. To help you understand some of these considerations, the following sample weight and balance condition checks represent airplanes that you will likely encounter when conducting commercial flights .



Computation Method

The computation method for checking weight and balance conditions can generally be used with any airplane.

- The first step is to locate the empty weight and empty weight CG position in the weight and balance report. In most cases, the report also includes the empty moment of the airplane.
- Once these are located, list them on a note pad or a copy of the weight and balance loading form supplied in the POH. Next, list the weight of all useful load items.
- To convert aviation fuel from gallons to pounds, you can use the standard six pounds per gallon or the weight specified by the manufacturer. By following a sample weight and balance condition check, you can see how a loading form helps you complete weight and balance computations.

LOADING FORM

	1	2	3
	Weight (lbs.)	Arm (in.)	Moment (lbs. - ins. /1000)
1. Basic Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel and fuel oil.)	2325	41.38	104.48
2. Usable Fuel (At 6 lbs./Gal.) Standard Tanks (89 Gal. Maximum) Standard Reduced Fuel (64 Gal.) *Long Range Tanks (115 Gal.) X 6 lbs. Long Ranged Reduced Fuel (80 Gal.)	690	42	28.98
3. Pilot and Front Passenger (Station 34 to 46)	320	37	11.84
4. Center Passengers (Station 59 to 76)	160	71	11.36
5. Aft Passengers	180	101	18.18
6. "Baggage (Area "A") (Station 124 to 152) 200 Lbs. Max.	150	138	20.70
7. "Baggage - Aft (Area "B") (Station 152 to 166) 80 Lbs. Max.	80	159	12.72
8. RAMP WEIGHT AND MOMENT	4105	59	208.26
9. Fuel allowance for engine start, taxi and rampup	-18	42	-.8
10. TAKEOFF WEIGHT AND MOMENT (Subtract step 9 from step 8)	4087		207.46

LOADING ARRANGEMENTS

NOTES:

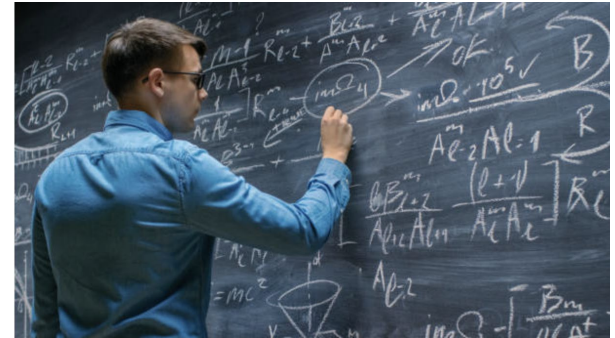
1. The usable fuel C.G. arm is located at station 43.0 (standard fuel tanks) and 42.0 (long range tanks).
2. The aft baggage wall (approximate station 166) can be used as a convenient interior reference point for determining the location of baggage area fuselage station.

By locating an item on the loading arrangements diagram, you can determine the arm of the item.

Figure 12-71. Using a weight and balance loading form allows you to perform an organized and complete evaluation of the airplane's loading conditions. A sample loading form is shown here on the left. To provide a convenient method of locating arm distances to be used with the loading form, manufacturers also provide loading arrangement charts, similar to the one shown on the right. By referring to this chart, you can readily visualize the arm distance of various useful load items.

Computation Method

- After you have entered weight and moment values on the loading form, add the weights to determine the total weight of the airplane and then add the moments to find the total moment. Before continuing, check to make sure that the total weight does not exceed the maximum ramp weight limit specified by the manufacturer.
- The ramp weight limit may be shown on the loading form, or you may need to determine maximum weight limits by locating them in the limitations section of the POH.
- By referring back to the loading form, you will notice that the manufacturer has determined that 18 pounds of fuel is considered to be used during engine start, runup, and taxi.
- This fuel weight and moment can be deducted from the total weight and moment amounts to determine the airplane weight and balance condition for takeoff.



Computation Method

- Once these adjustments have been made, a CG moment envelope chart can be used to determine if the adjusted weight and moment values are within allowable limits. These charts depict the forward and aft CG limits, maximum weight values and also include notes regarding special loading considerations.

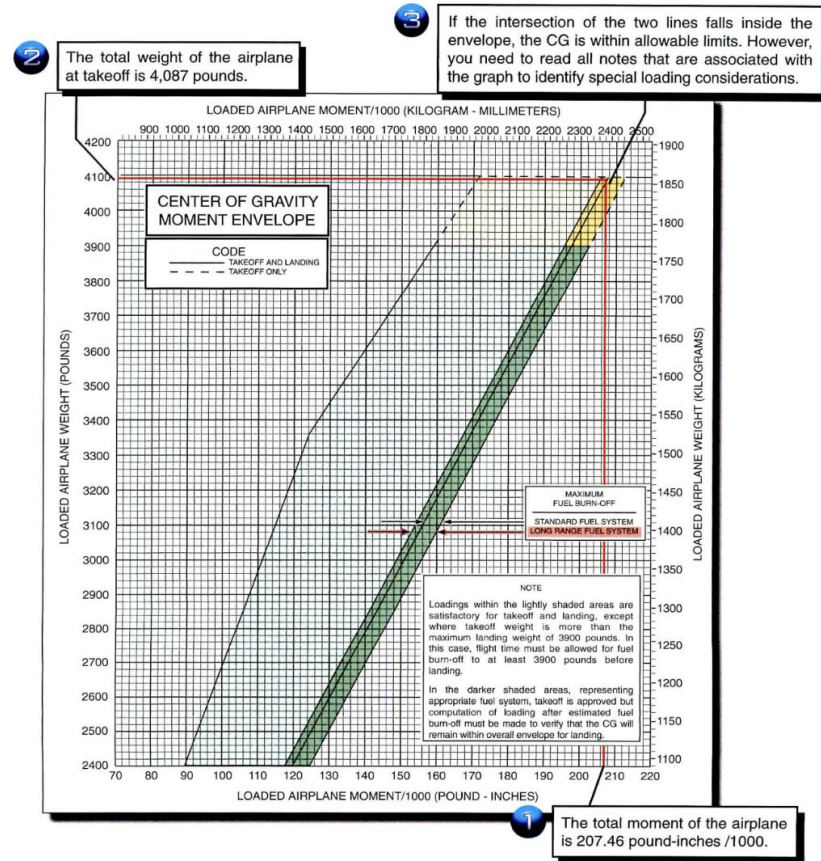
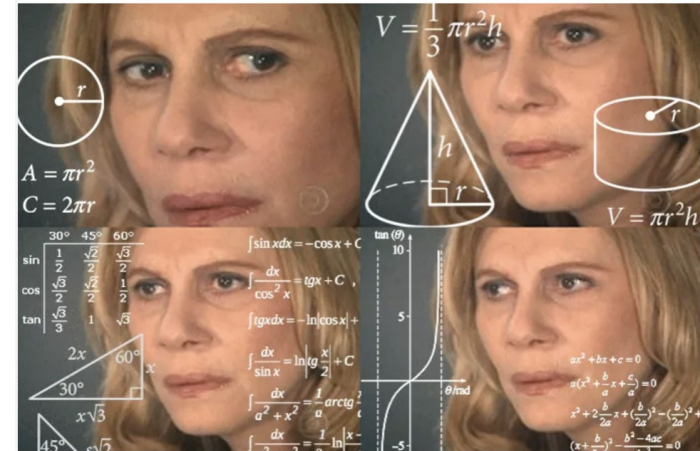


Figure 12-72. By using the CG moment envelope chart, you can see that the loading conditions of the sample airplane are within limits, but fall within a darker shaded area of the CG envelope. In this case, you need to comply with the notes contained on the chart.

Computation Methods

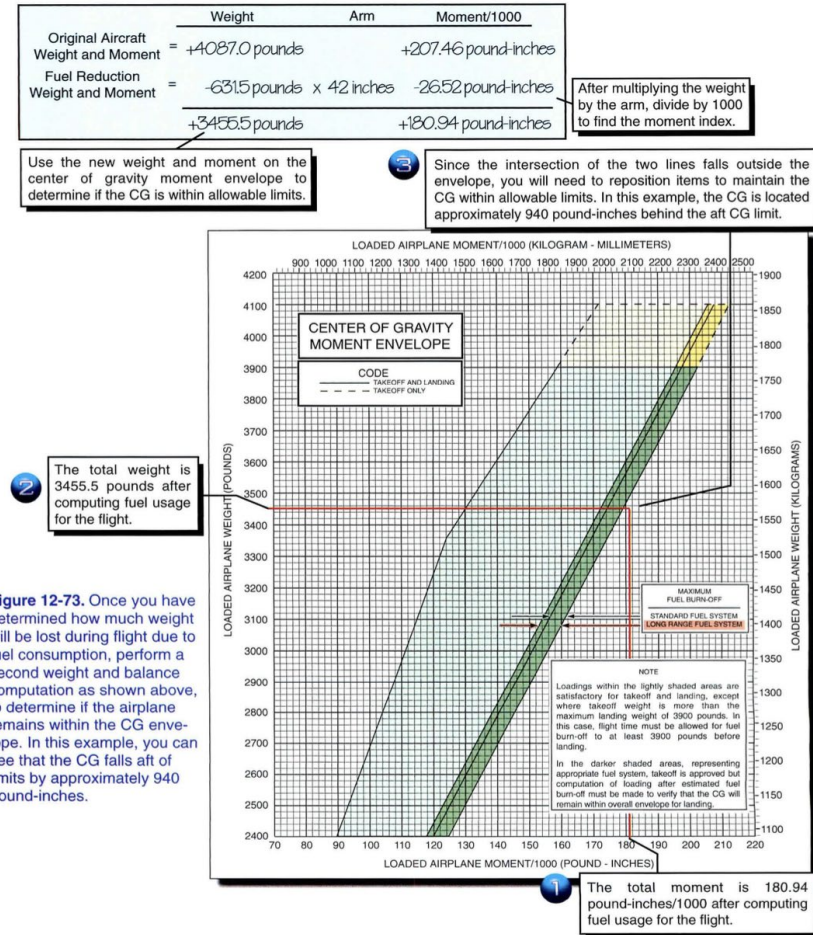
To determine if the CG of the sample airplane will remain within limits, you need to compute how much fuel will be used during flight. Normally this will include the amount used for takeoff, climb, and cruise. For example, assume that the sample airplane uses all but 45 minutes of fuel during flight. If the airplane burns 13 gallons per hour (g.p.h.) during cruise, you can divide 13 g.p.h. by 60 minutes to arrive at .217 gallons per minute (g.p.m.) fuel consumption. By multiplying .217 g.p.m. by 45 minutes, you find that the fuel remaining in the aircraft will be approximately 9.75 gallons. By multiplying 9.75 gallons by 6

Write your own confused text



Computation Method

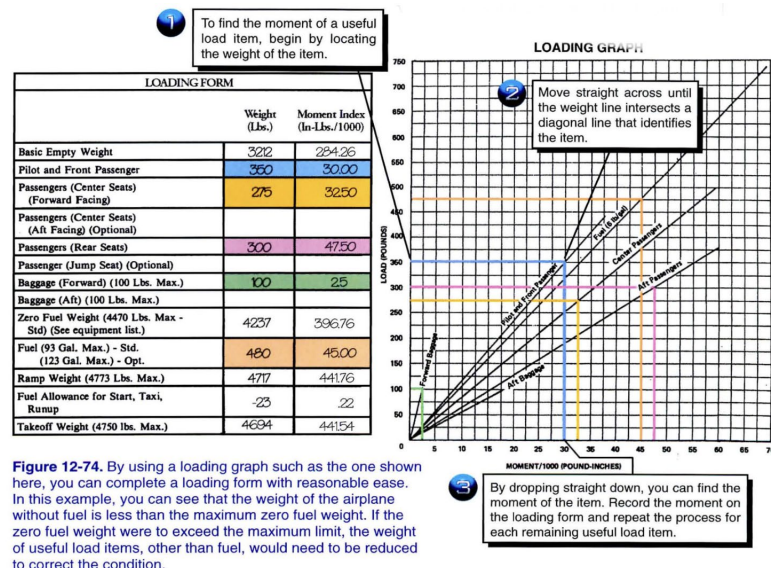
When the CG position falls out of allowable limits, you can correct the condition by repositioning items to different locations. When possible, it is more practical to move a heavy item since you only need to reposition it a short distance. To help determine the amount of weight that must be moved, you can perform a weight shift computation. A weight shift computation example is provided later in this section, and provides a solution to the out of balance condition of this airplane.



Graph Method

To reduce the need to perform arithmetic operations when performing weight and balance condition checks, some manufacturers provide graphs to check loading conditions. With the graph method, you essentially perform the same operations as those used with the computation method. However, determining the moment of an individual item is easier when you can consult a loading graph, which provides the moment of various items at different weights.

After you have computed the total weight and total moment of the airplane, you can refer to a CG range and weight chart to determine if the airplane is loaded within the CG envelope. These charts are similar to a CG moment envelope, except that you use the arm of the CG instead of the total moment of the airplane.



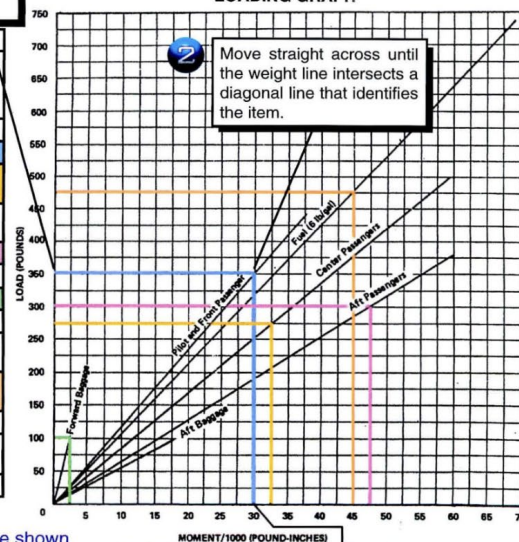
Graph Methods



To find the moment of a useful load item, begin by locating the weight of the item.

LOADING FORM		
	Weight (Lbs.)	Moment Index (In-Lbs./1000)
Basic Empty Weight	3212	284.26
Pilot and Front Passenger	350	30.00
Passengers (Center Seats) (Forward Facing)	275	32.50
Passengers (Center Seats) (Aft Facing) (Optional)		
Passengers (Rear Seats)	300	47.50
Passenger (Jump Seat) (Optional)		
Baggage (Forward) (100 Lbs. Max.)	100	25
Baggage (Aft) (100 Lbs. Max.)		
Zero Fuel Weight (4470 Lbs. Max - Std) (See equipment list.)	4237	396.76
Fuel (93 Gal. Max.) - Std. (123 Gal. Max.) - Opt.	480	45.00
Ramp Weight (4773 Lbs. Max.)	4717	441.76
Fuel Allowance for Start, Taxi, Runup	-23	22
Takeoff Weight (4750 lbs. Max.)	4694	441.54

LOADING GRAPH



Move straight across until the weight line intersects a diagonal line that identifies the item.



By dropping straight down, you can find the moment of the item. Record the moment on the loading form and repeat the process for each remaining useful load item.

Figure 12-74. By using a loading graph such as the one shown here, you can complete a loading form with reasonable ease. In this example, you can see that the weight of the airplane without fuel is less than the maximum zero fuel weight. If the zero fuel weight were to exceed the maximum limit, the weight of useful load items, other than fuel, would need to be reduced to correct the condition.

Graph Method

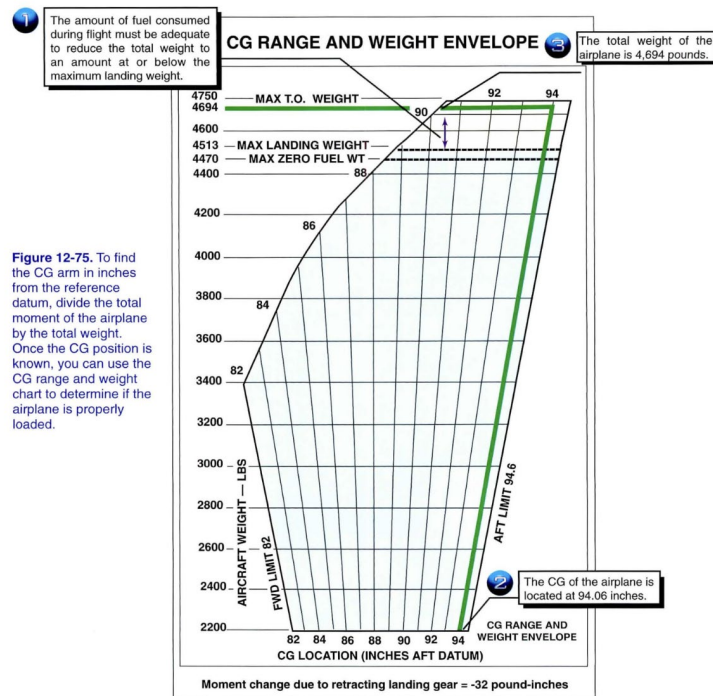


Figure 12-75. To find the CG arm in inches from the reference datum, divide the total moment of the airplane by the total weight. Once the CG position is known, you can use the CG range and weight chart to determine if the airplane is properly loaded.

Table Method

Many manufacturers of large airplanes supply tables to simplify weight and balance computations by tabulating the moments of useful load items at various weights and fuselage station locations. Because large airplanes often have a variety of possible cabin configurations, you need to first determine which tables to use. To accomplish this, manufacturers provide cabin configuration diagrams, which illustrate various positions of the cabin furnishings.

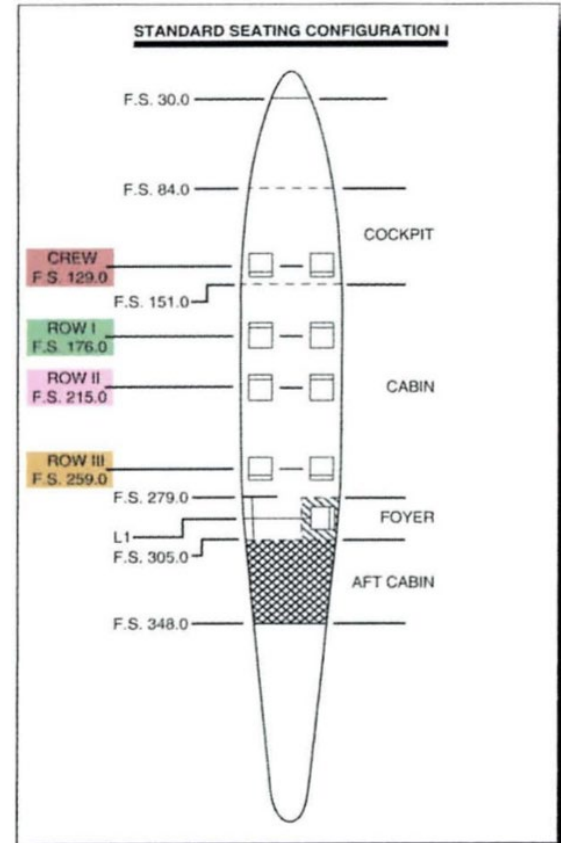


Table Method

By identifying the diagram that matches your airplane's configuration, you can determine which tables to use for weight and balance computations. Once the tables have been identified, use a loading form to list the weights, arms, and moments of the useful load items carried in the airplane.

For large airplanes, these loading forms may include additional weight considerations such as payload and basic operating weight. Payload can be thought of as potential revenue generating items such as passengers and baggage or cargo, while basic operating weight includes the airplane and crew, but without fuel and payload items.

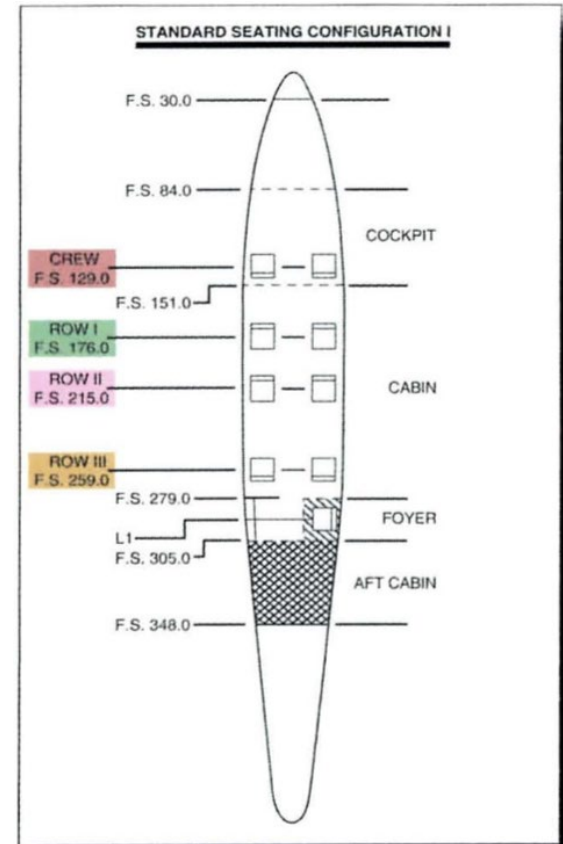


Table Method

PAYLOAD COMPUTATIONS			ITEM	WEIGHT	MOM/100
ITEM PASSENGERS OR CARGO	WEIGHT	MOM/100			
NO. LOCATION (ROW, F.S., ETC)					
2 pass @ Row 1 F.S. 176.0	340	299 x 2 598	1. BASIC EMPTY COND.	8,069	14,969
2 pass @ Row 2 F.S. 215.0	340	366 x 2 732	2. PILOT	170	219
2 pass @ Row 3 F.S. 259.0	340	440 x 2 880	3. PILOT'S BAGGAGE	10	33
			4. EXTRA EQUIPMENT	—	—
			5. TOTAL PAYLOAD	1,220	2,860
			6. SUBTOTAL ZERO FUEL COND. DO NOT EXCEED 10,400 LBS	9,469	18,081
			7. FUEL LOADING 200 gal	1,300	2,365
			8. SUB TOTAL RAMP CONDITION	10,769	20,446
			9. *LESS FUEL FOR START, TAXI, AND TAKEOFF	-90	-177
			10. SUB TOTAL TAKE OFF CONDITION	10,679	20,269
BAGGAGE F.S. 325.0	200	650	11. LESS FUEL TO DESTINATION 130 gal	-975	-1,761
CABINET CONTENTS	—	—	12. LANDING CONDITION	9,704	18,508
TOTAL PAYLOAD	1,220	2,860			

Fuel for start, taxi and take-off is normally 90 lbs at an average moment/100 of 177.

If the payload weight is not indicated on the table, determine the moment for half the payload. Multiplying the moment by 2 will give you the total payload moment.

USABLE FUEL		
GALLONS	WEIGHT	6.5 LB/GAL MOMENT 100
10	65	100
20	130	200
30	195	310
40	260	430
50	325	550
60	390	672
70	455	794
80	520	918
90	585	1039
100	650	1160
110	715	1280
120	780	1400
130	845	1519
140	910	1640
150	975	1761
160	1040	1881
170	1105	2002
180	1170	2122
190	1235	2244
200	1300	2365
210	1365	2486
220	1430	2607
230	1495	2728
240	1560	2850

OCCUPANTS							
USE COLUMNS MARKED X	CREW			CHAIR POSITIONS			LAVATORY SEAT
	F.S. 129	F.S. 171	F.S. 176	F.S. 215	F.S. 259	F.S. 293	F.S. 335
	X	X	X	X	X	X	X
WEIGHT	MOMENT/100						
80	103	137	141	172	207	234	268
90	116	154	158	194	233	264	302
100	129	171	176	215	259	293	335
110	142	188	194	237	285	322	369
120	155	205	211	258	311	352	402
130	168	222	229	280	337	381	436
140	181	239	246	301	363	410	469
150	194	257	264	323	389	440	503
160	206	274	282	344	414	469	536
170	219	291	298	365	440	498	570
180	232	308	317	387	466	527	603
190	245	325	334	409	492	557	637
200							
210							
220							
230							
240							

BAGGAGE			
WEIGHT	(Clothing on Hangers) FOYER F.S. 292	AFT CABIN F.S. 325 CONFIGURATIONS I & II *	AFT CABIN F.S. 332 CONFIGURATION III *
	MOMENT/100		
10	29	33	33
20	58	65	66
30	88	98	100
40	117	130	133
50	146	163	166
60	175	195	199
70	204	228	232
80	234	260	266
90	263	293	299
100	292	325	332
200		650	664
300		975	
370		1203	
400		1300	
410		1333	

Table Method

Once you have determined the total weight and total moment of the airplane, you can refer to a moment limit versus weight table to determine if the airplane is loaded within allowable CG limits.

Figure 12-77. By locating the total weight of the airplane, you can determine the range of moments that will produce an acceptable CG location for flight. In this illustration, the sample airplane's moment is found to be within allowable limits.

MOMENT LIMITS VS. WEIGHT			
	WEIGHT	MINIMUM MOMENT/100	MAXIMUM MOMENT/100
	7200	13032	14141
	7250	13122	14239
	7300	13213	14337
	7350	13304	14435
	7400	13394	14534
MAX ZERO FUEL WEIGHT	10150	18372	19935
	10200	18462	20033
	10250	18552	20131
	10300	18643	20229
	10350	18734	20327
	10400	18824	20426
	10450	18914	20524
	10500	19005	20622
	10550	19096	20720
	10600	19276	20818
	10650	19367	20917
	10700	19458	21015
	10750	19548	21113
	10800	19638	21211
	10850	19729	21309
	10900	19820	21408
	10950	19910	21506

By interpolating between the weight values, you can determine that the takeoff moment of 20,269 pound-inches /100 is within allowable limits.

Weight Shift Computation

During weight and balance computations, you may find that either the weight of the airplane or its CG location is beyond acceptable limits. Usually, decreasing weight is a fairly simple matter, especially if you accomplish it before the airplane's CG is calculated. However, if you change the load to adjust the CG, the computations are somewhat more complex. You can use the following formula to solve weight shift problems.

$$\frac{\text{Weight of cargo moved}}{\text{Airplane weight}} = \frac{\text{Distance CG moves}}{\text{Distance between arm locations}}$$

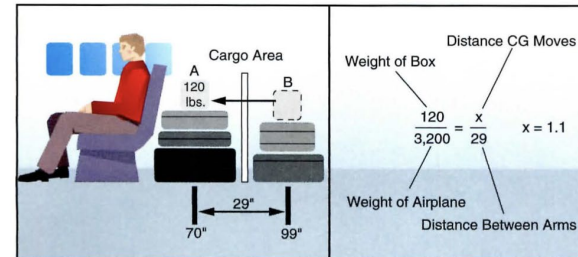


Figure 12-78. As shown in this illustration, the first step is to determine the known values. For example, the distance between cargo areas A and B is 29 inches. Next, insert the other known values into the formula and solve for the unknown variable. In this case, the unknown variable is the distance the CG moves forward when the weight is shifted. Solving this equation results in the answer of 1.1 inches.

Weight Shift Computation

By performing a few sample weight shift problems, you can see how to apply this formula. In the first example, assume you have a loaded airplane weight of 3,200 pounds and a CG of 45.6 inches. A box weighing 120 pounds is moved from cargo area B, which has an arm of 99 inches, to cargo area A, with an arm of 70 inches. How many inches will the CG move when this weight is shifted?

$$\frac{\text{Weight of cargo moved}}{\text{Airplane weight}} = \frac{\text{Distance CG moves}}{\text{Distance between arm locations}}$$

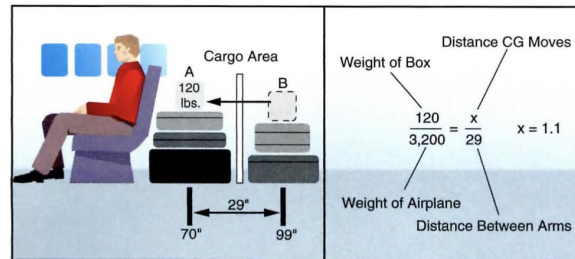


Figure 12-78. As shown in this illustration, the first step is to determine the known values. For example, the distance between cargo areas A and B is 29 inches. Next, insert the other known values into the formula and solve for the unknown variable. In this case, the unknown variable is the distance the CG moves forward when the weight is shifted. Solving this equation results in the answer of 1.1 inches.

Weight Shift Computation

For the next example, recall that the CG of the sample airplane used in the computation method problem exceeded aft limits when fuel was consumed during flight. To correct the aft CG condition, you need to reposition useful load items farther forward so that the CG will move approximately 940 pound-inches in order to remain within limits throughout the flight. In the sample aircraft, there are two baggage compartments; area A at 138 inches and area B at 159 inches. By moving a certain amount of weight from baggage area B into area A, you can cause the CG position to move forward within limits.

$$\frac{\text{Weight of cargo moved}}{\text{Airplane weight}} = \frac{\text{Distance CG moves}}{\text{Distance between arm locations}}$$



Weight Shift Computation

To determine how much weight to move between the compartments, you can use the weight shift formula. However, the formula uses CG positions expressed as arms, while the CG moment envelope, used in the sample problem, expresses balance limits in moment indexes. When moment indexes are used to convey balance limits, the first step to solving a weight shift problem is to convert moment values into CG locations or arms. Once these are determined, you can solve for the amount of weight to move by using the weight shift formula.

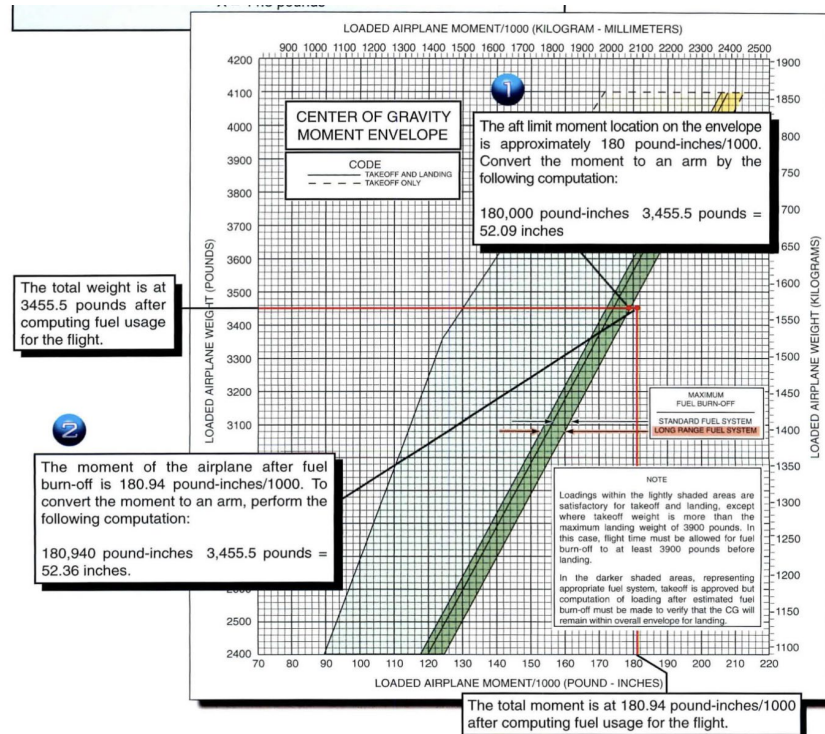
$$\frac{\text{Weight of cargo moved}}{\text{Airplane weight}} = \frac{\text{Distance CG moves}}{\text{Distance between arm locations}}$$

Weight Shift Computation

Figure 12-79. Notice that the aft moment limit of the sample airplane is located at 180 pound-inches /1000 when the airplane weighs 3,455.5 pounds. To find the arm of the aft limit, divide the aft limit moment by the weight of the airplane. In a similar fashion, you need to find the arm or CG of the loaded airplane. This is accomplished by dividing the airplane's total moment by its total weight. Once these computations are complete, you can use the weight shift formula to determine how much weight to move between the baggage areas. The solution to the weight shift problem is shown here.

Distance to Move CG		Distance Between Arms	
Airplane CG:	52.36 inches	Baggage Area B:	159 inches
Desired CG:	52.09 inches	Baggage Area A:	138 inches
	.27 inches		21 inches

Weight to Shift	$\times$		Distance CG moves
	3,445.5	=	$\frac{27}{21}$
Weight of Airplane			Distance Between Arms
			X = 44.3 pounds



Practice Question

The total weight of an airplane is 3,100 pounds and the total moment index is 310 pound-inches /1000. Where is the CG located in inches aft of the datum?

- +10 inches
- +100 inches
- +1,000 inches

Using the accompanying loading graph, what would be the CG of the total combined weight of the following items?

Pilot and Passenger 350 Pounds

Center Seat Passengers 100 Pounds

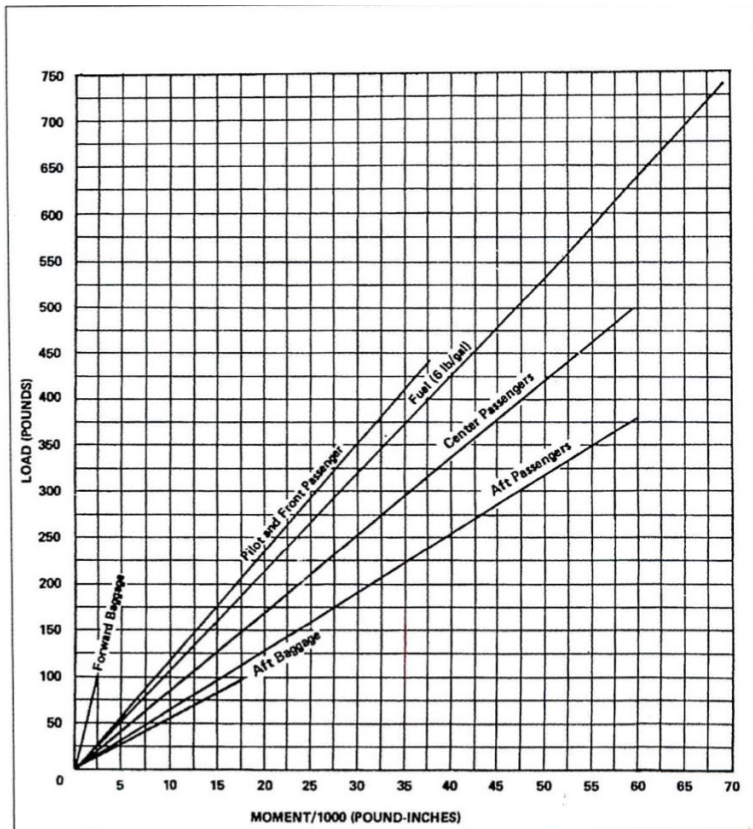
Usable Fuel 60 Pounds

Aft Baggage 50 Pounds

Approximately +101.27 inches aft of the reference datum

Approximately +156.38 inches aft of the reference datum

Approximately +105.13 inches aft of the reference datum





Practice Questions

Use the item information from the previous question and the CG range and weight graph shown here to determine if an airplane is loaded within the CG envelope. Assume the airplane has an empty weight of 3,200 pounds with an empty weight moment index of 2,842.6 pound-inches /100.

- The CG falls within the envelope and is safe for flight.
- The CG falls in the envelope, but exceeds the maximum zero fuel weight.
- The CG falls inside the envelope but the fuel burn-off in flight must be sufficient to reduce the total weight to below the maximum landing weight.



Problem

An aircraft is loaded with a ramp weight of 3,650 pounds and having a CG of 94.0, approximately how much baggage would have to be moved from the rear baggage area at station 180 to the forward baggage area at station 40 in order to move the CG to 92.0?

$$\frac{\underline{W1}}{W2} = \frac{\underline{CG1}}{CG2} \qquad \frac{\underline{?}}{3650} = \frac{\underline{2in}}{140in}$$

Problem

I have been planning to rob a gold depository for quite some time now. I plan to make my escape in a PA34-200. How much gold (Lbs) can I steal and safely fly away with? I will put the gold bars in the Aft Baggage.

- Max T/O Weight 4200 lbs
- Current Weight 3499.2 lbs
- Current CG 87.22 in
- Rear CG Limit 94 in
- Aft Baggage Sta. 178.7 in

$$\frac{\underline{W1}}{W2} = \frac{\underline{CG1}}{CG2}$$

$$\frac{\underline{?}}{4200} = \frac{\underline{6.78in}}{91.48in}$$

Problem

Because I am greedy I managed to steal 700 lbs of gold (\$8.75Million). In my haste to get to the Bahamas I loaded it all into the Aft Baggage Compartment. Can I store all of my gold in this station? How far out will my CG be if I try to do this?

Max T/O Weight	4200 lbs
Current Weight	3499.2 lbs
Weight incl. Gold	4199.2 lbs
Current CG	87.22 in
Rear CG Limit	94 in
Aft Baggage Sta.	178.7 in

$$\frac{W1}{W2} = \frac{CG1}{CG2}$$

$$\frac{700}{4199.2} = \frac{?in}{91.48in}$$

Problem

Stood at the plane, with the sound of sirens in the background, I REALLY need to know how much gold I now need to REMOVE from the aircraft to make it legal again. How much of the 700 lbs of gold should I remove from the Aft Baggage to get legal again?

Max T/O Weight	4200 lbs
Current Weight	4199.2 lbs
Current CG	102.4 in
Rear CG Limit	94 in
Aft Baggage Sta.	178.7 in

$$\frac{W1}{W2} = \frac{CG1}{CG2} \qquad \frac{?}{4199.2} = \frac{-8.4in}{84.7in}$$



Problem

Safely away with my 280 lbs of gold, I wonder what the effect of 2hrs of fuel burn will be on my CG?

Fuel Burn	32 gal/hr
Current Weight	3799.2 lbs
Current CG	94 in
Fuel Sta.	93.6 in

$$\frac{W1}{W2} = \frac{CG1}{CG2} \qquad \frac{-384}{3415.2} = \frac{?}{0.4in}$$



Problem

Many years later, whilst on the beach sipping a Pinicolada, I wonder how much gold I would have been able to steal had I put it in a different location in the aircraft.

Where would have been the best place to put the gold?

Why would this have been the best place?

Could I have put the whole 700Lbs there?

$$\frac{\underline{W1}}{W2} = \frac{\underline{CG1}}{CG2}$$

$$\frac{\underline{700}}{4200} = \frac{\underline{?}}{-1.72in}$$