

Center of Gravity Change after Repair or Alterations

The largest weight changes that occur during the lifetime of an aircraft are those caused by alterations and repairs. It is the responsibility of the aircraft mechanic or repairman doing the work to accurately document the weight change and record it in both the maintenance records and the POH/AFM.

Equipment List

A typical comprehensive equipment list is shown in Figure 2-22 on pages 2-12 and 2-13. The FAA considers addition or removal of equipment included in this list to be a minor alteration. The weights and arms are included with the items in the equipment list, and these minor alterations can be done and the aircraft approved for return to service by an appropriately rated aircraft mechanic or repairman. The only documentation required is an entry in the aircraft maintenance records and the appropriate change to the weight and balance record in the POH/AFM. [Figure 5-1]

Major Alteration and Repair

Within the following text, information concerning major repairs or major alterations does not apply to any aircraft within the light-sport category. This category of aircraft is not eligible for major repairs or alterations.

Any major alteration or repair requires the work to be done by an appropriately-rated aircraft mechanic or facility. The work must be checked for conformity to FAA-approved data and signed off by an aircraft mechanic holding an Inspection Authorization, or by an authorized agent of an appropriately rated FAA-approved repair station. A repair station record or FAA Form 337, Major Repair and Alteration, must be completed which describes the work. A dated and signed revision to the weight and balance record is made and kept with the maintenance records, and the airplane's new empty weight and empty weight arm or moment index are entered in the POH/AFM.

Weight and Balance Record													
(Continuous history of changes in structure or equipment affecting weight and balance)													
Airplane Model			Cessna 182L			Serial Number			18259080		Page Number		1
Date	Item No.		Description of Article or Modification	Weight Change						Running Basic Empty Weight			
	In	Out		Added (+)			Removed (-)			Wt. (lb)	Moment /1,000		
				Wt. (lb)	Arm (in)	Moment /1,000	Wt. (lb)	Arm (in)	Moment /1,000				
			AS DELIVERED								1,876	67.8	
4-22-05	Alteration Per FAA Form 337												
	Dated 4-22-95			7.38		.346					1,883.4	68.1	
		34-XX	Turn Coordinator				-2.5	15.0	-.037				
		34-XX	Directional Gyro				-3.12	13.5	-.042				
	22-XX		Auto Pilot System	13.0	32.7	.425							

Figure 5-1. A typical Part 23 weight and balance record.

Weight & Balance
Cessna 182L
 N42565
 S/N 18259080

Date: 04/22/95

Supersedes Computations of FAA Form 337, dated 10/02/90.

Removed the following equipment:

1. Turn Coordinator P/N C661003-0201	Weight	Arm	Moment
2. Directional Gyro P/N 0706000	2.5 lbs	15	37.5
	<u>3.12 lbs</u>	<u>13.5</u>	<u>42.12</u>
TOTAL	5.62		79.62
	1876.00	36.14	67798.64
	<u>-5.62</u>		<u>-79.62</u>
Aircraft after removal:	1870.38	36.20	67719.02

Installed the following equipment:

1. S-Tec 40 Autopilot system, includes Turn Coordinator and Directional Gyro.	Weight	Arm	Moment
	13 lbs	32.7	425.13
	1870.38	36.20	67719.02
	<u>+13.00</u>		<u>+425.13</u>
*REVISED LICENSED EMPTY WEIGHT	1883.38	36.18	68144.15
NEW USEFUL LOAD 1216.62			

Forward Check (Limit +33.0)

	Wt.	Arm	Moment
A/C Empty	1883.38	36.18	68144.15
Fwd. Seats	170.00	37.00	6290.00
Aft. Seats			
Fuel (min.)	115.00	48.00	5520.00
Baggage A			
Baggage B			
	<u>2168.38</u>	<u>+36.87</u>	<u>79954.15</u>

Rearward Check (Limit +46.0)

	Wt.	Arm	Moment
A/C Empty	1883.38	36.18	68144.15
Fwd. Seats	170.00	37.00	6290.00
Aft. Seats	340.00	74.00	25160.00
Fuel (max.)	528.00	48.20	25449.60
Baggage A	100.00	97.00	9700.00
Baggage B	<u>60.00</u>	<u>116.00</u>	<u>6960.00</u>
	3081.38	45.98	141703.75



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Figure 5-2. A typical CAR 3 airplane weight and balance revision record.

Weight and Balance Revision Record

Aircraft manufacturers use different formats for their weight and balance data, but Figure 5-2 is typical of a weight and balance revision record. All weight and balance records should be kept with the other aircraft records. Each revision record should be identified by the date, the aircraft make, model, and serial number. The pages should be signed by the person making the revision and his or her certificate type and number must be included.

The computations for a weight and balance revision are included on a weight and balance revision form. The date those computations were made is shown in the upper right-hand corner of Figure 5-2. When this work is superseded, a notation must be made on the new weight and balance revision form, including a statement that these computations supersede the computations dated “XX/XX/XX.”

Appropriate fore-and-aft extreme loading conditions should be investigated and the computations shown.

The weight and balance revision sheet should clearly show the revised empty weight, empty weight arm and/or moment index, and the new useful load.

Weight Changes Caused by a Repair or Alteration

A typical alteration might consist of removing two pieces of radio equipment from the instrument panel, and a power supply that was located in the baggage compartment behind the rear seat. In this example, these two pieces are replaced with a single lightweight, self-contained radio. At the same time, an old emergency locator transmitter (ELT) is removed from its mount near the tail, and a lighter weight unit is installed. A passenger seat is installed in the baggage compartment.

Computations Using Weight, Arm, and Moment

The first step in the weight and balance computation is to make a chart like the one in Figure 5-3, listing all of the items that are involved.

The new CG of 36.4 inches aft of the datum is determined by dividing the new moment by the new weight.

Item	Weight (lbs)	Arm (inches)	Moment (lb-in)	New CG
Airplane	1,876.0	36.1	67,723.6	
Radio removed	-12.2	15.8	-192.8	
Power supply removed	-9.2	95.0	-874.0	
ELT removed	-3.2	135.0	-432.0	
Radio installed	+8.4	14.6	+122.6	
ELT installed	+1.7	135.0	+229.5	
Passenger seat installed	+21.0	97.0	+2,037.0	
Total	1,882.5		68,613.9	+36.4

Figure 5-3. Weight, arm, and moment changes caused by typical alteration.

Computations Using Weight and Moment Indexes

If the weight and balance data uses moment indexes rather than arms and moments, this same alteration can be computed using a chart like the one shown on Figure 5-4.

Subtract the weight and moment indexes of all the removed equipment from the empty weight and moment index of the airplane. Add the weight and moment indexes of all equipment installed and determine the total weight and the total moment index. To determine the position of the new CG in inches aft of the datum, multiply the total moment index by 100 to get the moment, and divide this by the total weight to get the new CG.

Empty-Weight CG Range

The fuel tanks, seats, and baggage compartments of some aircraft are so located that changes in the fuel or occupant load have a very limited effect on the balance of the aircraft. Aircraft of such a configuration show an EWCG range in the TCDS. [Figure 5-5] If the EWCG is located within this range, it is impossible to legally load the aircraft so that its loaded CG will fall outside of its allowable range.

Empty-Weight CG Range	+12.5 to +16.2
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Figure 5-5. Typical notation in a TCDS when an aircraft has an empty-weight CG range.

If the TCDS list an empty-weight CG range, and after the alteration is completed the EWCG falls within this range, then there is no need to compute a fore and aft check for adverse loading.

But if the TCDS lists the EWCG range as “None” (and most of them do), a check must be made to determine whether or not it is possible by any combination of legal loading to cause the aircraft CG to move outside of either its forward or aft limits.

Adverse-Loaded CG Checks

Many modern aircraft have multiple rows of seats and often more than one baggage compartment. After any repair or alteration that changes the weight and balance, the A&P mechanic or repairman must ensure that no legal condition of loading can move the CG outside of its allowable limits. To determine this, adverse-loaded CG checks must be performed and the results noted in the weight and balance revision sheet.

Item	Weight (lbs)	Moment Indexes (lb-in/100)	New CG (inches from datum)
Airplane	1,876.0	+677.2	
Radio removed	-12.2	-1.93	
Power supply removed	-9.2	-8.74	
ELT removed	-3.2	-4.32	
Radio installed	+8.4	+1.23	
ELT installed	+1.7	+2.29	
Passenger seat installed	+21.0	+20.37	
Total	1,882.5	+686.1	+36.4

Figure 5-4. Weight and moment index changes caused by a typical alteration.

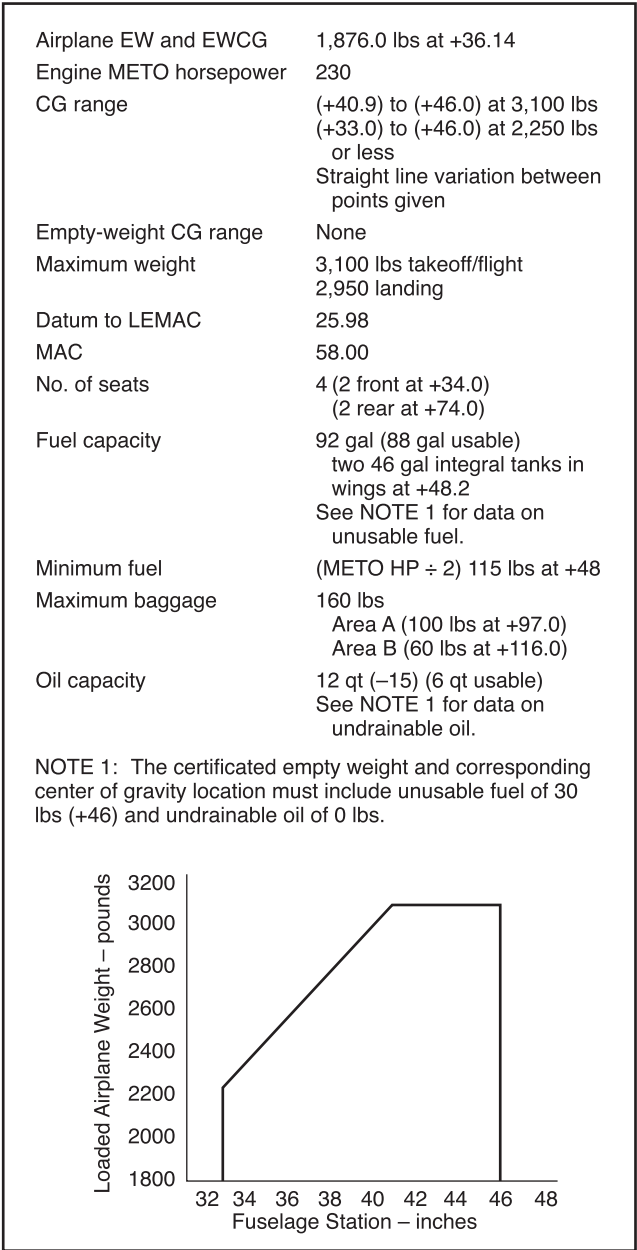


Figure 5-6. Weight and balance information used for adverse-loaded CG Checks.

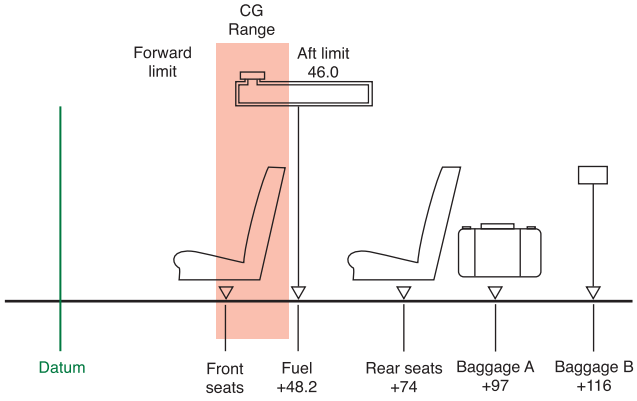


Figure 5-7. Loading diagram for adverse-loaded CG check.

Forward Adverse-Loaded CG Check

To conduct a forward CG check, make a chart that includes the airplane and any occupants and items of the load located in front of the forward CG limit. [Figure 5-7] Include only those items behind the forward limit that are essential to flight. This is the pilot and the minimum fuel.

In this example, the pilot, whose nominal weight is 170 pounds, is behind the forward CG limit. The fuel is also behind the forward limit, so the minimum fuel is used. For weight and balance purposes, the minimum fuel is no more than the quantity needed for one-half-hour of operation at rated maximum continuous power. This is considered to be 1/12 gallon for each maximum except takeoff (METO) horsepower. Because aviation gasoline weighs 6 pounds per gallon, determine the number of pounds of the minimum fuel by dividing the METO horsepower by 2; in this example minimum fuel is 115 pounds.

The front and rear seats and the baggage are all behind the forward CG limit, so no passengers or baggage are considered.

Make a chart like the one in Figure 5-8 to determine the CG with the aircraft loaded for its most forward CG. With the load consisting of only a pilot and the minimum fuel, the CG is +36.6, which is behind the most forward allowable limit for this weight of +33.0.

Item	Weight (lbs)	Arm (inches)	Moment (lb-in)	Most Forward CG +33.0
Airplane – empty	1,876.0	36.14	67,798.6	
Pilot	170.0	34.0	5,780.0	
Fuel (minimum)	115.0	48.0	5,520.0	
Total	2,161.0		79,098.6	+36.6

Figure 5-8. Load conditions for forward adverse-loaded CG check.

Aft Adverse-Loaded CG Check

To conduct an aft, or rearward, CG check, make a chart that includes the empty weight and EWCG of the aircraft after the alteration, and all occupants and items of the load behind the aft CG limit of 46.0. The pilot is in front of this limit, but is essential for flight and must be included. In this example, only the pilot will occupy the front seats. Since the CG of the fuel is behind the aft limit, full fuel will be used as well as the nominal weight (170 lbs) for both rear seat passengers and the maximum allowable baggage.

Under these loading conditions, the CG is located at +45.8, which is ahead of the aft limit of +46.0. [Figure5-9]

With only the pilot in front of the aft CG limit and maximum of all items behind the aft limit, the CG will be at +45.8 inches, which is ahead of the aft limit of +46.0 inches.

Ballast

It is possible to load most modern airplanes so the center of gravity shifts outside of the allowable limit. Placards and loading instructions in the Weight and Balance Data inform the pilot of the restrictions that will prevent such a shift from occurring. A typical placard in the baggage compartment of an airplane might read:

When rear row of seats is occupied, 120 pounds of baggage or ballast must be carried in forward baggage compartment. For additional loading instructions, see Weight and Balance Data.

When the CG of an aircraft falls outside of the limits, it can usually be brought back in by using ballast.

Temporary Ballast

Temporary ballast, in the form of lead bars or heavy canvas bags of sand or lead shot, is often carried in the baggage compartments to adjust the balance for certain flight conditions. The bags are marked “Ballast XX Pounds - Removal Requires Weight and Balance Check.” Temporary ballast must be secured so it cannot shift its location in flight, and the structural limits of the baggage compartment must not be exceeded. All temporary ballast must be removed before the aircraft is weighed.

Temporary Ballast Formula

The CG of a loaded airplane can be moved into its allowable range by shifting passengers or cargo, or by adding temporary ballast.

To determine the amount of temporary ballast needed, use this formula:

$$\text{Ballast weight needed} = \frac{\text{Total weight} \times \text{Distance needed to shift CG}}{\text{Distance between ballast location and desired CG}}$$

Permanent Ballast

If a repair or alteration causes the aircraft CG to fall outside of its limit, permanent ballast can be installed. Usually, permanent ballast is made of blocks of lead painted red and marked “Permanent Ballast - Do Not Remove.” It should be attached to the structure so that it does not interfere with any control action, and attached rigidly enough that it cannot be dislodged by any flight maneuvers or rough landing.

Item	Weight (lbs)	Arm (inches)	Moment (lb-in)	Most Aft CG +46.0
Airplane – empty	1,876.0	36.14	67,798.6	
Pilot	170.0	34.0	5,780.0	
Fuel (full tanks – 88 gal.)	528.0	48.2	25,449.6	
Rear seat occupants (2)	340.0	74.0	25,160.0	
Baggage A	100.0	97.0	9,700.0	
Baggage B	60.0	116.0	6,960.0	
Total	3,074.0		140,848.2	+45.8

Figure 5-9. Load conditions for aft adverse-loaded CG check.

Two things must first be known to determine the amount of ballast needed to bring the CG within limits: the amount the CG is out of limits, and the distance between the location of the ballast and the limit that is affected.

If an airplane with an empty weight of 1,876 pounds has been altered so its EWCG is +32.2, and CG range for weights up to 2,250 pounds is +33.0 to +46.0, permanent ballast must be installed to move the EWCG from +32.2 to +33.0. There is a bulkhead at fuselage station 228 strong enough to support the ballast.

To determine the amount of ballast needed, use this formula:

$$\begin{aligned}\text{Ballast weight} &= \frac{\text{Aircraft empty weight} \times \text{Dist. out of limits}}{\text{Distance between ballast and desired CG}} \\ &= \frac{1,876 \times 0.8}{228 - 33} \\ &= \frac{1,500.8}{195} \\ &= 7.7 \text{ pounds}\end{aligned}$$

A block of lead weighing 7.7 pounds attached to the bulkhead at fuselage station 228, will move the EWCG back to its proper forward limit of +33. This block should be painted red and marked "Permanent Ballast - Do Not Remove."

