



The weight of an aircraft and its balance are extremely important for operating an aircraft in a safe and efficient manner. When a manufacturer designs an aircraft and the Federal Aviation Administration (FAA) certifies it, the specifications identify the aircraft's maximum weight and the limits within which it must balance.

The maximum allowable weight is based on the surface area of the wing, and how much lift it will generate at a safe and appropriate airspeed. If a small general aviation airplane, for example, required a takeoff speed of 200 miles per hour (mph) to generate enough lift to support its weight, that would not be safe. Taking off and landing at lower airspeeds is certainly safer than doing so at higher speeds.

Where an aircraft balances is also a significant factor in determining if the aircraft is safe to operate. An aircraft that does not have good balance can exhibit poor maneuverability and controllability, making it difficult or impossible to fly. This could result in an accident, causing damage to the aircraft and injury to the people on board. Safety is the primary reason for concern about an aircraft's weight and balance.

A secondary reason for concern about weight and balance, but also a very important one, is the efficiency of the aircraft. Improper loading reduces the efficiency of an aircraft from the standpoint of ceiling, maneuverability, rate of climb, speed, and fuel consumption. If an airplane is loaded in such a way that it is extremely nose heavy, higher than normal forces will need to be exerted at the tail to keep the airplane in level flight. The higher than normal forces at the tail will create additional drag, which will require additional engine power and therefore additional fuel flow in order to maintain airspeed.

The most efficient condition for an aircraft is to have the point where it balances fall very close to, or perhaps exactly at, the aircraft's center of lift. If this were the case, little or no flight control force would be needed to keep the aircraft flying straight and level. In terms

of stability and safety, however, this perfectly balanced condition might not be desirable. All of the factors that affect aircraft safety and efficiency, in terms of its weight and balance, are discussed in detail in this chapter.

Need and Requirements for Aircraft Weighing

Every aircraft type certificated by the FAA, before leaving the factory for delivery to its new owner, receives a weight and balance report as part of its required aircraft records. The weight and balance report identifies the empty weight of the aircraft and the location at which the aircraft balances, known as the center of gravity. If the manufacturer chooses to do so, it can weigh every aircraft it produces and issue the weight and balance report based on that weighing. As an alternative, the manufacturer is permitted to weigh an agreed upon percentage of a particular model of aircraft produced, perhaps 10 to 20 percent, and apply the average to all the aircraft.

After the aircraft leaves the factory and is delivered to its owner, the need or requirement for placing the aircraft on scales and reweighing it varies depending on the type of aircraft and how it is used. For a small general aviation airplane being used privately, such as a Cessna 172, there is no FAA requirement that it be periodically reweighed. There is, however, an FAA requirement that the airplane always have a current and accurate weight and balance report. If the weight and balance report for an aircraft is lost, the aircraft must be weighed and a new report must be created. If the airplane has new equipment installed, such as a radio or a global positioning system, a new weight and balance report must be created. If the installer of the equipment wants to place the airplane on scales and weigh it after the installation, that is a perfectly acceptable way of creating the new report. If the installer knows the exact weight and location of the new equipment, it is also possible to create a new report by doing a series of mathematical calculations.

Over a period of time, almost all aircraft have a tendency to gain weight. Examples of how this can happen include an airplane being repainted without the old paint being removed, and the accumulation of dirt, grease, and oil in parts of the aircraft that are not easily accessible for cleaning. When new equipment is installed, and its weight and location are mathematically accounted for, some miscellaneous weight might be overlooked, such as wire and hardware. For this reason, even if the FAA does not require it, it is a good practice to periodically place an aircraft on scales and confirm its actual empty weight and empty weight center of gravity.

Some aircraft are required to be weighed and have their center of gravity calculated on a periodic basis, typically every 3 years. Examples of aircraft that fall under this requirement are:

1. Air taxi and charter twin-engine airplanes operating under Title 14 of the Code of Federal Regulations (14 CFR) part 135, section (§)135.185(a).
2. Airplanes with a seating capacity of 20 or more passengers or a maximum payload of 6,000 pounds or more, as identified in 14 CFR part 125, §125.91(b). This paragraph applies to most airplanes operated by the airlines, both main line and regional, and to many of the privately operated business jets.

Weight and Balance Terminology

Datum

The datum is an imaginary vertical plane from which all horizontal measurements are taken for balance purposes, with the aircraft in level flight attitude. If the datum was viewed on a drawing or photograph of an aircraft, it would appear as a vertical line which is perpendicular (90 degrees) to the aircraft's horizontal axis. For each aircraft make and model, the location of all items is identified in reference to the datum. For example, the fuel in a tank might be 60 inches (60") behind the datum, and a radio on the flight deck might be 90" forward of the datum.

There is no fixed rule for the location of the datum, except that it must be a location that will not change during the life of the aircraft. For example, it would not be a good idea to have the datum be the tip of the propeller spinner or the front edge of a seat, because changing to a new design of spinner or moving the seat would cause the datum to change. It might be located at or near the nose of the aircraft, a specific number of inches forward of the nose, at the engine firewall,

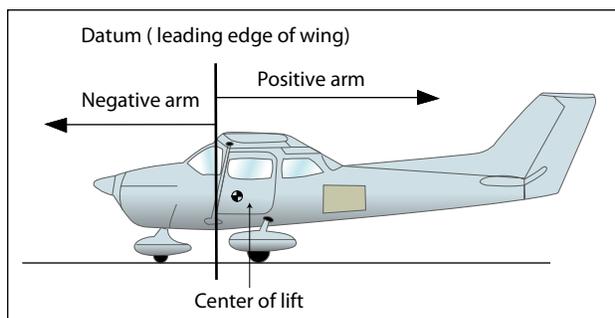


Figure 4-1. Datum location and its effect on positive and negative arms.

at the center of the main rotor shaft of a helicopter, or any place that can be imagined. The manufacturer has the choice of locating the datum where it is most convenient for measurement, equipment location, and weight and balance computation. Figure 4-1 shows an aircraft with the leading edge of the wing being the datum.

The location of the datum is identified in the Aircraft Specifications or Type Certificate Data Sheet. Aircraft certified prior to 1958 fell under the Civil Aeronautics Administration, and had their weight and balance information contained in a document known as Aircraft Specifications. Aircraft certified since 1958 fall under the FAA and have their weight and balance information contained in a document known as a Type Certificate Data Sheet. The Aircraft Specifications typically included the aircraft equipment list. For aircraft with a Type Certificate Data Sheet, the equipment list is a separate document.

Arm

The arm is the horizontal distance that a part of the aircraft or a piece of equipment is located from the datum. The arm's distance is always given or measured in inches, and, except for a location which might be exactly on the datum, it is preceded by the algebraic sign for positive (+) or negative (-). The positive sign indicates an item is located aft of the datum and the negative sign indicates an item is located forward of the datum. If the manufacturer chooses a datum that is at the most forward location on an aircraft (or some distance forward of the aircraft), all the arms will be positive numbers. Location of the datum at any other point on the aircraft will result in some arms being positive numbers, or aft of the datum, and some arms being negative numbers, or forward of the datum. Figure 4-1 shows an aircraft where the datum is the leading edge of the wing. For this aircraft, any item (fuel, seat, radio, and so forth) located forward of the wing leading edge will have a negative arm, and any item located aft of

the wing leading edge will have a positive arm. If an item was located exactly at the wing leading edge, its arm would be zero, and mathematically it would not matter whether its arm was considered to be positive or negative.

The arm of each item is usually included in parentheses immediately after the item's name or weight in the Aircraft Specifications, Type Certificate Data Sheet, or equipment list for the aircraft. In a Type Certificate Data Sheet, for example, the fuel quantity might be identified as 150 gallons (gal) (+138) and the nose baggage limit as 200 pounds (lb) (-55). These numbers indicate that the fuel is located 138" aft of the datum and the nose baggage is located 55" forward of the datum. If the arm for a particular piece of equipment is not known, its exact location must be accurately measured. When the arm for a piece of equipment is being determined, the measurement is taken from the datum to the piece of equipment's own center of gravity.

Moment

A moment is the product of a weight multiplied by its arm. The moment for a piece of equipment is in fact a torque value, measured in units of inch-pounds (in-lb). To obtain the moment of an item with respect to the datum, multiply the weight of the item by its horizontal distance from the datum. Likewise, the moment of an item with respect to the center of gravity (CG) of an aircraft can be computed by multiplying its weight by the horizontal distance from the CG.

A 5 lb radio located 80" from the datum would have a moment of 400 inch-pounds (in-lb) ($5 \text{ lb} \times 80"$). Whether the value of 400 in-lb is preceded by a positive (+) or negative (-) sign depends on whether the moment is the result of a weight being removed or added and its location in relation to the datum. This situation is shown in Figure 4-2, where the moment ends up being a positive number because the weight and arm are both positive.

The algebraic sign of the moment, based on the datum location and whether weight is being installed or removed, would be as follows:

- Weight being added aft of the datum produces a positive moment (+weight, +arm).
- Weight being added forward of the datum produces a negative moment (+weight, -arm).
- Weight being removed aft of the datum produces a negative moment (-weight, +arm).
- Weight being removed forward of the datum produces a positive moment (-weight, -arm)

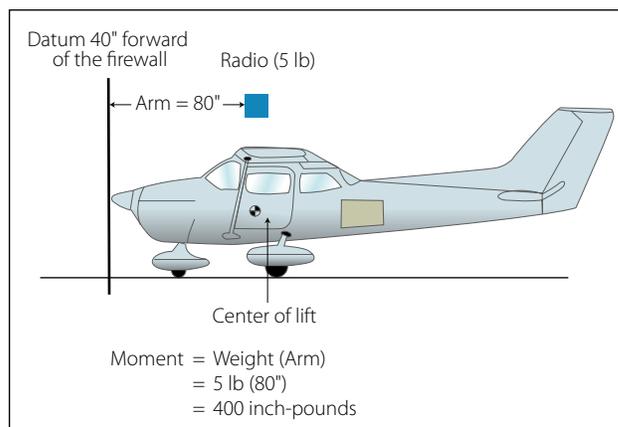


Figure 4-2. Moment of a radio located aft of the datum.

When dealing with positive and negative numbers, remember that the product of like signs produces a positive answer and the product of unlike signs produces a negative answer.

Center of Gravity

The center of gravity (CG) of an aircraft is a point about which the nose heavy and tail heavy moments are exactly equal in magnitude. It is the balance point for the aircraft. An aircraft suspended from this point would have no tendency to rotate in either a nose-up or nose-down attitude. It is the point about which the weight of an airplane or any object is concentrated.

Figure 4-3 shows a first class lever with the pivot point (fulcrum) located at the center of gravity for the lever. Even though the weights on either side of the fulcrum are not equal, and the distances from each weight to the fulcrum are not equal, the product of the weights and arms (moments) are equal, and that is what produces a balanced condition.

Maximum Weight

The maximum weight is the maximum authorized weight of the aircraft and its contents, and is indicated in the Aircraft Specifications or Type Certificate Data Sheet. For many aircraft, there are variations to the maximum allowable weight, depending on the pur-

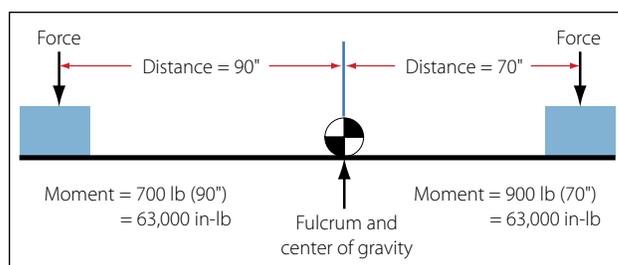


Figure 4-3. Center of gravity and a first class lever.

pose and conditions under which the aircraft is to be flown. For example, a certain aircraft may be allowed a maximum gross weight of 2,750 lb when flown in the normal category, but when flown in the utility category, which allows for limited aerobatics, the same aircraft's maximum allowable gross weight might only be 2,175 lb. There are other variations when dealing with the concept of maximum weight, as follows:

- **Maximum Ramp Weight**—the heaviest weight to which an aircraft can be loaded while it is sitting on the ground. This is sometimes referred to as the maximum taxi weight.
- **Maximum Takeoff Weight**—the heaviest weight an aircraft can have when it starts the takeoff roll. The difference between this weight and the maximum ramp weight would equal the weight of the fuel that would be consumed prior to takeoff.
- **Maximum Landing Weight**—the heaviest weight an aircraft can have when it lands. For large wide body commercial airplanes, it can be 100,000 lb less than maximum takeoff weight, or even more.
- **Maximum Zero Fuel Weight**—the heaviest weight an aircraft can be loaded to without having any usable fuel in the fuel tanks. Any weight loaded above this value must be in the form of fuel.

Empty Weight

The empty weight of an aircraft includes all operating equipment that has a fixed location and is actually installed in the aircraft. It includes the weight of the airframe, powerplant, required equipment, optional or special equipment, fixed ballast, hydraulic fluid, and residual fuel and oil. Residual fuel and oil are the fluids that will not normally drain out because they are trapped in the fuel lines, oil lines, and tanks. They must be included in the aircraft's empty weight. For most aircraft certified after 1978, the full capacity of the engine oil system is also included in the empty weight. Information regarding residual fluids in aircraft systems that must be included in the empty weight, and whether or not full oil is included, will be indicated in the Aircraft Specifications or Type Certificate Data Sheet.

Other terms that are sometimes used when describing empty weight include basic empty weight, licensed empty weight, and standard empty weight. The term "basic empty weight" typically applies when the full capacity of the engine oil system is included in the value. The term "licensed empty weight" typically applies when only the weight of residual oil is

included in the value, so it generally involves only aircraft certified prior to 1978. Standard empty weight would be a value supplied by the aircraft manufacturer, and it would not include any optional equipment that might be installed in a particular aircraft. For most people working in the aviation maintenance field, the basic empty weight of the aircraft is the most important one.

Empty Weight Center of Gravity

The empty weight center of gravity for an aircraft is the point at which it balances when it is in an empty weight condition. The concepts of empty weight and center of gravity were discussed earlier in this chapter, and now they are being combined into a single concept.

One of the most important reasons for weighing an aircraft is to determine its empty weight center of gravity. All other weight and balance calculations, including loading the aircraft for flight, performing an equipment change calculation, and performing an adverse condition check, begin with knowing the empty weight and empty weight center of gravity. This crucial information is part of what is contained in the aircraft weight and balance report.

Useful Load

To determine the useful load of an aircraft, subtract the empty weight from the maximum allowable gross weight. For aircraft certificated in both normal and utility categories, there may be two useful loads listed in the aircraft weight and balance records. An aircraft with an empty weight of 900 lb will have a useful load of 850 lb, if the normal category maximum weight is listed as 1,750 lb. When the aircraft is operated in the utility category, the maximum gross weight may be reduced to 1,500 lb, with a corresponding decrease in the useful load to 600 lb. Some aircraft have the same useful load regardless of the category in which they are certificated.

The useful load consists of fuel, any other fluids that are not part of empty weight, passengers, baggage, pilot, copilot, and crewmembers. Whether or not the weight of engine oil is considered to be a part of useful load depends on when the aircraft was certified, and can be determined by looking at the Aircraft Specifications or Type Certificate Data Sheet. The payload of an aircraft is similar to the useful load, except it does not include fuel.

A reduction in the weight of an item, where possible, may be necessary to remain within the maximum weight allowed for the category in which an aircraft

is operating. Determining the distribution of these weights is called a weight check.

Minimum Fuel

There are times when an aircraft will have a weight and balance calculation done, known as an extreme condition check. This is a pencil and paper check in which the aircraft is loaded in as nose heavy or tail heavy a condition as possible to see if the center of gravity will be out of limits in that situation. In a forward adverse check, for example, all useful load in front of the forward CG limit is loaded, and all useful load behind this limit is left empty. An exception to leaving it empty is the fuel tank. If the fuel tank is located behind the forward CG limit, it cannot be left empty because the aircraft cannot fly without fuel. In this case, an amount of fuel is accounted for, which is known as minimum fuel. Minimum fuel is typically that amount needed for 30 minutes of flight at cruise power.

For a piston engine powered aircraft, minimum fuel is calculated based on the METO (maximum except take-off) horsepower of the engine. For each METO horsepower of the engine, one-half pound of fuel is used. This amount of fuel is based on the assumption that the piston engine in cruise flight will burn 1 lb of fuel per hour for each horsepower, or 1/2 lb for 30 minutes. The piston engines currently used in small general aviation aircraft are actually more efficient than that, but the standard for minimum fuel has remained the same.

Minimum fuel is calculated as follows:

$$\text{Minimum Fuel (pounds)} = \frac{\text{Engine METO Horsepower} \div 2}{1}$$

For example, if a forward adverse condition check was being done on a piston engine powered twin, with each engine having a METO horsepower of 500, the minimum fuel would be 250 lb (500 METO Hp \div 2).

For turbine engine powered aircraft, minimum fuel is not based on engine horsepower. If an adverse condition check is being performed on a turbine engine powered aircraft, the aircraft manufacturer would need to supply information on minimum fuel.

Tare Weight

When aircraft are placed on scales and weighed, it is sometimes necessary to use support equipment to aid in the weighing process. For example, to weigh a tail dragger airplane, it is necessary to raise the tail in order to get the airplane level. To level the airplane, a jack might be placed on the scale and used to raise

the tail. Unfortunately, the scale is now absorbing the weight of the jack in addition to the weight of the airplane. This extra weight is known as tare weight, and must be subtracted from the scale reading. Other examples of tare weight are wheel chocks placed on the scales and ground locks left in place on retractable landing gear.

Procedures for Weighing an Aircraft

General Concepts

The most important reason for weighing an aircraft is to find out its empty weight (basic empty weight), and to find out where it balances in the empty weight condition. When an aircraft is to be flown, the pilot in command must know what the loaded weight of the aircraft is, and where its loaded center of gravity is. In order for the loaded weight and center of gravity to be calculated, the pilot or dispatcher handling the flight must first know the empty weight and empty weight center of gravity.

Earlier in this chapter it was identified that the center of gravity for an object is the point about which the nose heavy and tail heavy moments are equal. One method that could be used to find this point would involve lifting an object off the ground twice, first suspending it from a point near the front, and on the second lift suspending it from a point near the back. With each lift, a perpendicular line (90 degrees) would be drawn from the suspension point to the ground. The two perpendicular lines would intersect somewhere in the object, and the point of intersection would be the center of gravity. This concept is shown in Figure 4-4, where an irregular shaped object is suspended from two different points. The perpendicular line from the first suspension point is shown in red, and the new

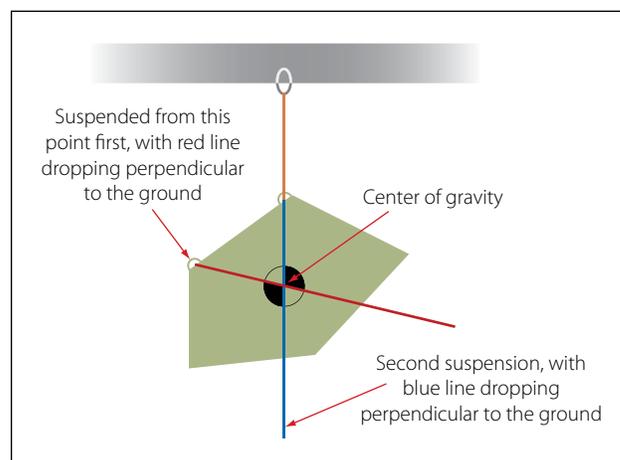


Figure 4-4. Center of gravity determined by two suspension points.

suspension point line is shown in blue. Where the red and blue lines intersect is the center of gravity.

If an airplane were suspended from two points, one at the nose and one at the tail, the perpendicular drop lines would intersect at the center of gravity the same way they do for the object in Figure 4-4. Suspending an airplane from the ceiling by two hooks, however, is clearly not realistic. Even if it could be done, determining where in the airplane the lines intersect would not be possible.

A more realistic way to find the center of gravity for an object, especially an airplane, is to place it on a minimum of two scales and to calculate the moment value for each scale reading. In Figure 4-5, there is a plank that is 200" long, with the left end being the datum (zero arm), and 6 weights placed at various locations along the length of the plank. The purpose of Figure 4-5 is to show how the center of gravity can be calculated when the arms and weights for an object are known.

To calculate the center of gravity for the object in Figure 4-5, the moments for all the weights need to be calculated and then summed, and the weights need to be summed. In the four column table in Figure 4-6, the item, weight, and arm are listed in the first three columns, with the information coming from Figure 4-5. The moment value in the fourth column is the

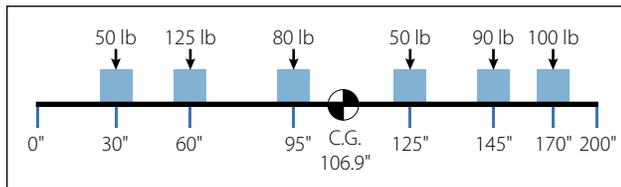


Figure 4-5. Center of gravity for weights on a plank, datum at one end.

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
50 pound weight	50	+30	1,500
125 pound weight	125	+60	7,500
80 pound weight	80	+95	7,600
50 pound weight	50	+125	6,250
90 pound weight	90	+145	13,050
100 pound weight	100	+170	17,000
Total	495	+106.9	52,900

Figure 4-6. Center of gravity calculation for weights on a plank with datum at one end.

product of the weight and arm. The weight and moment columns are summed, with the center of gravity being equal to the total moment divided by the total weight. The arm column is not summed. The number appearing at the bottom of that column is the center of gravity. The calculation would be as shown in Figure 4-6.

For the calculation shown in Figure 4-6, the total moment is 52,900 in-lb, and the total weight is 495 lb. The center of gravity is calculated as follows:

$$\begin{aligned} \text{Center of Gravity} &= \text{Total Moment} \div \text{Total Weight} \\ &= 52,900 \text{ in-lb} \div 495 \text{ lb} \\ &= 106.9" \text{ (106.87 rounded off to tenths)} \end{aligned}$$

An interesting characteristic exists for the problem presented in Figure 4-5, and the table showing the center of gravity calculation. If the datum (zero arm) for the object was in the middle of the 200" long plank, with 100" of negative arm to the left and 100" of positive arm to the right, the solution would show the center of gravity to be in the same location. The arm for the center of gravity would not be the same number, but its physical location would be the same. Figure 4-7 and Figure 4-8 show the new calculation.

$$\begin{aligned} \text{Center of Gravity} &= \text{Total Moment} \div \text{Total Weight} \\ &= 3,400 \text{ in-lb} \div 495 \text{ lb} \\ &= 6.9" \text{ (6.87 rounded off to tenths)} \end{aligned}$$

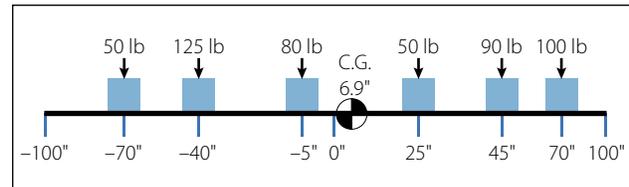


Figure 4-7. Center of gravity for weights on a plank, datum in the middle.

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
50 pound weight	50	-70	-3,500
125 pound weight	125	-40	-5,000
80 pound weight	80	-5	-400
50 pound weight	50	+25	1,250
90 pound weight	90	+45	4,050
100 pound weight	100	+70	7,000
Total	495	+6.9	3,400

Figure 4-8. Center of gravity calculation for weights on a plank with datum in the middle.

In Figure 4-7, the center of gravity is 6.9" to the right of the plank's center. Even though the arm is not the same number, in Figure 4-5 the center of gravity is also 6.9" to the right of center (CG location of 106.9 with the center being 100). Because both problems are the same in these two figures, except for the datum location, the center of gravity must be the same.

The definition for center of gravity states that it is the point about which all the moments are equal. We can prove that the center of gravity for the object in Figure 4-7 is correct by showing that the total moments on either side of this point are equal. Using 6.87 as the CG location for slightly greater accuracy, instead of the rounded off 6.9 number, the moments to the left of the CG would be as shown in Figure 4-9.

The moments to the right of the CG, as shown in Figure 4-7, would be as shown in Figure 4-10.

Disregarding the slightly different decimal value, the moment in both of the previous calculations is 10,651 in-lb. Showing that the moments are equal is a good way of proving that the center of gravity has been properly calculated.

Weight and Balance Data

In order to weigh an aircraft and calculate its empty weight and empty weight center of gravity, a technician must have access to weight and balance information

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
50 pound weight	50	76.87	3,843.50
125 pound weight	125	46.87	5,858.75
80 pound weight	80	11.87	949.60
Total	255	135.61	10,651.85

Figure 4-9. Moments to the left of the center of gravity.

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
50 pound weight	50	18.13	906.50
90 pound weight	90	38.13	3,431.70
100 pound weight	100	63.13	6,313.00
Total	240	119.39	10,651.25

Figure 4-10. Moments to the right of the center of gravity.

about the aircraft. Possible sources of weight and balance data are as follows:

- **Aircraft Specifications**—applies primarily to aircraft certified under the Civil Aeronautics Administration, when the specifications also included a list of equipment with weights and arms.
- **Aircraft Operating Limitations**—supplied by the aircraft manufacturer.
- **Aircraft Flight Manual**—supplied by the aircraft manufacturer.
- **Aircraft Weight and Balance Report**—supplied by the aircraft manufacturer when the aircraft is new, and by the technician when an aircraft is reweighed in the field.
- **Aircraft Type Certificate Data Sheet**—applies primarily to aircraft certified under the FAA and the Federal Aviation Regulations, where the equipment list with weights and arms is a separate document.

The document in Figure 4-11 is a Type Certificate Data Sheet (TCDS) for a Piper twin-engine airplane known as the Seneca (PA-34-200). The main headings for the information typically contained in a TCDS are included, but much of the information contained under these headings has been removed if it did not directly pertain to weight and balance. Information on only one model of Seneca is shown, because to show all the different models would make the document excessively long. The portion of the TCDS that has the most direct application to weight and balance is highlighted in yellow.

Some of the important weight and balance information found in a Type Certificate Data Sheet is as follows:

1. Center of gravity range
2. Maximum weight
3. Leveling means
4. Number of seats and location
5. Baggage capacity
6. Fuel capacity
7. Datum location
8. Engine horsepower
9. Oil capacity
10. Amount of fuel in empty weight
11. Amount of oil in empty weight

**DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION**

TYPE CERTIFICATE DATA SHEET NO. A7SO – REVISION 14

PIPER

PA-34-200

PA-34-200T

PA-34-220T

June 1, 2001

This data sheet, which is a part of type certificate No. A7SO, prescribes conditions and limitations under which the product for which the type certificate was issued meets the airworthiness requirements of the Federal Aviation Regulations.

Type Certificate Holder:

The New Piper Aircraft, Inc.

2926 Piper Drive

Vero Beach, Florida 32960

I. Model PA-34-200 (Seneca), 7 PCLM (Normal Category), Approved 7 May 1971.

Engines S/N 34-E4, 34-7250001 through 34-7250214:
1 Lycoming LIO-360-C1E6 with fuel injector,
Lycoming P/N LW-10409 or LW-12586 (right side); and
1 Lycoming IO-360-C1E6 with fuel injector,
Lycoming P/N LW-10409 or LW 12586 (left side).
S/N 34-7250215 through 34-7450220:
1 Lycoming LIO-360-C1E6 with fuel injector,
Lycoming P/N LW-12586 (right side); and
1 Lycoming IO-360-C1E6 with fuel injector,
Lycoming P/N LW-12586 (left side).

Fuel 100/130 minimum grade aviation gasoline

Engine Limits For all operations, 2,700 RPM (200 hp)

**Propeller and
Propeller Limits**

Left Engine

1 Hartzell, Hub Model HC-C2YK-2 () E, Blade Model C7666A-0;

1 Hartzell, Hub Model HC-C2YK-2 () EU, Blade Model C7666A-0;

1 Hartzell, Hub Model HC-C2YK-2 () EF, Blade Model FC7666A-0;

1 Hartzell, Hub Model HC-C2YK-2 () EFU, Blade Model FC7666A-0;

1 Hartzell, Hub Model HC-C2YK-2CG (F), Blade Model (F) C7666A

(This model includes the Hartzell damper); or

1 Hartzell, Hub Model HC-C2YK-2CGU (F), Blade Model (F) C7666A

(This model includes the Hartzell damper).

Note: HC-()2YK-() may be substituted for HC-()2YR-() per Hartzell Service Advisory 61.

Right Engine

1 Hartzell, Hub Model HC-C2YK-2 () LE, Blade Model JC7666A-0;

1 Hartzell, Hub Model HC-C2YK-2 () LEU, Blade Model JC7666A-0;

1 Hartzell, Hub Model HC-C2YK-2 () LEF, Blade Model FJC7666A-0;

1 Hartzell, Hub Model HC-C2YK-2 () LEFU, Blade Model FJC7666A-0;

1 Hartzell, Hub Model HC-C2YK-2CLG (F), Blade Model (F) JC7666A

(This model includes the Hartzell damper); or

Figure 4-11. Type Certificate Data Sheet.

1 Hartzell, Hub Model HC-C2YK-2CLGU (F), Blade Model (F) JC7666A
 (This model includes the Hartzell damper.)
 Note: HC-()2YK-() may be substituted for HC-()2YR-() per Hartzell Service Advisory 61.
 Pitch setting: High 79° to 81°, Low 13.5° at 30" station.
 Diameter: Not over 76", not under 74". No further reduction permitted.

Spinner: Piper P/N 96388 Spinner Assembly and P/N 96836 Cap Assembly, or
 P/N 78359-0 Spinner Assembly and P/N 96836-2 Cap Assembly (See NOTE 4)

Governor Assembly:
 1 Hartzell hydraulic governor, Model F-6-18AL (Right);
 1 Hartzell hydraulic governor, Model F-6-18A (Left).
 Avoid continuous operation between 2,200 and 2,400 RPM unless aircraft is
 equipped with Hartzell propellers which incorporate a Hartzell damper on both left
 and right engine as noted above.

Airspeed Limits	VNE (Never exceed)	217 mph	(188 knots)
	VNO (Maximum structural cruise)	190 mph	(165 knots)
	VA (Maneuvering, 4,200 lb)	146 mph	(127 knots)
	VA (Maneuvering, 4,000 lb)	146 mph	(127 knots)
	VA (Maneuvering, 2,743 lb)	133 mph	(115 knots)
	VFE (Flaps extended)	125 mph	(109 knots)
	VLO (Landing gear operating)		
	Extension	150 mph	(130 knots)
	Retract	125 mph	(109 knots)
	VLE (Landing gear extended)	150 mph	(130 knots)
VMC (Minimum control speed)	80 mph	(69 knots)	

CG Range
(Gear Extended) S/N 34-E4, 34-7250001 through 34-7250214 (See NOTE 3):
 (+86.4) to (+94.6) at 4,000 lb
 (+82.0) to (+94.6) at 3,400 lb
 (+80.7) to (+94.6) at 2,780 lb
 S/N 34-7250215 through 34-7450220:
 (+87.9) to (+94.6) at 4,200 lb
 (+82.0) to (+94.6) at 3,400 lb
 (+80.7) to (+94.6) at 2,780 lb
 Straight line variation between points given.
 Moment change due to gear retracting landing gear (-32 in-lb)

Empty Weight
CG Range None

Maximum Weight S/N 34-E4, 34-7250001 through 34-7250214:
 4,000 lb – Takeoff
 4,000 lb – Landing
 See NOTE 3.

Maximum Weight S/N 34-7250215 through 34-7450220:
 4,200 lb – Takeoff
 4,000 lb – Landing

No. of Seats 7 (2 at +85.5, 3 at +118.1, 2 at +155.7)

Maximum Baggage 200 lb (100 lb at +22.5, 100 lb at +178.7)

Figure 4-11. Type Certificate Data Sheet. (continued)

Fuel Capacity 98 gallons (2 wing tanks) at (+93.6) (93 gallons usable)
See NOTE 1 for data on system fuel.

Oil Capacity 8 qt per engine (6 qt per engine usable)
See NOTE 1 for data on system oil.

Control Surface Movements

Ailerons	(±2°)	Up 30°	Down 15°
Stabilator		Up 12.5° (+0,-1°)	Down 7.5° (±1°)
Rudder	(±1°)	Left 35°	Right 35°
Stabilator Trim Tab (Stabilator neutral)	(±1°)	Down 10.5°	Up 6.5°
Wing Flaps	(±2°)	Up 0°	Down 40°
Rudder Trim Tab (Rudder neutral)	(±1°)	Left 17°	Right 22°
Nosewheel		S/N 34-E4, 34-7250001 through 34-7350353:	
Travel	(±1°)	Left 21°	Right 21°
Nosewheel		S/N 34-7450001 through 34-7450220:	
Travel	(±1°)	Left 27°	Right 27°

Manufacturer's Serial Numbers 3449001 and up.

DATA PERTINENT TO ALL MODELS

Datum 78.4" forward of wing leading edge from the inboard edge of the inboard fuel tank.

Leveling Means Two screws left side fuselage below window.

Certification Basis Type Certificate No. A7SO issued May 7, 1971, obtained by the manufacturer under the delegation option authorization. Date of Type Certificate application July 23, 1968.

Model PA-34-200 (Seneca I):

14 CFR part 23 as amended by Amendment 23-6 effective August 1, 1967;
14 CFR part 23.959 as amended by Amendment 23-7 effective September 14, 1969;
and 14 CFR part 23.1557(c)(1) as amended by Amendment 23-18 effective May 2, 1977. Compliance with 14 CFR part 23.1419 as amended by Amendment 23-14 effective December 20, 1973, has been established with optional ice protection provisions.

Production Basis Production Certificate No. 206. Production Limitation Record issued and the manufacturer is authorized to issue an airworthiness certificate under the delegation option provisions of 14 CFR part 21.

Equipment The basic required equipment as prescribed in the applicable airworthiness regulations (see Certification Basis) must be installed in the aircraft for certification. In addition, the following items of equipment are required:

Figure 4-11. Type Certificate Data Sheet. (continued)

MODEL	AFM/POH	REPORT #	APPROVED	SERIAL EFFECTIVITY
PA-34-200(Seneca)	AFM	VB-353	7/2/71	34-E4, 34-7250001 through 34-7250214
	AFM	VB-423	5/20/72	34-7250001 through 34-7250189 when Piper Kit 760-607 is installed; 34-7250190 through 34-7250214 when Piper Kit 760-611 is installed; and 34-7250215 through 34-7350353
	AFM	VB-563	5/14/73	34-7450001 through 34-7450220
	AFM Supp.	VB-588	7/20/73	34-7250001 through 34-7450039 when propeller with dampers are installed
	AFM Supp.	VB-601	11/9/73	34-7250001 through 34-745017 when ice protection system is installed

NOTES

NOTE 1 Current Weight and Balance Report, including list of equipment included in certificated empty weight, and loading instructions when necessary, must be provided for each aircraft at the time of original certification. The certificated empty weight and corresponding center of gravity locations must include undrainable system oil (not included in oil capacity) and unusable fuel as noted below:

- Fuel: 30.0 lb at (+103.0) for PA-34 series, except Model PA-34-220T (Seneca V), S/N 3449001 and up
- Fuel: 36.0 lb at (+103.0) for Model PA-34-220T (Seneca V), S/N 3449001 and up
- Oil: 6.2 lb at (+ 39.6) for Model PA-34-200
- Oil: 12.0 lb at (+ 43.7) for Models PA-34-200T and PA-34-220T

NOTE 2 All placards required in the approved Airplane Flight Manual or Pilot’s Operating Handbook and approved Airplane Flight Manual or Pilot’s Operating Handbook supplements must be installed in the appropriate location.

NOTE 3 The Model PA-34-200; S/N 34-E4, 34-7250001 through 34-7250189, may be operated at a maximum takeoff weight of 4,200 lb when Piper Kit 760-607 is installed. S/N 34-7250190 through 34-7250214 may be operated at a maximum takeoff weight of 4,200 lb when Piper Kit 760-611 is installed.

NOTE 4 The Model PA-34-200; S/N 34-E4, 34-7250001 through 34-7250189, may be operated without spinner domes or without spinner domes and rear bulkheads when Piper Kit 760-607 has been installed. -----

NOTE 5 The Model PA-34-200 may be operated in known icing conditions when equipped with spinner assembly and the following kits: -----

NOTE 6 Model PA-34-200T; S/N 34-7570001 through 34-8170092, may be operated in known icing conditions when equipped with deicing equipment installed per Piper Drawing No. 37700 and spinner assembly.

Figure 4-11. Type Certificate Data Sheet. (continued)

- NOTE 7** The following serial numbers are not eligible for import certification to the United States: -----
- NOTE 8** Model PA-34-200; S/N 34-E4, S/N 34-7250001 through 34-7450220, and Model PA-34-200T; S/N 34-7570001 through 34-8170092, and Model PA-34-220T may be operated subject to the limitations listed in the Airplane Flight Manual or Pilot’s Operating Handbook with rear cabin and cargo door removed.
- NOTE 9** In the following serial numbered aircraft, rear seat location is farther aft as shown and the center seats may be removed and replaced by CLUB SEAT INSTALLATION, which has a more aft CG location as shown in “No. of Seats,” above:PA-34-200T: S/N 34-7770001 through 34-8170092.
- NOTE 10** These propellers are eligible on Teledyne Continental L/TSIO-360-E only.
- NOTE 11** With Piper Kit 764-048V installed weights are as follows: 4,407 lb – Takeoff 4,342 lb - Landing (All weight in excess of 4,000 lb must be fuel) Zero fuel weight may be increased to a maximum of 4,077.7 lb when approved wing options are installed (See POH VB-1140).
- NOTE 12** With Piper Kit 764-099V installed, weights are as follows: 4,430 lb - Ramp 4,407 lb - Takeoff, Landing, and Zero Fuel (See POH VB-1150).
- NOTE 13** With Piper Kit 766-203 installed, weights are as follows: 4,430 lb - Ramp 4,407 lb - Takeoff, Landing and Zero Fuel (See POH VB-1259).
- NOTE 14** With Piper Kit 766-283 installed, weights are as follows: 4,430 lb - Ramp 4,407 lb - Takeoff, Landing and Zero Fuel (See POH VB-1558).
- NOTE 15** With Piper Kit 766-608 installed, weights are as follows: 4,430 lb - Ramp 4,407 lb - Takeoff, Landing and Zero Fuel (See POH VB-1620).
- NOTE 16** With Piper Kit 766-632 installed, weights are as follows: 4,430 lb - Ramp 4,407 lb - Takeoff, Landing and Zero Fuel (See POH VB-1649).
- NOTE 17** The bolt and stack-up that connect the upper drag link to the nose gear trunnion are required to be replaced every 500 hours’ time-in-service. -----

Figure 4-11. Type Certificate Data Sheet. (continued)

Weight and Balance Equipment

Scales

Two types of scales are typically used to weigh aircraft: those that operate mechanically with balance weights or springs, and those that operate electronically with what are called load cells. The balance weight type of mechanical scale, known as a beam scale, is similar to that found in a doctor's office, in which a bar rises up when weight is put on the scale. A sliding weight is then moved along the bar until the bar is centered between a top and bottom stop.

The sliding weight provides the capability to measure up to 50 lb, and the cup holds fixed weights that come in 50 lb equivalent units. As an example of this scale in use, let's say the nosewheel of a small airplane is placed on the scale with an applied weight of 580 lb. To find out what the applied weight is, a technician would place 550 lb of equivalent weight in the cup, and then slide the weight on the beam out to the 30 lb point. The 580 lb applied by the nosewheel would now be balanced by the 580 lb of equivalent weight, and the end of the beam would be centered between the top and bottom stop.

A mechanical scale based on springs is like the typical bathroom scale. When weight is applied to the scale, a spring compresses, which causes a wheel that displays the weight to rotate. It would be difficult to use this type of scale to weigh anything other than a very small aircraft, because these scales typically measure only up to 300 lb. The accuracy of this type of scale is also an issue.

Electronic scales that utilize load cells come in two varieties: the platform type and the type that mounts to the top of a jack. The platform type of electronic scale sits on the ground, with the tire of the airplane sitting on top of the platform. Built into the platform is an electronic load cell, which senses the weight being applied to it and generates a corresponding electrical signal. Inside the load cell there is an electronic grid that experiences a proportional change in electrical resistance as the weight being applied to it increases. An electrical cable runs from the platform scale to a display unit, which interprets the resistance change of the load cell and equates it to a specific number of pounds. A digital readout on the display typically shows the weight. In Figure 4-12, a Piper Archer is being weighed using platform scales that incorporate electronic load cells. In this case, the platform scales are secured to the hangar floor and stay permanently in place.



Figure 4-12. Weighing a Piper Archer using electronic platform scales.

In Figure 4-13, a Mooney M20 airplane is being weighed with portable electronic platform scales. Notice in the picture of the Mooney that its nose tire is deflated (close-up shown in the lower right corner of the photo). This was done to get the airplane in a level flight attitude. This type of scale is easy to transport and can be powered by household current or by a battery contained in the display unit. The display unit for these scales is shown in Figure 4-14.

The display unit for the portable scales is very simple to operate. [Figure 4-14] In the lower left corner is the power switch, and in the lower right is the switch for selecting pounds or kilograms. The red, green, and yellow knobs are potentiometers for zeroing the three scales, and next to them are the on/off switches for the scales. Before the weight of the airplane is placed on the scales, each scale switch is turned on and the potentiometer knob turned until the digital display reads zero. In Figure 4-14, the nose scale is turned on and the readout of 546 lb is for the Mooney airplane in Figure 4-13. If all three scale switches are turned on at the same time, the total weight of the airplane will be displayed.

The second type of electronic scale utilizes a load cell that attaches to the top of a jack. The top of the load cell has a concave shape that matches up with the jack pad on the aircraft, with the load cell absorbing all the weight of the aircraft at each jacking point. Each load cell has an electrical cable attached to it, which connects to the display unit that shows the weight being absorbed by each load cell. An important advantage of weighing an aircraft this way is that it allows the technician to level the aircraft. An aircraft needs to be in a flight level attitude when it is weighed. If an aircraft is sitting on floor scales, the only way to level the aircraft might be to deflate tires and landing gear



Figure 4-13. Mooney M20 being weighed with portable electronic platform scales.

struts. When an aircraft is weighed using load cells on jacks, leveling the aircraft is easy by simply adjusting the height with the jacks. Figure 4-15 shows a regional jet on jacks with the load cells in place.

Spirit Level

Before an aircraft can be weighed and reliable readings obtained, it must be in a level flight attitude. One method that can be used to check for a level condition is to use a spirit level, sometimes thought of as a carpenter’s level, by placing it on or against a specified place on the aircraft. Spirit levels consist of a vial full of liquid, except for a small air bubble. When the air bubble is centered between the two black lines, a level condition is indicated.

In Figure 4-16, a spirit level is being used on a Mooney M20 to check for a flight level attitude. By looking in the Type Certificate Data Sheet, it is determined that the leveling means is two screws on the left side of the airplane fuselage, in line with the trailing edge of the wing.

Plumb Bob

A plumb bob is a heavy metal object, cylinder or cone shape, with a sharp point at one end and a string attached to the other end. If the string is attached to a given point on an aircraft, and the plumb bob is allowed to hang down so the tip just touches the ground, the point where the tip touches will be perpendicular to where the string is attached. An example of the use of



Figure 4-14. Display unit showing nosewheel weight for Mooney M20.



Figure 4-15. Airplane on jacks with load cells in use.



Figure 4-16. Spirit level being used on a Mooney M20.

a plumb bob would be measuring the distance from an aircraft's datum to the center of the main landing gear axle. If the leading edge of the wing was the datum, a plumb bob could be dropped from the leading edge and a chalk mark made on the hangar floor. The plumb bob could also be dropped from the center of the axle on the main landing gear, and a chalk mark made on the floor. With a tape measure, the distance between the two chalk marks could be determined, and the arm for the main landing gear would be known. Plumb bobs can also be used to level an aircraft, described on page 4-27 of the Helicopter Weight and Balance section of this chapter. Figure 4-17 shows a plumb bob being dropped from the leading edge of an aircraft wing.

Hydrometer

When an aircraft is weighed with full fuel in the tanks, the weight of the fuel must be accounted for by mathematically subtracting it from the scale readings. To subtract it, its weight, arm, and moment must be known. Although the standard weight for aviation gasoline is 6.0 lb/gal and jet fuel is 6.7 lb/gal, these values are not exact for all conditions. On a hot day versus a cold day, these values can vary dramatically. On a hot summer day in the state of Florida, aviation gasoline checked with a hydrometer typically weighs between 5.85 and 5.9 lb/gal. If 100 gallons of fuel were involved in a calculation, using the actual weight versus the standard weight would make a difference of 10 to 15 lb.

When an aircraft is weighed with fuel in the tanks, the weight of fuel per gallon should be checked with a hydrometer. A hydrometer consists of a weighted glass tube which is sealed, with a graduated set of markings on the side of the tube. The graduated markings and their corresponding number values represent units



Figure 4-17. Plumb bob dropped from a wing leading edge.

of pounds per gallon. When placed in a flask with fuel in it, the glass tube floats at a level dependent on the density of the fuel. Where the fuel intersects the markings on the side of the tube indicates the pounds per gallon.

Preparing an Aircraft for Weighing

Weighing an aircraft is a very important and exacting phase of aircraft maintenance, and must be carried out with accuracy and good workmanship. Thoughtful preparation saves time and prevents mistakes.

To begin, assemble all the necessary equipment, such as:

1. Scales, hoisting equipment, jacks, and leveling equipment.
2. Blocks, chocks, or sandbags for holding the airplane on the scales.
3. Straightedge, spirit level, plumb bobs, chalk line, and a measuring tape.
4. Applicable Aircraft Specifications and weight and balance computation forms.

If possible, aircraft should be weighed in a closed building where there are no air currents to cause incorrect scale readings. An outside weighing is permissible if wind and moisture are negligible.

Fuel System

When weighing an aircraft to determine its empty weight, only the weight of residual (unusable) fuel should be included. To ensure that only residual fuel is accounted for, the aircraft should be weighed in one of the following three conditions.

1. Weigh the aircraft with absolutely no fuel in the aircraft tanks or fuel lines. If an aircraft is weighed

in this condition, the technician can mathematically add the proper amount of residual fuel to the aircraft, and account for its arm and moment. The proper amount of fuel can be determined by looking at the Aircraft Specifications or Type Certificate Data Sheet.

2. Weigh the aircraft with only residual fuel in the tanks and lines.
3. Weigh the aircraft with the fuel tanks completely full. If an aircraft is weighed in this condition, the technician can mathematically subtract the weight of usable fuel, and account for its arm and moment. A hydrometer can be used to determine the weight of each gallon of fuel, and the Aircraft Specifications or Type Certificate Data Sheet can be used to identify the fuel capacity. If an aircraft is to be weighed with load cells attached to jacks, the technician should check to make sure it is permissible to jack the aircraft with the fuel tanks full. It is possible that this may not be allowed because of stresses that would be placed on the aircraft.

Never weigh an aircraft with the fuel tanks partially full, because it will be impossible to determine exactly how much fuel to account for.

Oil System

For aircraft certified since 1978, full engine oil is typically included in an aircraft's empty weight. This can be confirmed by looking at the Type Certificate Data Sheet. If full oil is to be included, the oil level needs to be checked and the oil system serviced if it is less than full. If the Aircraft Specifications or Type Certificate Data Sheet specifies that only residual oil is part of empty weight, this can be accommodated by one of the following two methods.

1. Drain the engine oil system to the point that only residual oil remains.
2. Check the engine oil quantity, and mathematically subtract the weight of the oil that would leave only the residual amount. The standard weight for lubricating oil is 7.5 lb/gal (1.875 pounds per quart (lb/qt)), so if 7 qt of oil needed to be removed, the technician would subtract 13.125 lb at the appropriate arm.

Miscellaneous Fluids

Unless otherwise noted in the Aircraft Specifications or manufacturer's instructions, hydraulic reservoirs and systems should be filled, drinking and washing water

reservoirs and lavatory tanks should be drained, and constant speed drive oil tanks should be filled.

Flight Controls

The position of such items as spoilers, slats, flaps, and helicopter rotor systems is an important factor when weighing an aircraft. Always refer to the manufacturer's instructions for the proper position of these items.

Other Considerations

Inspect the aircraft to see that all items included in the certificated empty weight are installed in the proper location. Remove items that are not regularly carried in flight. Also look in the baggage compartments to make sure they are empty. Replace all inspection plates, oil and fuel tank caps, junction box covers, cowling, doors, emergency exits, and other parts that have been removed. All doors, windows, and sliding canopies should be in their normal flight position. Remove excessive dirt, oil, grease, and moisture from the aircraft.

Some aircraft are not weighed with the wheels on the scales, but are weighed with the scales placed either at the jacking points or at special weighing points. Regardless of what provisions are made for placing the aircraft on the scales or jacks, be careful to prevent it from falling or rolling off, thereby damaging the aircraft and equipment. When weighing an aircraft with the wheels placed on the scales, release the brakes to reduce the possibility of incorrect readings caused by side loads on the scales.

All aircraft have leveling points or lugs, and care must be taken to level the aircraft, especially along the longitudinal axis. With light, fixed-wing airplanes, the lateral level is not as critical as it is with heavier airplanes. However, a reasonable effort should be made to level the light airplanes along the lateral axis. Helicopters must be level longitudinally and laterally when they are weighed. Accuracy in leveling all aircraft longitudinally cannot be overemphasized.

Weighing Points

When an aircraft is being weighed, the arms must be known for the points where the weight of the aircraft is being transferred to the scales. If a tricycle gear small airplane has its three wheels sitting on floor scales, the weight transfer to each scale happens through the center of the axle for each wheel. If an airplane is weighed while it is on jacks, the weight transfer happens through the center of the jack pad. For a helicopter

with skids for landing gear, determining the arm for the weighing points can be difficult if the skids are sitting directly on floor scales. The problem is that the skid is in contact with the entire top portion of the scale, and it is impossible to know exactly where the center of weight transfer is occurring. In such a case, place a piece of pipe between the skid and the scale, and the center of the pipe will now be the known point of weight transfer.

The arm for each of the weighing points is the distance from the center of the weight transfer point to the aircraft's datum. If the arms are not known, based on previous weighing of the aircraft or some other source of data, they must be measured when the aircraft is weighed. This involves dropping a plumb bob from the center of each weighing point and from the aircraft datum, and putting a chalk mark on the hangar floor representing each point. The perpendicular distance between the datum and each of the weighing points can then be measured. In Figure 4-18, the distance from the nosewheel centerline to the datum is being measured on a Cessna 310 airplane. Notice the chalk lines on the hangar floor, which came as a result of dropping a plumb bob from the nosewheel axle centerline and from the datum. The nosewheel sitting on an electronic scale can be seen in the background.



Figure 4-18. Measuring the nosewheel arm on a Cessna 310.

Center of Gravity Range

The center of gravity range for an aircraft is the limits within which the aircraft must balance. It is identified as a forward most limit (arm) and an aft most limit (arm). In the Type Certificate Data Sheet for the Piper Seneca airplane, shown earlier in this chapter, the range is given as follows:

CG Range: (Gear Extended)

S/N 34-E4, 34-7250001 through
34- 7250214 (See NOTE 3):

(+86.4") to (+94.6") at 4,000 lb

(+82.0") to (+94.6") at 3,400 lb

(+80.7") to (+94.6") at 2,780 lb

Straight line variation between points
given.

Moment change due to gear retracting
landing gear (-32 in-lb)

Because the Piper Seneca is a retractable gear airplane, the specifications identify that the range applies when the landing gear is extended, and that the airplane's total moment will be decreased by 32 when the gear retracts. To know how much the center of gravity will

change when the gear is retracted, the moment of 32 in-lb would need to be divided by the loaded weight of the airplane. For example, if the airplane weighed 3,500 lb, the center of gravity would move forward 0.009" ($32 \div 3500$).

Based on the numbers given, up to a loaded weight of 2,780 lb, the forward CG limit is +80.7" and the aft CG limit is +94.6". As the loaded weight of the airplane increases to 3,400 lb and eventually to the maximum of 4,000 lb, the forward CG limit moves aft. In other words, as the loaded weight of the airplane increases, the CG range gets smaller. The range gets smaller as a result of the forward limit moving back, while the aft limit stays in the same place.

The data sheet identifies that there is a straight line variation between the points given. The points being referred to are the forward and aft center of gravity limits. From a weight of 2,780 lb to a weight of 3,400 lb, the forward limit moves from +80.7" to +82.0", and if plotted on a graph, that change would form a straight line. From 3,400 lb to 4,000 lb, the forward limit moves from +82 to +86.4", again forming a straight line. Plotted on a graph, the CG limits would look like what is shown in Figure 4-19. When graphically plotted, the CG limits form what is known as the CG envelope.

In Figure 4-19, the red line represents the forward limit up to a weight of 2,780 lb. The blue and green lines represent the straight line variation that occurs for the forward limit as the weight increases up to a maximum of 4,000 lb. The yellow line represents the maximum weight for the airplane, and the purple line represents the aft limit.

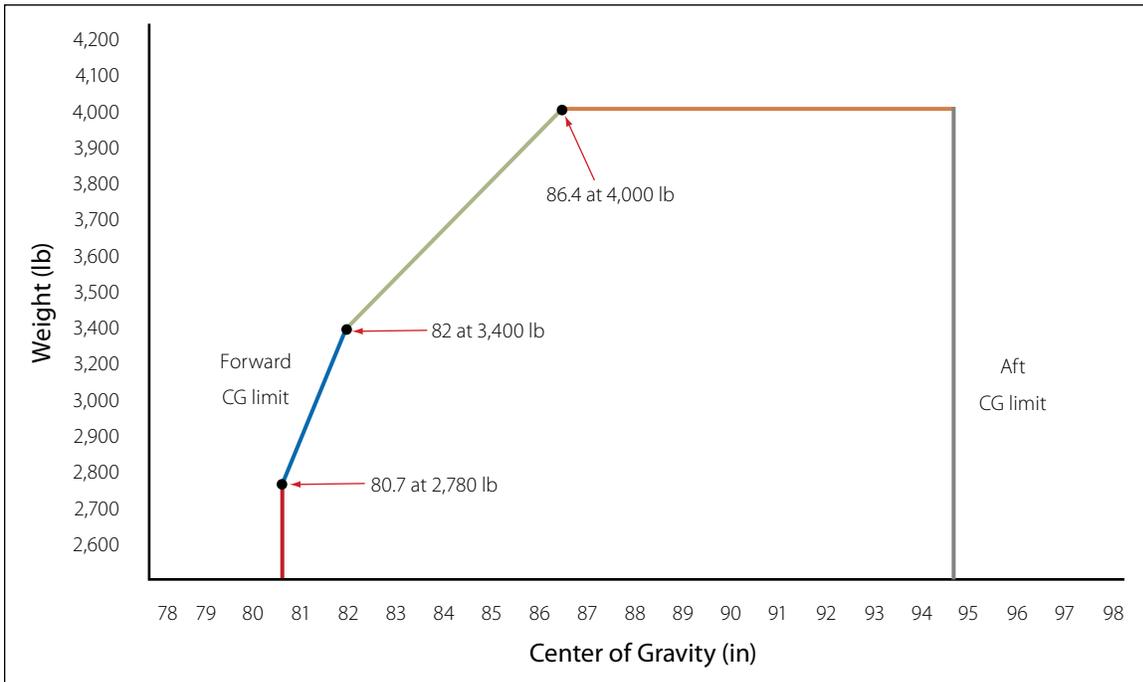


Figure 4-19. Center of gravity envelope for the Piper Seneca.

Empty Weight Center of Gravity Range

For some aircraft, a center of gravity range is given for the aircraft in the empty weight condition. This practice is not very common with airplanes, but is often done for helicopters. This range would only be listed for an airplane if it was very small and had limited positions for people and fuel. If the empty weight CG of an aircraft falls within the empty weight CG limits, it is known that the loaded CG of the aircraft will be within limits if standard loading is used. This information will be listed in the Aircraft Specifications or Type Certificate Data Sheet, and if it does not apply, it will be identified as “none.”

Operating Center of Gravity Range

All aircraft will have center of gravity limits identified for the operational condition, with the aircraft loaded and ready for flight. If an aircraft can operate in more than one category, such as normal and utility, more than one set of limits might be listed. As shown earlier for the Piper Seneca airplane, the limits can change as the weight of the aircraft increases. In order to legally fly, the center of gravity for the aircraft must fall within the CG limits.

Standard Weights Used for Aircraft Weight and Balance

Unless the specific weight for an item is known, the standard weights used in aircraft weight and balance are as follows:

- Aviation gasoline 6 lb/gal
- Turbine fuel 6.7 lb/gal
- Lubricating oil 7.5 lb/gal
- Water 8.35 lb/gal
- Crew and passengers 170 lb per person

Example Weighing of an Airplane

In Figure 4-20, a tricycle gear airplane is being weighed by using three floor scales. The specifications on the airplane and the weighing specific data are as follows:

- Aircraft Datum: Leading edge of the wing
- Leveling Means: Two screws, left side of fuselage below window
- Wheelbase: 100"
- Fuel Capacity: 30 gal aviation gasoline at +95"
- Unusable Fuel: 6 lb at +98"
- Oil Capacity: 8 qt at -38"
- Note 1: Empty weight includes unusable fuel and full oil
- Left Main Scale Reading: 650 lb
- Right Main Scale Reading: 640 lb
- Nose Scale Reading: 225 lb

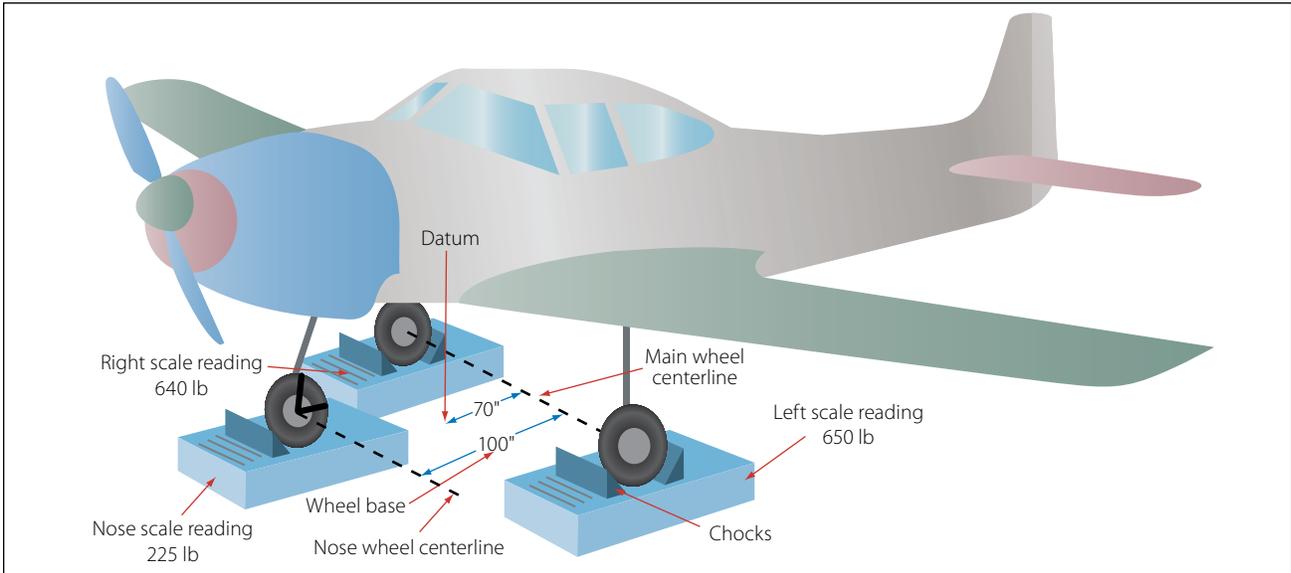


Figure 4-20. Example airplane being weighed.

- Tare Weight: 5 lb chocks on left main
5 lb chocks on right main
2.5 lb chock on nose
- During Weighing: Fuel tanks full and oil full
Hydrometer check on fuel shows 5.9 lb/gal
- Because wheel chocks are used to keep the airplane from rolling off the scales, their weight must be subtracted from the scale readings as tare weight.
- Because the main wheel centerline is 70" behind the datum, its arm is a +70".
- The arm for the nosewheel is the difference between the wheelbase (100") and the distance from the datum to the main wheel centerline (70"). Therefore, the arm for the nosewheel is -30".

By analyzing the data identified for the airplane being weighed in Figure 4-20, the following needed information is determined.

- Because the airplane was weighed with the fuel tanks full, the full weight of the fuel must be subtracted and the unusable fuel added back in. The weight of the fuel being subtracted is based on the pounds per gallon determined by the hydrometer check (5.9 lb/gal).

To calculate the airplane's empty weight and empty weight center of gravity, a six column chart is used. Figure 4-21 shows the calculation for the airplane in Figure 4-20.

Item	Weight (lb)	Tare (lb)	Net Wt. (lb)	Arm (inches)	Moment (in-lb)
Nose	225	-2.5	222.5	-30	-6,675
Left Main	650	-5	645	+70	45,150
Right Main	640	-5	635	+70	44,450
Subtotal	1,515	-12.5	1,502.5		82,925
Fuel Total			-177	+95	-16,815
Fuel Unuse			+6	+98	588
Oil			Full		
Total			1,331.5	+50.1	66,698

Figure 4-21. Center of gravity calculation for airplane being weighed.

Based on the calculation shown in the chart, the center of gravity is at +50.1", which means it is 50.1" aft of the datum. This places the center of gravity forward of the main landing gear, which must be the case for a tricycle gear airplane. This number is the result of dividing the total moment of 66,698 in-lb by the total weight of 1,331.5 lb.

Loading an Aircraft for Flight

The ultimate test of whether or not there is a problem with an airplane's weight and balance is when it is loaded and ready to fly. The only real importance of an airplane's empty weight and empty weight center of gravity is how it affects the loaded weight and balance of the airplane, since an airplane doesn't fly when it is empty. The pilot in command is responsible for the weight and balance of the loaded airplane, and he or she makes the final decision on whether or not the airplane is safe to fly.

Example Loading of an Airplane

As an example of an airplane being loaded for flight, the Piper Seneca twin will be used. The Type Certificate Data Sheet for this airplane was shown earlier in this chapter, and its center of gravity range and CG envelope were also shown.

The information from the Type Certificate Data Sheet that pertains to this example loading is as follows:

CG Range

(Gear Extended) S/N 34-7250215 through 34-7450220:
 (+87.9") to (+94.6") at 4,200 lb
 (+82.0") to (+94.6") at 3,400 lb
 (+80.7") to (+94.6") at 2,780 lb
 Straight line variation between points given.
 -32 in-lb moment change due to gear retracting landing gear

Empty Weight

CG Range None

Maximum Weight

S/N 34-7250215 through 34-7450220:
 4,200 lb— Takeoff
 4,000 lb— Landing

No. of Seats

7 (2 at +85.5", 3 at +118.1", 2 at +155.7")

Maximum

Baggage 200 lb (100 lb at +22.5, 100 lb at +178.7)

Fuel Capacity 98 gal (2 wing tanks) at (+93.6") (93 gal usable). See NOTE 1 for data on system fuel.

For the example loading of the airplane, the following information applies:

- Airplane Serial Number: 34-7250816
- Airplane Empty Weight: 2,650 lb
- Airplane Empty Weight CG: +86.8"

For today's flight, the following useful load items will be included:

- 1 pilot at 180 lb at an arm of +85.5"
- 1 passenger at 160 lb at an arm of +118.1"
- 1 passenger at 210 lb at an arm of +118.1"
- 1 passenger at 190 lb at an arm of +118.1"
- 1 passenger at 205 lb at an arm of +155.7"
- 50 lb of baggage at +22.5"
- 100 lb of baggage at +178.7"
- 80 gal of fuel at +93.6"

To calculate the loaded weight and CG of this airplane, a four column chart will be used, as shown in Figure 4-22.

Based on the information in the Type Certificate Data Sheet, the maximum takeoff weight of this airplane is 4,200 lb, and the aft-most CG limit is +94.6". The loaded airplane in the chart above is 25 lb too heavy, and the CG is 1.82" too far aft. To make the airplane

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Empty Weight	2,650	+86.80	230,020.0
Pilot	180	+85.50	15,390.0
Passenger	160	+118.10	18,896.0
Passenger	210	+118.10	24,801.0
Passenger	190	+118.10	22,439.0
Passenger	205	155.70	31,918.5
Baggage	50	+178.70	1,125.0
Baggage	100	+93.60	17,870.0
Fuel	480	11.87	44,928.0
Total	4,255	+96.42	407,387.5

Figure 4-22. Center of gravity calculation for Piper Seneca.

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Empty Weight	2,650	+86.8	230,020.0
Pilot	180	+85.5	15,390.0
Passenger	210	+85.5	17,955.0
Passenger	160	+118.1	24,801.0
Passenger	190	+118.1	22,439.0
Passenger	205	+118.1	24,210.5
Baggage	100	+22.5	2,250.0
Baggage	25	+178.7	4,467.5
Fuel	480	93.6	44,928.0
Total	4,200	+92.0	386,461.0

Figure 4-23. Center of gravity calculation for Piper Seneca with weights shifted.

safe to fly, the load needs to be reduced by 25 lb and some of the load needs to be shifted forward. For example, the baggage can be reduced by 25 lb, and a full 100 lb of it can be placed in the more forward compartment. One passenger can be moved to the forward seat next to the pilot, and the aft-most passenger can then be moved forward. If these changes are made, the four column calculation will be as shown in Figure 4-23.

With the changes made, the loaded weight is now at the maximum allowable of 4,200 lb, and the CG has moved forward 4.41". The airplane is now safe to fly.

Weight and Balance Extreme Conditions

A weight and balance extreme condition check, sometimes called an adverse condition check, involves loading the aircraft in as nose heavy or tail heavy a condition as possible, and seeing if the center of gravity falls outside the allowable limits. This check is done with pencil and paper. In other words, the aircraft is not actually loaded in an adverse way and an attempt made to fly it.

On what is called a forward extreme condition check, all useful load items in front of the forward CG limit are loaded, and all useful load items behind the forward CG limit are left empty. So if there are two seats and a baggage compartment located in front of the forward CG limit, two people weighing 170 lb each will be put in the seats, and the maximum allowable baggage will be put in the baggage compartment. Any seat or baggage compartment located behind the forward CG limit will be left empty. If the fuel is located behind

the forward CG limit, minimum fuel will be shown in the tank. Minimum fuel is calculated by dividing the engine's METO horsepower by 2.

On an aft extreme condition check, all useful load items behind the aft CG limit are loaded, and all useful load items in front of the aft CG limit are left empty. Even though the pilot's seat will be located in front of the aft CG limit, the pilot's seat cannot be left empty. If the fuel tank is located forward of the aft CG limit, minimum fuel will be shown.

Example Forward and Aft Extreme Condition Checks

Using the stick airplane in Figure 4-24 as an example, adverse forward and aft checks will be calculated. Some of the data for the airplane is shown in the figure, such as seat, baggage, and fuel information. The center of gravity limits are shown, with arrows pointing in the direction where maximum and minimum weights will be loaded. On the forward check, any useful load item located in front of 89" will be loaded, and anything behind that location will be left empty. On the aft check, maximum weight will be added behind 99" and minimum weight in front of that location. For either of the checks, if fuel is not located in a maximum weight location, minimum fuel must be accounted for. Notice that the front seats show a location of 82" to 88", meaning they are adjustable fore and aft. In a forward check, the pilot's seat will be shown at 82", and in the aft check it will be at 88". Additional specifications for the airplane shown in Figure 4-24 are as follows:

- Airplane Empty Weight: 1,850 lb
- Empty Weight CG: +92.45"
- CG Limits: +89" to +99"
- Maximum Weight: 3,200 lb
- Fuel Capacity: 45 gal at +95" (44 usable)
40 gal at +102" (39 usable)

In evaluating the two extreme condition checks, the following key points should be recognized.

- The total arm is the airplane center of gravity, and is found by dividing the total moment by the total weight.
- For the forward check, the only thing loaded behind the forward limit was minimum fuel.
- For the forward check, the pilot and passenger seats were shown at the forward position of 82".

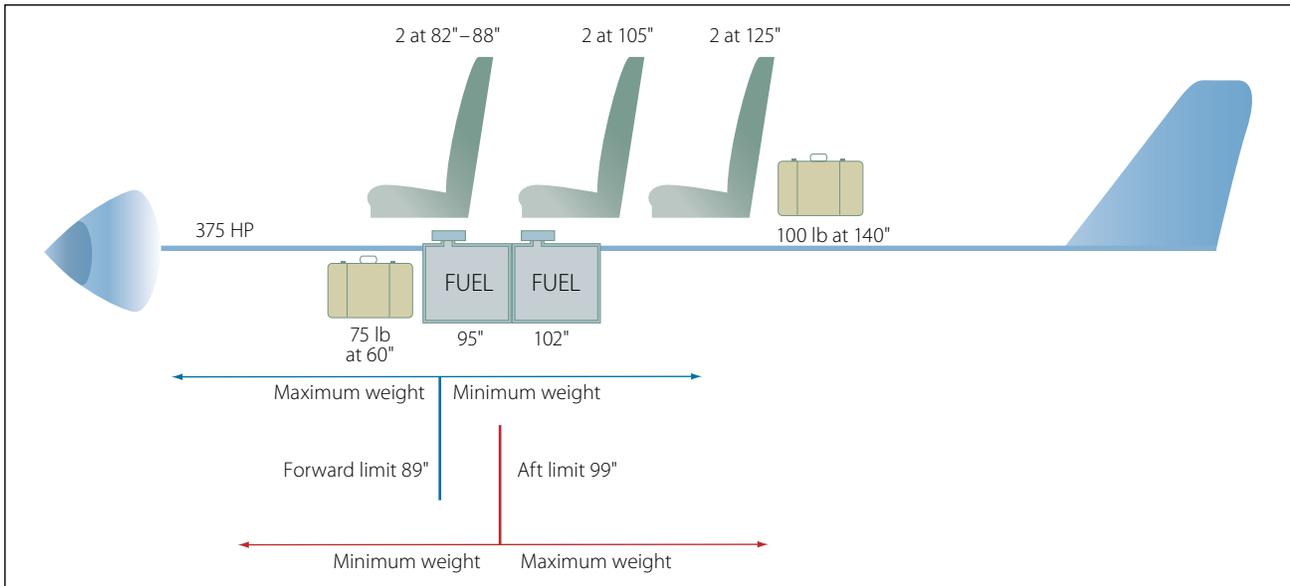


Figure 4-24. Example airplane for extreme condition checks.

- For the forward check, the CG was within limits, so the airplane could be flown this way.
- For the aft check, the only thing loaded in front of the aft limit was the pilot, at an arm of 88".
- For the aft check, the fuel tank at 102" was filled, which more than accounted for the required minimum fuel.
- For the aft check, the CG was out of limits by 0.6", so the airplane should not be flown this way.

Extreme Condition Forward Check			
Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Empty Weight	1,850.0	+92.45	171,032.5
Pilot	170.0	+82.00	13,940.0
Passenger	170.0	+82.00	13,940.0
Baggage	75.0	+60.00	4,500.0
Fuel	187.5	+95.00	17,812.5
Total	2,452.5	+90.20	221,225.0

Extreme Condition Aft Check			
Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Empty Weight	1,850	+92.45	171,032.5
Pilot	170	+88.00	14,960.0
2 Passengers	340	+105.00	35,700.0
2 Passengers	340	+125.00	42,500.0
Baggage	100	+140.00	14,000.0
Fuel	234	+102.00	23,868.0
Total	3,034	+99.60	302,060.5

Figure 4-25. Center of gravity extreme condition checks.

Equipment Change and Aircraft Alteration

When the equipment in an aircraft is changed, such as the installation of a new radar system or ground proximity warning system, or the removal of a radio or seat, the weight and balance of an aircraft will change. An alteration performed on an aircraft, such as a cargo door being installed or a reinforcing plate being attached to the spar of a wing, will also change the weight and balance of an aircraft. Any time the equipment is changed or an alteration is performed, the new empty weight and empty weight center of gravity must be determined. This can be accomplished by placing the aircraft on scales and weighing it, or by mathematically calculating the new weight and balance. The mathematical calculation is acceptable if the exact weight and arm of all the changes are known.

Example Calculation After an Equipment Change

A small twin-engine airplane has some new equipment installed, and some of its existing equipment removed. The details of the equipment changes are as follows:

- Airplane Empty Weight: 2,350 lb
- Airplane Empty Weight CG: +24.7"
- Airplane Datum: Leading edge of the wing
- Radio Installed: 5.8 lb at an arm of -28"
- Global Positioning System Installed: 7.3 lb at an arm of -26"
- Emergency Locator Transmitter Installed: 2.8 lb at an arm of +105"
- Strobe Light Removed: 1.4 lb at an arm of +75"
- Automatic Direction Finder (ADF) removed: 3 lb at an arm of -28"
- Seat Removed: 34 lb at an arm of +60"

To calculate the new empty weight and empty weight center of gravity, a four column chart is used. The calculation would be as shown in Figure 4-26.

In evaluating the weight and balance calculation shown in Figure 4-26, the following key points should be recognized.

- The weight of the equipment needs to be identified with a plus or minus to signify whether it is being installed or removed.
- The sign of the moment (plus or minus) is determined by the signs of the weight and arm.
- The strobe and the ADF are both being removed (negative weight), but only the strobe has a negative moment. This is because the arm for the ADF is also negative, and two negatives multiplied together produce a positive result.

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Empty Weight	2,350.0	+24.70	58,045.0
Radio Install	+5.8	-28.00	-162.4
GPS Install	+7.3	-26.00	-189.8
ELT Install	+2.8	+105.00	294.0
Strobe Remove	-1.4	+75.00	-105.0
ADF Remove	-3.0	-28.00	84.0
Seat Remove	-34.0	+60.00	-2,040.0
Total	2,327.5	24.03	55,925.8

Figure 4-26. Center of gravity calculation after equipment change.

- The total arm is the airplane's center of gravity, and is found by dividing the total moment by the total weight.
- The result of the equipment change is that the airplane's weight was reduced by 22.5 lb and the center of gravity has moved forward 0.67".

The Use of Ballast

Ballast is used in an aircraft to attain the desired CG balance, when the center of gravity is not within limits or is not at the location desired by the operator. It is usually located as far aft or as far forward as possible to bring the CG within limits, while using a minimum amount of weight. Ballast that is installed to compensate for the removal or installation of equipment items and that is to remain in the aircraft for long periods is called permanent ballast. It is generally lead bars or plates bolted to the aircraft structure. It may be painted red and placarded: PERMANENT BALLAST—DO NOT REMOVE. The installation of permanent ballast results in an increase in the aircraft empty weight, and it reduces the useful load.

Temporary ballast, or removable ballast, is used to meet certain loading conditions that may vary from time to time. It generally takes the form of lead shot bags, sand bags, or other weight items that are not permanently installed. Temporary ballast should be placarded: BALLAST, XX LB. REMOVAL REQUIRES WEIGHT AND BALANCE CHECK. The baggage compartment is usually the most convenient location for temporary ballast.

Whenever permanent or temporary ballast is installed, it must be placed in an approved location and secured in an appropriate manner. If permanent ballast is being bolted to the structure of the aircraft, the location must be one that was previously approved and designed for the installation, or it must be approved by the FAA as a major alteration before the aircraft is returned to service. When temporary ballast is placed in a baggage compartment, it must be secured in a way that prevents it from becoming a projectile if the aircraft encounters turbulence or an unusual flight attitude.

To calculate how much ballast is needed to bring the center of gravity within limits, the following formula is used.

Ballast Needed =

$$\frac{\text{Loaded weight of aircraft (distance CG is out of limits)}}{\text{Arm from ballast location to affected limit}}$$

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Empty Weight	1,850	+92.45	171,032.5
Pilot	170	+88.00	14,960.0
2 Passengers	340	+105.00	35,700.0
2 Passengers	340	+125.00	42,500.0
Baggage	100	+140.00	14,000.0
Fuel	234	+102.00	23,868.0
Total	3,034	+99.60	302,060.5

Figure 4-27. Extreme condition check.

Figure 4-24 on page 4-22 and Figure 4-27 show an aft extreme condition check being performed on an airplane. In this previously shown example, the airplane's center of gravity was out of limits by 0.6". If there were a need or a desire to fly the airplane loaded this way, one way to make it possible would be the installation of temporary ballast in the front of the airplane. The logical choice for placement of this ballast is the forward baggage compartment.

The center of gravity for this airplane is 0.6" too far aft. If the forward baggage compartment is used as a temporary ballast location, the ballast calculation will be as follows:

Ballast Needed =

$$\frac{\text{Loaded weight of aircraft (distance CG is out of limits)}}{\text{Arm from ballast location to affected limit}} = \frac{3,034 \text{ lb (0.6")}}{39"} = 46.68 \text{ lb}$$

When ballast is calculated, the answer should always be rounded up to the next higher whole pound, or in this case, 47 lb of ballast would be used. To ensure the ballast calculation is correct, the weight of the ballast should be plugged back into the four column calculation and a new center of gravity calculated.

Item	Weight (lb)	Arm (inches)	Moment (in-lb)
Loaded Weight	3,034	+99.60	302,060.5
Ballast	47	+60.00	2,820.0
Total	3,081	+98.96	304,880.5

Figure 4-28. Ballast calculation.

The aft limit for the airplane was 99", and the new CG is at 98.96", which puts it within acceptable limits. The new CG did not fall exactly at 99" because the amount of needed ballast was rounded up to the next higher whole pound. If the ballast could have been placed farther forward, such as being bolted to the engine firewall, less ballast would have been needed. That is why ballast is always placed as far away from the affected limit as possible.

In evaluating the ballast calculation shown above, the following key points should be recognized.

- The loaded weight of the aircraft, as identified in the formula, is what the airplane weighed when the CG was out of limits.
- The distance the CG is out of limits is the difference between the CG location and the CG limit, in this case 99.6" minus 99".
- The affected limit identified in the formula is the CG limit which has been exceeded. If the CG is too far aft, it is the aft limit that has been exceeded.
- The aft limit for this example airplane is 99", and the ballast is being placed in the baggage compartment at an arm of 60". The difference between the two is 39", the quantity divided by in the formula.

Viewed as a first class lever problem, Figure 4-29 shows what this ballast calculation would look like. A ballast weight of 46.68 lb on the left side of the lever multiplied by the arm of 39" (99 minus 60) would equal the aircraft weight of 3,034 lb multiplied by the distance the CG is out of limits, which is 0.6" (99.6 minus 99).

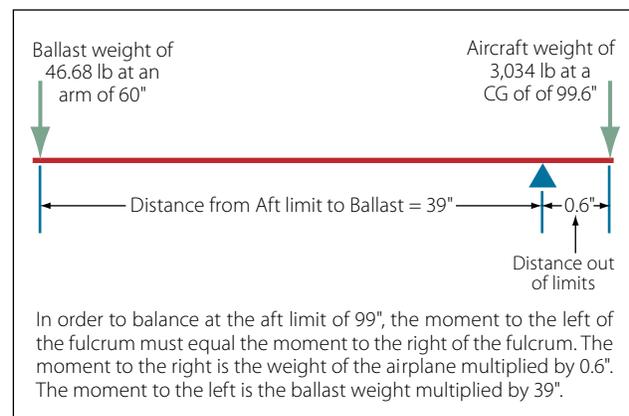


Figure 4-29. Ballast calculation as a first class lever.

Loading Graphs and CG Envelopes

The weight and balance computation system, commonly called the loading graph and CG envelope system, is an excellent and rapid method for determining the CG location for various loading arrangements. This method can be applied to any make and model of aircraft, but is more often seen with small general aviation aircraft.

Aircraft manufacturers using this method of weight and balance computation prepare graphs similar to those shown in Figures 4-30 and 4-31 for each make

and model aircraft at the time of original certification. The graphs become a permanent part of the aircraft records, and are typically found in the Airplane Flight Manual or Pilot's Operating Handbook (AFM/POH). These graphs, used in conjunction with the empty weight and empty weight CG data found in the weight and balance report, allow the pilot to plot the CG for the loaded aircraft.

The loading graph illustrated in Figure 4-30 is used to determine the index number (moment value) of any item or weight that may be involved in loading the aircraft. To use this graph, find the point on the verti-

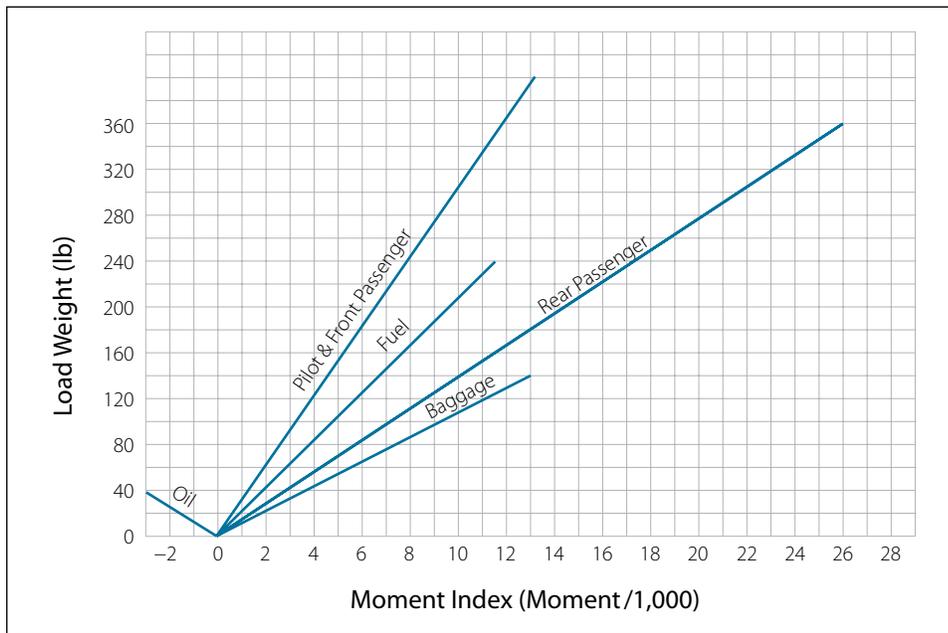


Figure 4-30. Aircraft loading graph.

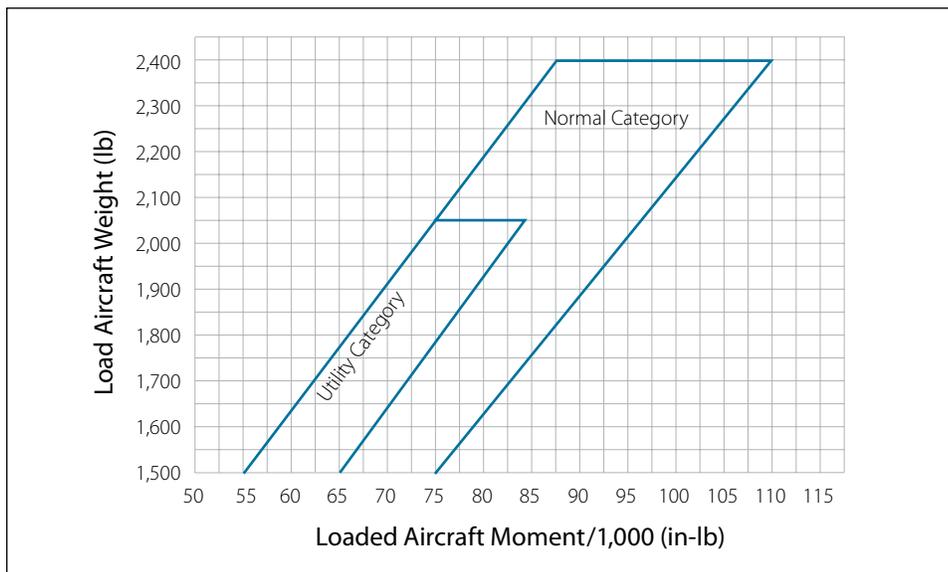


Figure 4-31. CG envelope.

cal scale that represents the known weight. Project a horizontal line to the point where it intersects the proper diagonal weight line (i.e., pilot, copilot, baggage). Where the horizontal line intersects the diagonal, project a vertical line downward to determine the loaded moment (index number) for the weight being added.

After the moment for each item of weight has been determined, all weights are added and all moments are added. The total weight and moment is then plotted on the CG envelope. [Figure 4-31] The total weight is plotted on the vertical scale of the graph, with a horizontal line projected out from that point. The total moment is plotted on the horizontal scale of the graph, with a vertical line projected up from that point. Where the horizontal and vertical plot lines intersect on the graph is the center of gravity for the loaded aircraft. If the point where the plot lines intersect falls inside the CG envelope, the aircraft CG is within limits. In Figure 4-31, there are actually two CG envelopes, one

for the aircraft in the Normal Category and one for the aircraft in the Utility Category.

The loading graph and CG envelope shown in Figures 4-30 and 4-31 are for an airplane with the following specifications and weight and balance data.

- Number of Seats: 4
- Fuel Capacity (Usable): 38 gal of Av Gas
- Oil Capacity: 8 qt (included in empty weight)
- Baggage: 120 lb
- Empty Weight: 1,400 lb
- Empty Weight CG: 38.5"
- Empty Weight Moment: 53,900 in-lb

An example of loading the airplane for flight and calculating the total loaded weight and the total loaded moment is shown in Figures 4-32 and 4-33. The use of the loading graph to determine the moment for each of the useful load items is shown in Figure 4-33. The color used for each useful load item in Figure 4-32 matches the color used for the plot on the loading graph.

The total loaded weight of the airplane is 2,258 pounds and the total loaded moment is 99,400 in-lb. These two numbers can now be plotted on the CG envelope to see if the airplane is within CG limits. Figure 4-34 shows the CG envelope, with the loaded weight and moment of the airplane plotted. The CG location shown falls

Item	Weight (lb)	Moment (in-lb)
Aircraft Empty Wt.	1,400	53,900
Pilot	180	6,000
Front Passengers	140	4,500
Rear Passengers	210	15,000
Baggage	100	9,200
Fuel	228	10,800
Total	2,258	99,400

Figure 4-32. Aircraft load chart.

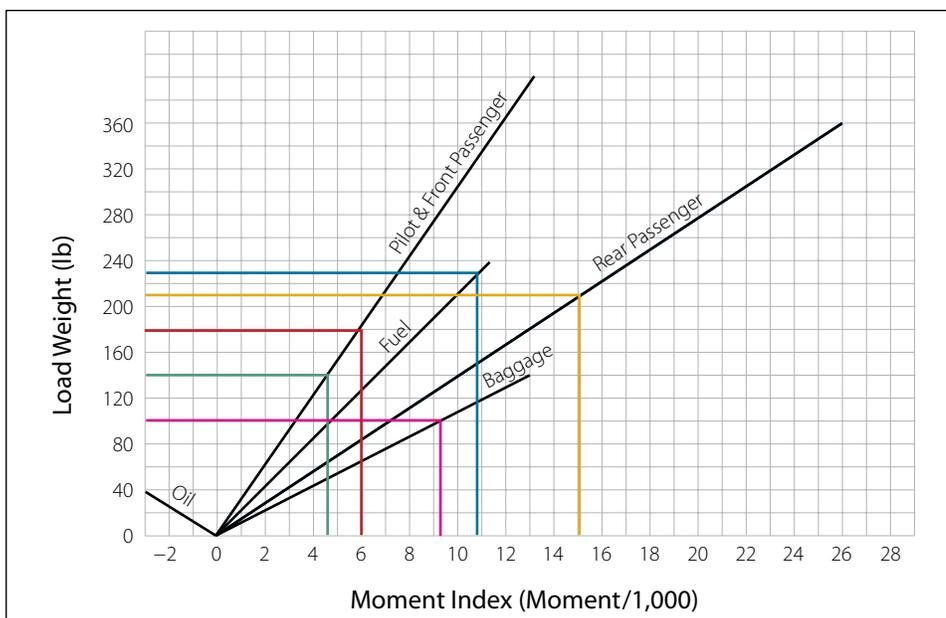


Figure 4-33. Example plots on a loading graph.

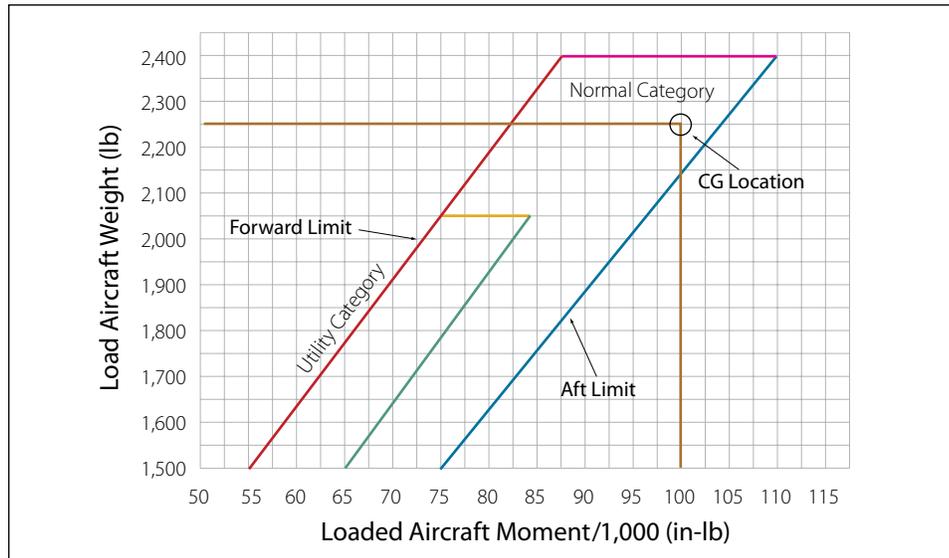


Figure 4-34. CG envelope example plot.

within the normal category envelope, so the airplane is within CG limits for this category.

It is interesting to note that the lines that form the CG envelope are actually graphic plots of the forward and aft CG limits. In Figure 4-34, the red line is a graphic plot of the forward limit, and the blue and green lines are graphic plots of the aft limit for the two different categories.

Helicopter Weight and Balance

General Concepts

All of the terminology and concepts that apply to airplane weight and balance also apply generally to helicopter weight and balance. There are some specific differences, however, which need to be identified.

Most helicopters have a much more restricted CG range than do airplanes. In some cases, this range is less than 3". The exact location and length of the CG range is specified for each helicopter, and usually extends a short distance fore and aft of the main rotor mast or centered between the main rotors of a dual rotor system. Whereas airplanes have a center of gravity range only along the longitudinal axis, helicopters have both longitudinal and lateral center of gravity ranges. Because the wings extend outward from the center of gravity, airplanes tend to have a great deal of lateral stability. A helicopter, on the other hand, acts like a pendulum, with the weight of the helicopter hanging from the main rotor shaft.

Ideally, the helicopter should have such perfect balance that the fuselage remains horizontal while in a hover.

If the helicopter is too nose heavy or tail heavy while it is hovering, the cyclic pitch control will be used to keep the fuselage horizontal. If the CG location is too extreme, it may not be possible to keep the fuselage horizontal or maintain control of the helicopter.

Helicopter Weighing

When a helicopter is being weighed, the location of both longitudinal and lateral weighing points must be known to determine its empty weight and empty weight CG. This is because helicopters have longitudinal and lateral CG limits. As with the airplane, the longitudinal arms are measured from the datum, with locations behind the datum being positive arms and locations in front of the datum being negative arms. Laterally, the arms are measured from the butt line, which is a line from the nose to the tail running through the middle of the helicopter. When facing forward, arms to the right of the butt line are positive; to the left they are negative.

Before a helicopter is weighed, it must be leveled longitudinally and laterally. This can be done with a spirit level, but more often than not it is done with a plumb bob. For example, the Bell JetRanger has a location inside the aft cabin where a plumb can be attached, and allowed to hang down to the cabin floor. On the cabin floor is a plate bearing cross hairs, with the cross hairs corresponding to the horizontal and lateral axis of the helicopter. When the point of the plumb bob falls in the middle of the cross hairs, the helicopter is level along both axes. If the tip of the plumb bob falls forward of this point, the nose of the helicopter is too low; if it falls to the left of this point, the left side of the helicopter is

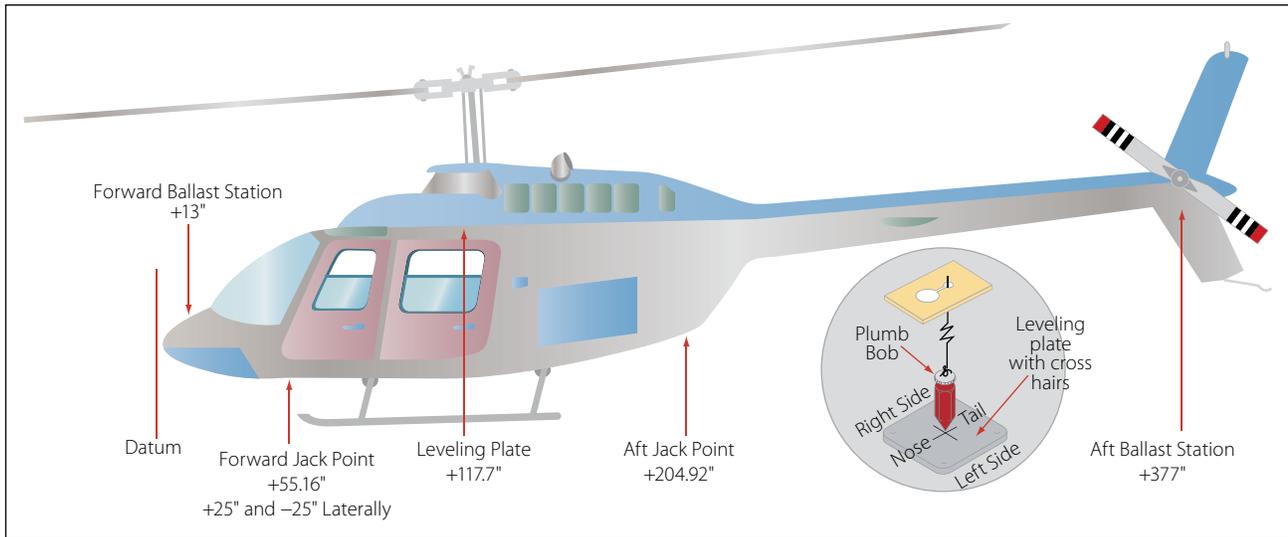


Figure 4-35. Bell JetRanger.

too low. In other words, the tip of the plumb bob will always move toward the low point.

A Bell JetRanger helicopter is shown in Figure 4-35, with the leveling plate depicted on the bottom right of the figure. The helicopter has three jack pads, two at the front and one in the back. To weigh this helicopter, three jacks would be placed on floor scales, and the helicopter would be raised off the hangar floor. To level the helicopter, the jacks would be adjusted until the plumb bob point falls exactly in the middle of the cross hairs.

As an example of weighing a helicopter, consider the Bell JetRanger in Figure 4-35, and the following specifications and weighing data.

- Datum: 55.16" forward of the front jack point centerline
- Leveling Means: Plumb line from ceiling left rear cabin to index plate on floor
- Longitudinal CG Limits:
 - +106" to +111.4" at 3,200 lb
 - +106" to +112.1" at 3,000 lb
 - +106" to +112.4" at 2,900 lb
 - +106" to +113.4" at 2,600 lb
 - +106" to +114.2" at 2,350 lb
 - +106" to +114.2" at 2,100 lb
 Straight line variation between points given

- Lateral CG Limits:
 - 2.3" left to 3.0" right at longitudinal CG +106.0"
 - 3.0" left to 4.0" right at longitudinal CG +108" to +114.2"
 Straight line variation between points given
- Fuel and Oil: Empty weight includes unusable fuel and unusable oil
- Left Front Scale Reading: 650 lb
- Left Front Jack Point: Longitudinal arm of +55.16" Lateral arm of -25"
- Right Front Scale Reading: 625 lb
- Right Front Jack Point: Longitudinal arm of +55.16" Lateral arm of +25"
- Aft Scale Reading: 710 lb
- Aft Jack Point: Longitudinal arm of +204.92" Lateral arm of 0.0"
- Notes: The helicopter was weighed with unusable fuel and oil. Electronic scales were used, which were zeroed with the jacks in place, so no tare weight needs to be accounted for.

Longitudinal CG Calculation					
Item	Scale (lb)	Tare Wt. (lb)	Nt. Wt. (lb)	Arm (inches)	Moment (in-lb)
Left Front	650	0	650	+55.16	35,854.0
Right Front	625	0	625	+55.16	34,475.0
Aft	710	0	710	+204.92	145,493.2
Total	1,985		1,985	+108.73	215,822.2

Lateral CG Calculation					
Item	Scale (lb)	Tare Wt. (lb)	Nt. Wt. (lb)	Arm (inches)	Moment (in-lb)
Left Front	650	0	650	-25	-16,250
Right Front	625	0	625	+25	+15,625
Aft	710	0	710	0	0
Total	1,985		1,985	+31	-625

Figure 4-36. Center of gravity calculation for Bell JetRanger.

Using six column charts for the calculations, the empty weight and the longitudinal and lateral center of gravity for the helicopter would be as shown in Figure 4-36.

Based on the calculations in Figure 4-36, it has been determined that the empty weight of the helicopter is 1,985 lb, the longitudinal CG is at +108.73", and the lateral CG is at -0.31".

Weight and Balance — Weight-Shift Control Aircraft and Powered Parachutes

The terminology, theory, and concepts of weight and balance that applies to airplanes also applies to weight-shift aircraft and powered parachutes. Weight is still weight, and the balance point is still the balance point. There are, however, a few differences that need to be discussed. Before reading about the specifics of weight and balance on weight-shift control and powered parachute aircraft, be sure to read about their aerodynamic characteristics in Chapter 3, Physics.

Weight-shift control aircraft and powered parachutes do not fall under the same Code of Federal Regulations that govern certified airplanes and helicopters and, therefore, do not have Type Certificate Data Sheets or the same type of FAA mandated weight and balance reports. Weight and balance information and guidelines are left to the individual owners and the companies with which they work in acquiring this type of aircraft. Overall, the industry that is supplying these aircraft is regulating itself well, and the safety record is good for those aircraft being operated by experienced pilots.

The FAA has recently (2005) accepted a new classification of aircraft, known as Light Sport Aircraft (LSA). A new set of standards is being developed which will have an impact on the weight-shift control and powered parachute aircraft and how their weight and balance is handled.

Weight-Shift Control Aircraft

Weight-shift control aircraft, commonly known by the name "trikes," have very few options for loading because they have very few places to put useful load items. Some trikes have only one seat and a fuel tank, so the only variables for a flight are amount of fuel and weight of the pilot. Some trikes have two seats and a small storage bin, in addition to the fuel tank.

The most significant factor affecting the weight and balance of a trike is the weight of the pilot; if the aircraft has two seats, the weight of the passenger must be considered. The trike acts somewhat like a single main rotor helicopter because the weight of the aircraft is hanging like a pendulum under the wing. Figure 4-37 shows a two-place trike, in which the mast and the nose strut come together slightly below the wing attach point. When the trike is in flight, the weight of the aircraft is hanging from the wing attach point. The weight of the engine and fuel is behind this point, the passenger is almost directly below this point, and the pilot is forward of this point. The balance of the aircraft is determined by how all these weights compare.

The wing attach point, with respect to the wing keel, is an adjustable location. The attach point can be loosened

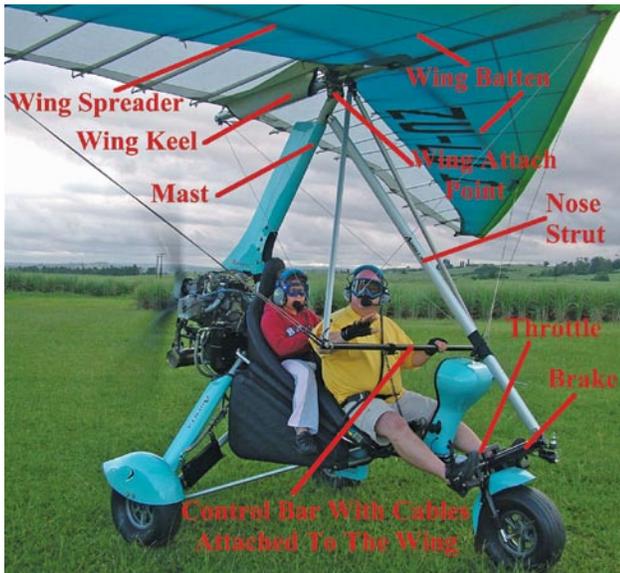


Figure 4-37. Weight and balance for a weight-shift aircraft.

and moved slightly forward or slightly aft, depending on the weight of the occupants. For example, if the aircraft is flown by a heavy person, the attach point can be moved a little farther aft, bringing the wing forward, to compensate for the change in center of gravity.

Figure 4-38 shows a close-up of the wing attach point, and the small amount of forward and aft movement that is available.

Powered Parachutes

Powered parachutes have many of the same characteristics as weight-shift control aircraft when it comes to weight and balance. They have the same limited loading, with only one or two seats and a fuel tank. They also act like a pendulum, with the weight of the aircraft hanging beneath the inflated wing (parachute).

The point at which the inflated wing attaches to the structure of the aircraft is adjustable to compensate for pilots and passengers of varying weights. With a very heavy pilot, the wing attach point would be moved forward to prevent the aircraft from being too nose heavy. Figure 4-39 illustrates the structure of a powered parachute with the adjustable wing attach points.

Weight and Balance for Large Airplanes

Weight and balance for large airplanes is almost identical to what it is for small airplanes, on a much larger scale. If a technician can weigh a small airplane and calculate its empty weight and empty weight center of gravity, that same technician should be able to do it for



Figure 4-38. Wing attach point for a weight-shift aircraft.



Figure 4-39. Powered parachute structure with wing attach points.

a large airplane. The jacks and scales will be larger, and it may take more personnel to handle the equipment, but the concepts and processes are the same.

Built-In Electronic Weighing

One difference that may be found with large airplanes is the incorporation of electronic load cells in the aircraft's landing gear. With this type of system, the airplane is capable of weighing itself as it sits on the tarmac. The load cells are built into the axles of the landing gear, or the landing gear strut, and they work in the same manner as load cells used with jacks. This system is currently in use on the Boeing 747-400, Boeing 777, Boeing 787, McDonnell Douglas MD-11, and the wide body Airbus airplanes like the A-330, A-340, and A-380.

The Boeing 777, utilizes two independent systems that provide information to the airplane's flight management computer. If the two systems agree on the weight and center of gravity of the airplane, the data being provided are considered accurate and the airplane can

be dispatched based on that information. The flight crew has access to the information on the flight deck by accessing the flight management computer and bringing up the weight and balance page.

Mean Aerodynamic Chord

On small airplanes and on all helicopters, the center of gravity location is identified as being a specific number of inches from the datum. The center of gravity range is identified the same way. On larger airplanes, from private business jets to large jumbo jets, the center of gravity and its range are typically identified in relation to the width of the wing.

The width of the wing on an airplane is known as the chord. If the leading edge and trailing edge of a wing are parallel to each other, the chord of the wing is the same along the wing's length. Business jets and commercial transport airplanes have wings that are tapered and that are swept back, so the width of their wings is different along their entire length. The width is greatest where the wing meets the fuselage and progressively

decreases toward the tip. In relation to the aerodynamics of the wing, the average length of the chord on these tapered swept-back wings is known as the mean aerodynamic chord (MAC).

On these larger airplanes, the CG is identified as being at a location that is a specific percent of the mean aerodynamic chord (% MAC). For example, imagine that the MAC on a particular airplane is 100", and the CG falls 20" behind the leading edge of the MAC. That means it falls one-fifth of the way back, or at 20% of the MAC.

Figure 4-40 shows a large twin-engine commercial transport airplane. The datum is forward of the nose of the airplane, and all the arms shown in the figure are being measured from that point. The center of gravity for the airplane is shown as an arm measured in inches. In the lower left corner of the figure, a cross section of the wing is shown, with the same center of gravity information being presented.

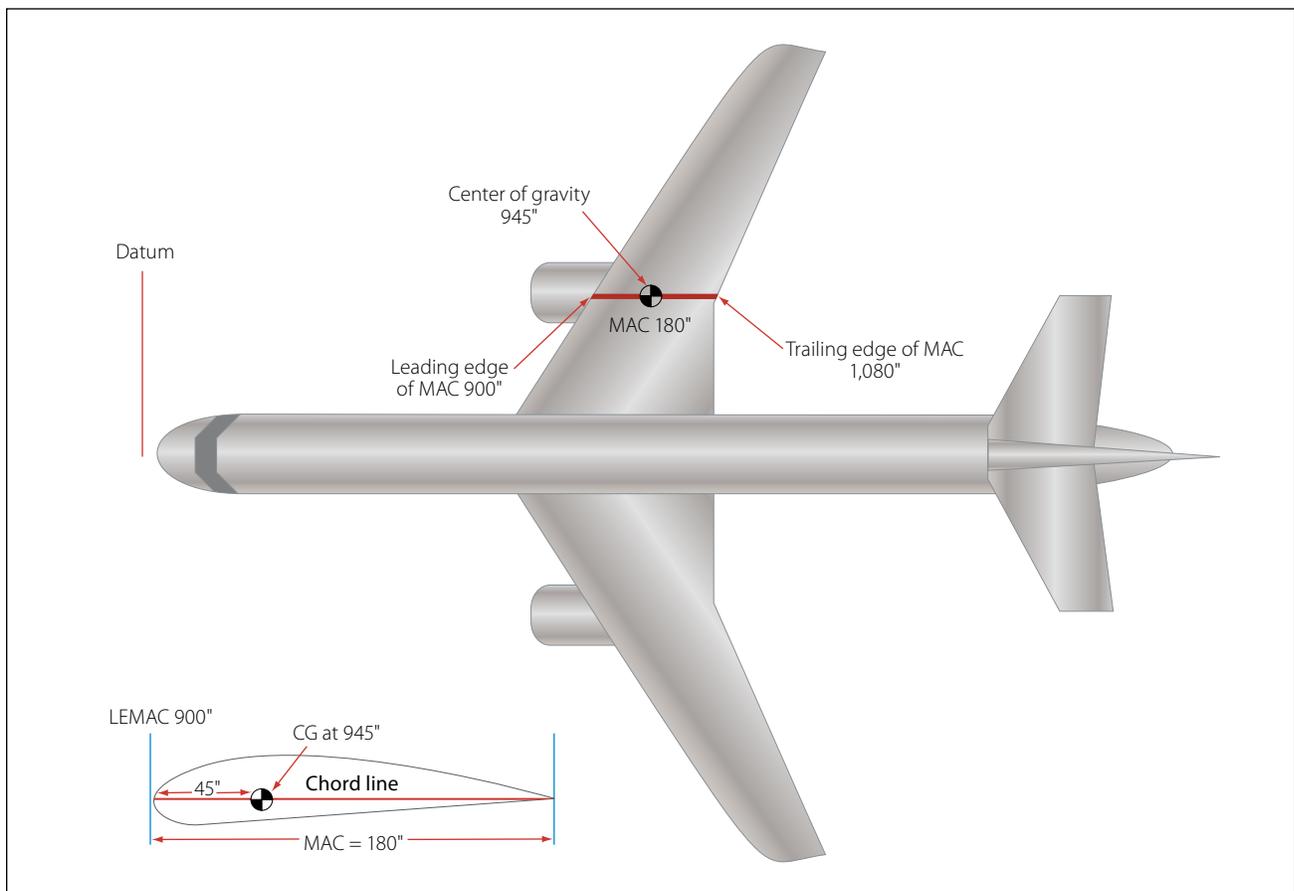


Figure 4-40. Center of gravity location on a large commercial transport.

To convert the center of gravity location from inches to a percent of MAC, for the airplane shown in Figure 4-40, the steps are as follows:

1. Identify the center of gravity location, in inches from the datum.
2. Identify the leading edge of the MAC (LEMAC), in inches from the datum.
3. Subtract LEMAC from the CG location.
4. Divide the difference by the length of the MAC.
5. Convert the result in decimals to a percentage by multiplying by 100.

As a formula, the solution to solve for the percent of MAC would be:

$$\text{Percent of MAC} = \frac{\text{CG} - \text{LEMAC}}{\text{MAC}} \times 100$$

The result using the numbers shown in Figure 4-40 would be:

$$\begin{aligned} \text{Percent of MAC} &= \frac{\text{CG} - \text{LEMAC}}{\text{MAC}} \times 100 \\ &= \frac{945 - 900}{180} \times 100 \\ &= 25\% \end{aligned}$$

If the center of gravity is known in percent of MAC, and there is a need to know the CG location in inches from the datum, the conversion would be done as follows:

1. Convert the percent of MAC to a decimal by dividing by 100.
2. Multiply the decimal by the length of the MAC.
3. Add this number to LEMAC.

As a formula, the solution to convert a percent of MAC to an inch value would be:

$$\text{CG in inches} = \text{MAC \%} \div 100 \times \text{MAC} + \text{LEMAC}$$

For the airplane in Figure 4-40, if the CG was at 32.5% of the MAC, the solution would be:

$$\begin{aligned} \text{CG in inches} &= \text{MAC \%} \div 100 \times \text{MAC} + \text{LEMAC} \\ &= 32.5 \div 100 \times 180 + 900 \\ &= 958.5 \end{aligned}$$

Weight and Balance Records

When a technician gets involved with the weight and balance of an aircraft, it almost always involves a calculation of the aircraft's empty weight and empty weight center of gravity. Only on rare occasions will the technician be involved in calculating extreme conditions, how much ballast is needed, or the loaded weight and balance of the aircraft. Calculating the empty weight and empty weight CG might involve putting the aircraft on scales and weighing it, or a pencil and paper exercise after installing a new piece of equipment.

The FAA requires that a current and accurate empty weight and empty weight center of gravity be known for an aircraft. This information must be included in the weight and balance report, which is a part of the aircraft permanent records. The weight and balance report must be in the aircraft when it is being flown.

There is no required format for this report, but Figure 4-41 is a good example of recording the data obtained from weighing an aircraft. As it is currently laid out, the form would accommodate either a tricycle gear or tail dragger airplane. Depending on the gear type, either the nose or the tail row would be used. If an airplane is being weighed using jacks and load cells, or if a helicopter is being weighed, the item names must be changed to reflect the weight locations.

If an equipment change is being done on an aircraft, and the new weight and balance is calculated mathematically instead of weighing the aircraft, the same type of form shown in Figure 4-41 can be used. The only change would be the use of a four column solution, instead of six columns, and there would be no tare weight or involvement with fuel and oil.

Aircraft Weight and Balance Report

Results of Aircraft Weighing

Make _____ Model _____

Serial # _____ N# _____

Datum Location _____

Leveling Means _____

Scale Arms: Nose _____ Tail _____ Left Main _____ Right Main _____

Scale Weights: Nose _____ Tail _____ Left Main _____ Right Main _____

Tare Weights: Nose _____ Tail _____ Left Main _____ Right Main _____

Weight and Balance Calculation

Item	Scale (lb)	Tare Wt. (lb)	Net Wt. (lb)	Arm (inches)	Moment (in-lb)
Nose					
Tail					
Left Main					
Right Main					
Subtotal					
Fuel					
Oil					
Misc.					
Total					

Aircraft Current Empty Weight: _____

Aircraft Current Empty Weight CG: _____

Aircraft Maximum Weight: _____

Aircraft Useful Load: _____

Computed By: _____ (print name)

_____ (signature)

Certificate #: _____ (A&P, Repair Station, etc.)

Date: _____

Figure 4-41. Aircraft weight and balance report.

