weight and balance calculation based on that table. In this problem, the total weight of 2,799 pounds and moment of 2,278/100 are within the limits of the table.

Computations With a Negative Arm

Figure 10-10 is a sample of weight and balance computation using an aircraft with a negative arm. It is important to remember that a positive times a negative equals a negative, and a negative would be subtracted from the total moments.

Computations With Zero Fuel Weight

Figure 10-11 is a sample of weight and balance computation using an aircraft with a zero fuel weight. In this example, the total weight of the aircraft less fuel is 4,240 pounds, which is under the zero fuel weight of 4,400 pounds. If the total weight of the aircraft without fuel had exceeded 4,400 pounds, passengers or cargo would have needed to be reduced to bring the weight at or below the max zero fuel weight.

Shifting, Adding, and Removing Weight

A pilot must be able to solve any problems accurately that involve the shift, addition, or removal of weight. For example, the pilot may load the aircraft within the allowable takeoff weight limit, then find that the CG limit has been exceeded. The most satisfactory solution to this problem is to shift baggage, passengers, or both. The pilot should be able to determine the minimum load shift needed to make the aircraft safe for flight. Pilots should be able to determine if shifting a load to a new location will correct an out-of-limit condition. There are some standardized calculations that can help make these determinations.

Weight Shifting

When weight is shifted from one location to another, the total weight of the aircraft is unchanged. The total moments, however, do change in relation and proportion to the direction and distance the weight is moved. When weight is moved forward, the total moments decrease; when weight is moved aft, total moments increase. The moment change is proportional to the amount of weight moved. Since many aircraft have forward and aft baggage compartments, weight may be shifted from one to the other to change the CG. If starting with a known aircraft weight, CG, and total moments, calculate the new CG (after the weight shift) by dividing the new total moments by the total aircraft weight.

Item	Weight	Arm	Moment
Licensed empty weight	1,011.9	68.6	69,393.0
Oil (6 quarts)	11.0	–31.0	–341.0
Fuel (18 gallons)	108.0	84.0	9,072.0
Fuel, auxiliary (18 gallons)	108.0	84.0	9,072.0
Pilot	170.0	81.0	13,770.0
Passenger	170.0	81.0	13,770.0
Baggage	70.0	105.0	7,350.0
Total	1,648.9		122,086.0
CG		74.0	

Figure 10-10. *Sample weight and balance using a negative.*

Item	Weight	Arm	Moment
Basic empty weight	3,230	CG 90.5	292,315.0
Front seat occupants	335	89.0	29,815.0
3rd & 4th seat occupants forward facing	350	126.0	44,100.0
5th & 6th seat occupants	200	157.0	31,400.0
Nose baggage	100	10.0	1,000.0
Aft baggage	25	183.0	4,575.0
Zero fuel weight max 4,400 pounds Subtotal	4,240	CG 95.1	403,205.0
Fuel	822	113.0	92,886.0
Ramp weight max 5,224 pounds Subtotal ramp weight	5,062	CG 98.0	496,091.0
* Less fuel for start, taxi, and takeoff	–24	113.0	–2,712.0
Subtotal takeoff weight	5,038	CG 97.9	493,379.0
Less fuel to destination	–450	113.0	–50,850.0
Max landing weight 4,940 pounds Actual landing weight	4,588	CG 96.5	442,529.0
*Fuel for start, taxi, and takeoff is normally 24 pounds.			

Figure 10-11. *Sample weight and balance using an aircraft with a published zero fuel weight.*

To determine the new total moments, find out how many moments are gained or lost when the weight is shifted. Assume that 100 pounds has been shifted from station 30 to station 150. This movement increases the total moments of the aircraft by 12,000 in-lb.

Moment when at station 150 = 100 lb x 150 in = 15,000 in-lb

Moment when at station 30 = 100 lb x 30 in = 3,000 in-lb

Moment change = [15,000 – 3,000] = 12,000 in-lb

By adding the moment change to the original moment (or subtracting if the weight has been moved forward instead of aft), the new total moments are obtained. Then determine the new CG by dividing the new moments by the total weight:

$$\text{Total moments} = 616{,}000 \text{ in-lb} + 12{,}000 \text{ in-lb} = 628{,}000 \text{ in-lb}$$

$$CG = \frac{628{,}000 \text{ in-lb}}{8{,}000 \text{ lb}} = 78.5 \text{ in}$$

The shift has caused the CG to shift to station 78.5.

Example

$$\frac{\text{Weight shifted}}{\text{Total weight}} = \frac{\Delta CG \text{ (change of CG)}}{\text{Distance weight is shifted}}$$

$$\frac{100}{8{,}000} = \frac{\Delta CG}{120}$$

$$\Delta CG = 1.5 \text{ in}$$

The change of CG is added to (or subtracted from when appropriate) the original CG to determine the new CG:
77 + 1.5 = 78.5 inches aft of datum

The shifting weight proportion formula can also be used to determine how much weight must be shifted to achieve a particular shift of the CG. The following problem illustrates a solution of this type.

Example

Given:
Aircraft total weight . . . . 7,800 lb
CG station. . . . . 81.5 in
Aft CG limit . . . . 80.5 in

Determine how much cargo must be shifted from the aft cargo compartment at station 150 to the forward cargo compartment at station 30 to move the CG to exactly the aft limit.

Solution:

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

$$\frac{\text{Weight to be shifted}}{7{,}800 \text{ lb}} = \frac{1.0 \text{ in}}{120 \text{ in}}$$

$$\text{Weight to be shifted} = 65 \text{ lb}$$

A simpler solution may be obtained by using a computer or calculator and a proportional formula. This can be done because the CG will shift a distance that is proportional to the distance the weight is shifted.

Weight Addition or Removal

In many instances, the weight and balance of the aircraft will be changed by the addition or removal of weight. When this happens, a new CG must be calculated and checked against the limitations to see if the location is acceptable. This type of weight and balance problem is commonly encountered when the aircraft burns fuel in flight, thereby reducing the weight located at the fuel tanks. Most small aircraft are designed with the fuel tanks positioned close to the CG; therefore, the consumption of fuel does not affect the CG to any great extent.

The addition or removal of cargo presents a CG change problem that must be calculated before flight. The problem may always be solved by calculations involving total moments. A typical problem may involve the calculation of a new CG for an aircraft which, when loaded and ready for flight, receives some additional cargo or passengers just before departure time.

Example

Given:
Aircraft total weight . . . . 6,860 lb
CG station. . . . . 80.0 in

Determine the location of the CG if 140 pounds of baggage is added to station 150.

Solution:

$$\frac{\text{Added weight}}{\text{New total weight}} = \frac{\Delta CG}{\text{Distance between weight and old CG}}$$

$$\frac{140 \text{ lb}}{6{,}860 \text{ lb} + 140 \text{ lb}} = \frac{\Delta CG}{150 \text{ in} - 80 \text{ in}}$$

$$\frac{140 \text{ lb}}{7{,}000 \text{ lb}} = \frac{\Delta CG}{70 \text{ in}}$$

$$CG = 1.4 \text{ in aft}$$

Add ΔCG to old CG
New CG = 80 in + 1.4 in = 81.4 in

Example

Given:
Aircraft total weight . . . . 6,100 lb
CG station. . . . . 80.0 in

Determine the location of the CG if 100 pounds is removed from station 150.

Solution:

$$\frac{\text{Weight removed}}{\text{New total weight}} = \frac{\Delta CG}{\text{Distance between weight and old CG}}$$

$$\frac{100 \text{ lb}}{6{,}100 \text{ lb} - 100 \text{ lb}} = \frac{\Delta CG}{150 \text{ in} - 80 \text{ in}}$$

$$\frac{100 \text{ lb}}{6{,}000 \text{ lb}} = \frac{\Delta CG}{70 \text{ in}}$$

$$CG = 1.2 \text{ in forward}$$

Subtract ΔCG from old CG
New CG = 80 in – 1.2 in = 78.8 in

In the previous examples, the △CG is either added or subtracted from the old CG. Deciding which to accomplish is best handled by mentally calculating which way the CG will shift for the particular weight change. If the CG is shifting aft, the △CG is added to the old CG; if the CG is shifting forward, the △CG is subtracted from the old CG.

Chapter Summary

Operating an aircraft within the weight and balance limits is critical to flight safety. Pilots must ensure that the CG is and remains within approved limits throughout all phases of a flight. For additional information on weight, balance, CG, and aircraft stability refer to the FAA handbook appropriate to the specific aircraft category.