Chapter 8

Use of Computers for Weight and Balance Computations

Almost all weight and balance problems involve only simple math. This allows slide rules and hand-held electronic calculators to relieve us of much of the tedium involved with these problems. This chapter gives a comparison of the methods of determining the CG of an airplane while it is being weighed. First, determine the CG using a simple electronic calculator, then solve the same problem using an E6-B flight computer. Then, finally, solve it using a dedicated electronic flight computer.

Later in this chapter are examples of typical weight and balance problems (solved with an electronic calculator) of the kind that pilots and AMTs will encounter throughout their aviation endeavors.

Using an Electronic Calculator to Solve Weight and Balance Problems

Determining the CG of an airplane in inches from the main-wheel weighing points can be done with any simple electronic calculator that has addition (+), subtraction (–), multiplication (?), and division (÷) functions. Scientific calculators with such additional functions as memory (M), parentheses (( )), plus or minus (+/–), exponential (y^x), reciprocal (1/?), and percentage (%) functions allow you to solve more complex problems or to solve simple problems using fewer steps.

The chart in Figure 8-1 includes data on the airplane used in this example problem.

Weighing Point	Weight (lbs)	Arm (in)
Right side	830	0
Left side	836	0
Nose	340	–78
Total	2,006	

Figure 8-1. *Weight and balance data of a typical nose wheel airplane.*

According to Figure 8-1, the weight of the nose wheel (F) is 340 pounds, the distance between main wheels and nose wheel (L) is –78 inches, and the total weight (W) of the airplane is 2,006 pounds. (L is negative because the nose wheel is ahead of the main wheels.)

To determine the CG, use this formula:

$$CG = \frac{F \times L}{W}$$

$$= \frac{340 \times -78}{2{,}006}$$

Key the data into the calculator as shown in red, and when the equal (=) key is pressed, the answer (shown here in blue) will appear.

(340)(?)(78)(+/–)(÷)(2006)(=) –13.2

The arm of the nose wheel is negative, so the CG is –13.2, or 13.2 inches ahead of the main-wheel weighing points.

Using an E6-B Flight Computer to Solve Weight and Balance Problems

The E6-B uses a special kind of slide rule. Instead of its scales going from 1 to 10, as on a normal slide rule, both scales go from 10 to 100. The E6-B cannot be used for addition or subtraction, but it is useful for making calculations involving multiplication and division. Its accuracy is limited, but it is sufficiently accurate for most weight and balance problems.

Positive/Negative Key

The (+/–) key changes the number just keyed in from a positive to a negative number.

The same problem that was just solved with the electronic calculator can be solved on an E6-B by following these steps:

$$CG = \frac{F \times L}{W}$$

$$= \frac{340 \times -78}{2,006}$$

First, multiply 340 by 78 (disregard the – sign): [Figure 8-2a]

- Place 10 on the inner scale (this is the index) opposite 34 on the outer scale (this represents 340) (Step 1).
- Opposite 78 on the inner scale, read 26.5 on the outer scale (Step 2).
- Determine the value of these digits by estimating: 300 ? 80 = 24,000, so 340 ? 78 = 26,500.

Then, divide 26,500 by 2,006: [Figure 8-2b]

- On the inner scale, place 20, which represents 2,006, opposite 26.5 on the outer scale. (26.5 represents 26,500) (Step 3).
- Opposite the index, 10, on the inner scale, read 13.2 on the outer scale (Step 4).
- Determine the value of 13.2 by estimating: 20,000 ÷ 2000 = 10, so 26,500 ÷ 2,006 = 13.2.
- The arm (–78) is negative, so the CG is also negative.

The CG is –13.2 inches, or 13.2 inches ahead of the datum.

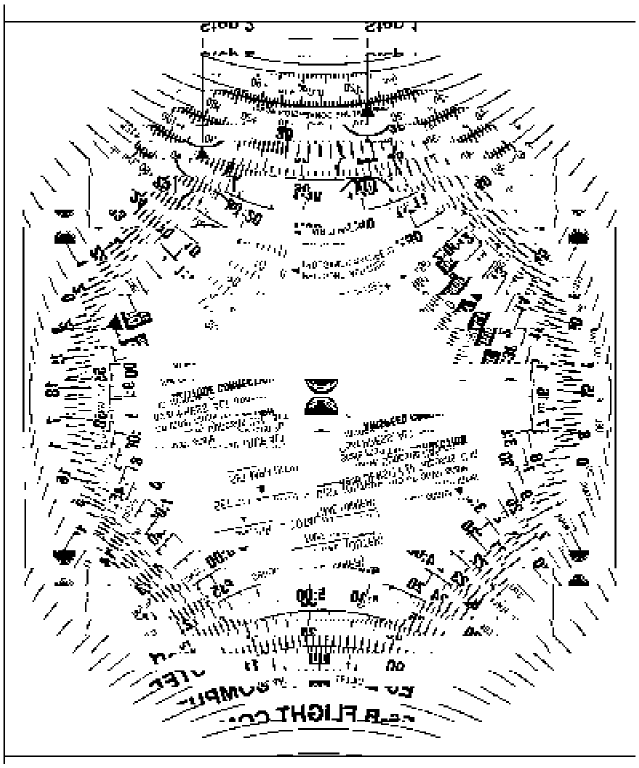

Figure 8-2a. *E6-B computer set up to multiply 340 by 78.*

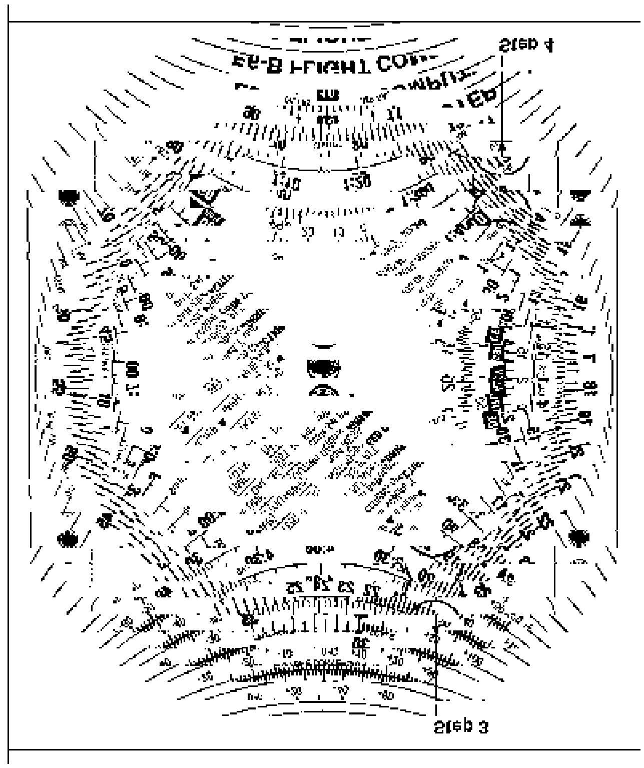

Figure 8-2b. *E6-B computer set up to divide 26,500 by 2,006.*

Using a Dedicated Electronic Flight Computer to Solve Weight and Balance Problems

Dedicated electronic flight computers like the one in Figure 8-3 are programmed to solve many flight problems, such as wind correction, heading and ground speed, endurance, and true airspeed (TAS), as well as weight and balance problems.

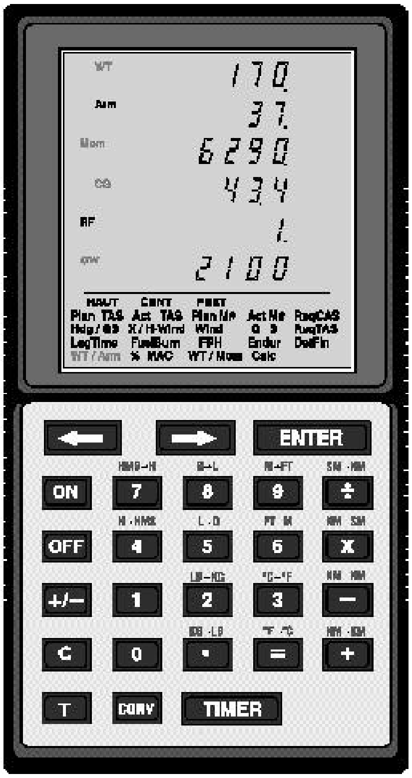

Figure 8-3. *Dedicated electronic flight computers are programmed to solve weight and balance problems as well as flight problems.*

The problem just solved with an electronic calculator and an E6-B can also be solved with a dedicated flight computer using the information in Figure 8-1.

Each flight computer handles the problems in slightly different ways, but all are programmed with prompts that solicit you to input the required data so you do not need to memorize any formulas. Weights and arms are input as called for, and a running total of the weight, moment, and CG are displayed.

Typical Weight and Balance Problems

A hand-held electronic calculator like the one in Figure 8-4 is a valuable tool for solving weight and balance problems. It can be used for a variety of problems and has a high degree of accuracy. The examples given here are solved with a calculator using only the (?), (÷), (+), (–), and (+/–) functions. If other functions are available on your calculator, some of the steps may be simplified.

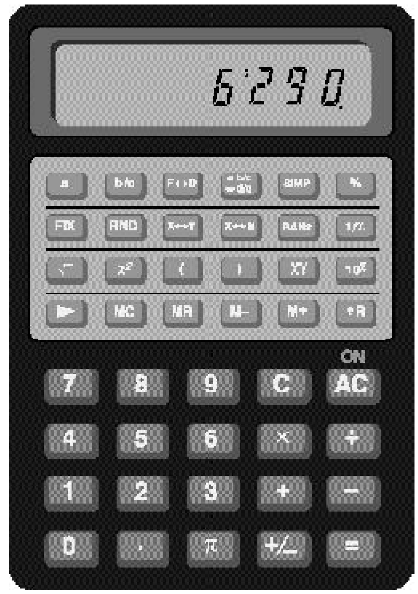

Figure 8-4. *A typical electronic calculator is useful for solving most types of weight and balance problems.*

Determining CG in Inches From the Datum

This type of problem is solved by first determining the location of the CG in inches from the main-wheel weighing points, then measuring this location in inches from the datum. There are four types of problems involving the location of the CG relative to the datum.

Nose Wheel Airplane with Datum Ahead of the Main Wheels

The datum (D) is 128 inches ahead of the main-wheel weighing points, the weight of the nose wheel (F) is 340 pounds, and the distance between main wheels and nose wheel (L) is 78 inches. The total weight (W) of the airplane is 2,006 pounds. Refer to Figure 3-5 on Page 3-5.

Use this formula:

$$CG = D - \left(\frac{F \times L}{W}\right)$$

1. Determine the CG in inches from the main wheels:

   (340)(?)(78)(÷)(2006)(=) 13.2

2. Determine the CG in inches from the datum:

   (128)(–)(13.2)(=) 114.8

The CG is 114.8 inches behind the datum.

Nose Wheel Airplane with Datum Behind the Main Wheels

The datum (D) is 75 inches behind the main-wheel weighing points, the weight of the nose wheel (F) is 340 pounds, and the distance between main wheels and nose wheel (L) is 78 inches. The total weight (W) of the airplane is 2,006 pounds. Refer to Figure 3-6 on Page 3-6.

Use this formula:

$$CG = -\left(D + \frac{F \times L}{W}\right)$$

1. Determine the CG in inches from the main wheels:

   (340)(?)(78)(÷)(2006)(=) 13.2

2. Determine the CG in inches from the datum:

   (75)(+)(13.2)(=) 88.2

The minus sign before the parenthesis in the formula means the answer is negative. The CG is 88.2 inches ahead of the datum (–88.2).

Tail Wheel Airplane with Datum Ahead of the Main Wheels

The datum (D) is 7.5 inches ahead of the main-wheel weighing points, the weight of the tail wheel (R) is 67 pounds, and the distance between main wheels and tail wheel (L) is 222 inches. The total weight (W) of the airplane is 1,218 pounds. Refer to Figure 3-7 on Page 3-6.

Use this formula:

$$CG = D + \left(\frac{R \times L}{W}\right)$$

1. Determine the CG in inches from the main wheels:

   (67)(?)(222)(÷)(1218)(=) 12.2

2. Determine the CG in inches from the datum:

   (7.5)(+)(12.2)(=) 19.7

The CG is 19.7 inches behind the datum.

Tail Wheel Airplane with Datum Behind the Main Wheels

The datum (D) is 80 inches behind the main-wheel weighing points, the weight of the tail wheel (R) is 67 pounds, and the distance between main wheels and tail wheel (L) is 222 inches. The total weight (W) of the airplane is 1,218 pounds. Refer to Figure 3-8 on Page 3-7.

Use this formula:

$$CG = -D + \left(\frac{R \times L}{W}\right)$$

1. Determine the CG in inches from the main wheels:

   (67)(?)(222)(÷)(1218)(=) 12.2

2. Determine the CG in inches from the datum:

   (80)(+/–)(+)(12.2)(=) –67.8

The CG is 67.8 inches ahead of the datum.

Weighing Point	Weight (lbs)	Arm (in)	Moment (lb-in)	CG
Right side	830	128	106,240	
Left side	836	128	107,008	
Nose	340	50	17,000	
Total	2,006		230,248	114.8

Figure 8-5. *Specifications for determining the CG of an airplane using weights and arms.*

Determining CG, Given Weights and Arms

Some weight and balance problems involve weights and arms to determine the moments. Divide the total moment by the total weight to determine the CG. Figure 8-5 contains the specifications for determining the CG using weights and arms.

Determine the CG by using the data in Figure 8-5 and following these steps:

1. Determine the total weight and record this number:

   (830)(+)(836)(+)(340)(=) 2006

2. Determine the moment of each weighing point and record them:

   (830)(?)(128)(=) 106240
   (836)(?)(128)(=) 107008
   (340)(?)(50)(=) 17000

3. Determine the total moment and divide this by the total weight:

   (106240)(+)(107008)(+)(17000)(=)(÷)(2006)(=) 114.8

This airplane weighs 2,006 pounds and its CG is 114.8 inches from the datum.

Determining CG, Given Weights and Moment Indexes

Other weight and balance problems involve weights and moment indexes, such as moment/100, or moment/1,000. To determine the CG, add all the weights and all the moment indexes. Then divide the total moment index by the total weight and multiply the answer by the reduction factor. Figure 8-6 contains the specifications for determining the CG using weights and moment indexes.

Determine the CG by using the data in Figure 8-6 and following these steps:

1. Determine the total weight and record this number:

   (830)(+)(836)(+)(340)(=) 2006

2. Determine the total moment index, divide this by the total weight, and multiply it by the reduction factor of 100:

   (1,062.4)(+)(1,070.1)(+)(170)(=)(2302.5)(÷)(2006)(=)
   (1.148)(?)(100)(=) 114.8

This airplane weighs 2,006 pounds and its CG is 114.8 inches from the datum.

Weighing Point	Weight (lbs)	Moment/100	CG
Right side	830	1,062.4	
Left side	836	1,070.1	
Nose	340	170	
Total	2,006	2,302.5	114.8

Figure 8-6. *Specifications for determining the CG of an airplane using weights and moment indexes.*

Determining CG in Percent of Mean Aerodynamic Chord

- The loaded CG is 42.47 inches aft of the datum.
- MAC is 61.6 inches long.
- LEMAC is at station 20.1.

1. Determine the distance between the CG and LEMAC:

   (42.47)(–)(20.1)(=) 22.37

2. Then, use this formula:

$$CG \text{ in } \% \text{ MAC} = \frac{\text{Distance aft of LEMAC} \times 100}{\text{MAC}}$$

   (22.37)(?)(100)(÷)(61.6)(=) 36.3

The CG of this airplane is located at 36.3% of the mean aerodynamic chord.

Determining Lateral CG of a Helicopter

It is often necessary when working weight and balance of a helicopter to determine not only the longitudinal CG, but the lateral CG as well. Lateral CG is measured from butt line zero (BL 0). All items and moments to the left of BL 0 are negative, and those to the right of BL 0 are positive. Figure 8-7 contains the specifications for determining the lateral CG of a typical helicopter.

Determine the lateral CG by using the data in Figure 8-7 and following these steps:

1. Add all of the weights:

   (1545)(+)(170)(+)(200)(+)(288)(=) 2203

2. Multiply the lateral arm (the distance between butt line zero and the CG of each item) by its weight to get the lateral offset moment of each item. Moments to the right of BL 0 are positive and those to the left are negative.

   (1545)(?)(.2)(=) 309
   (170)(?)(13.5)(+/–)(=) –2295
   (200)(?)(13.5)(=) 2700
   (288)(?)(8.4)(+/–)(=) –2419

3. Determine the algebraic sum of the lateral offset moments.

   (309)(+)(2295)(+/–)(+)(2700)(+)(2419)(+/–)(=) –1705

4. Divide the sum of the moments by the total weight to determine the lateral CG.

   (1705)(+/–)(÷)(2203)(=) – 0.77

The lateral CG is 0.77 inch to the left of butt line zero.

Determining ? CG Caused by Shifting Weights

Fifty pounds of baggage is shifted from the aft baggage compartment at station 246 to the forward compartment at station 118. The total airplane weight is 4,709 pounds. How much does the CG shift?

1. Determine the number of inches the baggage is shifted:

   (246)(–)(118)(=) 128

2. Use this formula:

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

   (50)(?)(128)(÷)(4709)(=) 1.36

The CG is shifted forward 1.36 inches.

Item	Weight	Lateral Arm	Lateral Offset Moment	Lateral CG
Helicopter empty weight	1,545	+0.2	309	
Pilot	170	–13.5	–2,295	
Passenger	200	+13.5	2,700	
Fuel 48 gal	288	–8.4	–2,419	
Total	2,203		–1,705	–0.77

Figure 8-7. *Specifications for determining the lateral CG of a helicopter.*

Determining Weight Shifted to Cause Specified ? CG

How much weight must be shifted from the aft baggage compartment at station 246 to the forward compartment at station 118, to move the CG forward 2 inches? The total weight of the airplane is 4,709 pounds.

1. Determine the number of inches the baggage is shifted:

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

(246)(–)(118)(=) 128

2. Use this formula:

(2)(?)(4709)(÷)(128)(=) 73.6

Moving 73.6 pounds of baggage from the aft compartment to the forward compartment will shift the CG forward 2 inches.

Determining Distance Weight is Shifted to Move CG a Specific Distance

How many inches aft will a 56-pound battery have to be moved to shift the CG aft by 1.5 inches? The total weight of the airplane is 4,026 pounds.

Use this formula:

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

(1.5)(???????? ??÷)(56)(=) 107.8

Moving the battery aft by 107.8 inches will shift the CG aft 1.5 inches.

Determining Total Weight of an Aircraft That Will Have a Specified ? CG When Cargo is Moved

What is the total weight of an airplane if moving 500 pounds of cargo 96 inches forward shifts the CG 2.0 inches?

Use this formula:

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

(500)(? ??? ? ??÷)(2)(=) 24000

Moving 500 pounds of cargo 96 inches forward will cause a 2.0-inch shift in CG of a 24,000-pound airplane.

Determining Amount of Ballast Needed to Move CG to a Desired Location

How much ballast must be mounted at station 228 to move the CG to its forward limit of +33? The airplane weighs 1,876 pounds and the CG is at +32.2, a distance of 0.8 inch out of limit.

Use this formula:

$$\text{Ballast weight} = \frac{\text{Aircraft empty weight} \times \text{Dist. out of limits}}{\text{Distance ballast to desired CG}}$$

(1876)(?)(.8)(÷)(195)(=) 7.7

Attaching 7.7 pounds of ballast to the bulkhead at station 228 will move the CG to +33.0.