CHAPTER 20: WEIGHT AND BALANCE

REVISIONS

From time to time, revisions to this assembly manual may be deemed necessary. When such revisions are made, you should immediately replace all outdated pages with the revised pages. Discard the out dated pages. Note that on the lower right corner of each page is a "revision date". Initial printings will have the number "0" printed and the printing date. All subsequent revisions will have the revision number followed by the date of that revision. When such revisions are made, a "table of revisions" page will also be issued. This page (or pages) should be inserted in front of the opening page (this page) of each affected chapter. A new "table of revisions" page will accompany any revision made to a chapter.

CONTENTS

Jerry Knapp

N 32
FW 39
Main 77
Fuell ~~Pilot~~ 77.73
Pilot 97
Bag 114

1. INTRODUCTION

Well, this is the moment we've all been waiting for. After all those hours of building an airframe as LIGHT as possible, the proof is on the dial! Of course, the weight not only has to be about right, but it must also be in the right place. Proper CG is absolutely critical to safe flight. This is where NO exceptions can be considered, you must verify that the center of weight is in the correct position and if it is not, you must correct it.

Individual builders' preferences, techniques, etc. can play a major roll in placing the initial empty CG of the airframe which is why we suggest that you make some preliminary weight and balance calculations during the latter part of assembly and prior to installing the battery since the battery is an excellent tool to use in adjusting the empty CG of the completed airframe.

Spend a little time to prepare a nice weight and balance sheet since the F.A.A. will require this for your airworthiness certificate. You should run several weight and balance calculations for a variety of loading variations. We have supplied you with three blank weight and balance sheets. For the following, you'll need a good (repeat GOOD) set of scales. Bathroom scales are simply not good enough.

2. PROCEDURE

WARNING: Do not attempt to calculate the center of gravity using common bathroom scales. They are not accurate enough for these expected weights and will give false reading. Flying outside of the approved center of gravity envelope could be dangerous.

You should borrow or rent for a day, a good set (3) of accurate beam scales or equivalent. These scales should be able to accurately handle up to 400 lbs. each. Often, a local EAA chapter will have a set or know where you can locate a set for use. Also, many FBO's have them.

1. First establish the airframe's empty weight and its empty center of gravity (CG). To do this you'll need to establish the aircraft as "level" while sitting on all three scales. This will require shim blocks under the main gear. These shim blocks can be 1x4's or similar, their weight will be referred to as "tare weight". That tare weight will always be deducted from any readings on its scale.

2. Establishing this empty CG is very easy once the aircraft is placed on the scales and levelled with shim blocks.

   NOTE: If you have not installed the battery yet, that's fine. You will later weigh the battery and its installation hardware, etc. and easily calculate where it should be placed. Or, you could actually place the battery in the desired locations in the plane and read the weights.

   WARNING: Be sure to conduct this weight and balance test indoors or on a very calm day. Even the slightest breeze can generate a few pounds of lift over the wings and totally ruin your accuracy. The ground base should also be flat and level.

3. Next, establish a "datum point". This is a point from which all measurements will have to be taken. The actual location of the datum is not important. What is important is that your selected datum point is easily determined and ALL measurements are from that same point. For convenience, we suggest the back edge of the spinner.

4. From your datum point, drop a plumb bob and mark a point on the floor where the plumb bob centers. Mark a centerline for the aircraft down along the floor as well. You can quickly do this by dropping a plumb bob line at the tail and then connecting the two points with a straight chalk line. The spinner center will actually be slightly right of center line but that's o.k., it's close enough for its intended purpose.

5. Drop a plumb bob down from the center of each wheel axle. Mark the nose gear axle center onto the ground at the centerline position. Mark the two main gear axle centers onto the ground and extend a straight line connecting the two, then mark that location where it crosses the fuselage center line that was previously marked onto the ground.

6. Read and record the actual weights of the leveled aircraft on the three scales. Log these weights in the appropriate lines of column A.

7. Log the weights of any shim stock that is on the scales (1x4's, etc.) as tare weight in column B.

8. Subtract the tare weights from the measured weights and place those figures in column C.

9. Next measure and record the distance from the datum point to the nose gear. Measure and record the distance from the datum point to the location of the main gear as marked along the fuselage center line. Log these distances in the appropriate lines of column D. These are the "moment arms".

10. You now have all the information necessary to establish the empty CG.

11. You will now need to arrive at the "moment weights" of the nose gear location and the main gear location. To do this, simply multiply the weight of the nose gear by the distance from the datum point. Record this number in column E. Do the same for the main gear.

12. Total lines C and E separately.

13. Now simply divide column E by column C and you will arrive at the empty weight CG, expressed as a distance from the datum point.
    This empty weight CG must ultimately be forward of the allowable CG since when the pilot gets into the aircraft, he will be aft of this point and that will move the CG aft into the beginning of the allowable range. You want to establish the empty CG such that when the plane is in its most nose heavy condition (full header tank and just the pilot in the plane) the CG is at the front limit.

Allowable Center of Gravity is from FS 24.5 to FS 30.3

You'll now need to locate FS 24.5 and FS 30.3 thus establishing a moment arm for them so that you can reference your actual CG in meaningful terms. This is not hard to establish.

14. There are two easy references:
a.) The back face of your firewall is FS-0 and is easily located through the nose gear well. Drop a plumb bob line down from that point and mark it onto the centerline on the floor. (This line will likely be on the nose gear scale platform but that's o.k.) Measure from your datum point to this FS-0 mark and record that dimension. You can now easily calculate your particular moment arm required to align with FS-24.5 and FS-30.3.

b. The front face of the main spar web is a very good reference point, and that is accessible from inside the cockpit. It should be (if you constructed your plane correctly) 27.5" back from the firewall at, of course, FS 27.5.

You should now, therefore, have established your minimum and maximum allowable moment arms that establish the CG range. Record these moment arm ranges on your CG calculation sheets.

15. Before you remove the aircraft from the scales, it is a very wise idea to also establish your exact moment arms for various loading items such as header tank fuel and pilot / passengers. The header tank fuel can be estimated with quite close accuracy since it is a well confined shape with known weights. The pilot and passenger moment arms should definitely be determined and not estimated. Factors like seat back angles can greatly affect the overall pilot CG when seated in the aircraft. Estimating body CG could easily be off by two to four inches which would invalidate your flying CG calculations.

16. To determine your pilot / passenger moment arm simply sit in the plane and have someone log the resultant weight changes on the three scales. You'll notice that the nose gear scale weight actually becomes *less* while the main gear increases by more than your known body weight. However, the net change in the aircraft weight will obviously be equal to your exact body weight. (If not, call the witch doctor!)

17. With the weight changes logged on the three scales, recalculate to determine your pilot's moment arm. Lets use an example:

EXAMPLE:

Let's say you weigh 170 lbs. The net change on the nose gear was (-50 lbs.) and the net gain on the main gear then had to be 170 + 50 = 220 lbs. Multiply the nose gear weight change (a negative number) by its moment arm and the main gear change by its moment arm. Combine those two numbers (moment weights) and divide by 170. (Remember that the nose gear number is a negative number so it will actually subtract from the other.) The resultant figure is the moment arm for your body. Log that dimension as the pilot / passenger moment arms.

18. You can use the above approach to calculate (accurately) any loading units like header tank fuel, wing tank fuel and baggage. It is recommended that you take the time to do so since it is the only means of attaining a truly accurate loading analysis. If you are measuring for fuel loads, accurately add measured gallons of fuel and use 6 lbs. per gallon to calculate the weights.
Fuel weight = 6 lbs. / gallon
Oil weight = 7 lbs. / gallon

19. If you have the battery positioned in the aircraft then the weights will be final and the aircraft's empty CG should be forward of the allowable forward CG limit. This is because virtually all flight load conditions will pull the CG aft. What is ideal is to have the CG located on the forward most point of the envelope when you have a full header tank and only the pilot in the plane. This will be your most forward CG flying condition, all other loads applied will only move the CG aft and as you use the header tank fuel, the CG will again move aft.
The best empty CG position (distance fwd of the allowable flight CG) is determined primarily by your pilot / passenger moment arm. An empty CG about 2" fwd (or FS-22.5) is about right but you should verify this for your own aircraft.

CAUTION: Do not set the aircraft <u>empty</u> CG at the fwd most point of the allowable CG range. This would be wasting available CG range since you would never be able to operate at the fwd CG limit. Thus, it would take less weight in the aircraft to move you out the back of the envelope which is very dangerous and not allowed.

20. Use the battery to establish the empty CG at the most opportune location (about 2" fwd of the fwd allowable CG range). This can be done by physically locating the battery in the aircraft during the weigh in and recording the changes. An easier method is to weigh the aircraft without the battery installed, then weigh the battery (add about 2 lbs. for the battery box installation) and simply calculate that position, you will likely have to compromise a bit since you would not want to stick the battery in the middle of the baggage bay, etc., but this is will allow you to come very close in establishing the most desirable empty CG possible.

21. To calculate the best battery location after a weigh in (without the battery installed), follow these steps as shown in a sample calculation.

SAMPLE CALCULATION FOR BATTERY PLACEMENT:

22. 1.) Establish the battery weight (include the master relay and add about 2 lbs. for the box installation). <u>Let's say it's 26 lbs.</u>
2.) Let's say your plane weighs 980 lbs. (less battery) & its moment arm calculates to be 56, thus providing an FS-20 location (this assumes a datum point that was 36" fwd of FS-0).

We have calculated that an FS-22.5 empty CG position is ideal and that's what we'll strive for. That will result in an ideal empty weight moment arm of 58.5 including the battery.

980 x 56 = 54,880	Moment Weight (plane less battery)
980 + 26 = 1,006	Final plane empty weight
58.5	Ideal aircraft empty weight moment arm
1,006 x 58.5 = 58,851	Ideal aircraft final moment weight
58,851 - 54,880 = 3,971	Ideal battery moment weight
3,971 / 26 = 152.7	Ideal battery moment arm (or FS 116.7)

23. Thus by the above sample calculation, you would mount the battery at FS 116.7.

24. If you need ballast weights in the aircraft to achieve proper CG, try to use required items such as a tool bag, etc., as the necessary ballast weights. There are ways within the engine compartment to change the weights by using either heavier starters or alternators. The last option should be the addition of useless lead to bring the plane into CG.

25. Now, to illustrate how this can work out o.k., let's pursue this sample problem a little farther. Let's assume that the pilot / passenger moment arm proved to be 83".

26.

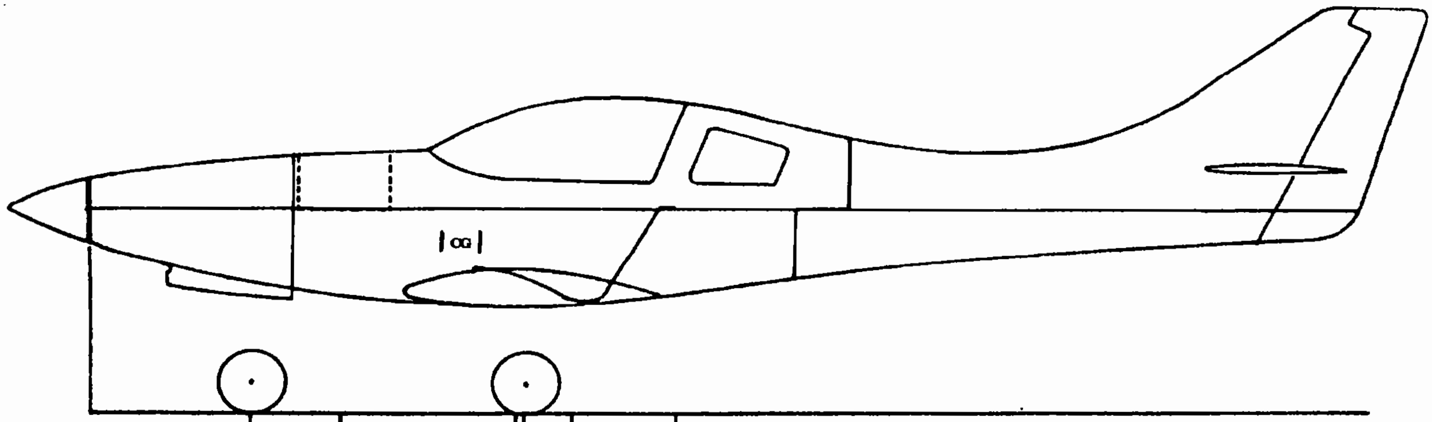
170 x 83 = 14,110	Moment weight of pilot (170 lbs.).
66 x 43 = 2,838	Moment weight for 11 gal. header tank @ 43" moment arm.
58,851 + 14,110 + 2,838 = 75,779	Total combined moment weight (plane, pilot, header fuel)
1,242 lbs.	Total combined weight of a/c (plane, pilot, header fuel)
75,799 / 1,242 = 61.0	Moment arm during this flight condition (or FS-25) O.K.

27. Now you can take all the calculated moment arms for fuel, pilot / passenger and baggage and make several sample loading analyses to verify that you will always remain within the allowable CG range.

28. If you arrive at loading calculations that move the plane out of the allowable CG range then you must placard the plane accordingly so as to not overload it. This is usually found in baggage limit placards. If you have fabricated a rear "hat rack" it should be placarded for a maximum weight since it is so far aft. Generally, 3-5 lbs. is max. so it is quite literally a "hat rack" and must not be used for anything heavier. Run several sample calculations at that extreme aft end (thus long moment arms) to establish good, safe limits for loading. The weight and balance sheets have a sample calculation row. It should be used and recorded. Perform additional calculations as required to verify that you will not inadvertently load the aircraft improperly. According to FAA regulations, one of these weight and balance sheets must be carried in the aircraft at all times.

WEIGHT & BALANCE SHEET

LANCAIR 320



"N" NUMBER ____________

BUILDER ____________________

CG Range: (inches) 5.8" ~~FS24.5~~ 22.84 - FS30.3 (Station_____ to ______)

	A Wt. (lbs)	B Tare Wt.	C Net Wt.	D Moment Arm (in.)	E Moment Wt. (in/lbs)	Station
Nose Gear						
Rt. Main Gear						
L. Main Gear						
Plane Empty CG (with oil)						E / C = AIRCRAFT STATION
Plane						
Pilot only						
Header Tank Full						
Maximum fwd CG condition						
Plane						
Pilot & Pass.						
Low Header Tank						
Wing Tanks						
Luggage]						
Maximum aft CG condition						
Plane						
Pilot						
Fuel (header)						
Fuel (wings)						
Luggage						
Sample condition						

Lancair 320/360

MAC 11%-29% FS 62.09-69.55

	weight	mom. Arm	Mom-wt	station	
nose gear	400	32	12800		
main gears	797.5	77	61407.5		
empty CG	1197.5		74207.5	61.97	
Aircraft	1197.5		74207.5	61.97	
Pilot	190	97	18430		
(min fuel)	0		0		
65 gal.@6 lbs	240	77.73	18655.2		
+copilot	170	97	16490		
"+baggage	5	114	570		
			0		
	0		0		
GWT	**1802.5**		128352.7	**71.21**	**CG**

To remain in CG, no more than 90 gallon total allowed with 4 passengers.