SECTION 14: WEIGHT AND BALANCE

Any aircraft must, for safety's sake, be operated within its weight and balance envelope. Weight and its distribution can severely affect performance, handling, controllability, and even structural integrity. This section will give you basic procedures for weighing your RV-6/6A and performing weight and balance calculations.

The forms presented and calculations performed here are only for standard operating conditions and for Standard FAA Pilot Weights. We all know that not all pilots and passengers weight exactly 170 lbs. Performing weight and balance calculations based on these weights provides both the pilot and the FAA with typical anticipated loading conditions. For operating the aircraft under conditions where the average pilot and passenger weights differ from 170 lbs., additional calculations must be performed to verify compliance with C.G. or Gross Weight limits.

The pilot should not only be familiar with the limit load and C.G. calculations as required by the FAA, but should also be familiar with the theory of how C.G. location affects aircraft stability and handling. Day-to-day flight operations will not always involve loads which are exactly matched to the limit load calculations, so accurate estimates or further calculation will be necessary to assure safe flight operations. It is possible to perform weight and balance computations for an airplane simply by following procedures and doing the mathematics, without really understanding all of the terms and computations. However, as pilot of the airplane, it is highly desirable that a person have a good understanding of weight and balance, the effects that weight and balance has on the flight characteristics of the airplane, and the reasons for C.G. limits.

Before getting into the details of performing weight and balance measurements and calculations for your RV-6/6A, let's review the definitions of some of the terms involved so that we can better understand the significance of weight and balance figures.

- **Empty Weight** - Weight of the airplane including fixed ballast, unusable fuel, and oil.
- **Gross Weight** - Sum of empty weight plus crew, passengers, fuel, and baggage. It is important because of the effect it has both on the structure and performance of the airplane. Obviously, higher gross weights will diminish all aspects of performance, particularly take-off and climb performance. Increased weight also increases stall speed. Higher gross weights will tend to overstress the airplane's structure both in flight and on the ground. In the Experimental Amateur Built Category -- the category in which the RV-6/6A would typically be licensed -- the aircraft builder is allowed to specify this weight. Van's recommends a 1650 pound (RV-6/6A) limit.
- **Maximum Gross Weight** - The maximum allowable operating weight, with all variable load items located such that the Center of Gravity (C.G.) remains within prescribed limits.
- **Aerobatic Gross Weight:** The maximum weight that the structure of the airplane can support at the 6G limit of the Aerobatic Category. For the RV-6/6A, this weight is 1375 lbs.
- **Payload** - Weight of passengers and baggage.
- **Useful Load** - Weight of passengers, fuel, and baggage.
- **Center of Gravity** - The point at which the mass of an object is considered to be concentrated. (The point at which the airframe plus all added weights are concentrated.)
- **Arm - (or Moment Arm)** The horizontal distance along the longitudinal axis from the datum to the C.G. of an item being considered, or from the datum to the point where a force is applied. Normally measured in inches; aft of datum is plus (+) and forward of datum is minus (-).
- **Moment** - The product of a weight or force and its moment arm (M=W x D)
- **Datum** - Arbitrary reference plane selected by the manufacturer (builder) from which all arm measurements are made for weight and balance computations. Normally, the datum chosen will be in front of the aircraft nose so that all arm measurements will be positive. This makes weight and balance computations easier. The weight and balance datum for the RV-6/6A has been established at 60 inches ahead of the leading edge of the wing. The weight and balance form and the sample calculations at the end of the chapter are based on this.
- **Leveling Datum** - A point or surface on the airframe where a level can be placed to determine when the aircraft is in a level position for weighing. For the RV-6/6A the Level Datum line is the fuselage top longeron at the cockpit.
- **C.G. Location (or range)** - Usually defined two different ways. One is by establishing certain positions or limits with reference to the chord of the wing such as "between 15% and 29% of chord". This position is then converted into inches by multiplying the wing chord by that percentage (for RV-6/6A, 15% x 58"= 8.7", and 29% x 58" = 16.8") The C.G. location with reference to datum is then computed by adding these distances (arms) to the distance from wing leading edge to datum.
- **Forward C.G. Limit** - An airplane operating at or near its forward C.G. limit will have improved stall and spin resistance and improved stall & spin recovery characteristics. It will also have higher elevator stick force and

trim force requirements, and will require more stick force for landing flare. When on the ground, it will place a greater percentage of the gross weight on the nose landing gear. It will have higher trim drag which will tend to decrease speeds, but will increase the pitch stability of the airplane. In general, it makes the airplane more stable and safe, but less fun to fly.

- **Rearward C.G. Limit** - An aircraft flown at or near its aft C.G. limit will have lighter elevator stick force requirements and will therefore be easier to rotate to a high angle of attack from which stall entry is more likely. Stall and spin recovery at a rearward C.G. is slower and requires more corrective control action. Trim drag is minimized and thus speeds tend to be at their highest when C.G. is more aft. In general, C.G.s in the aft half of the range make the airplane less stable but more fun to fly, at least when maneuvering. C.G.s at or beyond the aft limit can cause control reversals and other dangerous flight conditions.
- **Rearward "Aerobatic" C.G. Limits** - are often established because of the deteriorated aft C.G. stall and spin recovery characteristics and the increased likelihood of accidental stalls and spins due to the unusual attitudes associated with aerobatics. The aft aerobatic C.G. limit is always forward of the max. aft C.G. limit. For the RV-6/6A it has been established at 26.5% chord, 15.3" aft of the wing leading edge, or 75.3" aft of the datum.
- **Maximum Weight on Nosewheel** (Applicable to RV-6A only) - The weight on the nosewheel varies with both gross weight and CG location and must be checked so as to be sure that it is within limits. Because of the inter-relationship an aircraft with forward CG but low gross weight may place an unacceptably high load on the nosewheel. Use the chart on the last page to calculate the nosewheel weight for a particular CG and gross weight.

MAXIMUM BAGGAGE WEIGHT

The maximum allowable baggage is a weight determined by the structural limits of the baggage compartment floor, and is the maximum weight which should be carried in the baggage compartment under the most ideal conditions. For the RV-6/6A, the maximum permissible baggage limit is 100 lbs. This means that when C.G. limits and gross weight limits will permit, up to 100 lbs. of baggage can be carried in the RV-6/6A baggage compartment. An example of this condition would be for single pilot operation where this amount of baggage would not likely cause either the C.G. or the gross weight to exceed limits. With a single occupant, additional baggage could be carried in the passenger seat, but only if the C.G. and Gross weight remained within limits, and if it can be secured so that it cannot possibly interfere with the pilot's ability to operate the controls.

AIRCRAFT WEIGHING

Weigh your RV-6/6A with three platform type aircraft scales which have been certified for accuracy. At times, good scales are not available to homebuilders and they use bathroom scales instead. Bathroom scales are often highly inaccurate and usually do not have sufficient capacity to weigh an RV-6/6A main wheel. However, two can be ganged together with a plank over them if no other scales are available. Because a homebuilder can probably borrow any number of bathroom scales to use, it would be good to get 5 or 6 of them and weigh oneself on each. This way, the most accurate can be selected and the others calibrated based on it.

Regardless of the scales used, the airplane should be weighed in empty condition and in a level attitude. Level attitude is established at the datum line which is the cockpit rails. Scales should be placed simultaneously under both main wheels and the tail wheel. Use plumb lines or vertical levels to measure the locations of the main wheels relative to the wing leading edge, and then convert this to an arm relative to datum. The same applies to the tail wheel location, which can be accurately located by dropping a plumb line to the floor and measuring forward to the wing leading edge or to datum.

The forms at the end of this section show a sample calculation for the empty weight Center of Gravity for an RV-6/6A. To keep all moments positive, a datum has been selected at a point forward of the prop spinner. Only three moments must be calculated and combined to determine the C.G. position. This figure is not in itself too meaningful, but is important for further loaded weight C.G. calculations.

Also provided are sample calculations for gross weight loading conditions and other limiting conditions. The procedure is to enter the desired loads into the calculation, and then check the resultant C.G. location to see if it falls within the design limits. If not, then further calculations will be needed using varying loads until the resultant C.G. is within limits. This will then become the limit load, or load combination permitted. Such calculations are always based on the amount of fuel which will be on board during the most critical portion of the flight. In other words, if full fuel imposes the extreme loading condition (maximum allowable gross weight) it is the figure used. In other instances, most aft C.G. for example, the minimum fuel supply is assumed because this is the condition which could exist at the end of the flight. The airplane could be within limits at take-off, but outside the limits upon landing. This instance is illustrated in the sample calculations where we have substituted extra baggage and a heavy pilot in lieu of fuel to remain within design gross weight limits. The gross weight C.G. calculations show everything within limits. But, when we re-calculate the C.G. for this same condition, subtracting the weight of the fuel burned, the C.G. moves outside of the aft limit. A reduction in baggage weight would be needed to attain an acceptable loading condition. By trial and error calculations, we can thereby establish the maximum baggage permitted under minimum fuel conditions. C.G. calculations combine the effects of all loads placed in the aircraft and consider them as one, centered at a median point. Many different combinations of loads and locations are possible, to achieve the same end loading result.

In Sample 4 considers the most forward loading that can be achieved – full fuel, a very light pilot, no passenger, and no baggage. This low gross weight loading places the largest load on the nosewheel and must be checked to assure that it is within limits. Some aircraft, due to the builder's selection of propeller & engine as well as equipment mounted in the forward fuselage, may require that ballast be carried in the baggage compartment so as to reduce the nosewheel load to an acceptable level.

In Sample 5, consider a gross weight condition in which a 221 lb. pilot was installed in lieu of the 170 lb. pilot used in the gross wt. calculation. Also substituted was an increase in the baggage load up to the structural limit of 100 lbs. A reduction in the fuel load was needed to remain within the gross wt. limit of 1650 lbs. The calculations show that the C.G. will remain within limits for this loading condition.

In Sample 6, when an additional C.G. calculation is made for minimum fuel at this loading condition, the C.G. falls outside of limits. Further calculations, shown in Sample 3, are then necessary to determine the maximum baggage which could be carried along with the pilot and passenger weights specified. This sample loading condition was selected to illustrate an unacceptable loading condition, and the method for determining loading changes necessary to remain within C.G. limits. The pilot is responsible for additional C.G. calculations for any loading conditions other than the documented standard conditions listed on the FAA required papers.

Following the sample calculations is a blank C.G. form which may be used for calculating the C.G. for *your* RV-6/6A. Arms for the locations of the standard loads are provided in the sample calculations. If those for your airplane remain the same, (no changes in the seat locations, etc.) these figures can be used. The sample calculations are only representative figures and may not be the same as those you determine for your RV-6/6A. While the loads and weights of pilot, passenger, and fuel may be the same, a different empty weight C.G. for your RV-6/6A could cause the final loaded C.G. to be considerably different. Any changes in the airframe such as the use of a metal prop, particularly a constant speed prop, would considerably affect the empty C.G. Such changes may require relocation of other items, such as the battery, to keep the empty C.G. within an acceptable range. Increased empty weight will decrease useful load; either passenger weight, fuel weight, or baggage weight must be reduced to remain with the permissible gross weight. This is a common practice in production light planes where it is rare that full fuel, pilot and passengers, and baggage can all be loaded simultaneously and remain within gross weight limits.

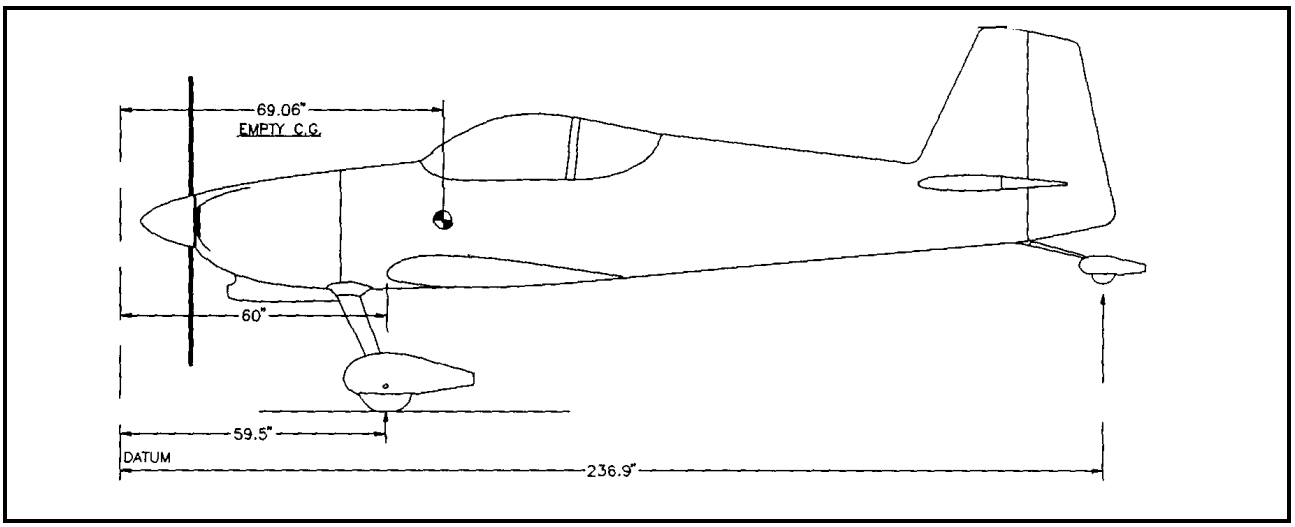
RV-6/6A WEIGHTS AND LIMITS - EASY REFERENCE

Recommended Gross Weight	1650 lbs
Aerobatic Gross Weight	1375 lbs
Forward CG Limit	15% of chord or 8.7" aft of leading edge
Aft CG Limit	29% of chord or 16.8" aft of leading edge
Aerobatic Aft CG Limit	26.5% of chord or 15.3" aft of leading edge
RV-6A Max Weight on Nosewheel	375 lb (if using any other gear leg other than U-00019)

SAMPLE WEIGHT & BALANCE FOR AN RV-6

Datum 60 inches forward of wing leading edge. (L.E.)
Design C.G. Range 15%-29% of wing chord, or 8.7"-16.8 inches from L.E., or 68.7-76.8 inches aft of Datum.
Wing L.E. 60 inches aft of datum.
Fuel 70" aft of datum
Pilot & Passenger 87.4" aft of datum
Baggage 117" aft of datum

Aircraft weighed in level flight attitude. (includes 8 qts. of oil, no fuel)



Main wheel, right 59.5" aft of datum.
Main wheel, left 59.5" aft of datum.
Tail Wheel 236.9" aft of datum

DETERMINING EMPTY CG

	Weight	Arm	Moment
Right Wheel -	456	59.5	27132
Left Wheel -	457	59.5	27192
Tail Wheel -	52	236.9	12319
Total:	965		66643

C.G. = 66643/965= 69.06" aft of datum for empty weight CG

SAMPLE SITUATION 1: GROSS WEIGHT CG

	Weight	Arm	Moment
Aircraft	965	69.06	66643
Fuel (38 Gal.)	228	70.00	15960
Pilot	180	87.40	15732
Passenger	180	87.40	15732
Baggage	97	117.00	11349
Total:	1650		125415.9

CG = 125415.9/1650= 76.00" aft of the datum. This is less than the limit of 76.8, so is within CG limits. RV-6A Load on Nosewheel = 242 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.

SAMPLE SITUATION 2 : MOST AFT CG (Gross weight, minimum fuel)

	Weight	Arm	Moment
Aircraft	965	9.06	66643
Fuel (5 gal.)	30	70.00	2100
Pilot	170	87.40	14858
Passenger	170	87.40	14858
Baggage	67	117.00	7839
Total:	1402		106298

CG=111577/1452=76.8" aft of datum. This IS the aft limit, so is acceptable. RV-6A Load on Nosewheel = 211 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.

SAMPLE SITUATION 3: MOST FORWARD C.G. (STD PILOT WT.)

	Weight	Arm	Moment
Aircraft	965	69.06	66643
Fuel (38 gal.)	228	70.00	15960
Pilot	170	87.40	14858
Total	1363		97461

CG= 97461/1363=71.5" aft of datum. This is greater than the forward limit of 68.7, so is within CG limits. RV-6A Load on Nosewheel = 311 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.

SAMPLE SITUATION 4: MOST FORWARD C.G. (MIN. PILOT WT.)

	Weight	Arm	Moment
Aircraft	965	69.06	66643
Fuel (38 gal)	228	70.00	15960
Pilot	105	87.40	9177
Total	1298		91780

CG=91780/1298=70.7" aft of datum. This is greater than the forward limit of 68.7, so is within CG limits. RV-6A Load on Nosewheel = 315 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.

SAMPLE SITUATION 5: GROSS WEIGHT WITH HEAVY PILOT & BAGGAGE, REDUCED FUEL

	Weight	Arm	Moment
Aircraft	965	69.06	66643
Fuel (24 gal)	144	70.00	10080
Pilot	221	87.40	19315
Passenger	220	87.40	19228
Baggage	100	117.00	11700
Total	1650		126966

*CG=*126966*/1650=76.62 aft of datum. This is within CG limits. RV-6A Load on Nosewheel = 226 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.*

SAMPLE SITUATION 6: AS ABOVE, BUT WITH MINIMUM FUEL

	Weight	Arm	Moment
Aircraft	965	69.06	66643
Fuel (5 gal)	30	70.00	2100
Pilot	221	87.40	19315
Passenger	170	87.40	14858
Baggage	100	117.0	11700
Total	1486		114616

CG=114616/1486=77.1" aft of the datum. THIS EXCEEDS THE AFT LIMIT OF 76.8', SO IS NOT WITHIN THE PRESCRIBED CG ENVELOPE. These examples illustrate how it might be possible to begin a flight within CG limits, but be out of limits upon landing. RV-6A Load on Nosewheel = 189 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.

SAMPLE SITUATION 7: AS ABOVE, BUT WITH REDUCED BAGGAGE

	Weight	Arm	Moment
Aircraft	965	69.06	66643
Fuel (5 gal)	30	70.00	2100
Pilot	221	87.40	19315
Passenger	170	87.40	14858
Baggage	87	117.00	10179
Total	1473		113095

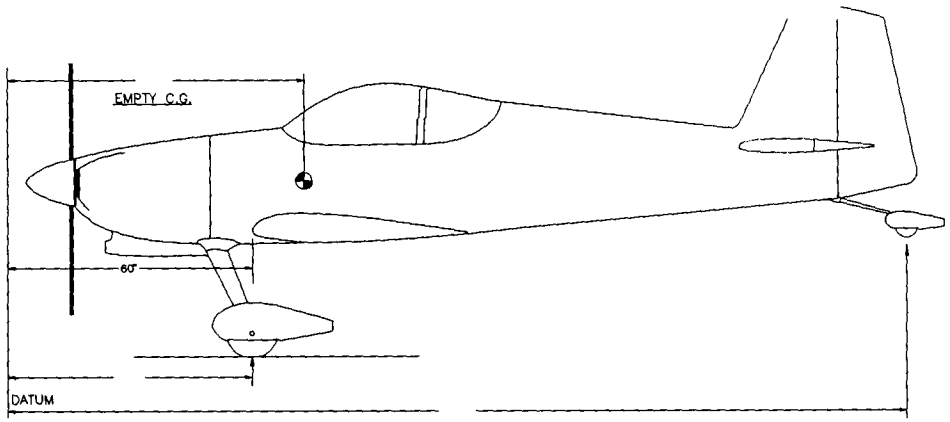
CG=113095/1473=76.78" aft of the datum. This is less than the aft limit, so by reducing the baggage by only 13 lbs, the CG is kept within limits at the end of the flight. . RV-6A Load on Nosewheel = 196 lb. This is less than the limit of 375 lb so is within max nosewheel load limits.

WEIGHT & BALANCE DATA for RV-6:

MAKE:_____ MODEL:_____ SERIAL_____
REGISTRATION_____

Datum	60 inches forward of wing leading edge. (L.E.)
Design C.G. Range	15%-29% of wing chord, or 8.7"-16.8 inches from L.E., or 68.7-76.8 inches aft of Datum
Wing L.E	60 inches aft of datum.
Fuel	70" aft of datum
Pilot & Passenger	87.4" aft of datum
Baggage	117" aft of datum

Aircraft Weighed empty in level flight attitude. Includes 8 qts. of oil, no fuel)



Main wheel, right _____in. aft of datum.
Main wheel, left _____in. aft of datum.
Tail wheel _____in. aft of datum.

DETERMINING EMPTY CG

	Weight	Arm	Moment
Right Wheel	_____	_____	_____
Left Wheel	_____	_____	_____
Tail Wheel	_____	_____	_____
Total:	_____		_____

EMPTY AIRCRAFT C.G. =_____/_____=_____inches aft of datum.

SITUATION 1: GROSS WEIGHT CG

	Weight	Arm	Moment
Aircraft	_____	_____	_____
Fuel (38 Gal.)	_____	_____	_____
Pilot	_____	_____	_____
Passenger	_____	_____	_____
Baggage	_____	_____	_____
Total:	_____		_____

C.G. = _____/_____ = _____in. aft of datum.

SITUATION 2: MOST AFT CG (GROSS WEIGHT, MINIMUM FUEL)

	Weight	Arm	Moment
Aircraft	_____	_____	_____
Fuel (5 Gal.)	_____	_____	_____
Pilot	_____	_____	_____
Passenger	_____	_____	_____
Baggage	_____	_____	_____
Total:	_____		_____

C.G. = _____/_____ = _____in. aft of datum.

SITUATION 3: MOST FORWARD C.G. (STD PILOT WT.)

	Weight	Arm	Moment
Aircraft	_____	_____	_____
Fuel (38 Gal.)	_____	_____	_____
Pilot	_____	_____	_____
Total:	_____		_____

C.G. = _____/_____ = _____in. aft of datum.

SITUATION 4: MOST FORWARD C.G. (MIN. PILOT WT.)

	Weight	Arm	Moment
Aircraft	_____	_____	_____
Fuel (38 Gal.)	_____	_____	_____
Pilot	_____	_____	_____
Total:	_____		_____

C.G. = _____/_____ = _____in. aft of datum.

SITUATION 5: GROSS WEIGHT (HEAVY PILOT & BAGGAGE, REDUCED FUEL)

	Weight	Arm	Moment
Aircraft	_____	_____	_____
Fuel [ ] Gal	_____	_____	_____
Pilot	_____	_____	_____
Passenger	_____	_____	_____
Baggage	_____	_____	_____
Total:	_____		_____

C.G. = _____/_____ = _____in. aft of datum.

SITUATION 6: AS ABOVE, BUT WITH MINIMUM FUEL

	Weight	Arm	Moment
Aircraft	_____	_____	_____
Fuel (5 Gal.)	_____	_____	_____
Pilot	_____	_____	_____
Passenger	_____	_____	_____
Baggage	_____	_____	_____
Total:	_____		_____

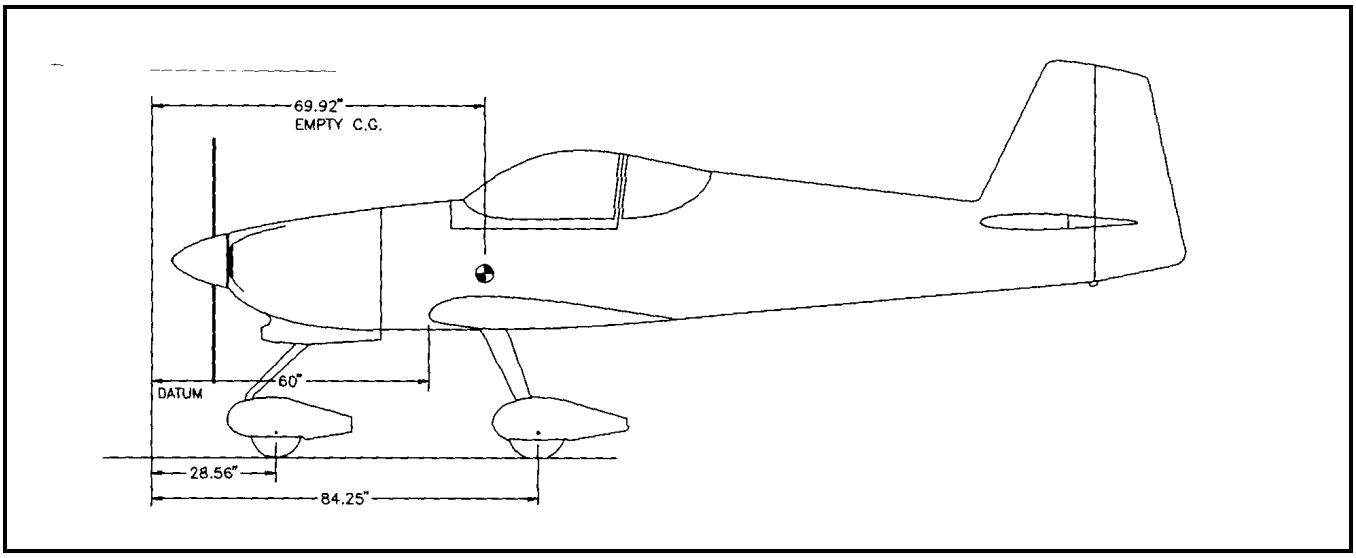
C.G. = _____/_____ = _____in. aft of datum.

SAMPLE WEIGHT & BALANCE FOR AN RV-6A

Datum	60 inches forward of wing leading edge. (L.E.)
Design C.G. Range	15% to 29% of wing chord, or 8.7" to 16.8 inches from L.E., or 68.7 to 76.8 aft of datum.
Wing L.E.	60 inches aft of datum.
Fuel	70" aft of datum
Pilot & Passenger	87.4" aft of datum
Baggage	117" aft of datum

Aircraft weighed in level flight attitude. (includes 8 qts. of oil, no fuel)

Main wheel, right	84.125" aft of datum.
Main wheel, left	84.25" aft of datum.
Nose wheel	28.56 aft of datum.



DETERMINING EMPTY CG

	Weight	Arm	Moment
Right Wheel -	369	84.125	31042
Left Wheel -	371	84.25	31257
Nose Wheel -	255	28.56	7283
TOTAL:	995		69582

C.G. = 69582/995= 69.92" aft of datum for empty weight CG

SEE RV-6 FOR SAMPLE SITUATIONS 1 THROUGH 6

WEIGHT & BALANCE DATA for RV-6A:

MAKE:_____MODEL:_____SERIAL_____REGISTRATION_____
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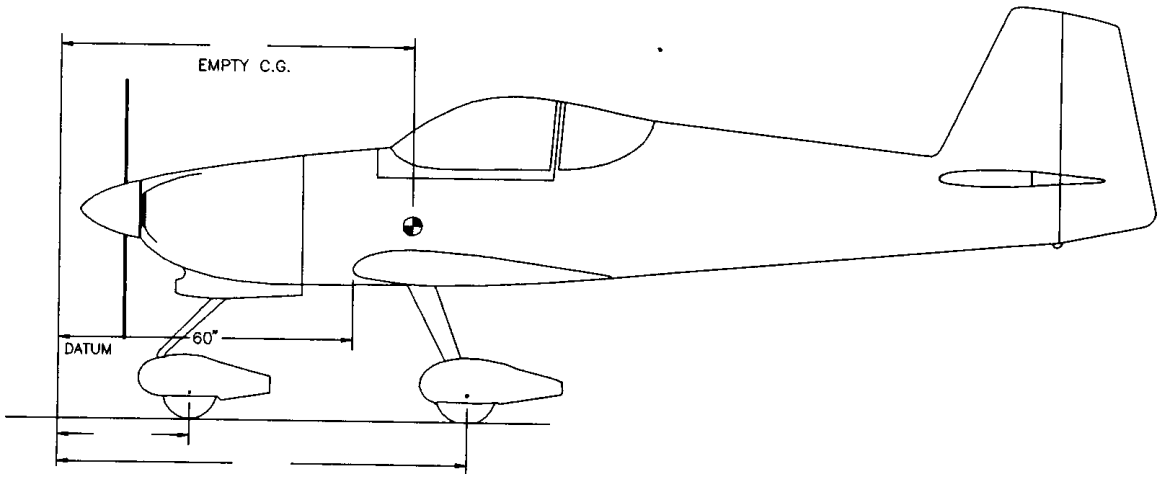
Datum	60 inches forward of wing leading edge. (L.E.)
Design C.G. Range	15% to 29% of wing chord, or 8.7" to 16.8 inches from L.E., or 68.7 to 76.8 aft of datum.
Wing L.E.	60 inches aft of datum.
Baggage	117" aft of datum
Fuel	70" aft of datum
Pilot & Passenger	87.4" aft of datum

Aircraft weighed in level flight attitude. (includes 8 qts. of oil, no fuel)

Main wheel, righ	_____aft of datum.
Main wheel, left	_____aft of datum.
Nose wheel	_____aft of datum.



DETERMINING EMPTY CG

	Weight	Arm	Moment
Right Wheel -	_____	_____	_____
Left Wheel -	_____	_____	_____
Nose Wheel -	_____	_____	_____
TOTAL:	_____		_____

C.G. =_____/_____ = _____" aft of datum for empty weight CG

After determining empty CG use sample problem sheet to calculate different conditions and loadings

SEE RV-6 FOR SITUATION PROBLEMS

NOTE: *This chart does not apply to aircraft equipped with U-00019.*