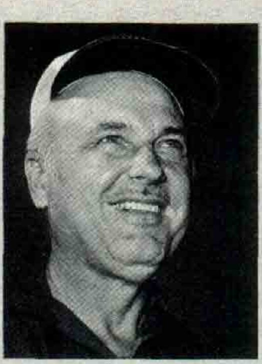


THE SPORTPLANE BUILDER

By Antoni (Tony) Bingelis
EAA Designee Program Advisor

8509 Greenflint Lane
Austin, Texas 78759

HOW TO MASS BALANCE CONTROL SURFACES

THE ASSUMPTION IS reasonable. Flutter in ordinary flap-type control surfaces can be prevented, at least in the speed ranges most homebuilts operate, by using properly distributed mass ballast to obtain a 100% balanced condition. Furthermore, if you were to add just a little extra mass balance weight to provide a slight static overbalance about the hinge line, the flutter problem would almost certainly be eliminated for all flutter modes. The balancing of control surfaces has always been a good practice and it is still the best single flutter preventative the homebuilder has.

There is another alternative. Quite possibly a worthwhile weight savings could be realized if the builder were able to first make a flutter analysis of his aircraft instead of arbitrarily going ahead with a mass balance of its surfaces . . . whether they need it or not. A flutter analysis could reveal, for instance, that the structural resonance frequencies of the control surfaces and the support structure are such that little or no mass is necessary.

Unfortunately, most of us do not have the capability to exercise that alternative. Instead, we either balance the control surfaces or go to the opposite alternative and postpone any further thinking on the matter until test flight time rolls around.

Working from a good set of plans helps resolve the dilemma. The designer will have already investigated and eliminated the problem in the construction and subsequent flight test evaluations of the prototype. If mass balancing is required, the plans probably will contain instructions regarding the exact degree of balance which must be obtained. The designer might state this requirement as "Balance 100%", or, "Add weight until X number of degrees (usually 10° to 20°) nose-down attitude of the surface is obtained."

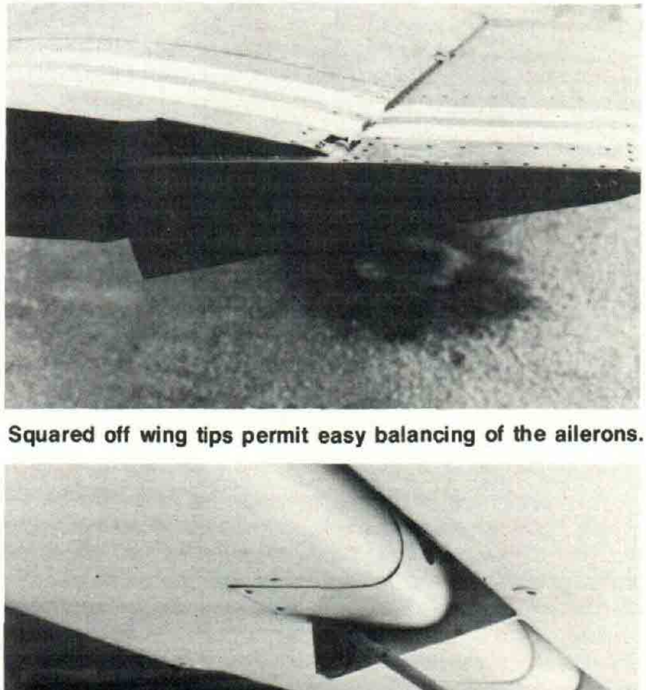
The least useful instruction might be one specifying an exact weight to be installed for the balance, with no information regarding the required balance attitude. This would not be a good practice because subsequent aircraft could turn out to be heavier than the original prototype upon which the designer based his calculations. In that event, the weight specified would, most likely, prove to be insufficient.

Static Balance

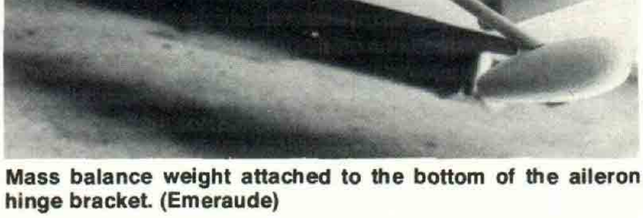
Remove the control surface from the aircraft structure and take it to a cleared-off space on your workbench . . . if you can find such a place. This work area must be in a draft free area to insure accurate results.

Mount the control surface on its own hinges, using the regular hinge bolts inserted in blocks or brackets secured to the work bench for the purpose. If, after slipping in the hinge bolts, the control surface does not rotate freely about its hinge axis because of friction, you may have to resort to substituting a couple of knife-edge mandrels or supports made especially for the purpose.

You may prefer to suspend the control surface from the ceiling or garage door tracks on strings or wires looped through the hinges or around the hinge bolts. Suspending the control surface from wires through the hinges would mean that for some designs (those with the hinge axis below the control surface) the surface would be hanging upside-down for the balancing. This doesn't matter one bit as you will be using the chordline as a horizontal alignment reference. Regardless of which mounting method is used, assure yourself that the control surface hinge axis is horizontal and that the control surface pivots freely. Too often control surfaces are balanced during construction and the builder forgets that, later, additional weight will be picked up in the finishing of the unit, resulting in an underbalanced condition. Therefore, it is well to remember that it is the balance of the control surface in its "as installed" condition that really matters. This means that ideally, a sur-



Squared off wing tips permit easy balancing of the ailerons.



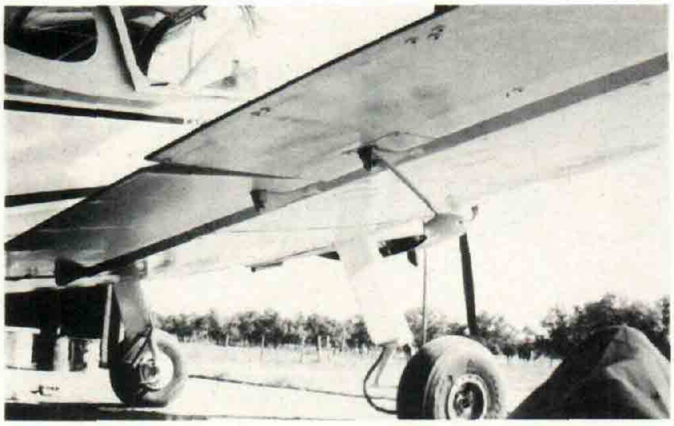
Mass balance weight attached to the bottom of the aileron hinge bracket. (Emeraude)

face should be fully painted and equipped with all fittings, tabs, seals and attachment hardware for its final weighing.

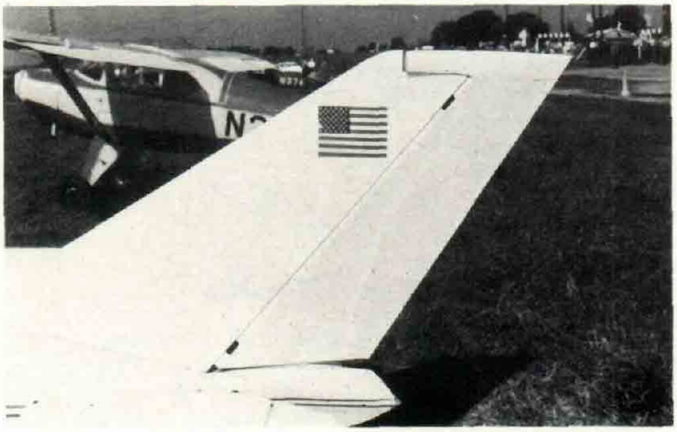
Now, For The Balancing

Although there are several methods used in balancing control surfaces, most are impractical for the homebuilder. There is no need to go into a time-consuming mathematical weight and balance computation, unless, of course, you are in the pencil, paper and computer stages of a new design.

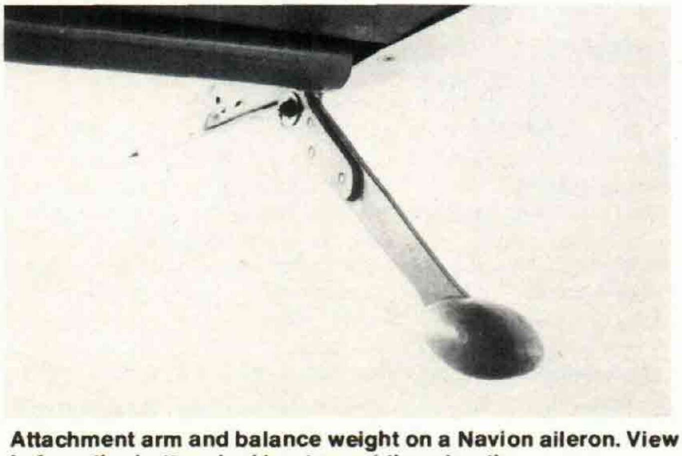
The old trial and error method is effective and hard to fault. That is, you simply add pieces of lead (old wheel balance weights are handy for this purpose) to the location where the weight is to be affixed, until the desired level of balance, or overbalance, is reached. You can do this by temporarily taping the lead pieces to the control surface or you can suspend a tin can (or any kind of small container) from the point where the lead weight is to be ultimately secured. Ducting tape, wire or a similar means should hold things in place during the process.



Flaps are not normally balanced although ailerons most frequently are. Tubular attachment arm should be rigid enough not to introduce vibration problems of its own.



Rudders are difficult to balance because most have very little structure ahead of the hinge axis.



Attachment arm and balance weight on a Navion aileron. View is from the bottom looking toward the wing tip.

Keep putting pieces of lead in the can until the control surface reaches the proper level attitude. Remove the can and weigh the whole thing on a scale. Now you know exactly how much weight it takes to balance the control surface.

If you have no weighing scale you can still balance the surfaces although you may never know how much dead weight you'll be hauling around.

Dump the lead pieces into a ladle or other container and melt them down for casting. Add a little extra lead to allow for the weight of the can, trimming and sloppy pouring. Skim the surface impurities from the molten lead with a "metal stick". The molten lead is now ready to be poured into whatever form you made. Be careful with that hot stuff, amigo!

It would seem as though lead were created specifically for the purpose of molding control surface balance weights. It is heavy and yet soft, making it easy to work and shape. Its low melting point permits it to be melted with almost any kind of torch and poured into any form the builder wants without the requirement for fancy equipment. Of course, its low strength characteristics render it unsuitable for aircraft construction but who cares about that? Nobody wants to build a lead sled anyway.

Lead does have peculiarities which can cause you trouble. Don't try to power sand it. The sandpaper will clog instantly. It will file easily with a coarse file, though.

Drilling lead could be an interesting experience for you if you haven't already been exposed to it. Being so soft, a regular drill bit will tend to "hog in" so I suggest you grind the cutting edge of the bit as shown in Figure 1 to reduce its rake angle. This bit modification will work for other soft metals as well as for plexiglass.

When drilling deep holes in lead, small drill bits have a decided tendency to wander off-center. Their flutes quickly become clogged and often the chips will wedge in the flutes, gripping the bit in the hole so tenaciously that it cannot be removed. To minimize this risk, remove the drill bit from the work frequently to clear the chips from the flutes. You cannot hurry the process. The lead just doesn't care who you are or whether you ever get that hole drilled. Sometimes using lard oil as a lubricant is helpful.

Surprisingly, a metal cutting band saw, even when operated at moderate speeds (as for cutting aluminum) cuts lead smoothly without jamming provided the blade is fairly sharp and the metal doesn't get too heated during the cutting process. If your weights are of a simple shape, you can saw and file them to shape. This is easier than going to the trouble of making a mold and casting the weight from molten lead. Of course, you would have to have a piece of lead large enough for that purpose.

Making Casting Molds

Before you can make a balance weight you will need to make a male plug (or form) of the weight, particularly if it has compound curves. A dummy balance plug can be carved of soft wood or balsa wood or foam or even modeled of clay or plaster. When you have the shape right, you are ready to use it in making a female mold into which the molten lead can be poured. See Figure 1.

You would expect wood to char badly when subjected to the molten metal. Surprisingly, it really does not. It will darken but its usefulness as a mold material is not adversely affected.

Of course, casting sand is an ideal mold material but how many of us just happen to have some on hand? Molds

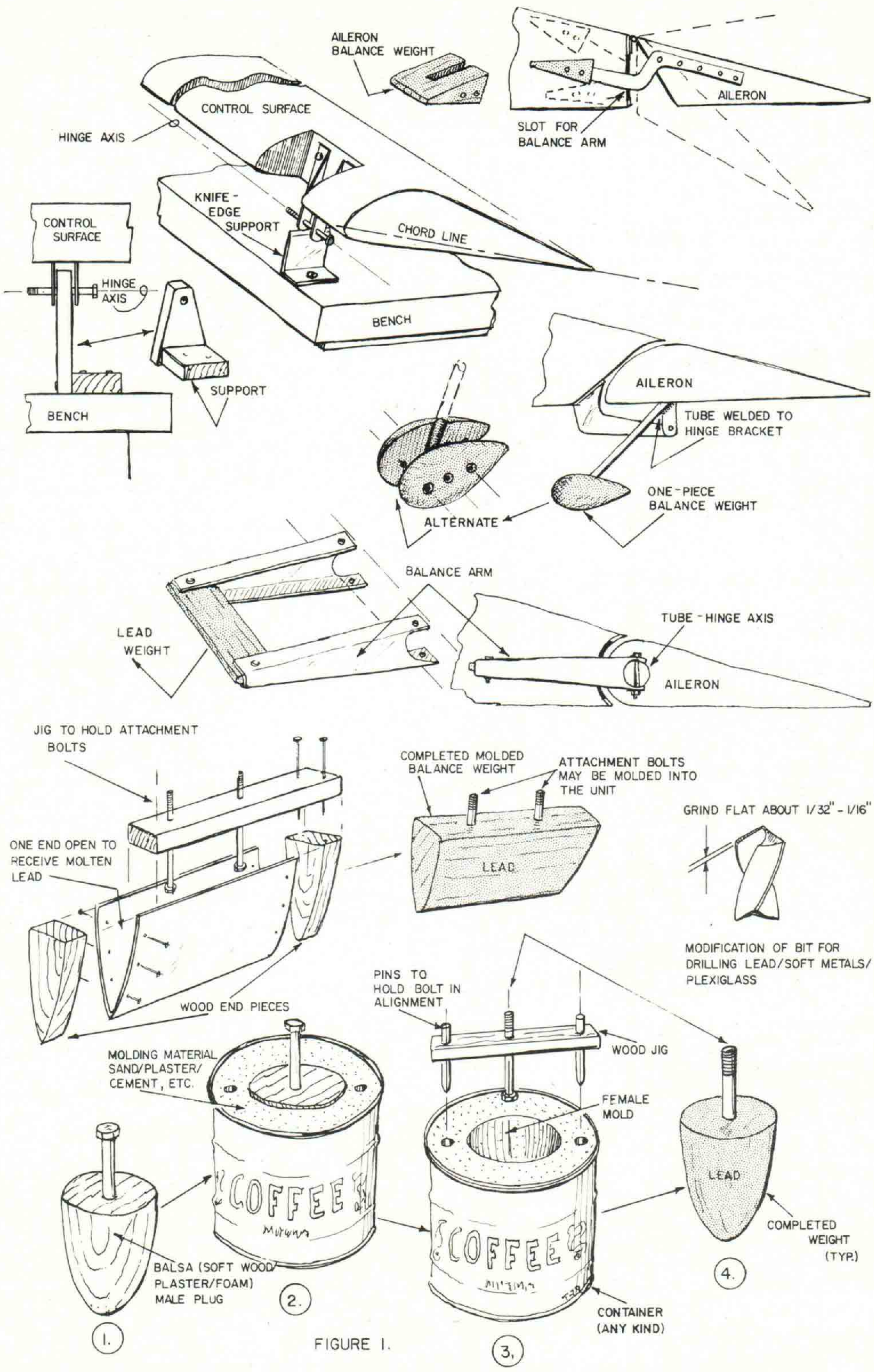
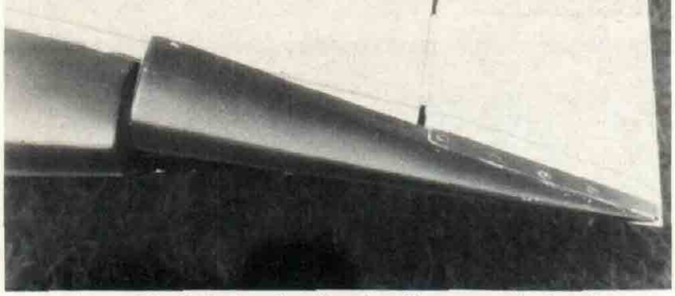
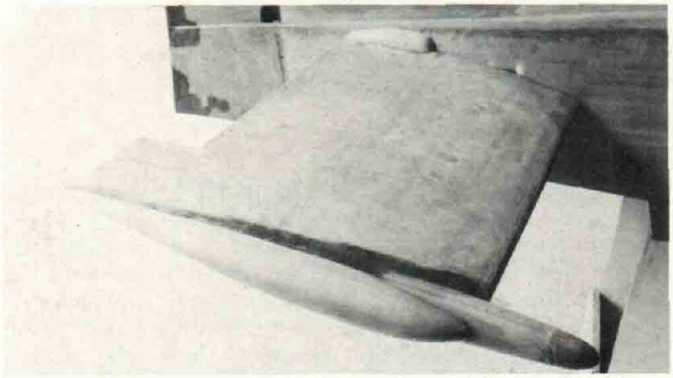


FIGURE 1.

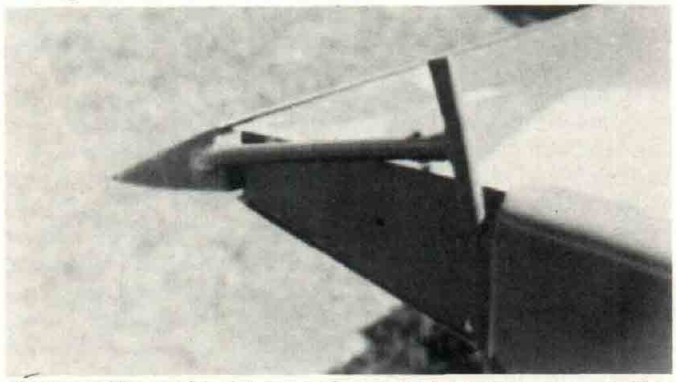
MAKING BALANCE WEIGHTS FOR CONTROL SURFACES



A neat installation lending itself to mass balancing.



Projectile-like balance weight on the stabilator of a Turner T-40. An additional weight is mounted inside the fuselage on a long arm.



Hammer-like welded tube balance arm permits the addition of lead in the hammer portion to increase effective weight.

made of cement, different plaster products and fiberglass also work quite well. It is very important to allow plaster or cement forms to dry, or cure, thoroughly before pouring in the hot lead. Any latent moisture present in the form will splatter, resulting in a spectacular performance, if not one that is dangerous to skin and eyes. The same caution holds true for a sand mold made of ordinary wet sand . . . should you, too conceive, such a misguided problem-solving idea. Don't do it! You can make a fairly good simple mold with sand that is mixed with some engine oil. It must, however, be tamped solidly to retain the form shape you intend to cast. The oiled sand will not splatter. Stink? Yes . . . splatter, no.

To insure easy removal of the cast weight, the insides of the mold should be parallel or be progressively larger toward the top surface. Of course, if the mold is a two piece affair which can be separated, this is not a factor to consider.

You can combine metal and wood pieces to fabricate a form of the required shape that will be suitable for casting balance weights. The forms do not have to be fancy as they will be discarded after one or two weights have been cast. Using aluminum sheet metal in combination with wood end pieces for your molds works well for small parts. It is not recommended for larger forms as aluminum has a relatively large coefficient of expansion that sometimes contributes to buckling or distortion. It is better to use galvanized roof flashing or even the metal snipped from "tin" cans. Some useful shapes and fabrication methods for a variety of balance weights are illustrated in Figure 1. Here is where a builder's ingenuity can serve him well.

If you need to cast an attachment bolt in the counterweight for attachment purposes, it would be easy enough to add a jig support to your form for holding the bolt in position while the lead is poured around it. Tubing used as an attachment mount should have one end flattened or otherwise shaped to prevent its loosening in the lead weight at some later date. A bolt head when imbedded in the lead will hold quite well under normal use and ordinarily no other provisions need to be made to further immobilize it.

Sometimes counterweights and balance arms are made of welded steel tubing into which hot lead may be poured to increase their effectiveness as counterweights.

Excess weight in a mass balance is removed by drilling shallow holes in the lead weights or by filing or grinding away some of the steel.

Distribution of Mass Balance

Concentrating a single externally mounted mass balance weight in one location to balance the control surface may not be ideal but because of limited space available inside the structure, it is usually more convenient to do so. However, whenever possible, distribute the weight uniformly along the span of the control surface. If the weights must be separate and attached in two or more locations along the span, they should be positioned, if possible, on either side of hinges to reduce flexing and torsional stresses on the structure.

A method for obtaining good distribution of balance is through the installation of a solid steel rod along the entire length of the leading edge or perhaps you could install a steel tube instead. Although the steel tube would be lighter than a steel rod, its weight could be increased to exceed that of the solid rod by pouring in molten lead to obtain whatever additional weight is needed. You may have to pre-heat the tube to achieve this objective. (Naturally, you will remember to plug the open end?)

Not only must balance weights be attached solidly, they must also be capable of withstanding high G loads. How high's high? Well, in a yesteryear study conducted at the NASA Langley Research Center by Arthur A. Regier (Flutter of Control Surfaces and Tabs), it was determined that the balance weights should be capable of withstanding 36 G's normal to the surface. However, more recently (1979), the FAA, in its AC23.629-1 "Means of Compliance with FAR 23.629, Flutter," states that all balance weight supporting structure should be designed for a limit static load of 24 G's normal to a plane containing the hinge and the weight and 12 G's within that plane parallel with the hinge. FAA also points out that proof of these criteria can be accomplished by simple static tests of the control surface mounted in a jig. That's really not too much as a 2 lb. weight need only be static tested to 48 lbs. to equal the requirement imposed on store bought aircraft.

Now that you have all this under control, take care that the weights will not work loose under prolonged use and vibration or all that G load capability will be for naught.

A Summary On Balancing Controls

Many aircraft currently flying do not have balanced ailerons or elevators or rudders. These designs, however, have proven to be inherently free from flutter problems for the most part. So, I can't say with any conviction that the designer intended for them to be balanced or that they need it. However, and of this you may be sure, regardless of whether your plans require mass balancing of one or more control surfaces, you will never be sure they are flutter-free until they have been tested in flight — for that tendency.