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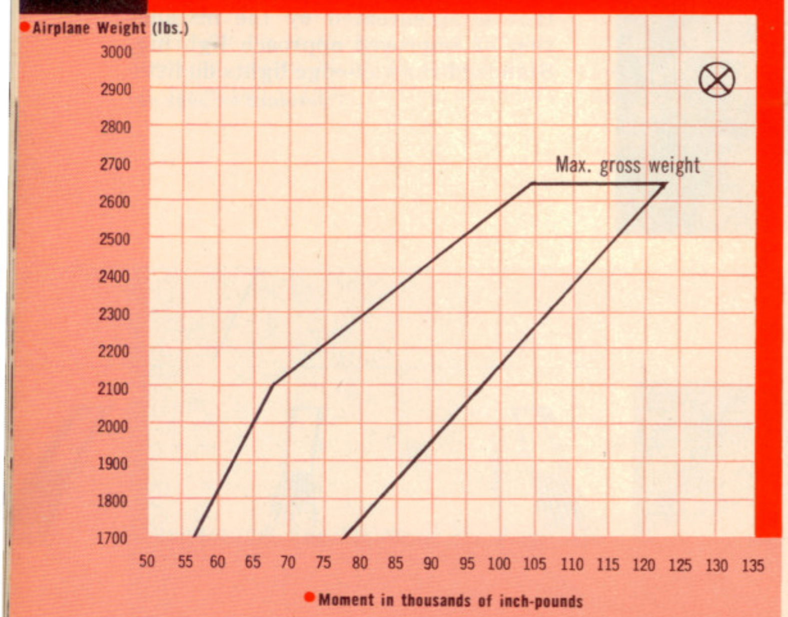
Watch Your Weight And Balance

It isn't hard to determine whether you can take off safely if you are familiar with your plane's loading limitations and keep tab on its center of gravity

FIGURE 1

TYPICAL CENTER OF GRAVITY ENVELOPE



This illustrates the center of gravity envelope of an airplane with a maximum gross weight of 2,650 pounds. Overloaded to a gross weight of 2,927.5 pounds, as indicated in Table 1, the center of gravity falls well outside the envelope (Note circled "X")

You were standing, engine ticking over, looking for a moment at the heat waves distorting the trees and wires at the other end of that short mountain runway, when that uneasy feeling came. It had been a good hunting trip and a good 60 pounds of fresh venison was stashed in the baggage compartment along with the rest of your gear.

You remembered planning the trip. It got cold in the mountains at night, so you and your three buddies had sleeping bags, and each had a knapsack. That was about 30 pounds each. Of course you had your guns, but they didn't weigh much — you thought. Then there was the inevitable movie camera addict. He turned up at the last moment with about 15 pounds of extra gear. So there it was, all in the back!

It had been a few years since your football days, but you were all pretty well built. You remembered how "Old Faithful's" tail hung low and swayed in the wind when you taxied out on the 7,000-foot runway back in the city. Of course you didn't have any trouble getting off that 7,000-foot runway, but you were surprised at how much nose-down trim you had to crank in once you were in the air. You didn't have any trouble landing either, because you landed into a 20-knot headwind. Your buddies commented on your skill, and you felt good. Now it was a dead calm on a hot day, and you didn't feel so good!

But you couldn't spoil a good day. The nearest airport was two hours' cab ride away, and the boys had to be in the office in the morning. You checked the mags again, cranked in a lot of nose-down trim, and ran her up all the way. Old Faithful made as much noise as ever, so you let her go! Seconds later, Old Faithful tucked up her heels a good 50 feet above those wires, and you wondered what you had been worried about. The boys complimented you again on your sharp flying and you felt good again. Fat, dumb and happy, you pointed Old Faithful's nose toward the city while a warm image of a row of Martinis crossing the airport bar began to grow in your mind.

The credit, if there was any, certainly was not yours. If anything, the credit for being airborne at all belongs to Old Faithful and the Federal Aviation Agency, who specified that she be designed with wide margins of safety, just so that she could protect herself from lunkheads like you. The point is not that you took off from a short runway overloaded, but that you took off when you weren't sure. You could have been sure. It isn't that hard to be sure. All it takes is a little knowledge of your airplane's loading limitations — weight and balance.

Get out the flight handbook and weight and balance data that came with your airplane. Look at them for a moment. Chances are that there are a few charts and graphs that are simple enough if you look at them for a while. But there are other phrases like moments, adverse loading, percent M.A.C., and other engineer talk that makes it sound like it's too much for you. So you just load her up, push the throttle, and hope.

In an article of this kind, we can't hope to cover all of the forms of weight and balance forms and graphs supplied with modern lightplanes, but we can try to clear up some of this engineer talk.

The most important point to consider in weight and balance is the center of gravity. This is the point through which the weight of the plane and everything in it may be said to be acting. It is as though the whole mass were concentrated in one place. When you add or remove weight at any point other than at the center of gravity itself, the center of gravity will move. Your airplane has a certain maximum gross weight beyond which it may not be safely or legally loaded. For every possible weight between the maximum gross weight specified for your airplane and the weight of the plane when flown empty, with minimum fuel, and by a solo pilot, there are certain limits, fore and aft, where the center of gravity may safely be permitted. A graph showing these limits is called a center of gravity envelope. (See Figure 1.) To load an airplane safely, you merely arrange to keep the center of gravity within the envelope.

In order to understand how the location of the center of gravity is controlled, two new ideas must be introduced. These are arm and moment. You will note that on the center of gravity envelope, the gross weight of the airplane is plotted against the moment. Imagine a see-saw. If two little girls of the same weight are sitting on the see-saw, the pivot will be in the middle. If one girl is heavier than the other, the pivot will have to be moved towards the heavy girl. When they balance, the weight of the heavier girl multiplied by her distance from the pivot will exactly equal the weight of the lighter girl multiplied by her respective distance from the pivot. This weight times distance business is called moment.

In aircraft computations, moments are usually calculated in inches times pounds, or inch-pounds. You can readily see how a small weight times a large arm can equal a large weight times a small arm. This explains why you can usually swing a tricycle geared plane around by the tail, even though it has a heavy engine up front. It also explains why putting a small weight on the tail like a rotating beacon, for example, may seriously affect the balance of the airplane. Since the moments in airplanes often come out to unwieldy figures for handy arithmetic, the pound-inches figure is usually divided by a convenient constant like 1,000. The resulting figure is called the "index."

Some weight and balance envelopes plot the allowable center of gravity location, measured from a convenient point on the plane called the "datum," against the gross weight. (See Figure 2.) There is another measurement, however, which measures the really important relationship of the center of gravity to the chord of the wing. Since most wings are tapered, and do not act uniformly over their entire surface, a kind of mathematical average chord is arrived at, called the mean aerodynamic chord (M.A.C.). Since the wing is what lifts the airplane, obviously the center of gravity must be well within the mean aerodynamic chord, or the airplane will be hopelessly nose heavy or tail heavy. Since the natural stability and trim of the airplane is able to compensate for considerable excursions, fore to aft, of the center of gravity within the mean aerodynamic chord, the allowable limits of center of gravity travel within the mean aerodynamic chord are expressed as a percentage of the mean aerodynamic chord.

Now that we know from our charts where our center of gravity should be, we are ready to go about getting it there. This brings up the subject of adverse loading. All that is meant by adverse loading is a set of tests and computations conducted by engineers to determine the extreme allowable loading limits of an airplane. The "do not exceed" placard on your baggage compartment, for example, is a result of adverse loading computations, as well as structural considerations. The overall result of adverse loading computations is a graph called a loading graph. (See Figure 3.) To use the loading graph, merely add the moments of the passengers, fuel, oil, and baggage as read from their respective lines on the graph. Having determined the total moments by addition, plot them against the total weight on the center of gravity envelope. If the plotted point comes out within the center of gravity envelope, you are okay. Bear in mind, however, that you may never exceed the baggage placard limitation, even though the charts might suggest that this might be done.

Proper use of the weight and balance forms and another chart, the takeoff distance chart (See Table 2 on page 61), enable you to get the most from your airplane legally and safely. You can be sure before you take off.

Now let's go back to that mountain takeoff and see how Old Faithful was actually loaded. This was a typical loading situation that could sneak up on any pilot

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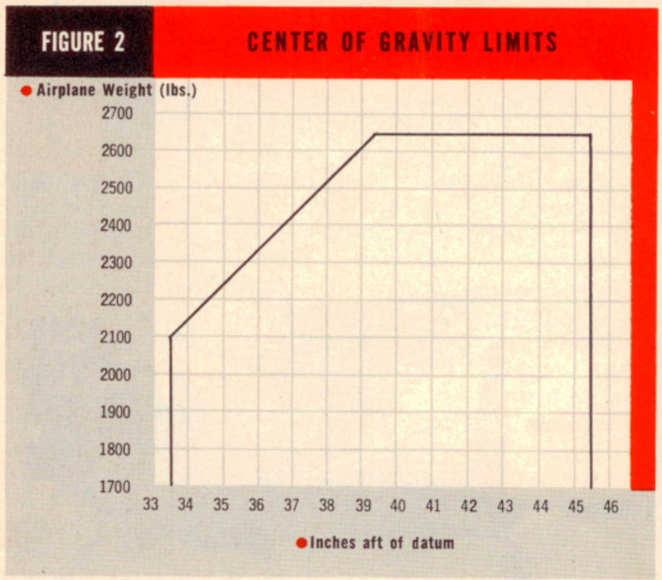
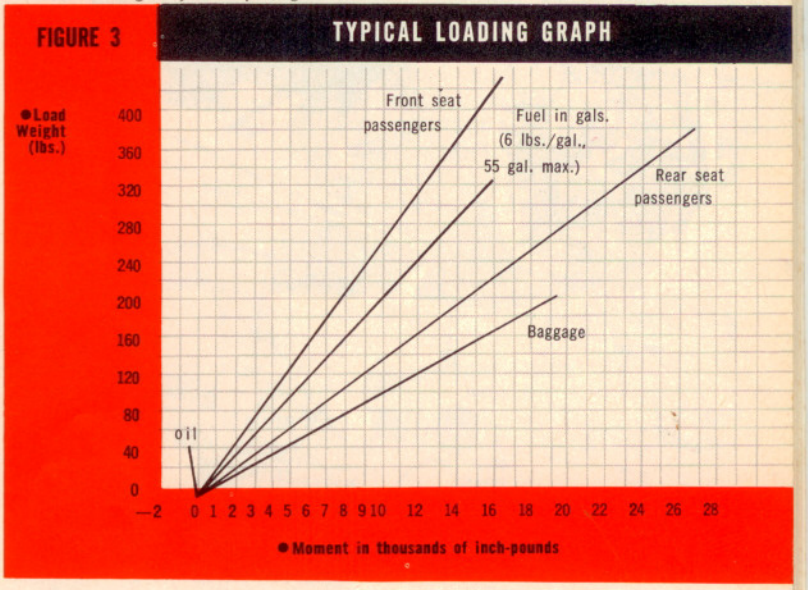


Allowable center of gravity of an airplane with a maximum gross weight of 2,650 pounds. Datum is a convenient point on the aircraft, determined from the weight and balance envelope. (On lightplanes "datum" usually falls up forward near the plane's engine)

To use loading graph, add the moments of fuel, oil, passengers as read from their respective lines on the graph, and plot the total against the total weight on the center of gravity envelope (Figure 1)



Weight and Balance

(Continued from page 35)

at any time. First let's find the total weight. (See Table 1.)

You will note from Table 1 that the gross weight of 2927.5 pounds is well over the maximum allowable gross weight. An inspection of the center of gravity envelope (See Figure 1), shows that the center of gravity will fall well outside of the allowable limits. Note also that the baggage compartment contains about twice its placarded limit. At least 75 pounds of baggage must go. Subtracting 75 pounds of baggage from the 322.5 pounds overweight leaves us with 147.5 pounds to eliminate. Note that an assumption was made that all four passengers weighed 170 pounds each. This is standard practice. An actual weighing of the passengers might enable you to save a few pounds. Actually, the 147.5 pounds overweight may be represented as 24.5 gallons of fuel at six pounds per gallon. Since we have 55 gallons of fuel available, we could eliminate 24.5 gallons, leaving 30.5 gallons of fuel. If the intermediate airports between our takeoff point and our destination are closely enough spaced we might get by with even less fuel and more baggage carried in the cabin, but flight with minimum fuel is not to be recommended at any time.

The above example illustrates one way that an aircraft may become improperly loaded before you know that it is happening. Airplanes also frequently have their weight and balance limitations exceeded inadvertently when the aircraft has been modified or new equipment has been added. Usually, when major modifications have been made, a new weighing is required and any limitations thus arrived at are prominently displayed in the cockpit. An example with which the author is familiar is a 90 h.p. trainer in which a full gyro panel was installed. The heavy gyro instruments so loaded the aircraft that it had to be placarded for a maximum of three-fourths of fuel capacity when two full size adults were carried. Because of the additional load on the aircraft structure, severe limitations on baggage were also established.

In thinking out our short field mountain takeoff, there were two other important factors that the pilot didn't think of. These were the altitude and the temperature. Most lightplane flight manuals have a graph or chart indicating the number of feet of takeoff run required to clear a 50-foot obstacle at the end of the field. Such charts usually plot temperature and pressure altitude against headwind component and runway length. Since we know that the wind was calm for our mountain takeoff, the takeoff chart for Old Faithful would look like Table 2. A rough, or uphill runway will require a longer run. A downhill runway will be a help.

TABLE 1 — Aircraft weights and moments.

	Weight	Arm	Moment
Empty weight	1700	35.7	61.0
Oil (12 qts.)	22.5	—15	—0.3
Pilot and front seat passenger	340	36	12.4
Rear seat passengers	340	70	23.4
Fuel (55 gal. usable)	330	48	15.8
Baggage	195	95	18.4
Totals	**2927.5**		**131.0**

Baggage compartment placard, 120 lbs.
Maximum gross weight, 2650 lbs.

TABLE 2 — Distance required to clear a 50 foot obstacle versus aircraft weight and air temperature.

Weight of aircraft, 2650 lbs.

Pressure altitude	Temperature 23°F	60°F	130°
S.L.	1310	1610	2360
1000	1460	1800	2620
3000	1810	2220	3250
5000	2230	2730	4150

Note: Pressure altitude is the altitude indicated by the altimeter when the altimeter setting is 29.92 inches Hg.

END

Runway Lights

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more than outline the runway limits; they don't light up the surface. A pilot coming in over the approach lighting system passes the runway threshold and in the last seconds as he makes his critical flare-out he sees before him what's described as a "black hole," into which he drops and hopes. To fill this hole with light by incandescent or fluorescent floodlights, or flush light units on the runway surface, is the goal of present experiments.

The United States adopted a standard "centerline" approach lighting configuration in 1958. It is not being challenged in the present FAA research program, but officials say this does not mean improvements can't be foreseen or that FAA is completely satisfied with the present system.

Approach lights are meant to guide the aircraft to the runway from where GCA or the ILS leaves off. This is usually some quarter to a half mile from the runway threshold. The better this lighting is, the lower minimum visibility conditions may be.

The standard centerline system starts 3,000 feet from the runway edge and consists of a series of 14 foot bar lights set 100 feet apart down the centerline of the approach to the runway. The pilot judges his glide angle by observing the apparent distance between the lighted bars and can tell from their apparent alignment whether he is left, right or on center for his approach. A 100-foot crossbar is installed 1,000 feet from the threshold to help him estimate distance from the runway.

Before 1958, another system called "slopeline" was the accepted unofficial standard in the United States. Here, too, the pilot's guide is the "apparent" alignment of lights. Two rows of lights on each side of the approach channel are installed so that when the aircraft is on course they are seen as an unbroken visual path leading to the runway edge. When the aircraft is off course, left or right of center or too high or low, his perspective cockpit view of the bars tells the pilot how to correct. The main difficulty with this system according to FAA is that it cannot be installed easily at many locations because of uneven terrain along the approach course.

The irony of improved approach lighting is that it accentuates the darkness of the runway itself as illuminated by standard edge lighting. The national standard since 1955 has called for uniformly spaced lights outlining the runway borders. Space between the two lateral rows of lights is not to exceed 200 feet.

Trouble is that such lights are pretty far out of the pilot's center of vision at touchdown, so the actual runway before him, despite his own landing lights appears dark.

If the idea of putting lights right in the runway pavement seems obvious, so too are the difficulties. Such lights must be flush and must be able to take a considerable beating from traffic passing over them as well as from heavy snowplows in northern areas. The problem has been to see if such a light could be installed cheaply enough to be practical, if it could stand up and be cheaply maintained and if, after all, it could do the job.

First experiment with a flush surface light is said to have been made by the Dutch at Schiphol Airport in Amsterdam as recently as 1956. They used an open grid light unit, planted in the pavement along each side of the runway centerline. Again the next year the Dutch installed similar lights at Soesterberg Airport and received favorable comment from pilots in preliminary tests.

That same year, 1957, the U. S. Air Force tried an experiment at Andrews Air Force Base that simulated light output of open grid fixtures, though because of expense, the actual units were not set in the runway. That year, the CAA and industry representatives met to discuss the results of the tests and all agreed that a 3,000-foot landing "mat" was desirable, the lights set on either side of the centerline but close in and therefore, called "narrow gauge."

On NAFEC's 10,000-foot Runway 13 at Atlantic City airport, FAA is now testing three separate kinds of narrow-