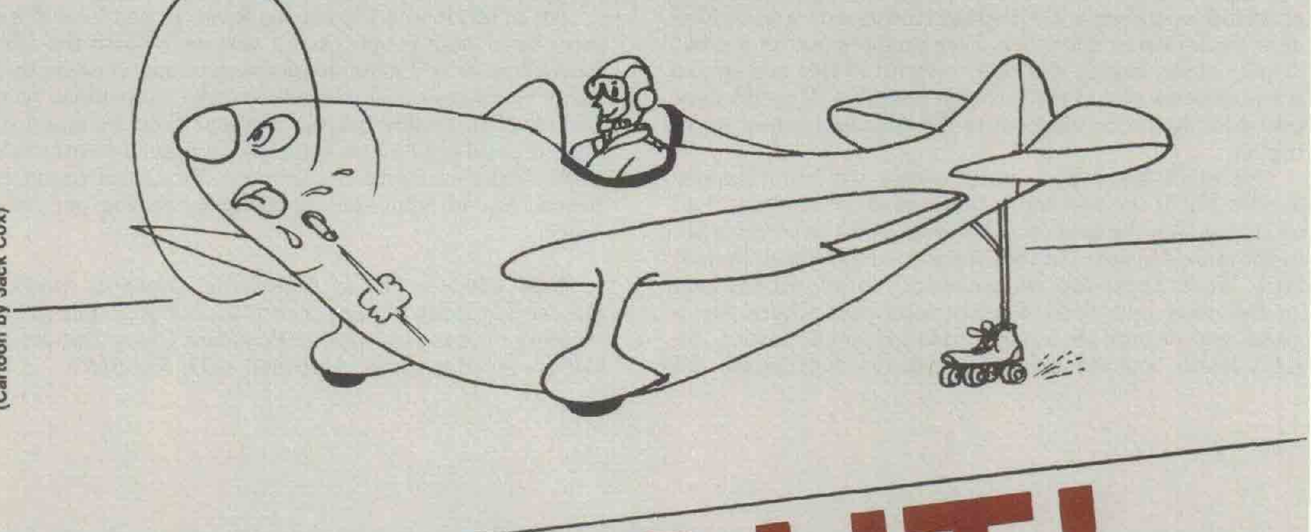
OVER WEIGHT!



(Cartoon by Jack Cox)

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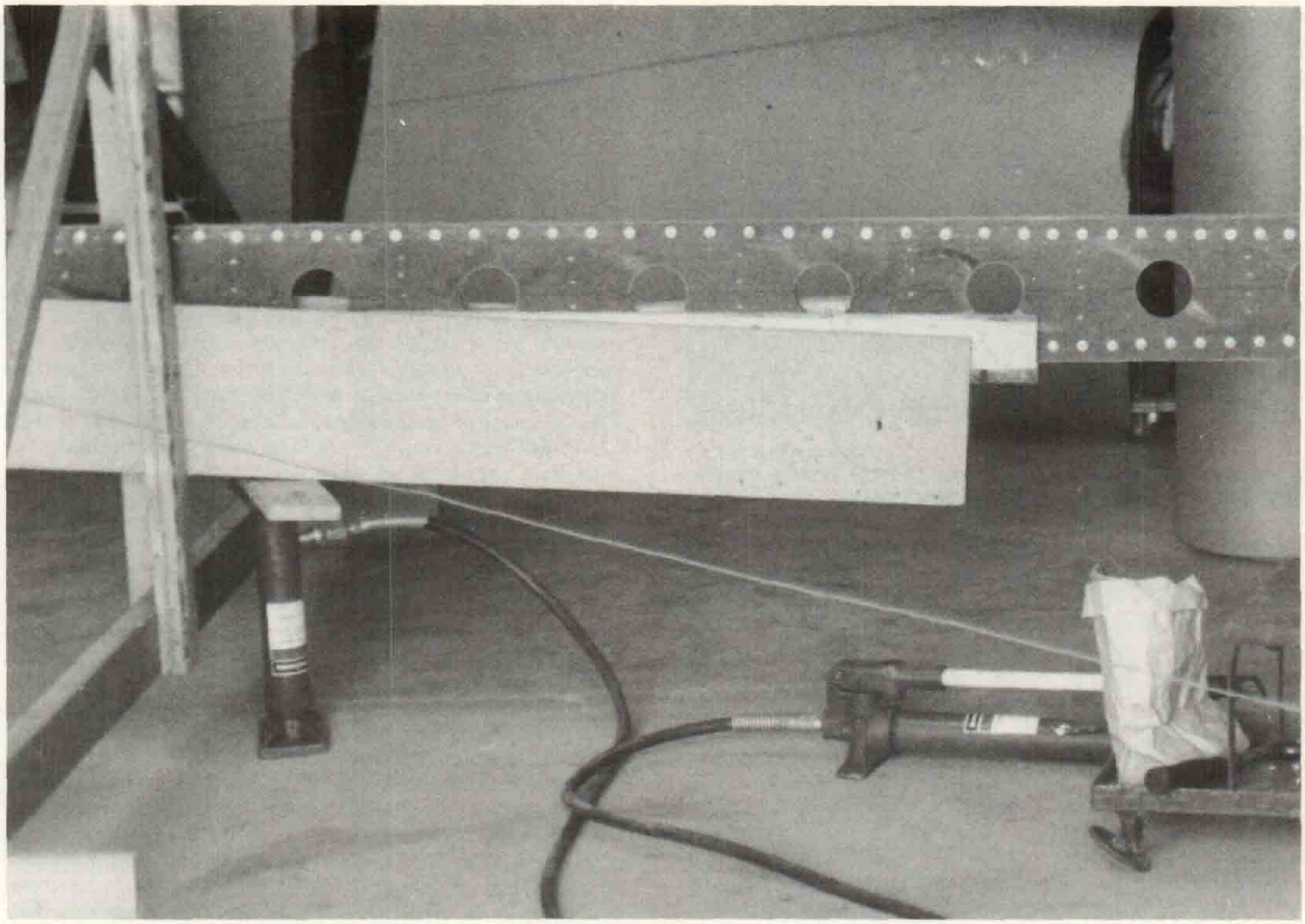
Editor's Note: We recently asked Molt Taylor to write an article on homebuilding's most persistent woe - excessive weight. He graciously agreed, as he always does. The article is timely because there have been accidents recently in which pilots pulled the wings off their airplanes, usually while involved in aerobatics. In almost every instance, post crash investigation revealed the airplanes to be considerably overweight. The pilots obviously were not aware or chose to ignore the fact that, with the additional weight, their planes were no longer 6 G or 9 G or whatever aircraft. Molt's article explains why.

UNFORTUNATELY, VERY FEW examples of any homebuilt aircraft design seem to end up with empty weights as low as the designer's prototype. This is apparently due to a number of factors, not the least of which is the fact that the individual builder seldom has the experience of the original designer, invariably interprets the drawings too broadly, and often apparently feels that the designer really didn't know what he was doing and, therefore, the builder seems to always want to build in **more strength.** This results in things being built in subsequent examples of most designs not only possibly stronger (although that isn't always the case), but, more importantly, they end up heavier. This is, unfortunately, a serious problem since the builder seldom adds the additional strength where it may be needed to make the design actually stronger, and most such modifications result in heavier things like bigger wheels, more upholstery, larger engines, heavier landing gear and usually much more equipment than the original designer ever anticipated anyone putting in the aircraft. Many designs which were never intended to have retractable gear, flaps, electric systems and full IFR panels end up with all this "stuff" and more. The builder may make the landing gear heavier (and possibly stronger) after he finds that the gear as originally designed has "sagged" and the propeller may be too close to the ground, or the wheels splay out and the airplane won't taxi worth a darn with the resulting misalignment of the wheels . . . because of that extra weight.

All of these little things can be cured fairly easily once they are discovered, but the real problem comes from the



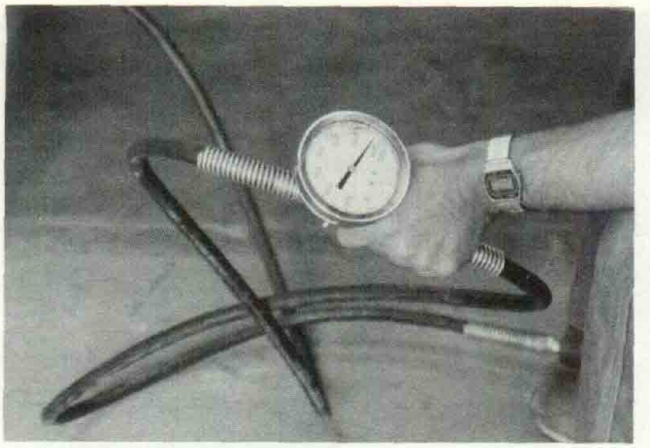
(Photo by Molt Taylor)

A hydraulic jack being used to apply ultimate load (CG) to the spar of Molt's new design, the Taylor Bullet. The spar is being tested here without the rest of the wing structure to evaluate the paper/glass spar web in shear.

fact that the designer (if he knows what he is doing at all) usually has designed his aircraft so that it will be suitable for some basic maximum gross weight. He then takes this weight and usually multiplies it by the load factor he selects for the probable use the airplane is being designed for. Thus, if he anticipates that his design is going to be used for routine flying, he may select the load factors required by Civil Air Regulations for aircraft in the normal category. This means that the airplane should be capable of withstanding normal operating loads of 3.8 times the gross weight he has selected. For convenience, most designers round out the 3.8 to a factor of 4.0, and then since the FAA requires a safety factor of 50% over this, he ends up with an ultimate load factor of 6.0. What this all means is that the FAA anticipates that a normal category airplane can expect to possibly encounter situations where the wings (and other structures) may be subjected to loads of at least four times the gross weight of the airplane. This is usually called limit load. The load factor of 50% additional (for safety?) is called ultimate load. If the airplane is being designed to be aerobatic the FAA requires a minimum loading of 6 times the gross weight for the limit loading and nine times the gross weight for the ultimate.

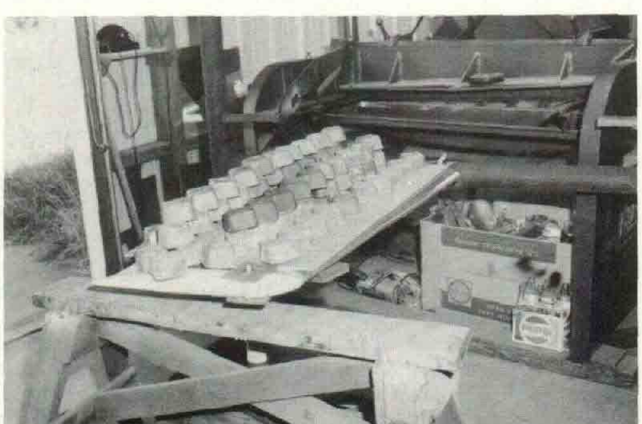
All this means that if the designer static tests his design as he builds his prototype, he will actually impose static loads on the structure of at least 4.0 times the expected gross weight. Since he can expect the aircraft to possibly encounter situations in normal operations where loads of this magnitude will be encountered (such as in rough air), he should at **least** have tested to the 4.0 G condition. At this loading the aircraft should not exhibit any permanent deformation, and structures should always return to original shape without any damage. If the designer is really going all out to test his design, he will continue his loadings until his structure is loaded to something close to the 6 G condition. Since he usually is not in a position to lose his prototype, and has been testing the "one and only" example of his design, he may decide that if things will go something well over the maximum expected load of 4.0 G, he may not actually test his design to the 6.0 G condition where he can expect things to fail. Usually, the amount of test loading carried on by most designers will take things to where it is evident that something is going to fail, and if at all possible the designer may stop the loadings, take the loads off the test structure and beef-up the point of expected failure, then test things again to see that he has actually made things so that they will ultimately take the 6.0 G (or 9.0 G) loads. This is called non-destructive testing, and if properly pursued, can result in the test example actually ending up taking the ultimate loading of 6.0 G (or 9.0 G for aerobatic aircraft) without actual failure and destruction of the test unit. The process of "creeping up on it" is a costly, time consuming activity, but since analysis alone seldom is adequate to establish the actual strength of a structure, it is about the only reliable way one can go about being really sure that a structure is sound.

Since the designer is interested in developing a structure (aircraft) which will take the desired loads and at the



(Photo by Molt Taylor)
Hydraulic pressure guage in the line to the jack. It measures the load applied - p.s.i. times jack ram area equals load.

same time keep the weight down, it is obvious that he is not going to have a bit more material (or structure) in the airplane than is absolutely necessary to meet the loadings that he anticipates **at the selected gross weight** that he designed for in the first place. It is here that the individual homebuilder gets into trouble when he ends up with an empty weight somewhat higher than the designer's prototype. The designer has based his anticipated gross weight on his own empty weight, and his structure is only good enough to handle that weight. This gets to be a real problem. For instance, a designer ends up with a 1400 pound empty weight for his prototype. He decides that the airplane should have a useful load of 550 pounds which gives him a gross weight (for design) of 1950 pounds. Multiplying 1950 by the expected 4.0 G load factor means that his wings should be able to stand expected loads in normal operation of 7800 pounds. If he is responsible, he will then test his structure by imposing a full 7800 pounds of weight (or he may use hydraulic jacks or some other way of actually loading the structure to this weight). If he encounters a failure as he builds up the weight, he may stop the test, remove the load and reinforce the structure several times before he gets it so that it will hold the full 7800 pound load. The FAA requires that the structure support the full ultimate load for at least 10 seconds before it fails. It can then take a permanent set (bend), but will not fail catastrophically. Aircraft structures loaded to these ultimate conditions are something to see, and anyone who has witnessed such a test can testify to the care with which engineers approach the final few pounds when



(Photo by Molt Taylor)
Static load testing of the MiniIMP H-tail. The rows of lead weights simulate forward, mid and rear air loads.

they see things getting almost "jelly-like" under the imposed loads at the ultimate condition. It should be pointed out that any material will usually elongate (stretch), bend or otherwise deform considerably and still snap back to its original shape once the load that bent it is removed. Thus, a wing panel being static loaded can bend greatly under even limit load, and still resume its original shape and position. It is not at all uncommon for wings on some aircraft to bend many feet at the tips when they are tested. However, under the ultimate loading condition they can fail. Thus, if our well meaning homebuilder ends up with an empty weight of 1550 pounds (which is not at all uncommon for a builder of a design which originally only weighed 1400 pounds for the prototype), **he no longer has an example of the design which is *good* for 4 G loadings.** This is because his 1550 pound airplane probably is still going to be expected to carry the same 550 pound useful load that the designer says it is good for. However, his example of the design now has a gross weight of 2100 pounds. At 4 G loading it is now expected to carry at least 8400 pounds of load. However, the designer has possibly only tested the structure to the 7800 pound limit. Or as can be seen, if the designer tested a 6 G where things possibly had failed, he had imposed a maximum loading of 11,700 pounds on his test sample. Our well meaning builder thus has an aircraft that is only good structurally for a little over 5.5 G ultimate or 3.6 G limit. Thus, the man with the overweight aircraft can expect to possibly bend things in normal operations if he gets into rough air, pulls out of a dive too rapidly, etc. All this assumes that the homebuilder has duplicated the minimum strength of the original design, has used exactly the same guage of materials, and has selected materials of the same exact specification, all of which may or may not be possible. Certainly it is evident that builders should make every possible effort to avoid any conditions of overweight construction. It should be noted that overweight examples of most designs never become overweight in the wings, but rather in the fuselage where the overweight condition merely imposes higher loads on the wings.

It is interesting to note that this problem of overweight building can result in a situation where a design can end up actually being unable to fly because the builder has overbuilt, added too much equipment, etc. While such poor attention to the weight detail can often result in the center of gravity coming out so that CG limits are exceeded and result in the aircraft being dangerous to fly, the situation in a flying boat or amphibian can be even more disconcerting since a hull (or floats) are designed for a given displacement. Thus, if the amphibian comes out too heavy, it may end up sinking down further in the water than the original designer ever intended, and as the poor builder trys to accelerate for take-off, he may find that the engine just does not have enough power to push the airplane over the wave of water that piles up ahead of the hull. This is particularly a problem if the flying boat (or amphibian) is equipped with a fixed pitch propeller. This is one reason why amphibians should always be equipped with controllable (or constant speed) propellers - then they can develop the maximum available power, particularly for take-off from water.

We hope we have given prospective builders a good idea of the importance of building their examples of any design at least as light as the designer indicates as being necessary to get a good example of his design. And certainly, if their own example is overweight, they should not expect it to fly as well, be as strong or as suitable as the prototype that they are trying to copy for their own use. The writer would be pleased to discuss this problem further with any builders and can be reached at the address listed at the beginning of the article.