Safety Considerations On Fuselage Structures

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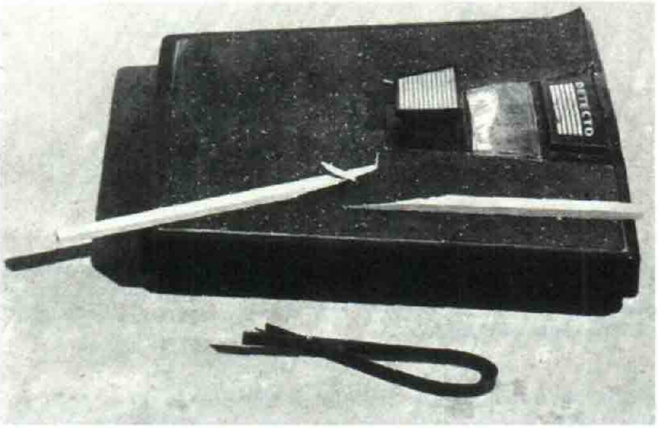
AUTHOR'S NOTE:—Perhaps some information on my background would be of interest to you. In 1951 I received a Bachelor of Science Degree in Mechanical Engineering from the University of California and have since been engaged in the design of aerospace equipment. I am registered by the State of California as a Mechanical Engineer.

I hope this arcticle will be of use to you. Any comments or suggestions from you or your staff are welcome. I fully expect some violent comments from proponents of wooden fuselages if the article is published, but the saving of lives outweighs the fear of such criticism.



A comparison of the specimens after failure. The wood specimen has completely separated while the metal one, even though bent double, will require the input of additional energy in order to change its shape further.

THE OTHER day while cleaning out the workshop I came across some scrap pieces of wood too long for the trash barrel but which were made to fit very easily by breaking them over my knee. Later I came across some empty cans (oil, not beer) and proceeded to crush them underfoot so they would take up less space when discarded and after some pounding on the cans and some jolting of the foot-bone, they were flat enough to be thrown into the barrel. About that time I could almost hear a faint voice telling me that there was something very significant in what I had just done, and naturally my guilt-wracked conscience caused me to think that the voice was referring to my finally cleaning up the mess. Then the realization of the actual significance of these actions caused sufficient change in my trim that it made me sit down, which I had been wanting to do anyway, and give this matter some deep consideration.

Why did the sticks break so easily when the cans were so difficult to flatten? Some might say the wood was easier to manhandle because it's not as strong as the metal in the cans. But is that the real story? Let's check this out by performing a simple home experiment using some easily obtained materials. Take a wire coat hanger that has an unbent lower portion (that used for the trousers) and snip out a straight section about 10 in. long. The wire is about .095 in. in diameter and probably made of AISI 1010 steel with a yield strength of about 28,000 psi. This means the wire can support 200 lbs. in tension without any permanent set or stretch.

Then get a piece of spruce, fir or other soft wood used in building and cut a piece about the same length and about .20 in. square. If spruce is used it will also support about 200 lbs. in tension.

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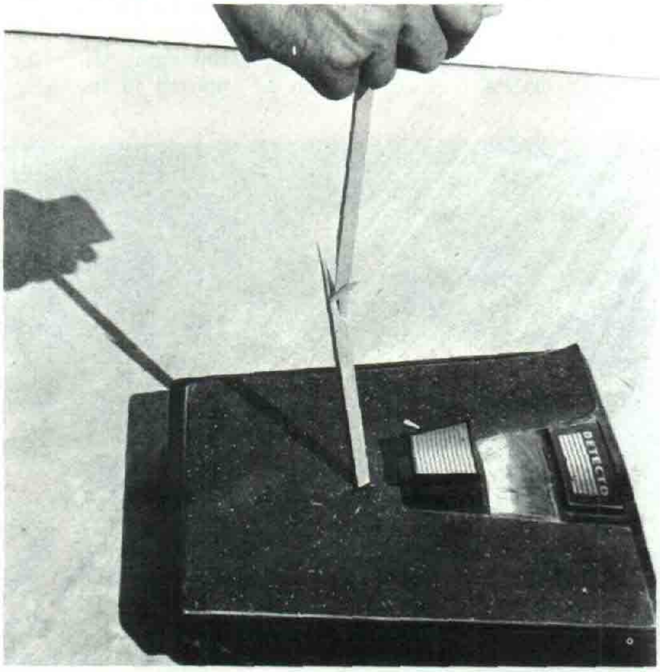
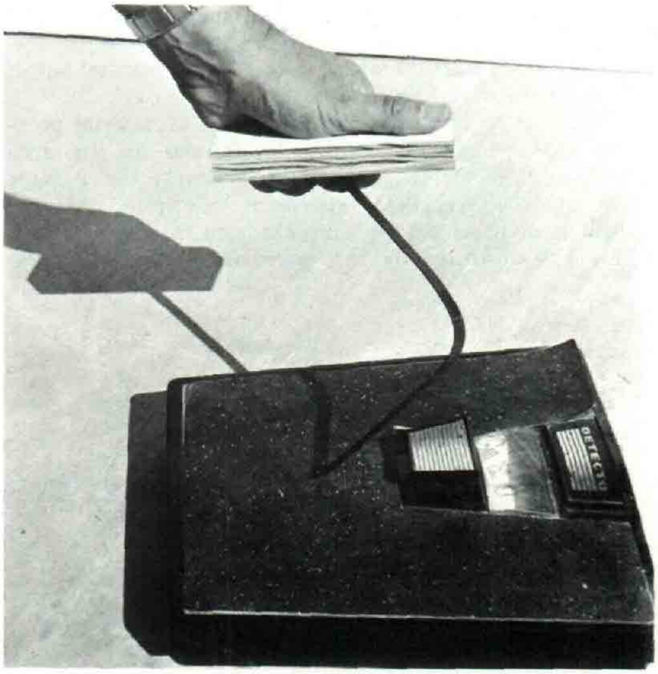


The spruce specimen has fractured and it can no longer absorb energy. The material used here had spiral grain (note the tapered fracture) which is another hazard to be avoided. Wood without runout should be used for the actual experiment.



The metal specimen has bent. Additional energy has to be applied to the material in order to deform it further. The specimens used in these photographs had larger cross-sections than described in the text for photographic clarity.

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Now stand the wire on one end and push down on the other end until it bends slightly and stays bent, noting the approximate force required. Doing this on a bathroom scale might make the observation less subjective. Do the same with the spruce and you'll probably observe first that the spruce specimen supported a greater force and second that it broke before any permanent set occurred. Now try this again with the bent wire and you'll note that even though the elastic limit was reached (permanent set occurred) the wire still offered resistance to the applied force until it bent to the extent that both ends touched. You could even tie knots in it if you're strong enough. About the only way you can break it by hand is by bending it again and again in the same place, fatiguing the metal, and all the while this material is absorbing energy.

If anyone is wondering at this point how many airplanes are made of coat hanger wire, let me say that what goes on inside that wire would be the same even if the specimen were 4130 or aluminum. About the only wrought steels and aluminum that don't behave this way are the very hard ones. The materials used in hacksaw blades and files are extreme examples.

Also the use of wire as a compression member in this experiment is merely a convenient substitute for a slender compression member such as a longeron.

Meanwhile, back at the airdrome—. Actually to say steel is stronger than wood in cases like this doesn't mean much since, as we saw by our experiment, even though both specimens would support the same load in tension, the steel specimen was actually weaker in compression (due to its slender shape). In aircraft structures there are many members that are incapable of realizing their full yield strength because they are subject to buckling and therefore have to be made of a larger cross section. Wooden members of this nature will fracture, or separate, long before metal ones and this is a very important point.

We can see from what we've found here, which further investigation would confirm, that either a metal or wood structure can be made, in most cases, equally strong. But what concerns us at this juncture is the behavior of the structure after it is bent up, or to put it another way, after failure occurs.

What we're actually talking about is a material property called "toughness" which is defined as the area under the stress-strain curve. This is simply the average stress on the structural specimen multiplied by the amount it deforms before it breaks, and this also defines the energy absorbed by the material. Even though the spruce was slightly stronger in compression, the metal was capable of deforming much more than the wood. Therefore, the metal specimen is the tougher one and able to absorb more energy.

The diagrams compare the energy absorption characteristics of a wood and metal compression member such as a longeron. Ordinarily these curves would relate stress to strain, but to make the problem more easily understood we are comparing load to deflection (which is almost the same thing) with design load assumed to be the same in each case. In the case of a typical wooden longeron loaded in compression (Fig. 1), total deflection before fracture would be in the order of an inch or less and all the energy absorption would occur in this portion of the curve, while after fracture no energy would be absorbed, obviously, since the force (load) goes to zero. Whatever contacts the impacting obstruction next will have to absorb some or all the remaining energy, and this could be the passengers.

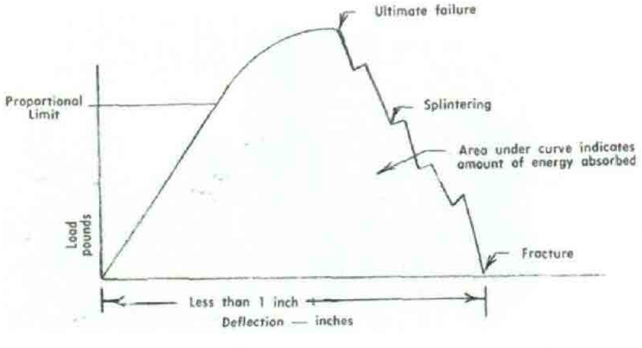


FIG. 1 A typical wooden longeron loaded in compression to failure behaves in this manner. Note that energy is absorbed only during a small percentage of the collapse length of the bay of which the longeron is a part.

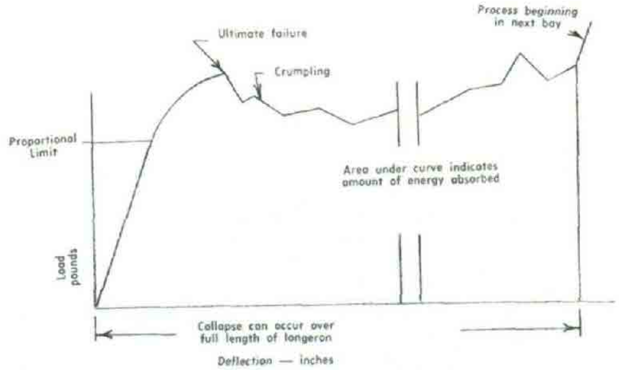


FIG. 2 A typical tubular longeron loaded in compression to failure. Note that the curve does not go to zero during deflection (but can go to a low value). Energy is absorbed during full collapse.

In the case of the metal longeron (Fig. 2), energy is being absorbed during the full collapse of the member and the force can fluctuate anywhere from a very low value to one even higher than the initial value since the tube can become a short column as opposed to the long,

The *instrument panel* and firewall disintegrated in this particular accident, offering the pilot no protection whatsoever.

slender column before collapse. When the longeron has collapsed its full length, the next bay picks up the load and continues the energy absorption process. Hence, a metal fuselage can absorb much more energy than a wooden one and chrome-moly (4130) is excellent in this regard—it's pretty tough stuff.

Let's put aside this toughness consideration for a moment and examine another very important part of the crash picture—deceleration. Let's think of deceleration in a way we've all observed it many times—the way it manifests itself in an automobile. Consider first an automobile cruising down the highway at 60 mph coming to a normal stop. The energy due to its motion (kinetic energy) is dissipated through friction (mainly in the brakes and air drag) gently enough so that the occupants feel no discomfort. If, on the other hand, the stop were a heavily braked panic stop, the stopping force developed by the brakes would be greater and the deceleration might be rapid enough to cause passengers not wearing seat belts to slide off their seats.

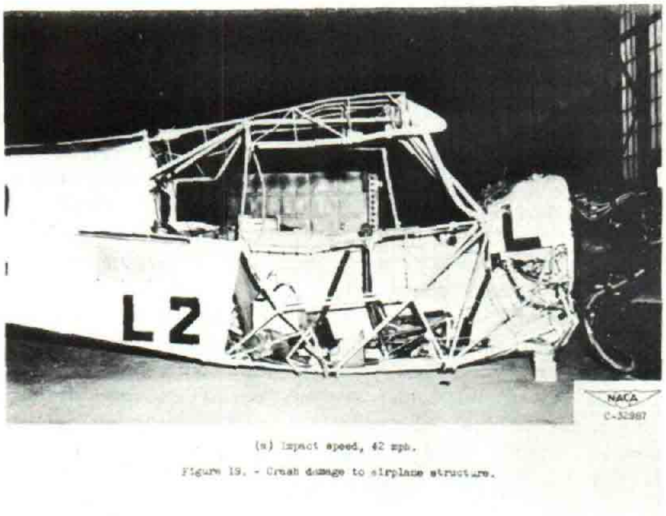
But if the car were stopped by a concrete abutment, the energy would be absorbed by the deformation of the front end of the car in somewhat the same manner we deformed the oil can. The metal would crumple until all the energy due to the car's motion were absorbed. If the occupants were securely harnessed in the car and if they did not strike anything during deceleration, they might survive.

This energy exchange is in keeping with the law of conservation of energy which says energy can neither be created nor destroyed but can be transformed from one form to another. In the above cases the energy due to motion was given up through heat in the brakes or through work in deforming the car metal.

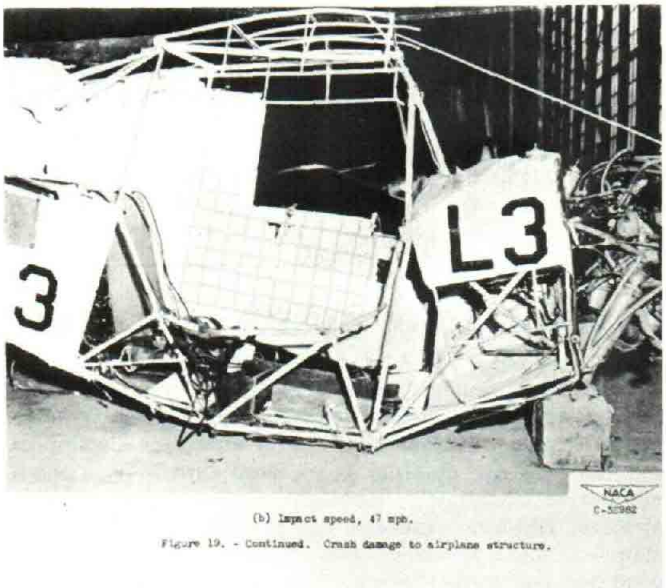
Perhaps now we can begin to see why certificated airplanes in this country began, years ago, to utilize metal fuselages no matter what material was used in the rest of the structure. Even during World War II, when metals were so scarce that pots and pans were turned in to aid the war effort, all operational U. S. military airplanes had metal fuselages. This type of structure was better able to absorb crash energy than a wooden one.

But wood does have advantages in structural members such as wing spars since wood is able to withstand slight overloads for very short times such as might be experienced in rough air. Permanent deformation of aerodynamic surfaces would probably cause such high air loads that a fracture would result anyway, so wood is often used in wings and tails.

NACA conducted an investigation of passenger harness loads on stall-spin type accidents in a Piper J-3 and published their findings in Technical Note 2991. Even at impact speeds of 60 mph, crumpling of the forward



This is what the J-3 in NACA Technical Note 2991 looked like after impacting at 42 mph. Crash energy was absorbed by the bending of the tubular structure. It must be kept in mind that this airplane was designed before extensive knowledge of designing for crash resistance was developed.



This J-3 impacted at 47 mph. Note that while the structure has deformed, none of the members have fractured or separated.

The nose section of this all-wood airplane gave away clear back to the turtledeck, and provided no structural protection for the pilot.

fuselage structure prevented the maximum deceleration at the rear seat location from exceeding 26 to 33 Gs. With proper harnessing the survivability chances of the rear seat passenger are good at these levels of deceleration.

In other words, if the passengers could be slowed down over some reasonable distance like 3 or 4 ft., their chances of survival would be good even if impact occurred at flying speed, provided they were properly harnessed. This means that collapse of the structure would have to occur to absorb energy but this should be limited to the forward portion of the fuselage. The excellent energy absorption capabilities of a metal fuselage makes this possible.

But this is not to say that all metal fuselages are good in this respect. In some airplanes (both metal and wood) the cockpit area is the weakest part of the structure and all the crumpling could occur in that portion. Also none of the cockpit structure should crumple in-

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ward, nor should this area contain death dealing projections.

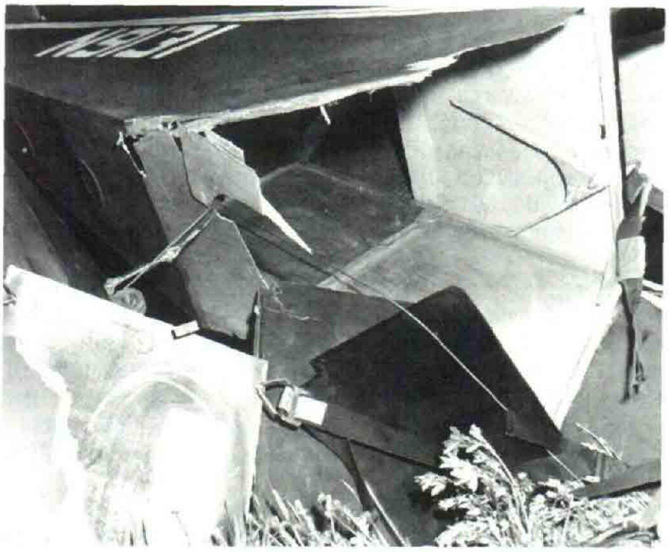
Large masses such as engines or fuel tanks behind the cockpit are dangerous since the forward fuselage has to absorb the kinetic energy of these items as well as that of the passengers. When this cannot be avoided these masses should be securely mounted and the forward fuselage strengthened to accommodate these loads.

A few years ago Fred Weick, the designer of the Ercoupe and the Piper Pawnee and Cherokee, while doing research on an agricultural airplane developed a "progressive crumple" forward fuselage structure. On impact the forwardmost section would collapse at say 15 Gs, the next at 30 and so on until the cockpit, which should be the strongest part of the fuselage, was reached. If I'm not mistaken, one of the "aggie" planes incorporating this feature crashed at something like 70 mph with no injury to the pilot.

In discussions regarding the above points some pilots (usually heavily insured) have indicated that this sort of thing doesn't concern them because they don't intend to crack up. This means nothing—cemeteries are full of people (including some high-time pilots) who didn't plan on being there. Flight safety concerns all of us, and as homebuilders we want our ships to be at least as safe as production aircraft. Actually if we incorporated features described here, homebuilts would be more crash resistant than some of the airplanes that don't have experimental ratings.

Maybe I'm a nut on this subject, but every time I learn of someone getting seriously injured or killed in a ship that has a low energy absorption fuselage, I feel that this was a needless loss. All of us, I'm certain, have known pilots who were victims of relatively low impact speed accidents who would be alive today if they had been flying ships having built-in life insurance in the form of fuselages made to absorb energy effectively.

And if this discussion helps in any way to make homebuilts safer, or even if it improves the understanding of what takes place in a crash, then my efforts are not wasted.



Had this fuselage been of sturdier steel tube construction, the chances of survival for the pilot might have been considerably improved.

NATIONAL AIR MUSEUM PROBLEMS

(From NAA's "Washington Bulletin")

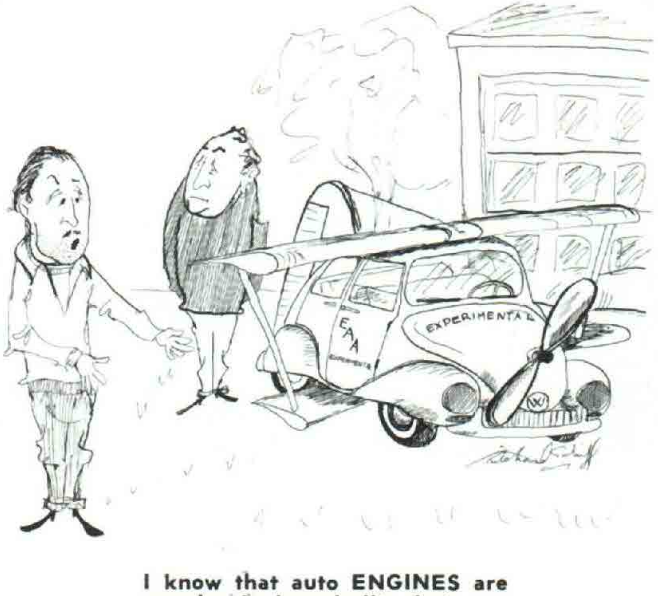
Although some of the world's most famous aircraft are on display in prime condition at the Smithsonian Institution in Washington, the total aircraft collection of the National Air Museum is so large that a far greater number of historically important aircraft are in storage at Silver Hill near Andrews Air Force Base in Maryland. Many of these machines are outdoors and in very sad condition due to lack of funds for their care and restoration. Some famous aircraft dating back to World War I are dismantled and stored in sheds that give only minimal protection from the weather and no protection from rust, dirt and general neglect. These wonderful old machines are begging for loving care.

Due to pressure on the national budget caused by the Viet Nam war and social problems, it is likely that it will be a long time before Congress will appropriate money for expanding the National Air Museum. The Smithsonian is therefore giving serious thought to loaning out their aircraft to responsible groups who could restore them under proper supervision. EAA has offered to take two such machines and restore them in the EAA Air Education Museum shops and display them at Headquarters. Eventually it may be possible to arrange for responsible EAA chapters to take over one each of the Smithsonian's aircraft for restoration. There is also interest in the idea of assigning some of the planes to properly equipped trade schools to be restored by interested students under careful supervision.

It is apparent that unless private resources express some interest in the Smithsonian's neglected aircraft, many of them will be lost forever under the inadequate storage conditions they face at Silver Hill.

CHAPTER SHIRTS

A common sight at Rockford is EAA members walking around the field wearing distinctive "chapter shirts." The designs are many and varied, some having distinctive styling and others having easily recognized colors or trim. Such shirts have a very practical advantage at big fly-ins; they make it much easier for members of a chapter to find each other. Has your chapter got one?



I know that auto ENGINES are popular in homebuilts, but . . .