SPORTPLANE BUILDER...

By Tony Bingelis

It doesn't take a mental giant to be able to install a bolt in a hole, slip on a nut and torque (that means 'tighten", Wilbur) it. It does, however, take a bit of thought, knowledge, self discipline and skill to do it correctly most of the time, and under different installation limitations.

For the most part, I would assume that the folks building and rebuilding warbirds, racers and space shuttles are the most likely group that would use aircraft hardware correctly. I am not as sure about the ultralight, lightplane and other amateur builders as they are as contrasting a group of individuals as they are innovative. For this reason, if for no other, I make this plea.

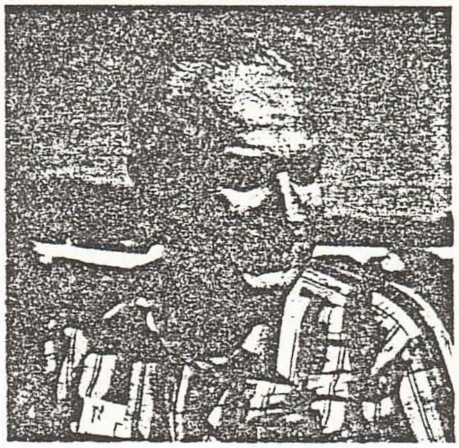
Please don't even think of putting hardware store nuts and bolts in your aircraft project, even if they don't look like stove bolts. The importance of correctly selecting and correctly using the hardware that will be holding your airplane together deserves your most careful attention. After all, the safe and efficient operation of your aircraft will greatly depend on it.

I am told that the reason some first-time builders use commercial grade hardware is because nobody told them they shouldn't. Well, consider yourself told.

It is quite understandable that a builder who needs a particular sized bolt would be tempted to substitute anything else that would fit. After all, it is mighty convenient to be able to dash off to the hardware store and pick up a few bolts in the correct size just when you need them most. Unfortunately, they simply will not do. Most hardware store bolts have less than half the strength of similar sized aircraft bolts. In addition, they are prone to corrode and weather poorly, even though they are plated. See the difference for yourself . . . place two bolts side by side and compare the aircraft bolt to the hardware store bolt. The aircraft bolt will have a smoother finish and look much better than the commercial example. You will notice, too, that almost all commercial bolts have a coarse thread and you can't find self-locking nuts for them. Of course, there are high quality commercial bolts that have high tensile strengths and could probably be substituted safely.

Even the experienced builder sometimes finds himself without the proper hardware (bolt, etc.). And he, too, may decide to substitute something else for the missing item. He substitutes the needed bolt deliberately, but due to his

ARE YOU USING AIRCRAFT HARDWARE CORRECTLY?



knowledge and experience, the substitution is fairly safe, or at least acceptable for a particular use. Not so with an individual who may be a whiz at a podium or among the "software set" but not so comfortable with things mechanical. He might make an unacceptable substitution, when faced with the same problem, simply to get on with his project. Actually, I don't think anyone, regardless of his background, should make substitutions in important structural applications without at least checking with the designer.

Even though it seems that rules are destined to be broken either deliberately or through blissful unawareness (ignorance, I think it's called), rules are useful and can even be important. A few written and unwritten topical rules follow.

As a rule, a bolt assembly generally consists of a bolt, a single washer and a nut. You can get by with a single washer provided the bolt length is correct for that particular location (see Figure 1).

The washer is always placed under the end that will be torqued. In all normal installations this would be under the nut. Does that mean that if you put a washer under the head of the bolt it would be O.K. to torque it? Well, the unwritten rule says it is bad practice to tighten a nut by turning the bolt head (it abrades the cadmium plating and tends to loosen the fit, that's why). Still, there are times when this is necessary.

I am sure most of you have heard of the rule that the bolt head always goes up or faces forward into the slipstream. This concept is based on the notion that if the nut comes off, gravity (or the slipstream) will hold the bolt in place. Using the same reasoning, you would put the head of the bolt on the inboard side of a helicopter rotor head so that centrifugal force would keep it in place.

Nice thinking there and I'm sure that the "heads up" and "heads forward" practice is a good one. However, in some installations, it matters little how the bolt is inserted. If the nut comes off, the assembly will fall off, period. You should be aware of this. Sometimes it is absolutely impossible to install a bolt with the head up due to a lack of access or due to some structural peculiarity. So, install the thing head-down and don't worry about it. Just make sure that you use a good self-locking nut, or one that can be safetied in some other manner.

Why do you suppose aircraft manufacturers have a rule against cutting bolts or reworking threads without special permission? Since you are the manufacturer of your airplane what do you think about the practice? Cutting the end of a bolt off is no monumental thing, at worst the end would get rusty. Rethreading the shank, however, could be risky if the bolt were to be used in a highly stressed area or subjected to load reversals.

There is a rule about bolt lengths. It says that the bolt should be long enough that no threads bear on the structure or fitting. Other variations of the rule say that no more than 1-1/2 threads shall bear on the structure or fitting. Another way of saying essentially the same thing is to say that the grip length (unthreaded part of the shank) shall equal that of the parts being connected. At any rate, getting the correct bolt length is important.

The catalogs list the various AN (Army/Navy Specification) bolt lengths in 1/8 inch increments so an AN3-7 bolt would be a 3/16" bolt 7/8" long. Don't forget that about 3/8" of that bolt are taken up by threads and the grip length will be considerably shorter than the total length.

Plans are getting better as the years go by and designers are now doing a fairly good job of calling out the correct bolt sizes and lengths. However, you should check each installation to see that the grip length is correct for your project and that the bolt is not too short. If you can see the edges of the material being bolted together, or if you know the total thickness, arriving at the cor-

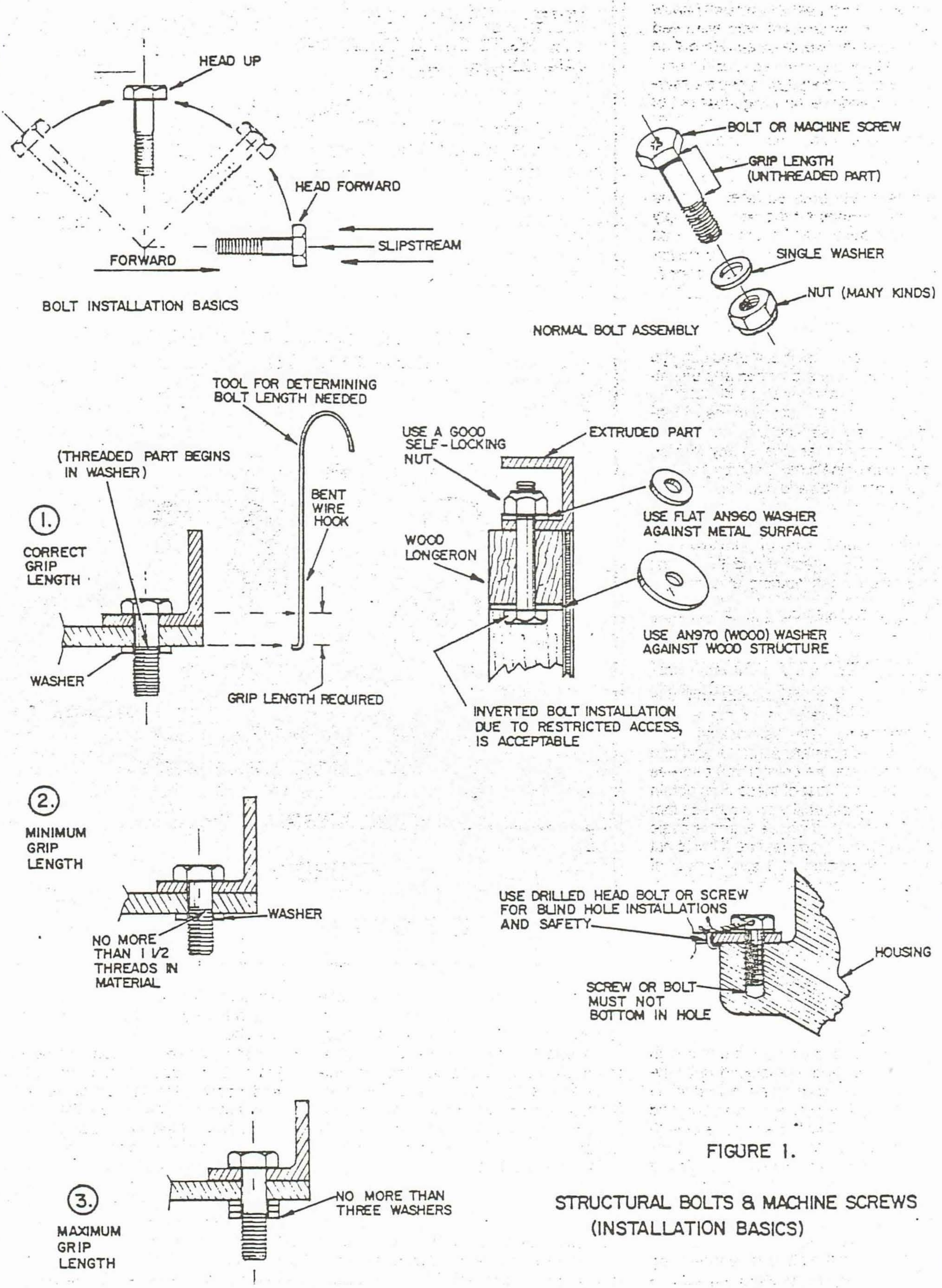


FIGURE 1.

STRUCTURAL BOLTS & MACHINE SCREWS
(INSTALLATION BASICS)

rect bolt length is easy. There are places, however, where you don't know exactly how long a bolt you will need unless you try two or three. Here's an easier way.

Make and use your own grip measuring tool. Bend this handy gadget out of a piece of 1/16" welding rod, or .040" safety wire, into approximately the shape shown in Figure 1. Insert the wire in the bolt hole so that the short hook catches on the back surface. Mark the top surface level on the wire or simply hold your thumb and fingernail over that location. Withdraw the wire and measure the grip length that will be needed.

There Are Nuts And There Are Nuts

I don't know what that means but, you guessed it, there are written and unwritten rules regarding the use of nuts.

It is said that all nuts, with the exception of safety (self-locking) nuts, must be locked by cotter pins, safety wire or, if because of inaccessibility, by painting the end of the bolt and nut. Locking may also be achieved by peening the end of the bolt when a plain or castellated nut is used. Sounds kind of primitive (and it is), but it is effective and the safest thing to do when nothing else can be done.

Fortunately, there are many varieties of nuts and often any one of several kinds of nuts can be used in a specific installation.

One rule says you should only use high temperature nuts in the engine compartment. The self-locking high temperature nuts are all-metal and can withstand temperatures of 450 degrees F and higher. Most of these nuts obtain their locking capability from threads that are slightly out of phase with the basic threads. Other types feature a basic nut that has a portion of it slightly "out of round". Another type has saw cuts (vertical slots) around its outer end circumference. These are pinched in to effect the locking feature.

The self-locking nut that has a fiber/nylon (usually red) insert cannot be subjected to temperatures above 250 degrees F without causing the locking feature to deteriorate.

Obviously, it is all right to use a high temperature type self-locking nut anywhere in the aircraft . . . even if it doesn't get hot there. Right? However, you had better keep the fiber insert type of self-locking nut out of the engine compartment. That is a pretty clear cut rule but if you knew where the temperatures were moderate enough you could still use the fiber nut there with confidence, but why waste time running studies and tests? Use the high temperature type nuts in the engine compartment and be done with it.

The same kind of reasoning is applied to shear nuts. You have self-locking shear nuts and you have castle shear nuts. Both are very thin when compared to the regular nuts. Shear nuts should never be used for other than shear applications. Regular self-locking or Castle nuts may be used for both shear and tension installations. So you can replace that skinny nut with a fat one but do not use a shear nut where it is subjected to tension loads.

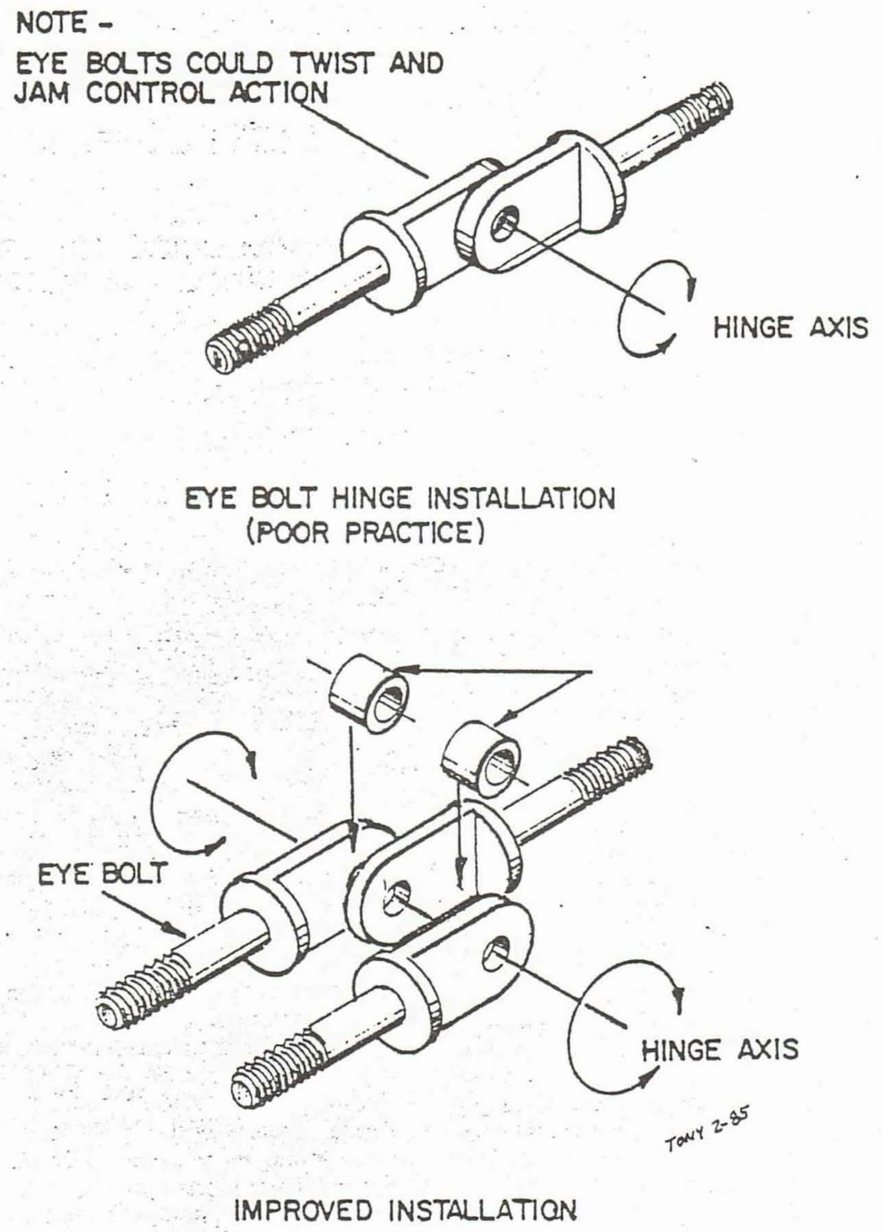


FIGURE 2.

EYE BOLT CONTROL HINGES

There is still another rule that affects the use of self-locking nuts. It says that you should never ever use a self-locking nut next to a surface that is subjected to movement (turning, twisting, rotating or whatever). That movement under a self-locking nut could ultimately cause it to loosen and fall off. You can, however, use self-locking nuts any place there is no relative movement between the nut and the part to which it is attached.

For example, you can use self-locking nuts in a pulley installation, in a rod end bearing installation or against an anti-friction bearing where the nut tightly binds against the inner race of the bearing or against a part of the fitting that tightly binds the inner race of the bearing. Figure 4 has an example shown.

Ready for another one? Never run a thread cutting tap through a self-locking locking nut as this will ruin its self-locking capability. This is especially applicable to the fiber insert self-locking nuts used with machine screws.

Often safety nuts are very difficult to torque onto a machine screw because

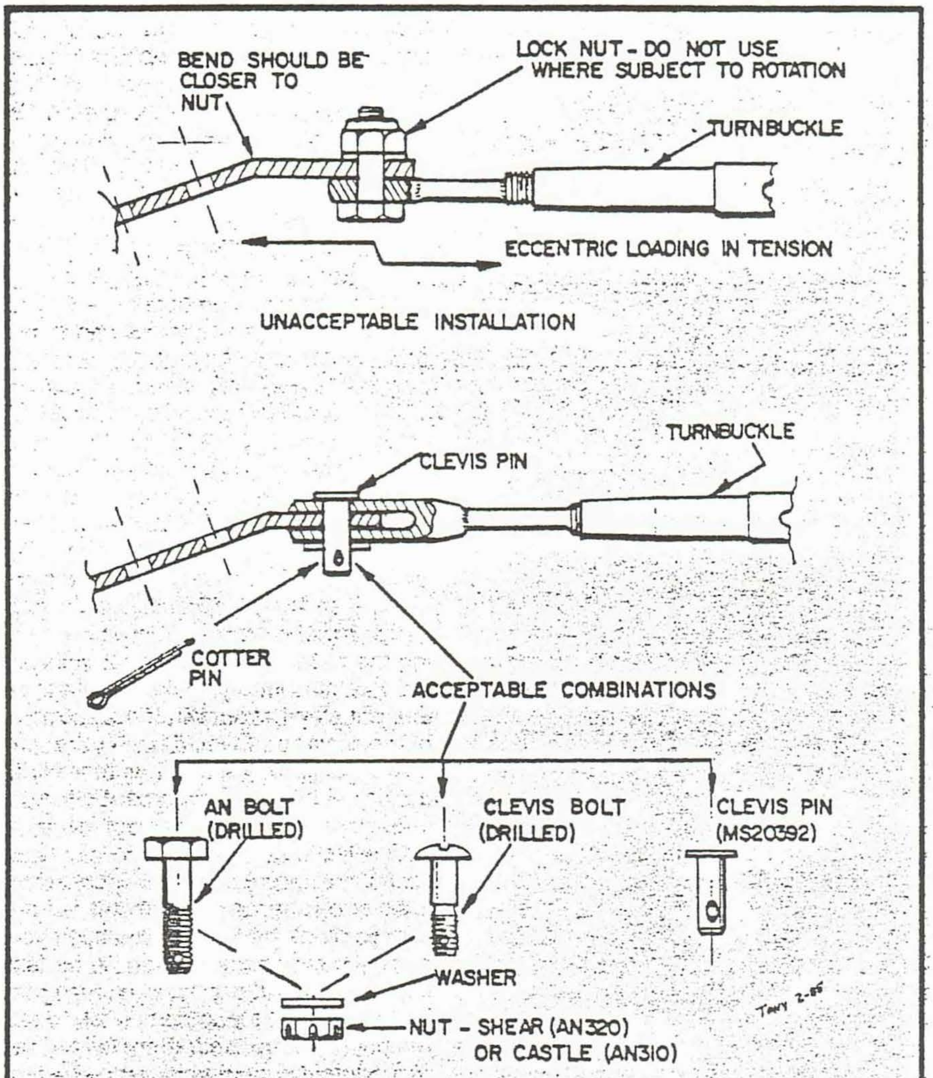


FIGURE 3.

TURNBUCKLE INSTALLATIONS (TYPICAL)

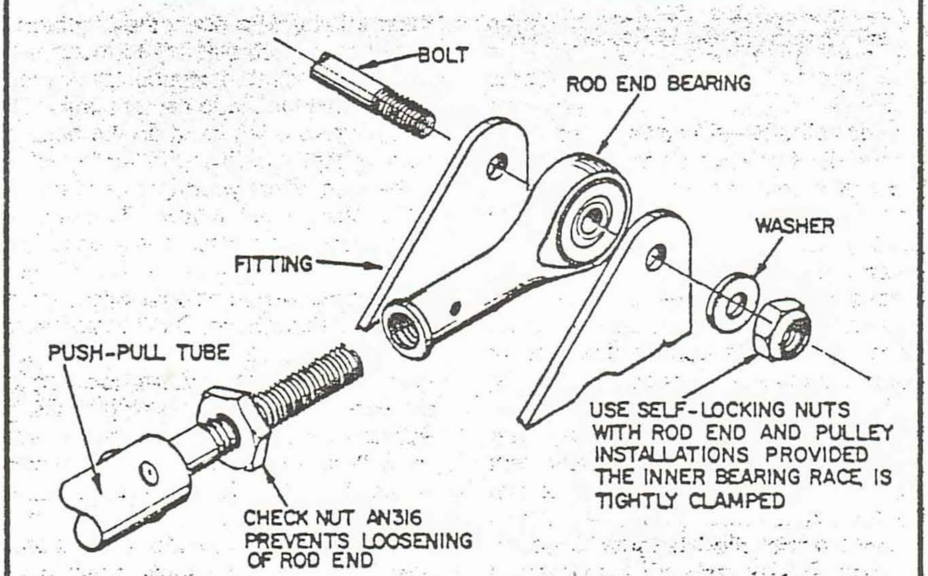


FIGURE 4.

ROD END INSTALLATIONS (TYPICAL)

they have to be turned with a screw driver. A screw driver cannot deliver the twisting force possible with a wrench on a hex head bolt. Some builders solve the difficulty by running a tap through the nut. Wrong, wrong. Of course, if you only need a nut and the self-locking feature is unimportant . . . but why not do it right?

Some people will tell you (more rules) that you shouldn't ever reuse a self-locking nut. Others say don't reuse one more than twice. (Saw a manufacturer's claim, somewhere, saying their nut was good enough for 50 reuses!) Pray tell, how would you know how many times it has already been used? So far, we don't have to keep a Nut Log Book.

My own rule is simple. Don't reuse any self-locking nut but if you do, make sure that it will not spin on all the way just using your fingers. In other words, make sure that the locking resistance of the nut is still effective. Alas, I just learned that there is an all-metal self locking nut that can be spun on by hand and the self locking feature does not engage until it is torqued with a wrench. Now what? I guess I'll just have to know what kind of nuts I am working with.

Here is another reminder about self-locking fiber nuts (reminders are sort of rules, too). Do not make a habit of using a self-locking fiber insert type of nut on a drilled bolt smaller than 5/16" in diameter. If you do use a drilled bolt, be sure that there are no burrs arond the cotter pin hole that could tear into the elastic insert. Maybe they make too much of this rule but then again, who wants to drive around with slashed tires even if they do hold air?

Let me give you one more and then I'll quit.

Inspectors and EAA Designees like to point out casually that that bolt is too long or that this one is too short, simply by looking at the nut. The rule they go by is one that says, when more than 3 threads are showing outside the nut the bolt may be too long. If the bolt is too long, the nut may not even be securing the bolt. (The nut has merely bottomed against the shank.)

But, wait, sometimes even one's eyes can be fooled. Some of the newer types of aerospace nuts appearing on the market are much smaller than the standard self-locking nuts. Using these can result in many more of the bolt threads being visible beyond the nut. This gives the erroneous impression that the bolt is too long.

Just proves that you can't believe everything you see or hear . . . you've got to think, too.

End of Sermon.

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Building Basics

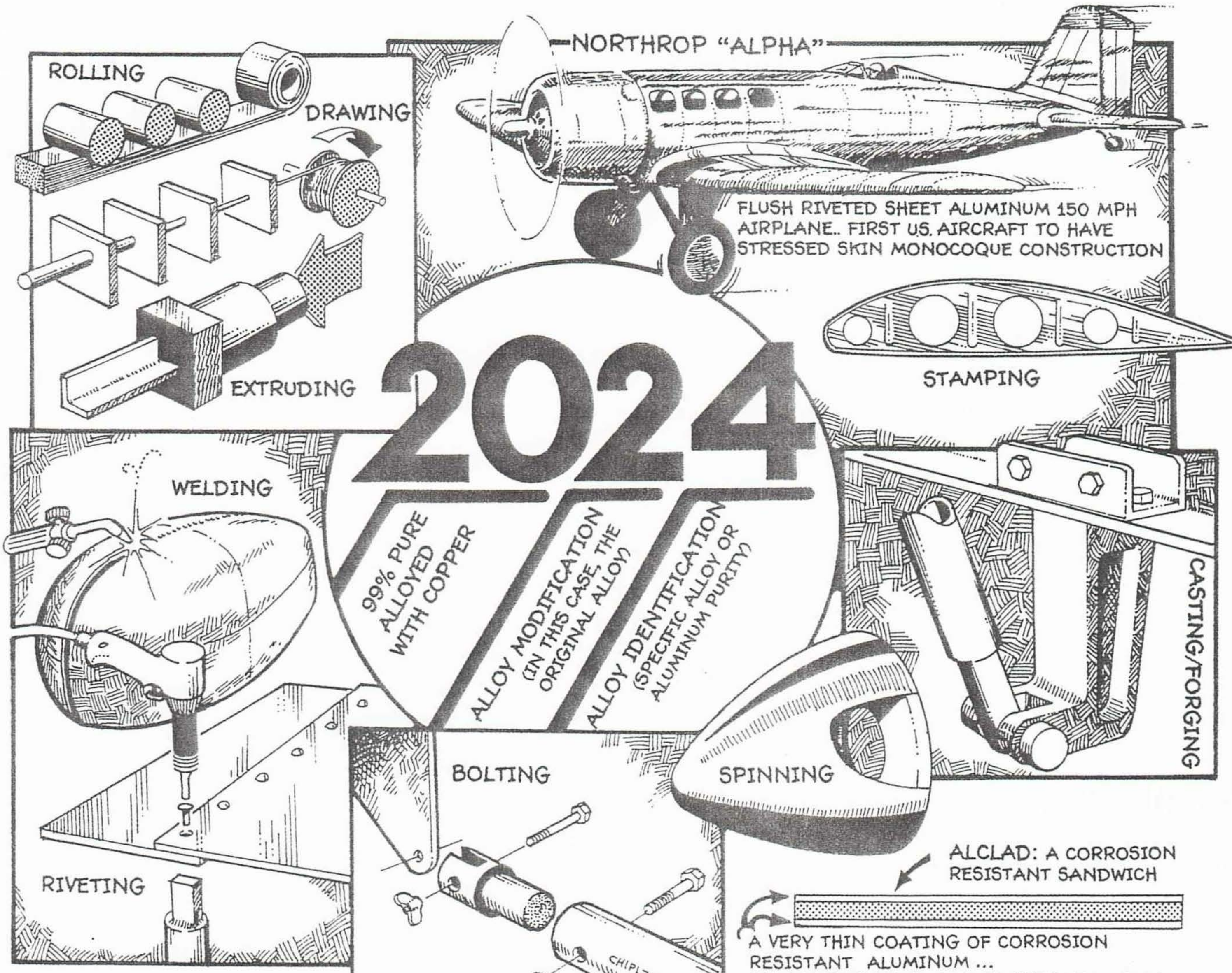
Gauging Aluminum

Aviation's wonder metal

H.G. FRAUTSCHY

ALUMINUM IS AN EXTRAORDINARY material, and without the "wonder metal" it could easily be argued that aviation would still be in the Dark Ages. Relatively inexpensive compared to other lightweight metals, aluminum possesses an outstanding strength to weight ratio. It doesn't exist in nature as a free metal, but aluminum oxide, the raw material needed to produce alumina, is found in one of the world's most common ores, bauxite.

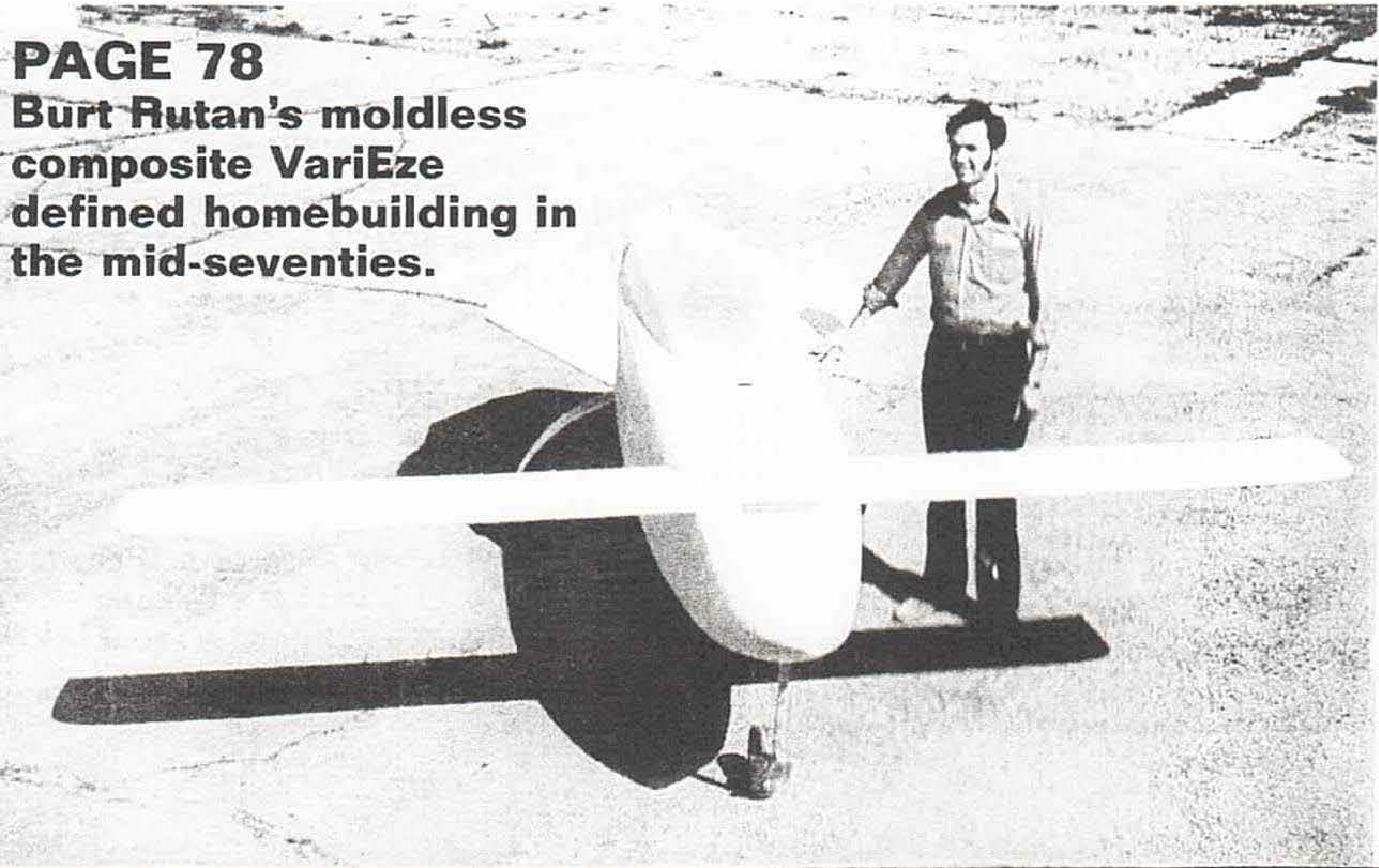
Higher-grade bauxite ore contains 45 to 60 percent alumina, which is refined using a complex series of steps into pure molten aluminum, which is then cast into ingots or billets. Manufacturers then process the pure aluminum by melting it and adding alloying elements such as copper, manganese, silicon, magnesium, zinc, and other elements to get the desired mechanical properties. (If you're interested



NUTS & BOLTS

STICK & RUDDER

DEPARTMENTS



PAGE 78
Burt Rutan's moldless composite VariEze defined homebuilding in the mid-seventies.

Glossary

Alodine: A chemical process for applying a protective or decorative coating to aluminum. It differs from anodizing by not using electricity in the process.

Anodize: An electrochemical process for applying a protective or decorative coating to aluminum.

Alclad: An aluminum or aluminum alloy coating that is metallurgically bonded to either one or both surfaces of an aluminum alloy product, and that is anodic to the ally to which it is bonded, thus electrolytically protecting the core alloy against corrosion. In aviation use, the coating is bonded to both sides, and the "cladding" for 2024 sheet .063_ and under, the thickness of the coating is 5 percent of the total sheet thickness.

in the specifics of aluminum production, visit Alcoa's primary metals website at *www.alcoa.com/primarymetals*.

To make things from this wonder metal you can roll (hot or cold), extrude, draw, cast, weld, and rivet it. Aluminum resists corrosion to varying degrees, is non-sparking, so it can be used in proximity with flammable substances, and conducts electricity, making it easy to ground when used in a structure. It's nonmagnetic, so nearby navigation equipment, especially the compass, are not affected by it.

Aluminum can carry heavy loads (some alloys have tensile strengths higher than 80,000 psi), and you can finish it in a variety of ways, from no finish to painting or applying alodine and anodized coatings. Because the alloying process alters the aluminum's resistance to corrosion, at times it may be desirable to add a thin coating of corrosion-resistant aluminum or aluminum alloy to the surface of another sheet aluminum alloy, creating a sheet of alloy with the desired strength and corrosion resistance. This combination is called Alclad.

The thickness of aluminum sheets is measured in thousandths of an inch, and often given as a gauge number. Aluminum sheet ranges from the thinnest, 38 gauge (0.00396 inch.), to the thick 3 gauge (nearly a 1/4 inch). Anything thicker is considered aluminum plate. Commonly used sizes in aviation include 22 gauge (0.0253), 20 gauge (0.032 inch); 14 gauge (0.0641 inch).

Aluminum Numbers

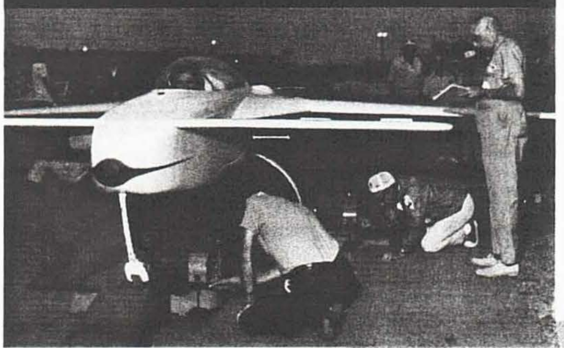
A bewildering set of four digit numbers identifies the different aluminum alloys used in aircraft, with

HOMEBUILDING'S Heritage

#3 in a series

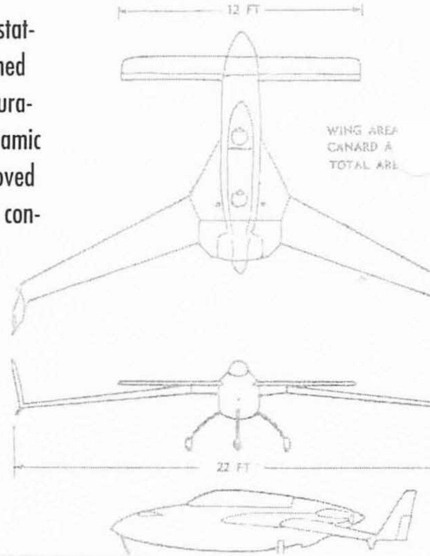
RUTAN VARIEZE

N7EZ, the VariEze piloted by Dick Rutan that set a closed-course duration record at EAA Oshkosh in 1975, is displayed in the EAA AirVenture Museum. Below, Dick Scott supervises the weigh-in before the first record attempt.



The Rutan Aircraft Factory in Mojave, California, was an incubator of forward-thinking designs. Burt Rutan's outside-the-box creativity kept EAA convention-goers guessing as to what aeronautical wonder he would introduce next.

The VariEze product brochure stated that the aircraft was designed to prove that a canard configuration, using the latest aerodynamic technology, could offer improved flight efficiency over current conventional aircraft.



Burt Rutan, after having made a name for himself amongst EAAers with his radical VariViggen, one-upped himself with the introduction of the VariEze in 1975. No one could argue that the VariEze's moldless composite construction—fiberglass and epoxy laid up over cores of foam—would literally revolutionize the homebuilding movement. In 1978, *Popular Science* aviation editor Ben Kocivar asked, "Is this foam and fiberglass homebuilt the shape of the future?" The VariEze not only had a futuristic look by virtue of its glass backward canard design, but it used, according to Rutan Aircraft Factory, "tomorrow's technology" in the construction process. At EAA Oshkosh in 1975, Burt's brother Dick set a closed-course endurance record, covering 1,638 miles in just more than 13 hours in the VariEze. In 1976, Wicks, a supplier of raw materials for the VariEze, quoted a cost for the total kit of $2,106.56.

Rutan's VariViggen was designed in 1965, construction was started in 1969, and first flight was in May 1972. That year, the all-wood canard pusher won the Stan Dzik trophy for design contribution at EAA Oshkosh. The stall-resistant design eventually sired the VariEze and the popular Long-EZ, and homebuilding has never looked back.

each having a particular strength and ductility. 1100 series aluminum is the softest, registering a tensile strength of about 11,000 psi. It's the easiest to weld and form, but you can't heat treat it to make it harder (or stronger), so it's used only for decorative and non-structural applications.

Alloying aluminum with copper creates 2024, which is commonly used in aviation, and it's often used in Alclad sheet form. With high strength and resistance to fatigue, it's a good choice for structures. Stamped wing ribs are most often made with 2024T3, and it can be machined easily. 2024 is often used in Alclad sheet form.

Alloying aluminum with manganese creates 3003, which is more commonly used than 2024 in all applications. If you have aluminum cookware, it's most likely made from 3003 because deep drawing easily forms it. In aviation, spinners and other cups and covers can be made with 3003.

Alloyed with magnesium, 5052 has the greatest strength of the non-heat treatable aluminum alloys. It, too, is used in deep draw applications, like fuel tanks, because it resists tearing better than 3003. Among the heat-treatable alloys, 7075 (a zinc alloy) is rated at up to 77,000 psi when heat-treated to the T6 condition.

Of the heat treatable alloys, 6061 is the most versatile and has good resistance to corrosion. Alloyed with magnesium and silicon, it can be formed using most fabrication techniques, including welding and furnace brazing.

Heat Treatment

Alloys that can be heat treated have a letter with their numerical designation. F means "as fabricated," and O stands for annealed, the process of heating the metal and letting it cool slowly to make it softer and easier to form. T is for "temper," and it means the aluminum is heat treated, as in 7075 T6 or 2024 T6. One of the more common designations, T6 is the result of solution heat treating and artificial aging. Another is T3, solution heat treatment and cold worked.

Because some alloys cannot be heat-treated, an H followed by a number designate their hardness. H1 means the metal has been strain hardened, 2 means strain hardened and then partially annealed, and 3 means it's been strain hardened and then stabilized. A second number, digit from 2 to 9, denotes temper from quarter-hard to extra-hard. A sheet of 3003 H14 would be a strain hardened, half-hard aluminum that's alloyed with manganese.

Fabrication Methods

You can connect sheets of aluminum in many different ways, which is one reason its use is so common in aviation. Riveting is the most common method, and has been since the 1930s. In 1930, Northrop built the Alpha, a breakthrough airplane that used stress-skin construction, where the airplane's skin, riveted to formers, carries the airplane's structural loads. (We'll address rivets in an upcoming "Building Basics.")

Welding is another way to join two pieces of aluminum, and "Craft & Technique" discusses this process starting on page 92. Bolting aluminum pieces together to create components is usually reserved for major structural sections such as a wing center section. In larger manufacturing applications, rivet-like fasteners have replaced bolts. Builders of ultralights often bolt together pieces of reinforced aluminum tubing to create wings, tail surfaces, and fuselages. Bolts make construction and repair easy, but the penalty is the increased weight of the bolt, washer, and nut.

Mechanical forming is a catch-all phrase that means a builder uses some mechanical means to shape (or form) a sheet of aluminum. The mechanical devices include a male and female die, a drop hammer, die press, English wheel, hydoforming, and a hammer and dolly. Hand forming can take place using a wide range of devices, from using simple tools like a hammer and a lead shot-filled bag to a multi-thousand dollar power-driven planishing hammer.

Spinning is also a popular method for forming aluminum, and the prop spinner is the most common aviation example. Casting aluminum is another common way to make parts. Some homebuilders cast their own non-structural parts, but structural items, such as landing gear trunnions and other critical components, should be left to the pros.

Aluminum remains one of aviation's most commonly used materials, and will continue be a mainstay for many more years. When time and craftsmanship come together, who can resist the lure of a brightly polished airplane, be it a Cessna 195 or an RV-6? ■

JACK COX

George Graham's Mazda EZ

George Graham's EZ is a true homebuilt if there ever was one! He bought building instructions for the Long-EZ, E-Racer, Cozy and Velocity, then picked the parts of each he liked best to scratch-build his two-place, side-by-side canard aircraft he simply calls an EZ. He built the airframe parts in a 9′ x 12′ bedroom in his home in Tonawanda, NY, relying heavily on building tips gleaned from his friend, VariEze builder Nigel Field of Embrun, Ontario.

"Nigel was my guru throughout the project. Every question I ever had, he had the answer - even how to make propellers."

One of the ideas was "hard shelling" the composite structure - applying fill and getting the foam perfectly smooth **before** applying the glass cloth.

On the advice of his stepson, a Memphis, TN auto mechanic, George converted a 1985 Mazda RX-7 rotary engine to power his EZ. Among his innovations were the use of a five-speed automobile transmission as his propeller reduction unit. He retained only second gear, which has a ratio of 2.2 to 1. With a 66″ x 75″ wood propeller he carved himself, the engine will produce 2,300 static rpm and he normally cruises at 2,500 rpm. He retained the Mazda's electronic dual ignition, but eliminated its electronic fuel injection in favor of his own homemade intake manifold and an old Dodge truck carburetor.

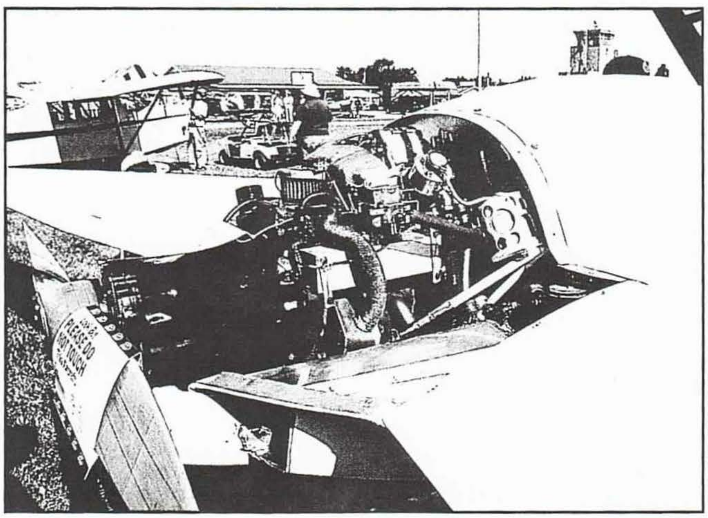
The engine has thus far proven to be as bulletproof as his stepson said it would be. George and his wife, Fran, had flown the airplane 127 hours over the previous eight months when they landed at Oshkosh this summer, including trips all over the Eastern U. S.

The EZ came out weighing 940 pounds empty. Gross is 1,800 pounds. George cruises it at 180 mph and lands at about 75.

Building an airplane is just the latest adventure in George Graham's multifaceted career. He started building his first hotrod when he was 13 and began racing it when he reached 16. He joined the Air Force in 1965, became an aircraft mechanic and ended up in Vietnam before mustering out four years later. After his return to civilian life, he bought a sawmill and operated it for a time, but eventually transitioned into the construction business, building schools, super markets, shopping centers, etc. After a brief sojourn as car builder/crew chief for a championship SCCA race car team, he tired of all the travel, returned home to Buffalo and got into the computer business., He began as a salesman and, later, the manager of a Computerland store, working for free just to learn about computers, then went into his own software business. He sold that company to build his airplane . . . and who knows what he will tackle next!

George certainly is unafraid of challenge. When he began building his EZ, he was not yet a pilot. He soloed a friend's airplane during the four year construction period and built up some solo time, then took an intensive eight day, 21 hour course at a flying school in Florida to get his Private license in time to test fly his EZ!

George Graham (EAA 454272) of Tonawanda, NY.



JACK COX PHOTOS

COMPOSITE CONSTRUCTION BONDING

BY RON ALEXANDER

During this series on composite construction, I am attempting to convey to potential builders the very basic knowledge necessary to construct a composite airplane. Composite building is not difficult. It simply requires a fundamental knowledge of the basics. When you undertake the building of a composite aircraft, the plans or assembly manual will guide you through the process. The basic skills needed for this type of construction consist of 2 primary items: knowledge of how to do a basic layup and knowledge of how to bond pieces of material together. Building a composite airplane from a kit is similar to building a model airplane. You glue the pieces together. Now, obviously the gluing procedure for an aircraft is much more critical and sophisticated than with a model, but the basic principles are very similar.

To review the material previously presented in the two preceding issues, I discussed the primary elements of a composite structure: core materials, reinforcement materials, and resin systems. Workshop space and tools needed were presented along with how to work with all of the basic materials. Various types of fillers were discussed and how to use them. The June article presented safety issues and outlined how to do a basic layup using fiberglass and resin. The proper inspection of a completed laminate was also given. We will now pick up at the next step of our layup — application of peel ply.

PEEL PLY

Peel ply is a polyester or nylon cloth material applied to the completed laminate while the resin is still wet. This cloth will not adhere to the layup thus allowing it to be peeled off at a later time, hence the words "peel ply". The application of peel ply is suggested when you are going to complete another laminate at a later time. If you are immediately going to apply another layer of cloth this step is not necessary. Peel ply provides an added benefit of absorbing excess resin from the composite skins.

Assuming you are going to apply another laminate later, or you are completing the final laminate, you will want to place peel ply onto the completed surface. Cut the peel ply to the proper size and lay it over the laminate while the resin is still wet. One layer of peel ply is all you will need. Use a squeegee and a brush to work the resin up through the peel ply. You may have to add a small amount of resin to get the peel ply to bond adequately to the laminate and to completely impregnate the peel ply and thus fill the weave. After ensuring the peel ply is saturated onto the layup, set the piece aside to cure. After the resin has cured you must then remove the peel ply. This is very important! Failure to remove peel ply will result in an unsafe bond of the next layer of reinforcement material. (Note that a number of kit manufacturers will ship pre-molded parts that still

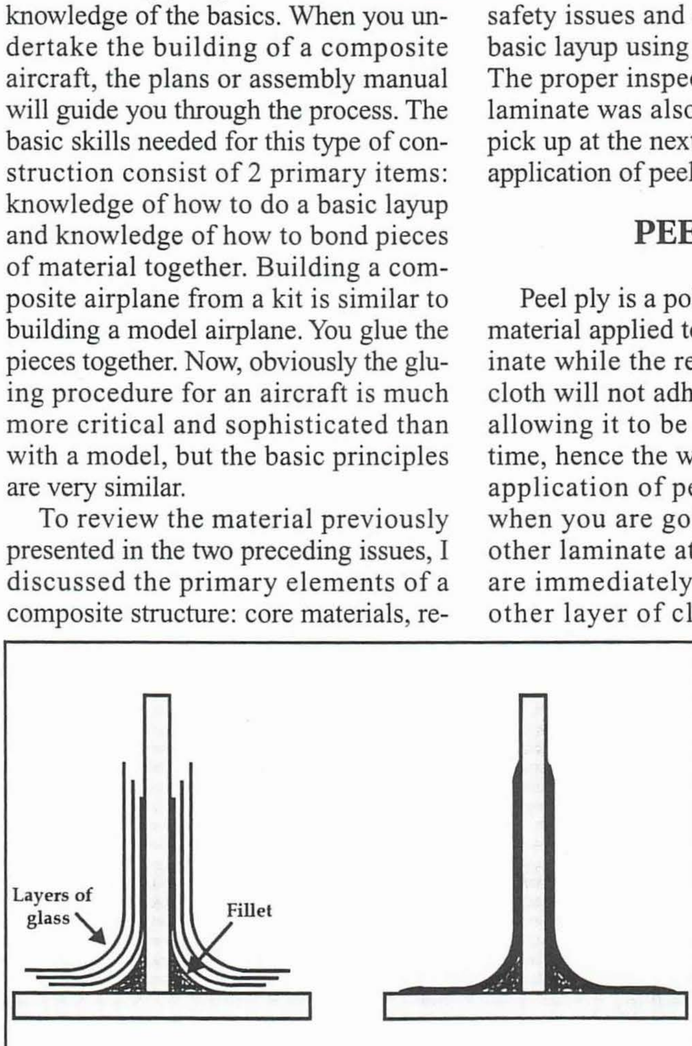
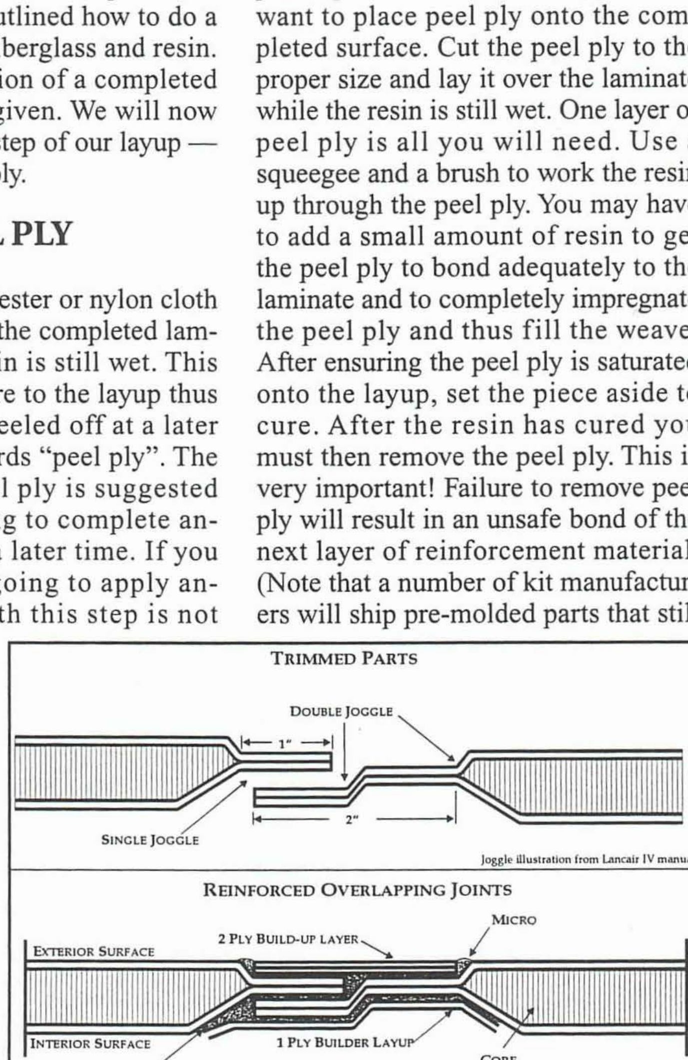


Figure 1



Joggle illustration from Lancair IV manual

Figure 2

Joggle illustration from Lancair IV manı have peel ply attached. It is imperative this be removed prior to bonding the pieces together.)

After removal of the peel ply you will see that the laminate is very smooth and requires little preparation for the next layer of cloth or for the finishing process. The resulting surface is actually fractured somewhat leaving it better prepared for additional bonding or painting. Small glossy areas will be present on the peel-plied surface requiring abrading with 180 grit sandpaper or Scotchbrite™ pads. Without using peel ply, the composite surface will require extensive sanding or filling to prepare it for bonding or painting.

BONDING

Definition

Bonding is not a new process in aircraft building. In fact, bonding has been used in aircraft construction since the very beginning. The technique of gluing wood structures together has been used for years. Many of the same gluing elements found in wood is also found in composites. The term bonding, as applied to composites, is used to describe a common method for joining composite structures. Bonding is the process in which previously manufactured component parts are attached together during assembly of the airplane. Bonding composites can also be compared to welding metal. It is designed to be a permanent joining method. Several important points must be considered in bonding. We must know how much strength is needed in the joint, the bonding area required, what type of material must be used to provide the adhesion, and the procedure used to apply the bonding material. Preparing the surfaces that are to be bonded together is also crucial. As stated earlier, the majority of composite kit aircraft require some type of bonding procedure.

The first method of bonding used in amateur-built aircraft involves a four-step process. The first step is to cut and trim the component parts to get the proper shape and fit. The second step is to position the two pieces together. This can be accomplished by using temporary jigs or by temporarily gluing them together with a non-structural adhesive. Third, we must fill any gaps that may exist as a result of butting the two pieces together. The final step consists of actually creating the structural joint using wet (resin laden) strips of reinforcement material (usually fiberglass) bonded over the area connecting the two components together (see Figure 1). If we are bonding together two pieces that are perpendicular to each other as in Figure 1, then we must create a fillet.

The strength of a joint that is joined by a fillet is derived from the reinforcement material and not the fillet itself. The fillet is needed to prevent the reinforcement fibers from making a direct 90-degree bend without any radius. Composite materials must have a bending radius just like sheet metal. The number of strips of reinforcement material laid down over the fillet determines the strength of the bond.

An example of the type of construction explained is found in mating a wing rib to the wing skin. Another example is placing a bulkhead into a fuselage. Both of these are common types of construction techniques used when building a kit composite airplane.

The second method of composite bonding is termed "adhesive bonding." Adhesive bonding involves assembling component parts together using a structural adhesive in place of resins and fiberglass. Structural adhesives range from preformulated, two part mixtures that are in paste form to structural laminating resins that are mixed with flocked cotton or milled fiber to provide the necessary strength. The first method of bonding discussed uses laminating resins and reinforcement material to create a bonding overlap. Adhesive bonding requires the bonding area to be formed into the part when it is molded. This is usually accomplished by lowering one side of a part and raising a side of the second part. This allows the two pieces that will be bonded to slide over each other providing a precise fit. The joint that is formed when the pieces are joined in this manner is referred to as a "joggle" (see Figure 2). With this type of overlap the builder is required to lay down the structural adhesive and apply some clamping pressure.

Some kit manufacturers prefer to

Figure 3

combine both bonding methods to achieve the greatest possible strength. The key to achieving strength in any joint is to properly prepare the surfaces that will be joined. The laminating resin or structural adhesive must bond well to the surfaces. The surfaces must be cleaned properly and sanded.

You will often hear the term "secondary bonding" used in composite construction. This type of bonding simply refers to the bonding together of previously cured composite parts using the methods outlined above. Secondary bonding is commonly found in most composite kit aircraft. It requires proper surface preparation. Prepare the surfaces according to the instructions provided by the kit manufacturer. Usually, the surface will be abraded using 180-grit sandpaper or a Scotchbrite pad. Each of these will provide the proper surface preparation without cutting or damaging underlying fibers.

Steps of Bonding

When you receive your kit it will usually consist of many pre-molded parts that need to be bonded together. Sounds relatively simple — and it is — provided you carefully follow instructions. You must first of all remove any peel ply, prepare the surfaces, and then the pieces must be properly jigged to maintain an accurate alignment. Then the actual process begins. So, let's take the steps one at a time. We will use a simple "T" bond of 2 pieces of material to illustrate the steps.

Preparation

Most of the construction process of a kit aircraft involves secondary bonding. This means it is critical to properly prepare the surface. With a plans-built airplane or a kit airplane where you have just completed building a part, the piece is already prepared for the bonding step.

Assuming you are working with pre-molded parts, you must abrade the surface to ensure an adequate bond. Failure to do so will result in an unsafe bond. We have discussed this process earlier. Prepare the piece according to the instructions of the kit manufacturer. They will usually have you use sandpaper or Scotchbrite™ pads to scratch up the surface. 3M™ Rol-loc disks also work very quickly to prepare glass surfaces for bonding. You will want to make sure you have the proper fit between the pieces. A certain amount of sanding may be necessary to ensure this fit. You do not want any gaps between the pieces that are to be bonded together. The pieces must then be thoroughly cleaned to remove any contaminants. Often residue from a mold release compound will be present on the piece. This must be removed. Acetone is often recommended for the initial cleaning followed immediately by a dry rag. The part should then be cleaned with soap and water to remove any solvents and then dried. Again, follow the directions of the kit manufacturer. I will amplify on the cleaning process in the next article.

Tack the Parts Together

The next step in the bonding process is to mate the pieces together and glue them in place using a non-structural glue (Figure 3). This simply allows you to begin the bonding process. You can use 5-minute epoxy, hot glue or instant glue to hold the pieces together. The parts only need to be tacked in just enough areas to hold them in place. This is not the final bonding of the pieces — it is simply a method of holding them together while we actually complete the bonding operation. None of the glues mentioned should be considered as structurally sound. Hold the pieces together until the glue sets up. Figure 2 shows our two pieces glued together using 5-minute epoxy. Assembly instructions will often require the use of clecos, screws, or clamps to attach the pieces together for the bonding process.

Note: As a reminder, remember to remove any peel ply that may be present on the component parts prior to bonding.

Create a Fillet

Once the temporary bond has hardened, a fillet needs to be made. This fillet provides a radius for the reinforcement material that will be bonded on next. The fillet alone is not strong enough to bond the parts together. Dry micro or SuperFil is used to make a non-structural fillet. Structural fillets, if required, are made by substituting microballoons with cotton flox.

Creating a fillet is relatively simple. Mix the SuperFil or micro and place it in a sandwich bag or in the middle of a piece of plastic. Close it up and snip a small hole in the bottom of the bag (see Figure 4). This is similar to a cake-icing dispenser. Now squeeze the mixture from the bag along the corner area where the pieces are joined. A small amount is sufficient. An optimal fillet will have about a 3/16-inch to 5/16-inch radius.

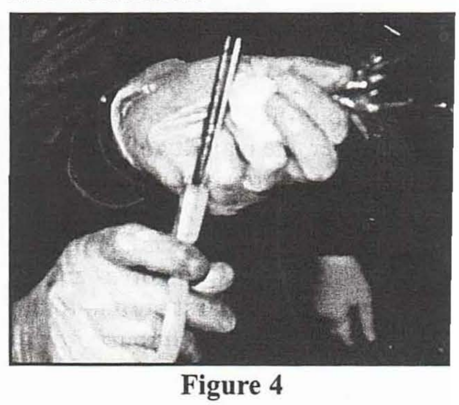


Figure 4

After placing the SuperFil along the fillet area, take a tongue depressor and smooth the mixture into the corner area. Rounding the end of a tongue depressor with a pair of scissors wil

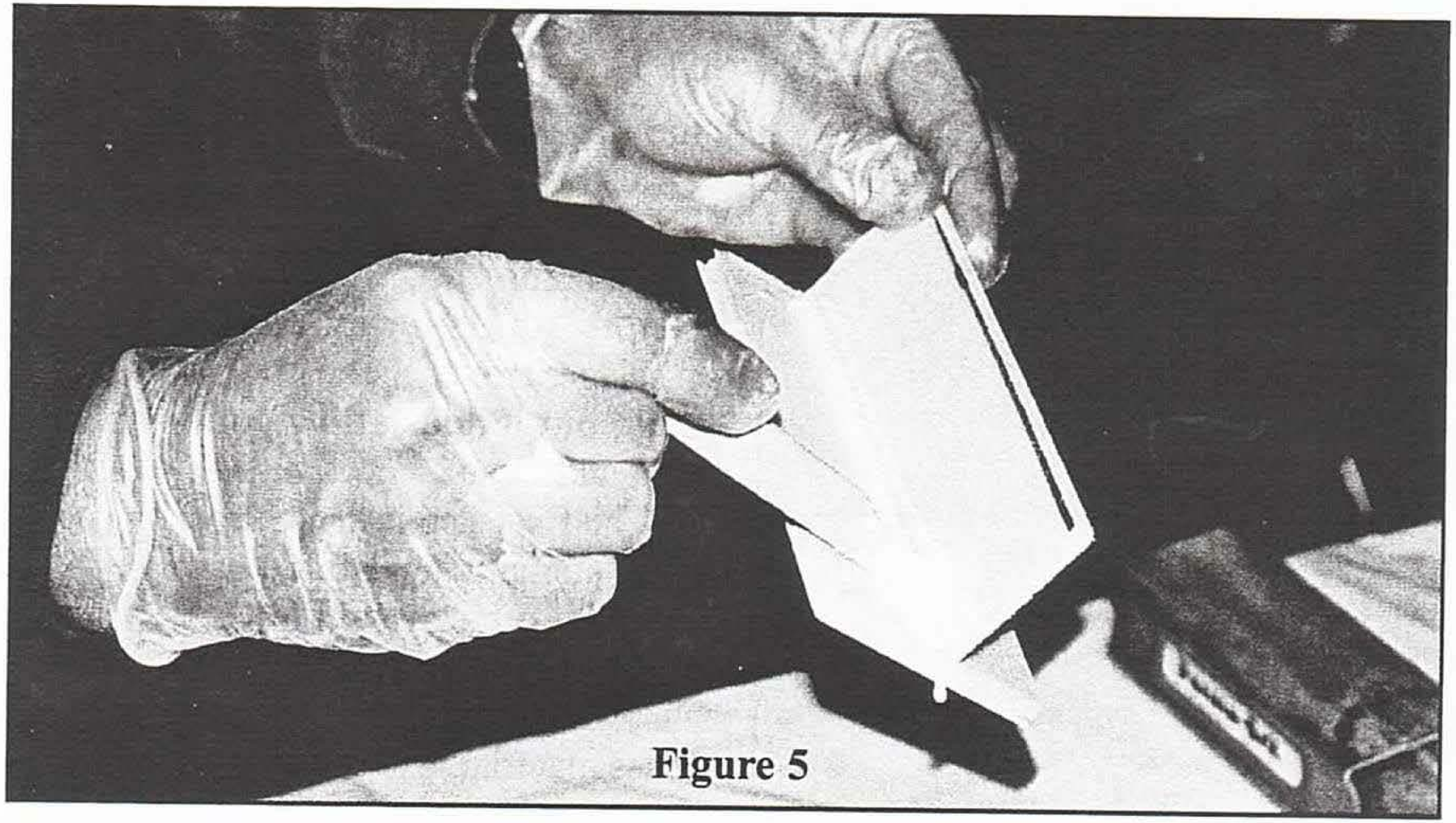


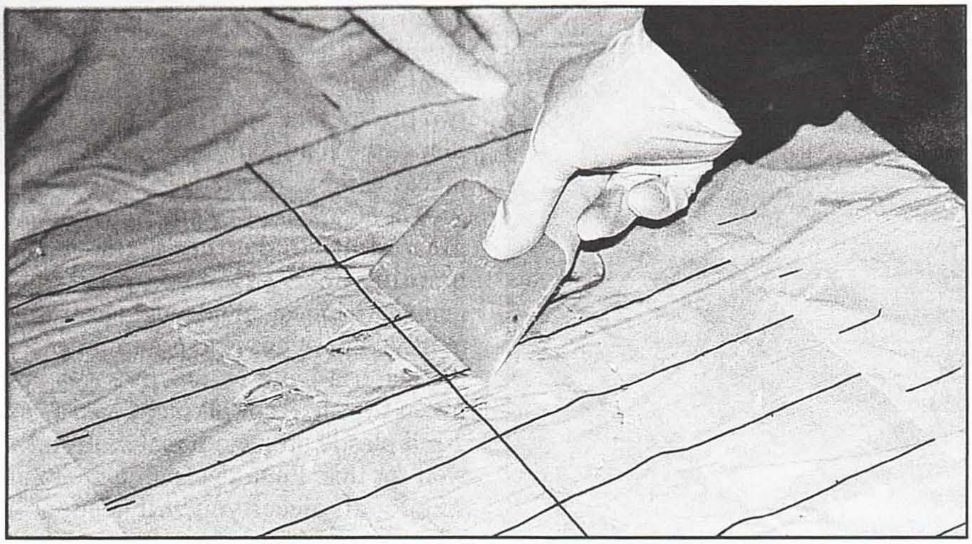
Figure 5

provide the exact size fillet you desire. Use the tongue depressor, holding it perpendicular to the fillet and not leaned fore or aft (see Figure 5). Remove any excess material that may have formed near the fillet along the sides of the pieces. This can be done using the tongue depressor. You do not want any micro or SuperFil where the glass will be applied except at the fillet itself. The completed piece should have the appearance of a smooth fillet. You are now ready to bond the pieces using reinforcement material.

Tape Glassing

In our example, we are going to use fiberglass to complete the bonding process of our two parts. This is often referred to as "tape glassing." On your project, you will complete this process according to the manufacturer's instructions. Usually at least 2-3 layers of cloth will be placed between the two pieces. Once the glass tapes are in place, the load path between the two pieces will be complete.

Wet layup strips of fiberglass cut at plus/minus 45 degrees are used for bonding nearly all components together. The most simple and clean way to make the layups is to pre-impregnate the material with resin while it is between two sheets of plastic. Clean 1- or 2-mil plastic drop cloth material works well for this. First, determine the total size for all pieces you will need. Obtain a piece of fiberglass slightly larger than this total size. Next obtain two pieces of plastic and cut them 3-4 inches larger than the fiberglass both in length and in width. Using a Sharpie marker, draw lines on the plastic to form the necessary strips of cloth that will be the exact length and width needed. Flip the plastic over so the resin is not placed on the marks. Mix the required amount of resin necessary to saturate the cloth. Pour the resin



Smoothing resin into cloth between sheets of plastic.

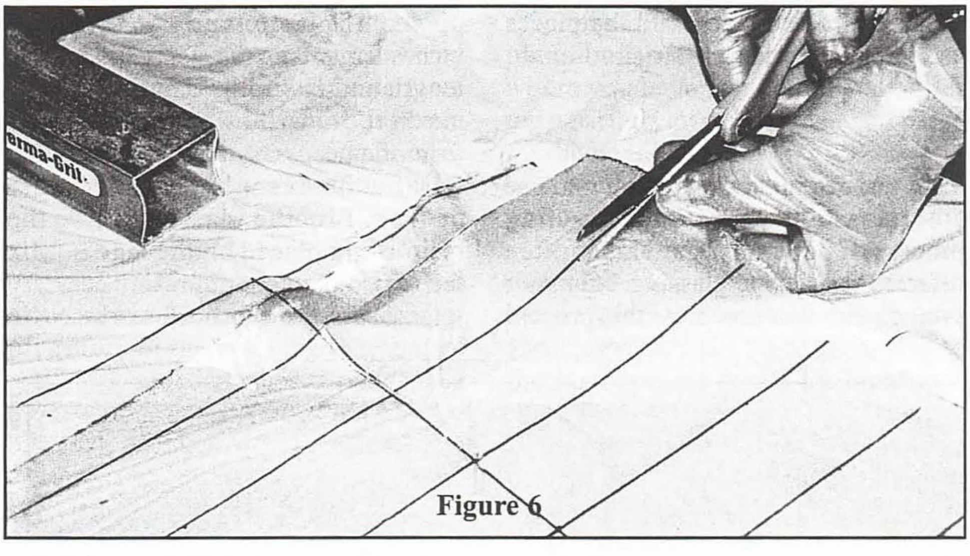


Figure 6

over the plastic and place the fiberglass on top of the resin. Next place the second piece of plastic over the resin.

Using a squeegee, work the resin into the fibers through the plastic. In other words, you will be placing the squeegee on the plastic, not on the cloth. This enables you to keep everything clean and neat. Wet out the fibers completely just like any other layup. You can now pick up the entire piece of material and handle it without getting resin everywhere.

The next step is to use standard scissors and cut out the tapes you will need along the lines on the plastic (see Figure 6). As you cut the strips, draw the scissors slightly toward you. This will enable you to make neat, easy cuts.

Next, lightly moisten the area to be laminated (on our "T") with resin using a brush. This will ensure that the bond is not resin-starved. Remove the plastic from one side of the tape. Place the strip down with the remaining piece of plastic facing up. Use a squeegee over the top of the plastic to remove any air bubbles and to smooth the resin evenly. After the tape is in place you can then remove the top piece of plastic. The process is then repeated for additional layers of cloth. Be sure to remove the plastic. Plans usually call for the pieces of reinforcement material to be stepped out with succeeding layers. In other words, if the first layer is 2 inches wide the next layer would be 3 inches wide. The widest piece will be on the top.

Thoroughly inspect the piece for air bubbles and resin starved areas.

As you will see from the completed piece (Figure 7), the tape is providing the strength of the bond. This is a very efficient and effective method of bonding two composite parts together. Again, it is a commonly used technique for installing ribs in wings or bulkheads in a fuselage. Use of the plastic is not necessary, but it does allow you to remain neat and clean.

The final step is to place peel ply over the material. Laminate a strip of peel ply over the surface and allow the resin to cure. This will eliminate the sharp edges that will otherwise result from the fiberglass material. Remember to remove the peel ply after the resin has cured.

Joggles

Joggles are simply joints that have been pre-molded to fit precisely together. They overlap each other and are usually bonded together using a structural adhesive. This type of construction is very common in the mating together of fuselage parts. After bonding the parts together at the joggle, reinforcement material is usually applied for added strength.

Often you will be required to trim excess material off a joggle prior to bonding. Usually you will place the two pieces together and then drill holes to allow for the installation of clecos. (The same clecos used for sheet metal construction.) Some instructions call for the use of clamps or even strips of wood glued on the surface to hold it in place and to maintain proper alignment. This will often be done in a jig to ensure alignment of the parts.

After the pieces are mated together, and the proper fit attained, you will then mix the structural adhesive. Structural adhesives are usually in a thick paste form. They consist of a Part A and a Part

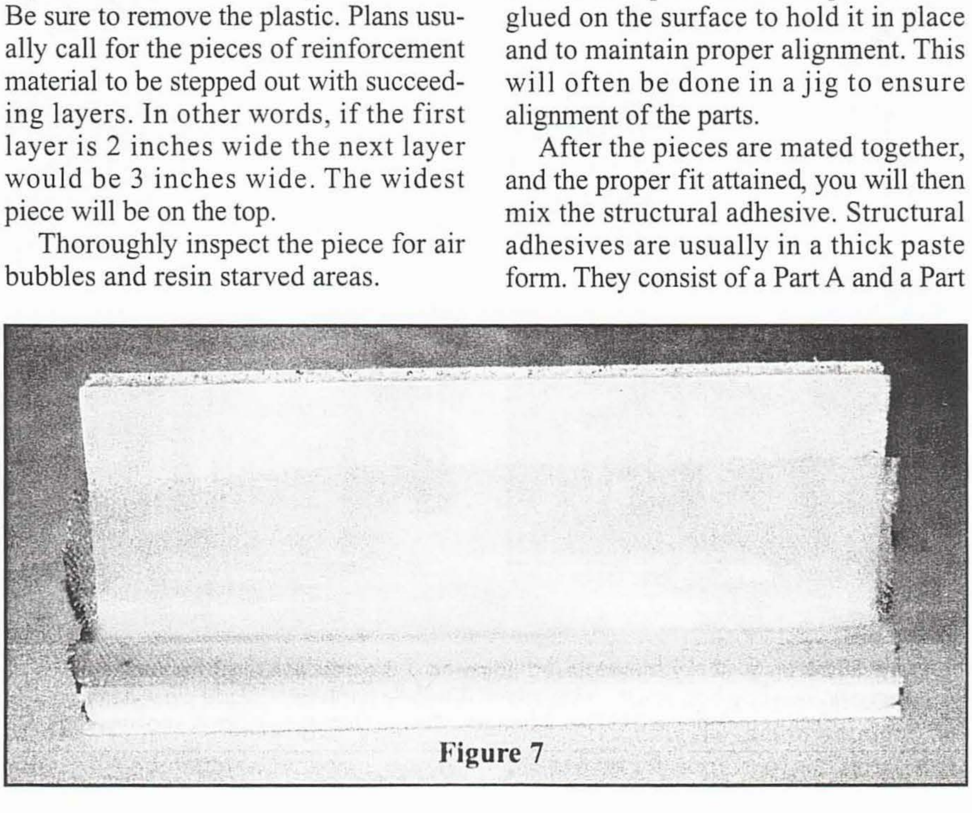
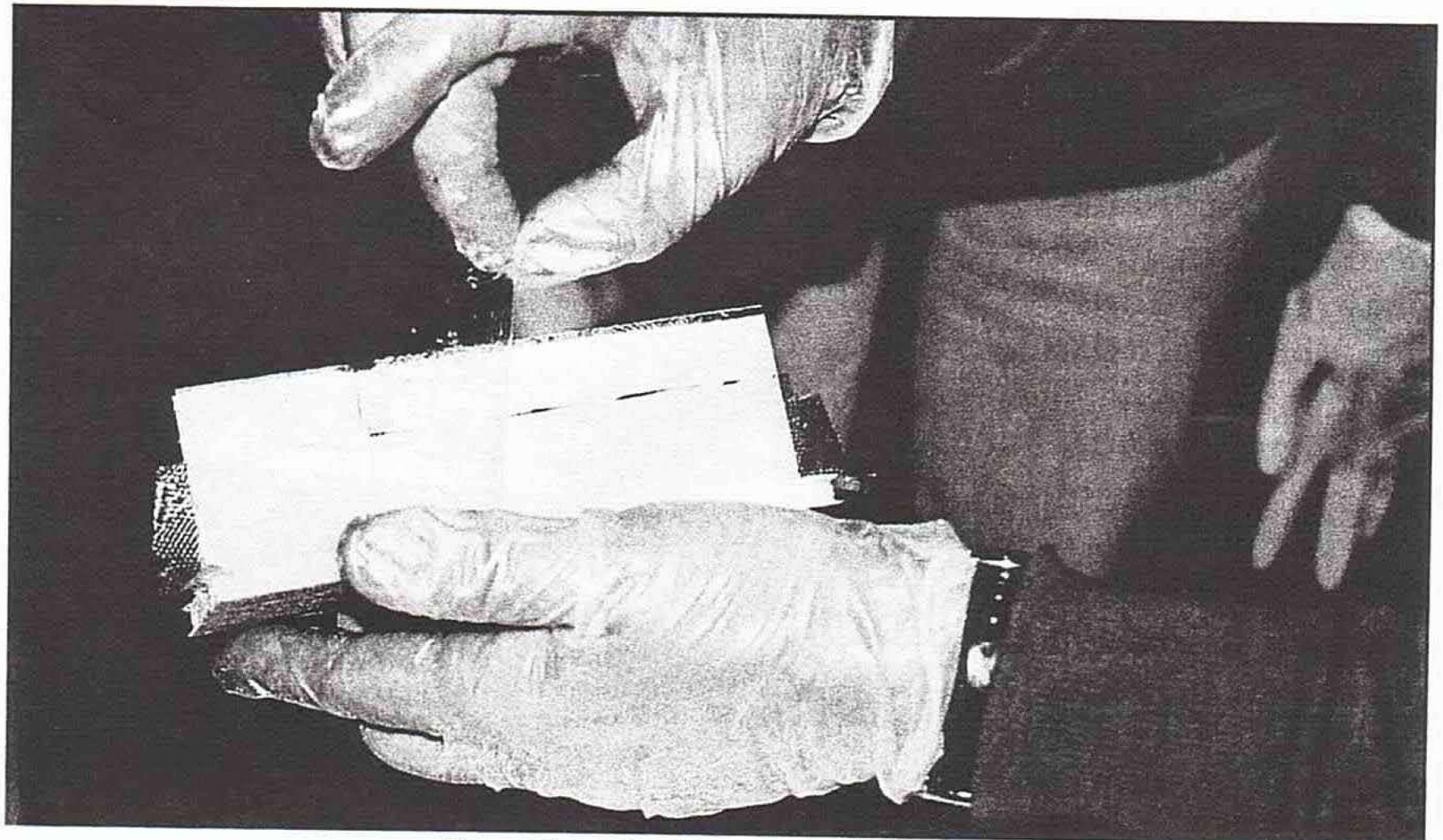


Figure 7



Removing plastic from glass tape.

B mixed according to instructions. You want to be sure the ambient temperature is at least 60+ degrees. Most of the adhesives have a working time of 1-2 hours at 77 degrees F. Be sure you are ready to glue prior to mixing the adhesives.

Remove the clecos or other fasteners as you apply the adhesive to both parts. Instructions will often tell you to replace the clecos with rivets after applying the adhesive. The rivets are later drilled out after the adhesive cures. The resulting holes are then filled. Fiberglass strips are usually applied as a final step.

This provides you with a very basic idea of how to accomplish composite bonding. The key to doing this correctly is to practice. Cut a few pieces to form a "T" and bond them together until you perfect the process. This will save you a lot of problems when you begin working on the real thing.

Next month we will continue our discussion of composite construction with some advanced techniques and methods of fabrication. ◆

The EAA/SportAir Workshop schedule is as follows:

August 28, 1999 — **Chino, CA (one day conference)**

August 28-29, 1999 — **North Hampton, NH**

October 9-10, 1999 — **Battle Creek, MI**

Information on these workshops can be obtained by calling 800-967-5746 or by contacting the website at www.sportair.com. The author may be emailed at ralexander@sportair.com

SportAir also has available a video on Basic Composites. This video may be obtained through the EAA Video Sales.

Klaus Savier, shown here in his ultra-efficient VariEze at the start of the 1999 Sun 100 air race, had an interesting flight to Florida from his home base at Santa Paula, CA. Climbing to 17,500 ft. to take advantage of a lower level jet stream with steady west to east winds averaging between 50 and 60 knots, he cruised non-stop to Memphis, TN in six hours and twenty-six minutes. His ground speed over the 1,450 nautical mile straightline distance averaged out to 224 knots (257.94 mph). The total fuel burn was 25 gallons, and the average fuel burn, from take-off to landing, including taxi and warmup/check-out, was 3.88 gph.

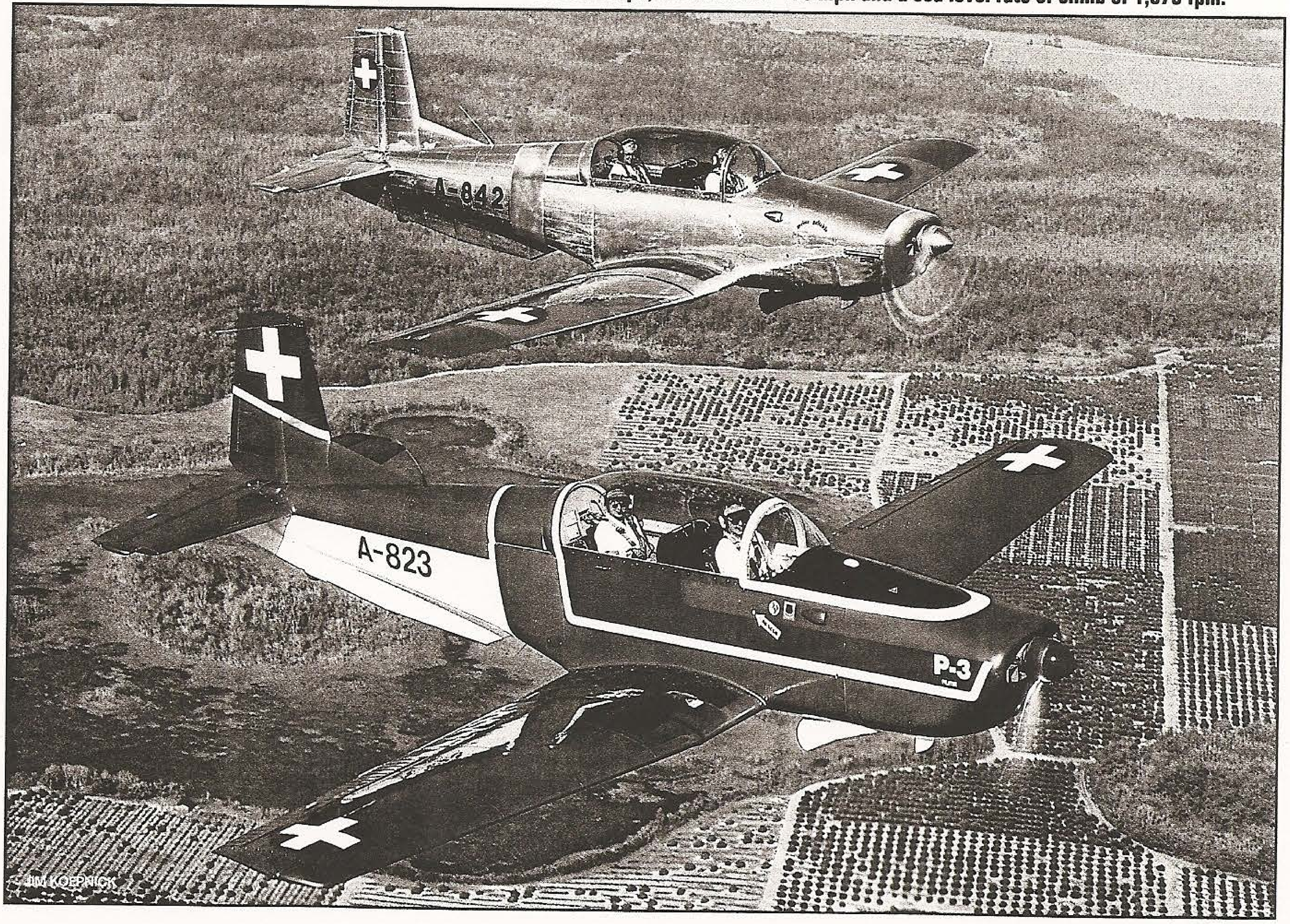
GOLDA COX

Tailwinds were, of course, a major factor, but the ability to take advantage of them is in part due to the large diameter propeller Klaus has designed and built for the airplane's non-turboed Cont. O-200. It allows him to climb to altitude quickly and continue to pull a lot of power - on this flight, 2,600 rpm at 15 inches of manifold pressure. True airspeed was 190 knots.

Klaus's VariEze is one of the most highly refined airplanes in the world, benefitting from extensive but subtle aerodynamic tweaks, his experimental propellers and, of course, his Light Speed Engineering Plasma capacitive discharge ignition system (check www. lsecorp.com for info) which automatically optimizes the spark timing for rpm, MP and altitude conditions to maximize fuel economy and power.

Klaus and his VariEze, N57LG, currently hold two FAI Class C-1.A world records: 1,000 and 2,000 km speed without payload (203.67 and 200.12 mph, respectively). They have been consistent CAFE and air race winners for years.

Below. Warbird enthusiasts keep coming up with interesting ex-military aircraft from all over the world. Shown here are two Pilatus P-3s: the red, white and blue NX4103T, foreground, owned by Norbert and Evelyn Steinwedel of Cornelius, NC and N842JM owned by Jerry Jeffers of Asheboro, NC. The Pilatus P-3 was an all-purpose (primary through advanced) trainer developed for the Swiss Air Force in the early 1950s. 72 were ultimately delivered and many have made their way to the U. S. in recent years to serve as sportplanes. Powered by a 260 h.p. Lycoming GO-435-C2A turning a 3-blade Hartzell CS propeller, the P-3 has a Vne of 310 mph, max cruise of 170 mph and a sea level rate of climb of 1,378 fpm.



JIM KOEPNICK

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BASIC COMPOSITE CONSTRUCTION . . .

Continued

BY RON ALEXANDER

Over the past few months we have discussed most aspects of building a composite airplane. This article will focus on a few specific items that require explanation such as proper preparation of parts prior to bonding, post-curing, blushing problems, etc.

PREPARATION OF COMPOSITE PARTS

In the last issue, I outlined a brief procedure for preparing composite parts prior to bonding. This step is most important and needs to be amplified. The quality of a bond is directly affected by the preparation of the two parts being joined together. If contamination exists on either part, the bond may be weakened even to the point of subsequent failure. Let me emphasize that you should follow the directions found in the kit manufacturer's manual regarding proper cleaning techniques. However, the preparation procedure is important enough to warrant more detailed discussion.

First of all, when bonding to an outside mold surface (such as many of the parts you receive from the kit manufacturer) cleaning and sanding of the parts is always required. When aircraft parts are molded, a release agent is applied to the inside of the mold itself allowing the part to be removed when cured. This mold release agent must be removed prior to any bonding activity. The agent is barely visible. Water will usually remove this agent. After removal of the agent and any contaminants, sanding is then accomplished.

Any surface that is smooth because of being next to a mold must be sanded prior to bonding. Any primer that may be present must also be removed. Sanding is generally the accepted way to prepare the surface. Opinions vary on the proper grit of sandpaper to be used. Usually 80 grit to 180 grit is recommended. Our workshop experience has shown that 180 grit sandpaper is usually satisfactory to prepare the surface. Use of 180 grit will ensure the underlying fibers are not damaged or cut. The surface should be thoroughly abraded (roughed) to completely remove any glossy areas.

Abaris Training, located in Reno, Nevada, instructs the military, airlines and aerospace industry on composite construction and repair. I consult with Mike Hoke, the President of Abaris, regularly concerning composite construction. His company is considered to be one of the leading composite training companies in the United States. The following quote was taken directly from their training manual regarding surface preparation. "High surface energy is the goal, not mechanical roughness. One must shear up the top layer of molecules on the surface, creating many broken bonds, without damaging or breaking underlying fibers. A water break test can be used to determine surface energy. If surface energy is high, clean distilled water will spread out in a thin uniform film on the surface, and will not break into beads. If a water break free surface can be maintained for 30 seconds, one has achieved a clean, high energy surface suitable for bonding. If the surface is contaminated or at low energy, the water will break into rivulets and bead up.

"Note that tap water will not work. It is dirty enough to contaminate the surface itself, and one will never pass a water break test using it.

"It is important to note that the 'high energy"' condition, once achieved, is short-lived. Within about 2-4 hours the effect is lost. In composites, one should therefore wait as late as possible in the process before surface abrasion is performed, so that all else is ready and the adhesive can be quickly applied."

Dry the water off of the laminate with a hair dryer prior to applying the adhesive. If it is wiped with a cloth it will likely contaminate the area again. Do not use a heat gun for this process. The heat is too intense and may damage the cured resin.

This process also applies to peel ply surfaces. Even though a peel ply surface fractures the top layer of resin, it leaves a glossy, low energy surface in the weave pattern of woven cloth. This must be abraded for proper bonding.

So, how should you clean parts prior to bonding? The best procedure is to simply sand the surface, as discussed, and follow by a thorough cleaning with soap and water. If you are using solvents, use them initially to remove contaminants and then abrade the surface. Follow by soap and water and then immediately dry using a hair dryer. Remember to begin the bonding process within a few hours after preparing the surface.

AMINE BLUSH

Sometimes when working with epoxy resins, you may encounter what is referred to as an amine blush. The development of an amine blush is most visible under high humidity conditions. An amine blush is a surface effect resulting from the curing agent reacting with Carbon Dioxide (CO_2) in the atmosphere rather than the epoxy resin. The by-product of this reaction is a compound that forms on the surface of the curing resin and readily absorbs moisture from the air. Under high humidity conditions, it will cause white streaks to appear on the surface of the resin and the uncured laminate. During cure, the white streaks usually disappear, but left behind will be a greasy or oily residue. Sometimes, this residue appears in the form of sweat-like droplets. This residue is water-soluble and will wash off with warm water. Depending on the severity of the blushing event there may even be areas of surface tackiness. This tackiness is only on the surface, and will not affect the overall properties of the cured laminate.

Amine blush must be removed before any additional laminates are initiated. Sanding will remove blush but it will also quickly gum up your sandpaper. Wiping the surface with a warm wet rag prior to sanding will reduce the gumming tendency.

The best approach is to avoid amine blush altogether. Some resin systems are inherently resistant to developing amine blush. And for others, it may seem impossible to avoid it. But there are some things you can do to minimize it greatly. Number one and foremost is, DO NOT use unventilated combustion type heating sources to warm your shop. Gas or kerosene fired salamander heaters produce copious amounts of CO_2 and H_2O. These are the primary ingredients needed for producing an amine blush. So, use electric heaters or ventilated exhaust type combustion heaters to keep your shop warm.

You should avoid mixing resins or doing any layups if the temperature is less than 65 degrees F. If you do a layup at this temperature you should immediately move the part into a warm room for curing. Purchase a thermometer and a humidity indicator and place them in your work area. Avoid mixing resins and working with resins if the temperature is below 65 degrees F or if the humidity rises above 80%. The best solution is to place an air conditioning unit in your workshop area.

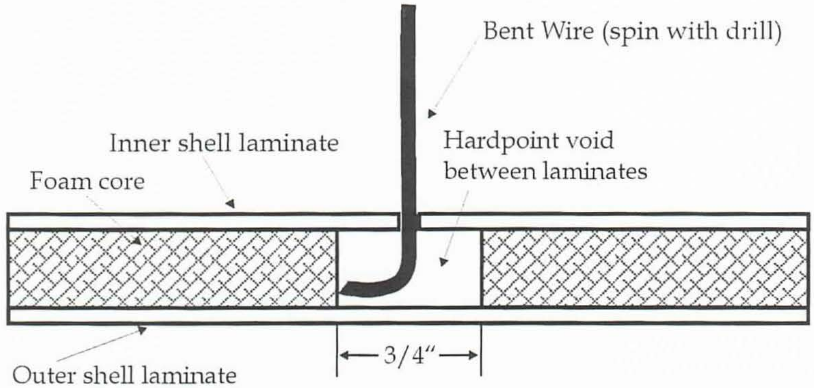
You can reduce the susceptibility to blush in the following ways:

- Work in the prescribed environmental conditions.
- Use "dry" and ventilated heating sources
- Use peel ply. Amine blush usually forms on the outer-most portion of a layup. By using peel ply the amine blush is removed when the peel ply is removed.
- Cap all resins as soon as possible. This reduces their exposure to the elements.
- Use a resin with demonstrated blush resistance. Some resins are more susceptible to blushing than others.

Use of peel ply, purchasing a blush resistant resin, and working in the right temperature and humidity will all work together to minimize amine blush.

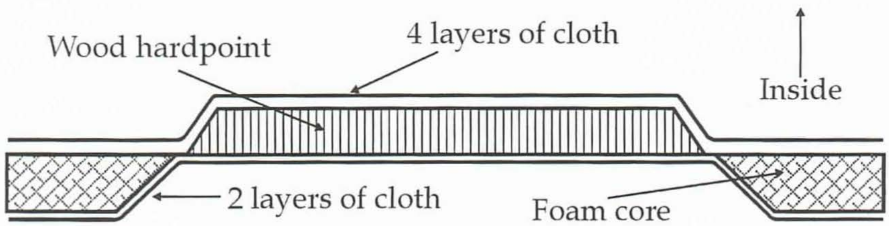
Figure 1

Preparing Hardpoint Void



Hardpoint void illustration from Glastar assembly manual

Example of wooden hardpoint



Wood hardpoint illustration from Velocity assembly manual

HARDPOINTS

Often you will be required to mechanically attach another piece to a composite structure. One method of doing this is to fabricate a "hardpoint". If you mechanically attach a piece to a fiberglass part, the fiberglass must be reinforced in the area where it will be fitted to accept the loads imposed by the attachment. An example of a hardpoint is found on the GlaStar airplane. A welded fuselage frame is placed inside a pre-molded fuselage shell. The two are attached using machine screws that are placed through hardpoints fabricated in the fiberglass shell.

The most common method of fabricating a hardpoint is to route out a small amount of foam core material between the inner and outer laminates of the shell (see Figure 1). You must be sure not to remove any of the reinforcement material on the outer and inner shells. A piece of piano wire bent 90 degrees and placed in a drill works well for this step. The core material may then be removed using a shop vacuum. After the core material has been removed, a mixture of resin and milled fiber is injected to fill the void. After the material is injected through the drilled hole, a small piece of tape may be applied to keep the resin mixture from escaping. After curing, this material provides the strength needed to serve as an attach point. You must ensure that the entire area is filled with material and no air bubbles are present. After the material completely cures, a hole is drilled through the reinforced area to receive the screw or bolt.

This is one example of a hardpoint. Various kit manufacturers use different methods. Complete instructions on fabricating a hardpoint will be included in your assembly manual.

POST CURING

Post curing is a process used to obtain increased strength from a resin. If an epoxy resin is allowed to cure only at room temperature, its ultimate strength

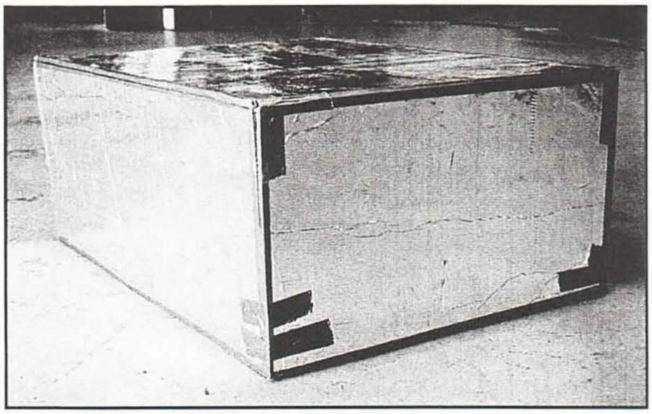
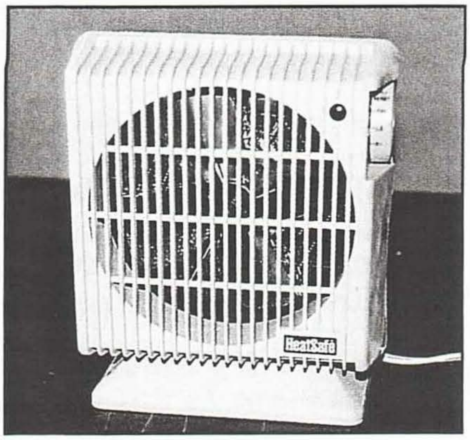
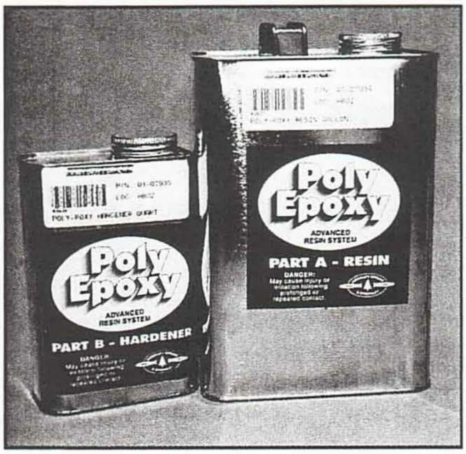


Figure 2 - Post cure oven.



Post cure electric heater



Example of a premium epoxy

is rarely achieved. Post curing will increase two critical performance properties of an epoxy, chemical resistance and heat resistance. Fuel tanks constructed using an epoxy will benefit considerably from post curing. Post curing the entire airplane will increase overall resistance to the heat build-up inside the airplane resulting from the high temperatures found on any ramp in the summer. This build-up of heat can reach the glass transition temperature causing a weakened state of the resin itself.

To understand post curing, it is necessary to define the term glass transition temperature or Tg. The glass transition temperature is the point where the physical properties of a resin material start to decrease as temperatures are elevated. The temperature at which the resin "transitions" (T) from a hard, glassy state (g) to a soft rubbery state is called its Tg. At the Tg the tensile strength, chemical resistance, and hardness are significantly reduced while the flexibility is increased. As you might imagine, we do not want our completed airplane to reach the Tg temperature. To prevent this from occurring, one method is to post cure the resin. Another way is to paint our airplane a light color (usually white) to preclude the temperature on the inside of the airplane from being excessive. On a 90 degree F day, it is not unusual for the temperature inside your airplane structure to reach 180 degrees F plus. This is why you see most composite airplanes painted white. The white color helps reflect the heat keeping the temperature inside the airplane component parts as low as possible.

Another term often used is referred to as the Heat Deflection Temperature (HDT). The value of this number provides us with an idea of the upper service temperature limit for a plastic. This is the temperature at which a resin will begin to soften if placed under a load. The HDT is usually about 20-30 degrees C lower than the Tg of a resin. The reason this is true is because the test to determine this value is accomplished under a load. For this reason, HDT is often a better indicator of the true upper service temperature limit for a given resin.

Regardless, it may be difficult for you to find the value of the Tg and/or the HDT of a resin. Resin manufacturers sometimes display one or both of these values within their instructions but many do not. You will have to seek out this information and determine the temperature and time required at that temperature for a post curing operation.

Should you post cure? Post curing is not absolutely necessary but it certainly is advantageous for all epoxy resins. Some resin manufactures require a post cure as standard practice. Basically, post curing your component parts and your composite airplane will ease your mind concerning the quality of your layups and bonds. If you are somewhat unsure about whether or not the resin properly cured on a particular layup or bond, post curing will likely solve that problem. If you are using epoxy to construct a fuel tank, you should definitely post cure that area. Post curing will ensure adequate fuel resistance not only for today's fuel compositions, but tomorrow's as well. Without post curing, you may encounter a gummy substance in your fuel tank that can plug gascolator screens and filters.

The bottom line in discussing this issue with Gary Hunter — an acknowledged expert on resins who works for Shell Chemical Company (a major manufacturer of epoxy resins) and EAA Technical Counselor — Gary recommends post curing a composite airplane. In his opinion, it takes all of the worries out of the construction process as it pertains to resins. It is a little more insurance that you are getting the maximum performance available from your resin system.

What about vinyl ester resins — do they require post curing? It is not necessary to post cure vinyl esters but it is helpful. Room temperature cured vinyl ester resins develop a larger portion of their ultimate properties, than most room temperature cured epoxies, and as such, they tend to be more resistant to chemicals overall. Therefore, the benefits of a post cure are not as significant. However, post curing simply improves these attributes even more.

How do we post cure? Raising the temperature of a typical laminate above standard room cure temperature performs post curing. Again, most resin systems will not reach their full strength unless they are cured at a temperature considerably above room temperature. Usually this temperature is about 40 degrees F below the Tg specified for the resin. The post cure temperature should never surpass the maximum temperature of another material in the laminate such as the foam. (As an example, polystyrene foam swells at a temperature around 165 degrees F.) Without post curing the Tg of a resin used on your airplane will only be approximately 40 degrees F above the temperature at which the resin was cured. On a hot day the temperature of a structure can exceed the Tg. That could result in the entire composite matrix softening. This softening can result in the matrix of the heated portion being weakened and pulled away. The once smooth surface now exposes the weave of the fabric. High temperatures inside structures that have not been post cured can also affect structural integrity.

With this in mind, it is important that you follow a post curing procedure. You can do this yourself by introducing the proper amount of heat into a fireproof tent-like structure containing a specific part or the entire airplane. Introduce the heat gradually to raise the temperature to that specified by the resin manufacturer. Usually this will be between 140 degrees to 180 degrees F. Let it warm up slowly and evenly. The resin manufacturer will specify the amount of time required at this temperature. An excellent method of post-curing is to rent a paint booth from a local car painter. These booths are usually heated and you can place your parts or the entire airplane in the booth. Put a couple of fans within the booth to circulate the air for even heating rates. Another built-in area to post cure is your attic. The temperature of most attics will reach 140 degrees F. Granted, you have little control over the heating but small parts can be post cured in an attic area. A regular oven can be very effectively used to post cure parts. You can purchase foil back insulation material and construct a small post cure booth. The insulation can be taped together using duct tape (see Figure 2). You can then place a thermostat controlled electric heater in the booth with a couple of thermometer probes placed through the insulation to indicate the temperature.

It is important that you properly support parts to prevent any distortion. This does not mean that you have to place a wing back in a jig. This is assuming the resin has cured for at least a week. (If you are immediately post curing then you should leave the wings in the jig.) Regardless, you must provide adequate support. This means positioning a wing on a flat surface with the leading edge down, as an example. Cowlings should be in place on the airplane or set on the floor with the forward edges down.

After the part has been heated for the required amount of time, slowly cool the temperature. Do not simply pull the part out of the heated area. Again, care must be taken to not exceed the break down temperature of other components such as the foam.

Many kit planes are manufactured from heat cured prepregs and as such, they are essentially post cured as delivered. However, the adhesive bond lines and tape layups the builder makes to assemble the prefab pieces will only have a room temperature cure. It only makes sense to post cure these bond lines and layups so the properties will better match the prefab parts from the manufacturer. This can be accomplished by introducing heat into a closed-up fuselage or wing area for a certain amount of time. After all, being made from foam or honeycomb cored composites, they are naturally insulating structures.

One way to do this is to use the exhaust from a vacuum cleaner as a mild source of heat. Many builders have used this procedure to introduce heat into a fuselage area for a period of time. All of the bulkheads that have been bonded and other resin applications will be post cured.

When to post cure is another question. It really does not matter when you post cure. It is usually best to wait at least two weeks after you have completed your layup or bonding to allow the resin to cure as much as possible at room temperature. Even if you have completed the work 6 months ago or longer you will still derive benefits from post curing.

Similarly, the fillers and faring compounds used to smooth and contour your airplanes painted surfaces will benefit from a post cure. Fillers inherently shrink as they cure, and after a few months in the hot sun a show quality finish can literally shrink away exposing the weave of the reinforcing fabric and other unsightly discontinuities. This is commonly referred to as "Print Through". Post curing your airplane after the filling work but prior to priming and painting will essentially pre-shrink these fillers and allow you to see and re-fill any resultant print through prior to final painting.

As you can see, there are many ways to post cure. There is nothing absolutely critical about the method. The slow introduction of heat up to the desired level followed by the proper time at that temperature is important. Again, slowly lower the temperature when you are through. As Gary Hunter states, "Post curing is not absolutely necessary, but the results are always comforting on that first encounter with clear air turbulence."

Next month I will conclude this series on composite construction. That article will focus on forming and proper finishing techniques. ◆

The EAA/SportAir Workshop schedule is as follows:

August 28, 1999	**Chino, CA (one day conference)**
August 28-29, 1999	**North Hampton, NH**
October 9-10, 1999	**Battle Creek, MI**
November 6-7, 1999	**Lakeland, FL**

Information on these workshops can be obtained by calling 800-967-5746 or by contacting the website at www.sportair.com. The author may be emailed at ralexander@sportair.com

SportAir also has available a video on Basic Composites. This video may be obtained through the EAA Video Sales.

Speed has always been one of the big selling points for aircraft. A fair question would then be, "How does the performance of a canard aircraft compare to a similar conventional aircraft?" There have been quite a few records set by canard aircraft, which is a good indication that they can do very well. AIAA Paper 84-2507, "Design and Analysis of Optimally-Loaded Lifting Systems," by Ilan Kroo is a theoretical look at the big debate, and its conclusion gives the performance edge to a conventionally configured aircraft. Figure 5 provides a parasite-drag-area comparison of several high-performance canard and conventional homebuilt aircraft designs. The data came from David Lednicer and various CAFE Foundation flight tests. It has been adjusted to remove the estimated landing-gear drag area in order to provide a fair comparison. If we take the drag area for a particular design and divide the value by its exposed surface (wetted) area, we get its wetted drag coefficient. This coefficient is an overall indication of how clean a design is. Looking at **Figure 5**, we can see that the canard aircraft have a wetted drag coefficient around 0.0050 (50 "drag counts" in aerodynamic speak). This drag area is comparable to that of the T-18 and Glasair, but higher than a few of the other high-performance aircraft. The higher value is likely due to the higher drag of the canard airfoils used and the relatively blunt after-body on the VariEze and Long-EZ.

Depending on the designer's goals, it is likely that the canard configuration will continue to be used on some future designs. As Rutan stated, "The designers' database for these types of designs is extremely limited, and the importance of understanding their aerodynamics is great." EAA

An EAA member since 1981, Neal Willford learned to fly in an ultralight in 1982 and received his pilot certificate in 1987. He has done design work on a variety of aircraft at Cessna, from the 172 to the Citation X. In recent years he has been heavily involved in the development of the Cessna NGP and 162 SkyCatcher. In his spare time he is finishing a Thorp T-211 Sky Scooter.

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EAA Sport Aviation articles are available online in the members-only section at *www.Oshkosh365.org.*

Opportunity

How a visit to Oshkosh changed my life

THANK YOU, EAA, FOR the gift of flight and the opportunity to live my dream. You have enabled thousands of homebuilders like me to pursue our passion for flight. The experience I gained building and flying my own VariViggen and Long-EZ led me to the ultimate opportunity—flight testing SpaceShipOne. More importantly, I never would have become the first commercial astronaut. From the VariViggen to SpaceShipOne—dreams and a passion for flight can make anything possible!

My first taste of flight occurred at age 7 when my uncle took me up in his Tiger Moth. Like others before me, I built model aircraft, starting with free-flight gliders and then graduating to powered "U-Control" models. I was hooked for life!

My wife, Sally, and I immigrated to the United States in 1967; I worked as a machinist in Anderson, Indiana, and learned many of the skills necessary to complete my first homebuilt. When our small company needed a pilot, I volunteered and earned my private pilot certificate in 1969. Later I found it expensive to rent an airplane, so we looked into building one of our own.

In July 1970, Sally and I attended the EAA fly-in convention at Wittman Regional Airport (OSH). I was amazed at the selection of homebuilts and astonished to discover that anyone so inclined could build such aircraft, receive an amateur-built airworthiness certificate from the FAA, and ultimately fly that plane.

At EAA Oshkosh 1974 I purchased a set of VariViggen plans from a fellow named Burt Rutan. He was selling plans out of his plane on the flightline. When I was close to my first flight, Burt stopped by for a visit. Later he invited Sally and me to Mojave where I got checked out, first in the rear seat and then in the front seat, of Burt's VariViggen. He demonstrated the entire envelope of his creation, including its quirks and shortcomings.

This was a huge benefit to me. On September 22, 1977, I made the first flight of my VariViggen and thus achieved my lifelong dream. In May 1978, Sally and I flew our 'Viggen to Mojave. Shortly after we arrived, Burt flew it and announced that it indeed met his standards.

That day he asked if we would consider coming to work for him. This was all we talked about on the flight home and...well, the rest is history. Sally and I joined Burt at the Rutan Aircraft Factory (RAF) in his new facility on the Mojave airport. Dick Rutan retired from the U.S. Air Force and also joined RAF where he took me under his wing, teaching me all I know about air combat maneuvering, close formation flying, and aerobatics.

Burt saw promise in my abilities and began coaching me on the basics of test flying. Soon I was sharing test-flight duties with Dick. Sally and I moved to Scaled Composites full time in 1985 when RAF closed down. We both retired in October 2007, but soon I was recalled and have been helping out by flying the Proteus as well as the original WhiteKnight. Occasionally I fly chase on the new WhiteKnightTwo.

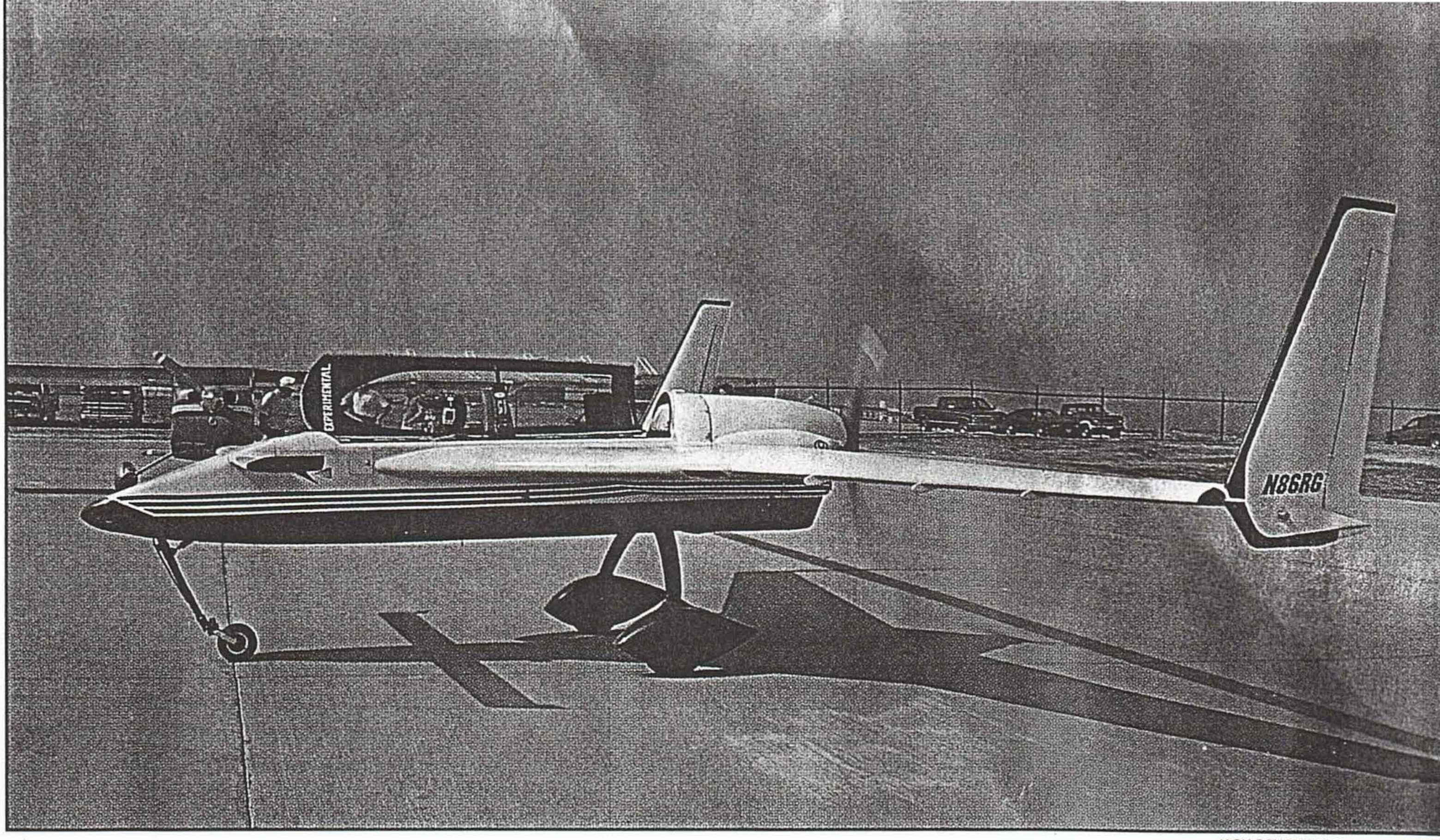
Over the past 31 years I have been privileged to make 10 first flights of Burt's original designs and have been involved in flight testing almost all of his remarkable designs.

Thanks to EAA and the vision of its leadership, I was able to build and fly my own flying machines and to ascend into the wild blue, feeling the magic of flight. This privilege is precious, and through the constant vigilance of all EAA members, it must be preserved. Each of us must take the responsibility to continually improve the safety record of amateur-built aircraft, using the tools available to us through EAA and its members.

I encourage anyone interested in flying to visit EAA AirVenture Oshkosh. Who knows, you too may be able to experience the thrill and infinite satisfaction of building and flying your dream as I have. From there, the sky is the limit! *EAA*

Sally joined Mike in the SpaceShipOne cockpit after it landed safely following its second glide flight in August 2003.

Mike Melvill, EAA 53387, made history becoming the first commercial astronaut when he piloted SpaceShipOne on its first flight past the edge of space on June 21, 2004.



JACK COX PHOTOS

A LONG-EZ THAT GOES HM-M-M-M

Power by Mazda

BY DICK CAVIN

If you were one of the fortunate ones who attended Oshkosh '95 you probably noticed there were two full lines of auto engine powered homebuilts on display. If you saw the extra heat around the area, it was probably the result of imaginations being set afire again.

One of those who caused blood to pound in EAAers veins again was a Mazda 13B powered Long-EZ by a young Delta Airlines mechanic, Ron Gowan of Roanoke, TX.

It was a decade or so back when news of the NSU Wankel rotary reached the U.S. and excited EAAers with the prospect of a turbine-like en-