Building Basics

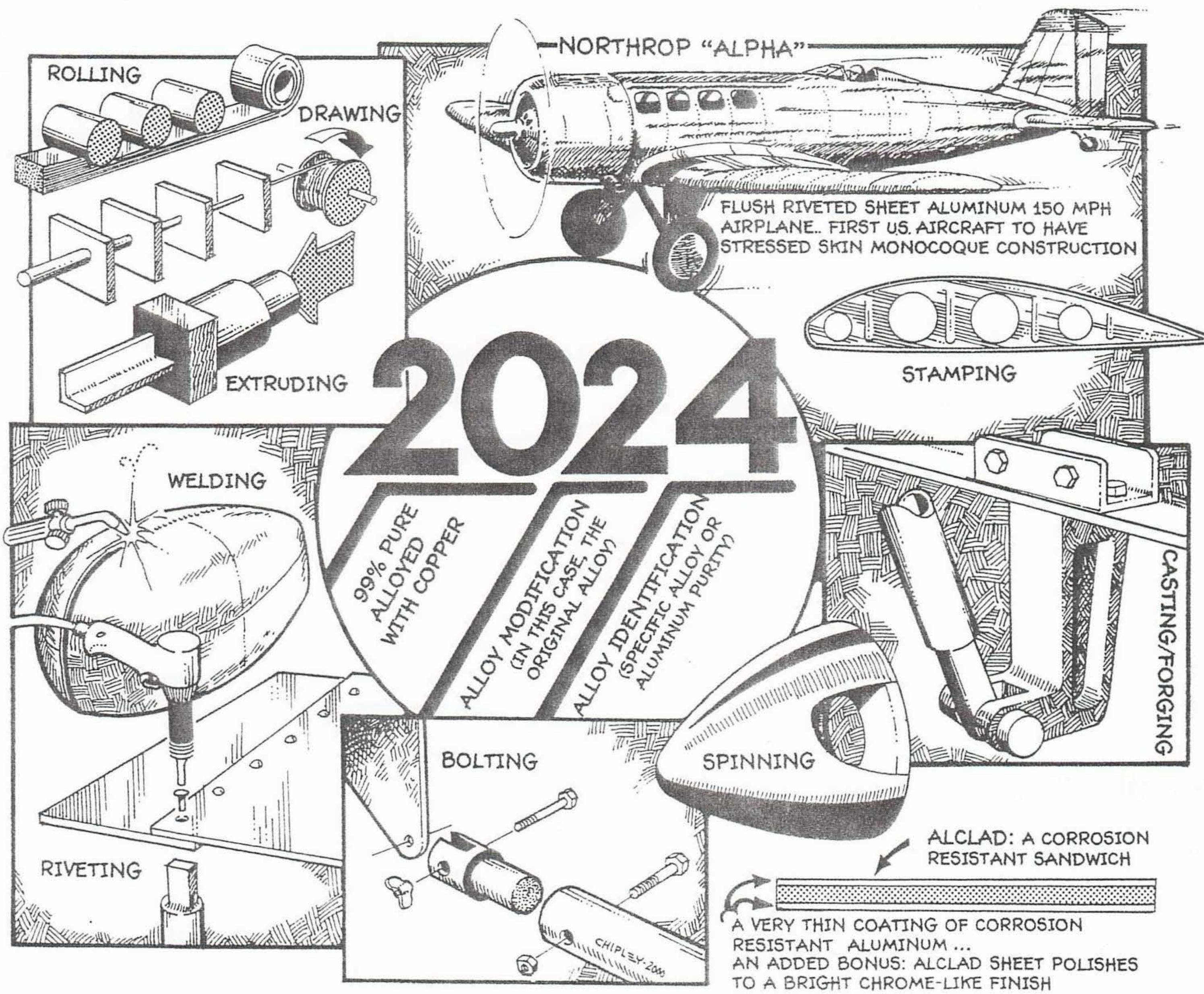
Gauging Aluminum

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.

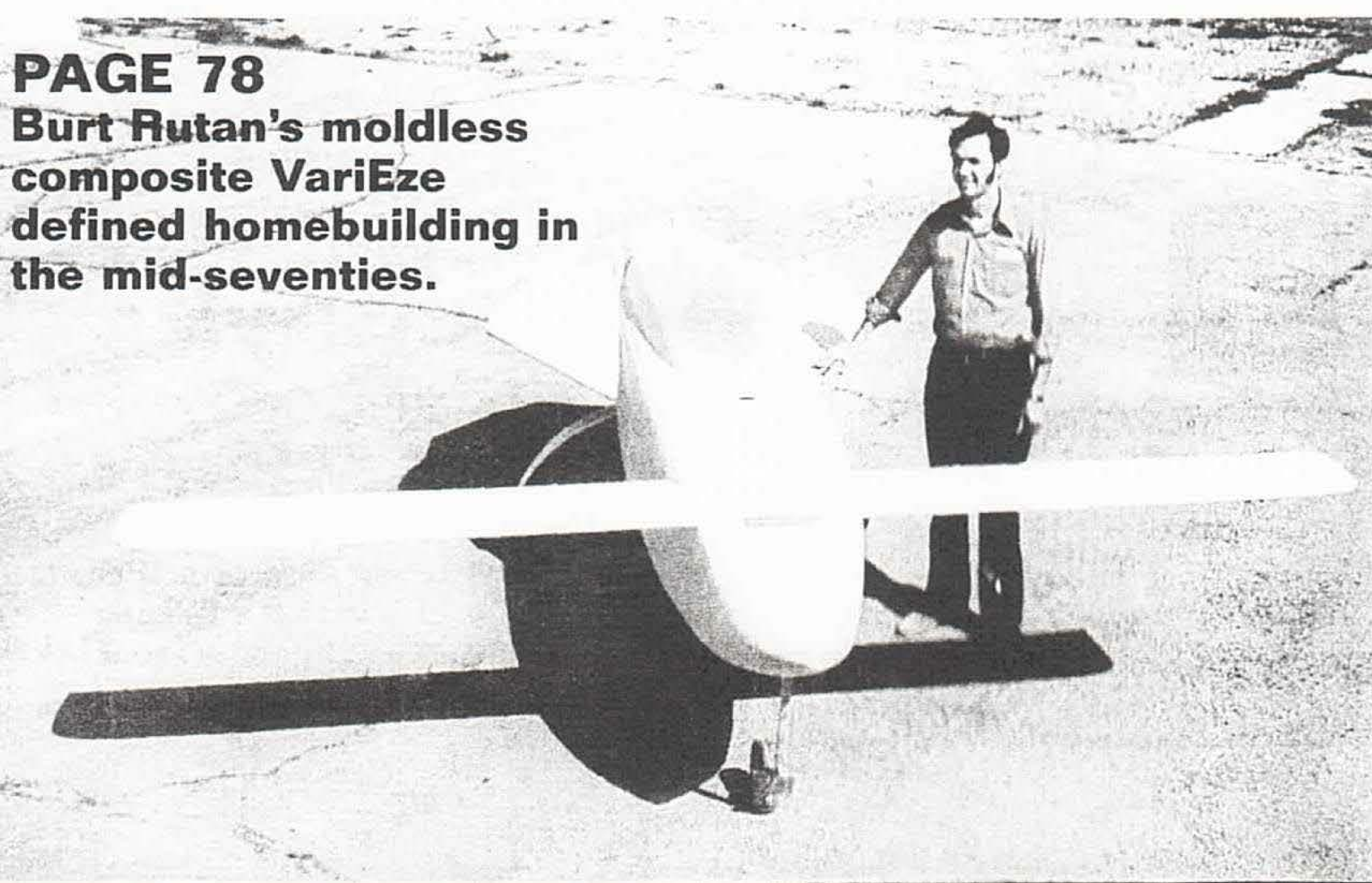
Higher-grade bauxite ore contains 45 to 60 percent alumina, which is refined using a complex series of steps into pure molten aluminum, which is then cast into ingots or billets. Manufacturers then process the pure aluminum by melting it and adding alloying elements such as copper, manganese, silicon,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



NUTS & BOLTS

STICK & RUDDER

DEPARTMENTS



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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.

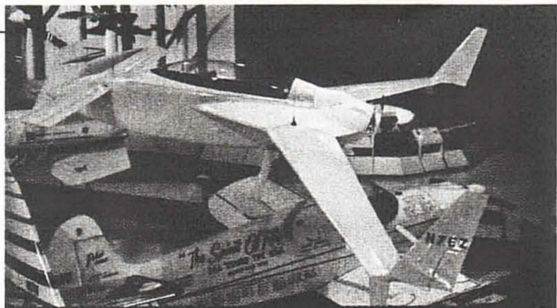
Aluminum can carry heavy loads (some alloys have tensile strengths higher than 80,000 psi), and you can finish it in a variety of ways, from no finish to painting or applying alodine and anodized coatings. Because the alloying process alters the aluminum's resistance to corrosion, at times it may be 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).

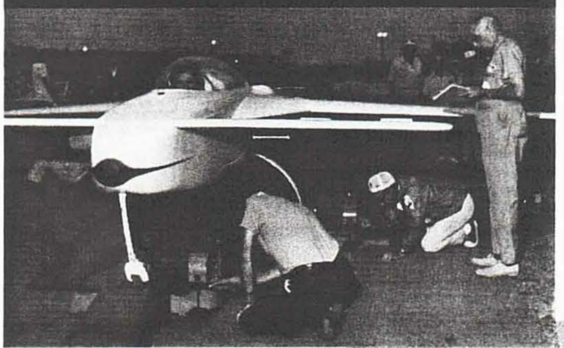
Aluminum Numbers

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

RUTAN VARIEZE

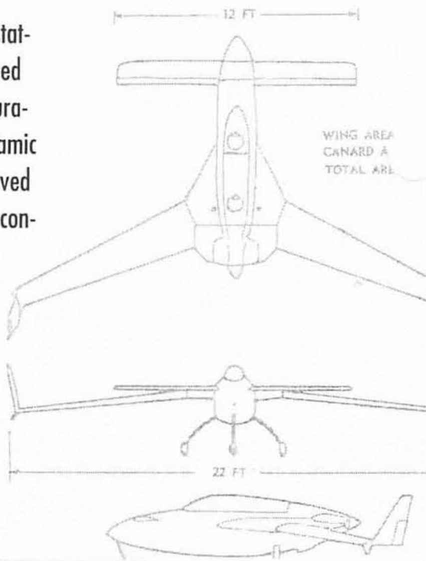


N7EZ, the VariEze piloted by Dick Rutan that set a closed-course duration record at EAA Oshkosh in 1975, is displayed in the EAA AirVenture Museum. Below, Dick Scott supervises the weigh-in before the first record attempt.



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? ■