PRICE: $2.50 in the U.S.A.

HORNBEAM ROTOR

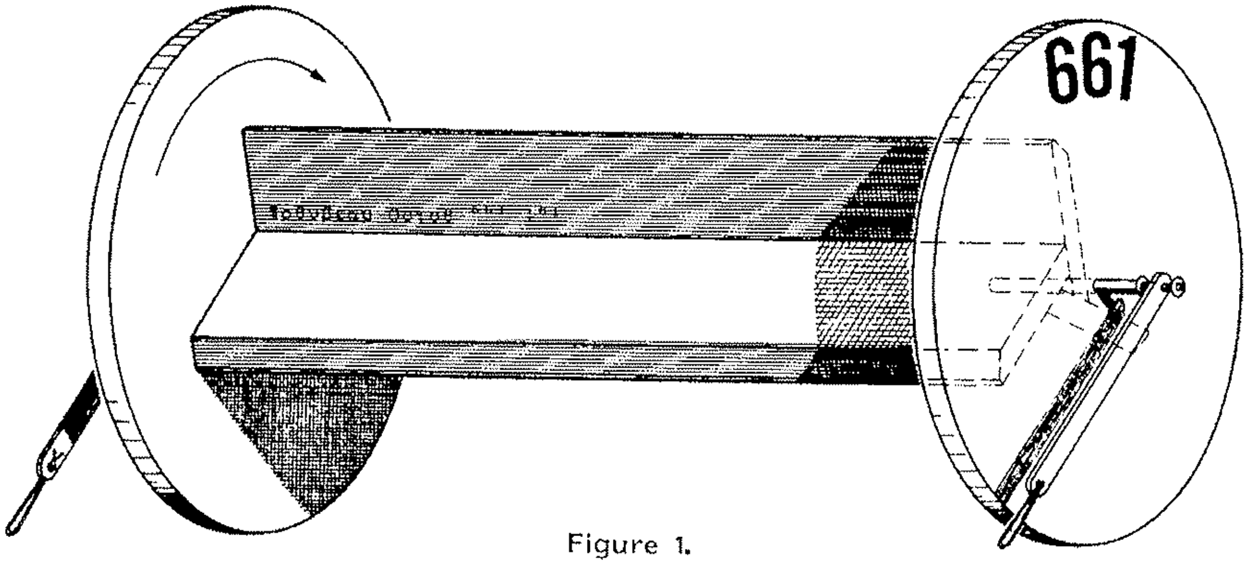

Figure 1.

LITHO IN U.S.A

A PINEY MOUNTAIN AIR FORCE PLAN

Dear Kiteflier:

HORNBEAM ROTOR 661 KITE PLAN has been prepared for Virginia's Piney Mountain Air Force by an active designer who has designed and flown dynamic rotor craft in a variety of forms and sizes ever since December of 1947, the month when Jesse Donaldson's spool-type rotor kite invention was featured in *LIFE* magazine: 8 December, 1947, on pp. 57-8.

EFFICIENT ROTOR KITES have been difficult for the novice to build and fly, especially on single-strand kitelines. But we have kept the interests of beginners in mind during the preparation of HORNBEAM ROTOR 661 KITE PLAN, a happy compromise that trades some efficiency in exchange for ease of fabrication from readily found materials and for a high degree of stability in flight. There is something here for seasoned kite experts, too: The *Magnus effect** discussion should prompt them to direct creative skills towards the production of sophisticated and efficient rotor kites after they have flown No. 661.

A DISCUSSION OF MAGNUS EFFECT

Gyrating or rotating *lifting bodies* are relatively young in full-scale aviation, but they are especially so in practical kiting. Rotating *gliding bodies* have been available to the attentions of reasoning creatures for countless aeons. Long, slender leaves and seed membranes continue to fall, to rotate, and to glide for great distances—even in still air—just as they have done for many thousands of years.

At the beginning of the twentieth century, as successful powered flight for mankind was about to be realized, all natural flight phenomena were being re-examined —researched—with sharp attention; and it became evident that successful fixed-wing aircraft were reasonably attainable with a combination of simple structural and aerodynamic approaches. Fixed-wing aircraft became dominant types and continue to be

(continued on page 2)

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*Magnus (Ref.): *Vom Magnus Effekt und Flettners Walzensegel: FLUGSPORT*, Vol. 16, No. 22, 29 November, 1924, pp. 424-425

("Magnus Effect," continued from page 1)

so today. Yet, experimenters persist in studying rotor-craft applications because it is now well known that compact, rotating dynamic surfaces are capable of yielding attractively high lift, especially if those surfaces or bodies are *power-spun* as opposed to being passively *auto-rotated* by their surrounding air motion.

The phenomenal lift or drift that occurs to a spinning body moving through a fluid (air) is often called *Magnus effect*, after G. Magnus, a mid-nineteenth century observer; however, we have to go back a few centuries to pick up what was probably the first practical, successful attempt to manage the Magnus effect: the invention of the rifled gun-bore. Very early in the development of firearms, the ballistics engineers discovered that ball projectiles, randomly spun, yielded dismal accuracy against selected targets. Their observations inspired the development of rifled gun-bores; bores cleverly machined with helically disposed *lands* and *grooves* that obliged properly fitted ball-bullets (and the later developed slug-bullets) to spin in predictable rotational senses and to find their targets with predictable accuracy.

Nowadays, canny athletes and sportsmen commonly exploit Magnus effect with crafty dedication: They produce spin-determined curve-balls, hooks, slices, droppers, and floaters in hopes of victimizing opponents. *But how many jocks ever heard of Magnus?*

*

ANTON FLETTNER AND HIS ROTOR SHIP

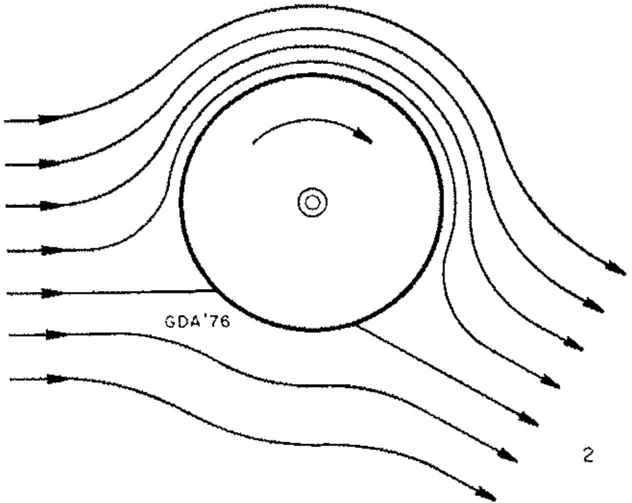
Late in the year 1924, a strange sailing ship—a sailing ship without recognizable sails—arrived in New York Harbor after having left Hamburg to cross the Atlantic. Instead of masts and conventional canvas sails, the vessel was furnished with two towering cylindrical metal *rotors* that resembled large smokestacks.

Although Herr Anton Flettner had rigged his ship with cylindrical metal sails, they weighed only one-fifth as much as the sails and top hamper normally rigged on a ship having the same length and displacement. Anton Flettner ably demonstrated the discovery of physicist Magnus: "that a cylinder rotated in an air current perpendicular to its axis always tends to move bodily in a direction mutually perpendicular to the air current and the axis." Flettner discovered that twenty horsepower applied to rotating one of his "sails" could induce up to one-thousand horsepower of propulsion equivalent from the wind.

If an experimenter chooses to insert a horizontal-axis rotating cylinder in an air current, the induced Magnus force will occur as *lift* if the rotational sense of the cylinder is correct (see Figure 2).

◎

In classical rotor concepts, the cylinders are rotated by motors or engines; but the purity of the kite concept is compromised by such devices. Since we expect the wind to supply ALL of the buoyancy forces, we must contrive to cause the wind to provide the rotation if we wish to fly rotor kites.



FLETTNER ROTOR

Figure 2. Schematic Diagram of the Rotor Lift Principle—Streams of uniform density air, uniformly spaced (representing identical volumes), are seen approaching from the left and impinging on the clockwise rotating cylinder. Because of skin friction, the moving surface partially captures—entrains—a boundary layer of air that causes most of the approaching air to pass over the cylinder with enhanced velocity, but with diminished pressure. The portion of air that passes under the cylinder does so with relatively low velocity and with high pressure. Lift occurs because of the differences in the air pressures.

SOME AIRFOIL SECTIONS THAT AUTO-ROTATE AND PROVIDE LIFT

SIGURD J. SAVONIUS, inspired by the rotor ship of Flettner, laterally displaced the halves of a hollow cylinder with respect to the original cylindrical center (Figure 3) and discovered that the body, if properly pivoted and offered to the wind, became a self-starting auto-rotator; furthermore, it was evident that a potentially useful side force—the Magnus effect—was produced.

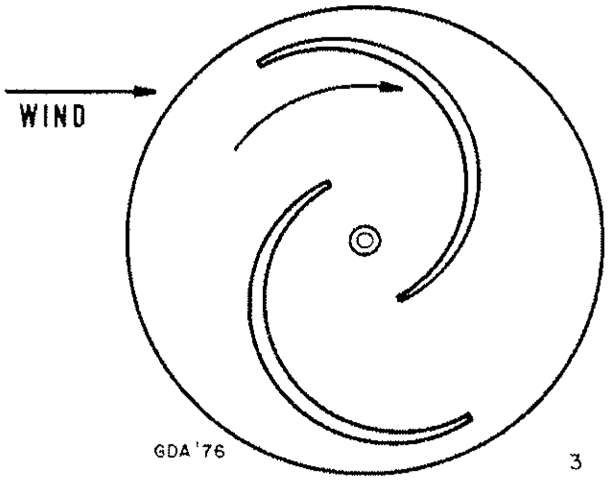


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Figure 3. The S-rotor of Sigurd Savonius —Inspired by the successful Flettner rotor ship; about 1924.

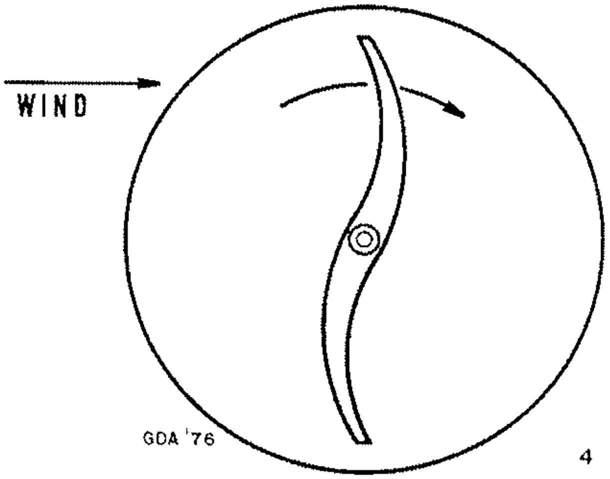

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Figure 4. The Thin S-rotor—Perhaps the most popular airfoil section to be found on commercially available rotor kites, but the section tends towards structural weakness and is only moderately efficient as a lifting shape. [The author of this article has discovered that thicker sections are stronger and are better lifters in low velocity air.]

In 1962, the late Stanley E. Albertson Jr. patented his "Rotary Winged Kite" that was subsequently marketed for a few years under the trade name "ROTOKI"; a two-rotor kite that used Savonius S-rotors.

A thin S-rotor (Figure 4) works reasonably well as an auto-rotating lifting body, but it is not as efficient as the Savonius configuration or the Aydlett 290-A (Figure 5). The thin S-rotor has the disadvantage, too, of yielding a structurally weak kite.

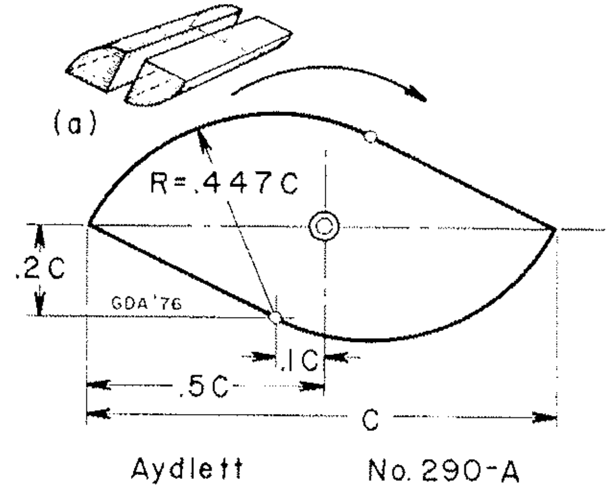


Figure 5. The No. 290-A Rotorfoil Section — This highly efficient airfoil section employs straight lines, sharp corners, and circular arcs in its layout. The auxiliary view (a) shown in the upper left of the diagram reveals that this autorotative section is composed of a pair of quarter-cylinders merged into an asymmetric demi-cylinder.

Dead flat oblong shapes can be made to rotate and provide lift; but initial rotation in the air stream or wind has to be started manually before auto-rotation commences. (Butler Ames's flat-plate rotor kite of 1910 may have been the first application of the Magnus effect to a kite.)

The three-lobed construction illustrated on page 1 (Figure 1) provides a kite with good beam-strength, good auto-rotation, and moderately good lifting efficiency. *[A four-lobed experimental kite, fabricated in the same materials and general proportions as HORNBEAM ROTOR 661, was a splendid auto-rotator; but it was a dismal failure as a lifting body. Aerodynamics = surprises.]*

MAKING HORNBEAM ROTOR 661 KITE

MATERIALS AND PROCEDURES

HORNBEAM ROTOR 661 requires one full sheet (13-5/8" x 47-13/16" x 11/16") of expanded polystyrene panel insulation for its dynamic surfaces. The material is readily available from building supply sources under registered trade names such as: *Chemfoam PIP*, *Cellofoam*, *Therm-R-Panel*, and others. It is a snow-white, low density material: about 0.84 ounces/square foot.

Two End-plate Disks, (A) Figure 6, and three Rotor Vanes, (B) Figure 6, are so-dimensioned that a standard sheet of "styrofoam" provides ample material for all of the parts even when 1/8" wide saw-cuts are made by the kitebuilder.

A silicone-lubricated, well-honed carton knife (Stanley® No. 299, or equivalent) will slice the material quite well with the guidance of a good, flat straightedge, or metal rule. Even the circles can be neatly approximated with multiple cuts guided by the straightedge; but if the kitebuilder has access to a table saw with a disk-sanding capability, the parts can be produced accurately and quickly. If the roughed-out end-plate disks are center-drilled with 1/4" diameter holes that are fortified with well-dried white glue, they can be pivoted about a 1/4" diameter pin on a homemade circle-sanding jig clamped to the saw table. Such a simple fixture will produce smooth, true circles in identical sizes. The "chamfer option" shown encircled in Figure 6 can be whittled or sanded to reduce some of the kite weight and to improve flight efficiency.

Refer to Figure 6 and make all parts in the quantities, materials, and dimensions that are specified in the caption below it:

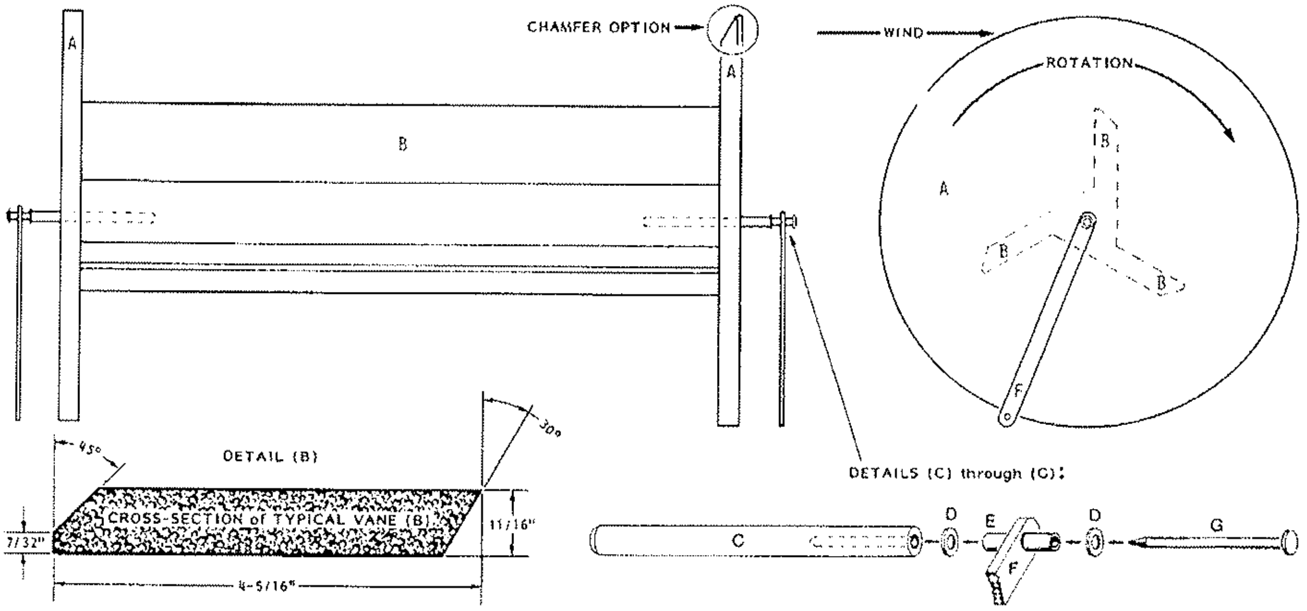
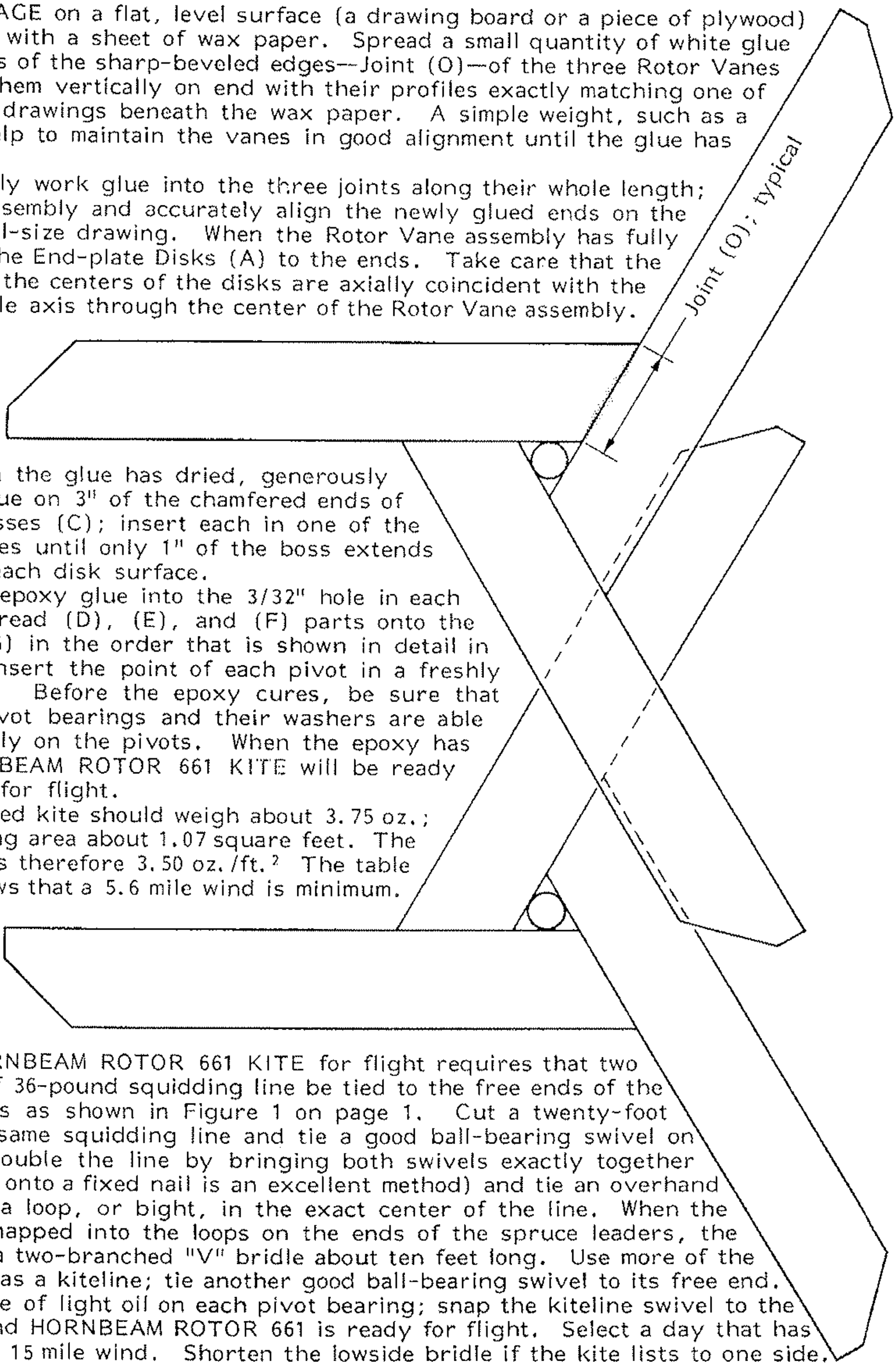


Figure 6. Hornbeam Rotor 661 Kite Details—Make two End-plate Disks (A) of 11/16" thick styrofoam. Drill a 1/4" diameter hole in each center; finish outside diameters to 13-1/2". Make three Rotor Vanes (B) 20-1/2" long; accurately reproduce the cross-section that is shown in Detail B. Make two Pivot Bosses (C) of 4" lengths of 1/4" diameter birch dowel; chamfer one end of each; drill the other ends—accurately centered—3/32" diameter and 1" deep. Purchase or make four Washers (D): 1/4" outside diameter; 0.100" bore (use brass, steel, or nylon about 0.020" thick). Make two Pivot Bearings (E) of brass tubing: 1/8" outside diameter; 0.013" wall thickness; 3/4" long. Make two Leaders (F) of 1/8" x 3/8" x 7-1/2" spruce; drill 1/8" diameter holes 1/4" from the ends. Use epoxy cement to fix each Pivot Bearing (E) in one end of each Leader (F) (see detail). The two Pivots (G) are made from six-penny (6d) iron box-nails (0.093" in diameter and 2" long; file and polish away any asperities that were caused by the pointing and cold-heading process.)

ASSEMBLY of HORNBEAM ROTOR 661 KITE

LAY THIS PAGE on a flat, level surface (a drawing board or a piece of plywood) and cover it with a sheet of wax paper. Spread a small quantity of white glue near the ends of the sharp-beveled edges--Joint (O)—of the three Rotor Vanes (B); stand them vertically on end with their profiles exactly matching one of the full-size drawings beneath the wax paper. A simple weight, such as a book, will help to maintain the vanes in good alignment until the glue has dried.

Next, gently work glue into the three joints along their whole length; invert the assembly and accurately align the newly glued ends on the remaining full-size drawing. When the Rotor Vane assembly has fully dried, glue the End-plate Disks (A) to the ends. Take care that the 1/4" holes in the centers of the disks are axially coincident with the triangular hole axis through the center of the Rotor Vane assembly.



Again when the glue has dried, generously coat fresh glue on 3" of the chamfered ends of the Pivot Bosses (C); insert each in one of the 1/4" disk-holes until only 1" of the boss extends outboard of each disk surface.

Work some epoxy glue into the 3/32" hole in each boss-end; thread (D), (E), and (F) parts onto the two Pivots (G) in the order that is shown in detail in Figure 6. Insert the point of each pivot in a freshly epoxied hole. Before the epoxy cures, be sure that the leader/pivot bearings and their washers are able to rotate freely on the pivots. When the epoxy has cured, HORNBEAM ROTOR 661 KITE will be ready to be rigged for flight.

The completed kite should weigh about 3.75 oz.; effective lifting area about 1.07 square feet. The area loading is therefore 3.50 oz./ft.^{2} The table on page 6 shows that a 5.6 mile wind is minimum.

RIGGING HORNBEAM ROTOR 661 KITE for flight requires that two equal loops of 36-pound squidding line be tied to the free ends of the spruce leaders as shown in Figure 1 on page 1. Cut a twenty-foot length of the same squidding line and tie a good ball-bearing swivel on each end. Double the line by bringing both swivels exactly together (hooking them onto a fixed nail is an excellent method) and tie an overhand knot to make a loop, or bight, in the exact center of the line. When the swivels are snapped into the loops on the ends of the spruce leaders, the line becomes a two-branched "V" bridle about ten feet long. Use more of the same 36# line as a kiteline; tie another good ball-bearing swivel to its free end.

Place a trace of light oil on each pivot bearing; snap the kiteline swivel to the bridle loop; and HORNBEAM ROTOR 661 is ready for flight. Select a day that has a steady 10 to 15 mile wind. Shorten the lowside bridle if the kite lists to one side.

HORNBEAM

THE HORNBEAM WIND VELOCITY EQUATION FOR KITES

MOST KITES function in an aerial environment that is close to what aerodynamics scholars call *standard density*; that is, the Standard Air Density = ρ = 0.002378 slug per cubic foot at 15° Celsius. With that premise assumed, we can use the standard textbook formulae, choose units more familiar to the everyday kiteflier, and state:

$$L = 0.0409\ C_l S V^2 \qquad (1)$$

where

L = Lift in ounces
C_l = A lift coefficient that depends on the aerodynamic qualities of a kite
S = Area of the kite in square feet
V = Wind velocity in miles per hour

We can re-arrange equation (1) and use it to predict the minimum wind velocity that is necessary to barely sustain the weight of the kite (line angle = 0°):

$$V = 4.943 \times (L/C_l S)^{\frac{1}{2}} \qquad (2)$$

or

$$V = 4.943 \times (W/C_l S)^{\frac{1}{2}} \qquad (3)$$

where L = W = Weight of the kite in ounces

If, for an ordinary kite, we select a lift coefficient of 0.977 (reasonable for a kite that is attempting to rise at a high angle of attack), equation (3) becomes:

$$V = 5\ (W/S)^{\frac{1}{2}} \qquad (4)$$

It has been determined—both theoretically and empirically—that the maximum lift coefficient for a *driven* cylindrical rotor=kite is 4 × π, or 12.566. But our 3-lobed rotor kite is not a cylinder, nor is it power driven; therefore, a modest lift coefficient of about 2.715 is more appropriate: and we get this equation:

$$V = 3\ (W/S)^{\frac{1}{2}} \qquad (5)$$

From equation (5) we can make a table of Weight/Area versus Wind Velocity that will be good for HORNBEAM ROTOR 661 KITES made in most practical sizes and weights:

WEIGHT/AREA vs WIND VELOCITY TABLE for HORNBEAM ROTOR 661 KITE

(Weigh your kite in ounces and divide that weight by the projected area of the kite in square feet. Find that quotient in a "W/S" column. The "V" value that is paired with the quotient is the minimum wind velocity—in miles per hour—that will sustain your kite.)

W/S	V	W/S	V	W/S	V	W/S	V	W/S	V
1.0	3.00	2.0	4.24	4.0	6.00	9.0	9.00	17.0	12.37
1.1	3.15	2.2	4.45	4.5	6.36	9.5	9.25	18.0	12.73
1.2	3.29	2.4	4.65	5.0	6.71	10.0	9.49	19.0	13.08
1.3	3.42	2.6	4.84	5.5	7.04	10.5	9.72	20.0	13.42
1.4	3.55	2.8	5.02	6.0	7.35	11.0	9.95	21.0	13.75
1.5	3.67	3.0	5.20	6.5	7.65	12.0	10.39	22.0	14.07
1.6	3.79	3.2	5.37	7.0	7.94	13.0	10.82	23.0	14.39
1.7	3.91	3.4	5.53	7.5	8.22	14.0	11.22	24.0	14.70
1.8	4.02	3.6	5.69	8.0	8.49	15.0	11.62	25.0	15.00
1.9	4.14	3.8	5.85	8.5	8.75	16.0	12.00	26.0	15.30

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