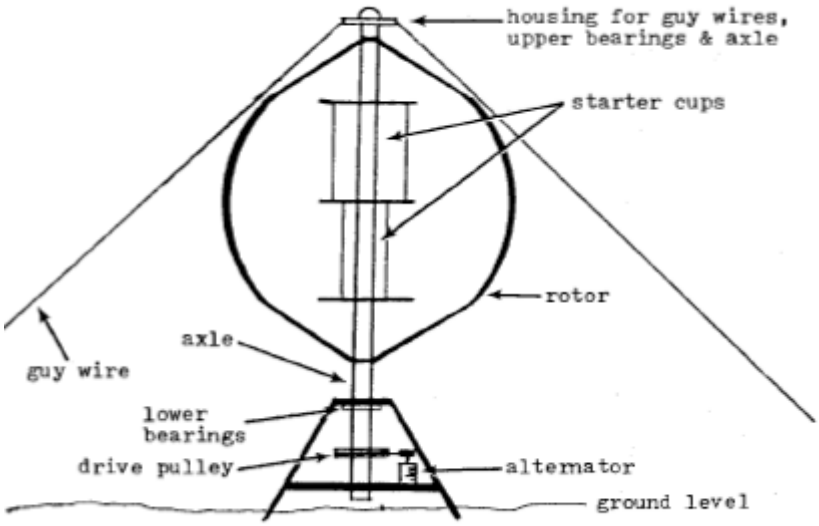
Wind Generator
Darrieus Type

VERSION 1.0



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Introduction

About the publisher

Richard Jemmett's keen interest in the generation and use of energy has helped to shape his formal career and provide an incentive to write on the subject. He graduated from the University of Leeds in 1980 with a degree in fuel and energy engineering and has held various positions within energy and consultancy companies working in the UK, Europe the Middle East and Asia.

He has written many articles, essays, and conference presentations on utility industry strategy, energy industry development, energy market deregulation, renewable energy, distributed generation and high reliability organisational design.

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Introduction to the Darrieus wind turbine

Wind units can be divided into two major types, horizontal axis and vertical axis machines.

Horizontal machines some times known as HAWT (Horizontal Axis Wind Turbines) are the traditional conventional design, they consist of a rotor with one to twenty blades driving a generator or a pump either directly or through a gearbox, chain or belt system. A tail vane or fantail is required to direct the machine into the wind.

They are usually more efficient than vertical axis units known as VAWT (Vertical Axis Wind Turbines). Savonius and Darrieus are two designs of vertical axis machines. This type of unit is often not situated on a tower and does not have to be directed into the wind. Materials and construction are usually cheaper than horizontal axis machines.

In the original versions of the Darrieus design, the aerofoils are arranged so that they are symmetrical and have zero rigging angle, that is, the angle that the aerofoils are set relative to the structure on which they are mounted. This arrangement is equally effective no matter which direction the wind is blowing -- contrast to the conventional type, which must be rotated to face into the wind.
When the Darrieus rotor is spinning, the aerofoils are moving forward through the air in a circular path. Relative to the blade, this oncoming airflow is added vectorially to the wind, so that the resultant airflow creates a varying small positive angle of attack (AoA) to the blade. This generates a net force pointing obliquely forwards along a certain 'line-of-action'. This force can be projected inwards past the turbine axis at a certain distance, giving a positive torque to the shaft, thus helping it to rotate in the direction it is already travelling in.

As the aerofoil moves around the back of the apparatus, the angle of attack changes to the opposite sign, but the generated force is still obliquely in the direction of rotation, because the wings are symmetrical and the rigging angle is zero. The rotor spins at a rate unrelated to the windspeed, and usually many times faster. The energy arising from the torque and speed may be extracted and converted into useful power by using a electrical generator.

The aeronautical terms lift and drag are, strictly speaking, forces across and along the approaching net relative airflow respectively, so they are not useful here. We really want to know the tangential force pulling the blade around, and the radial force acting against the bearings.

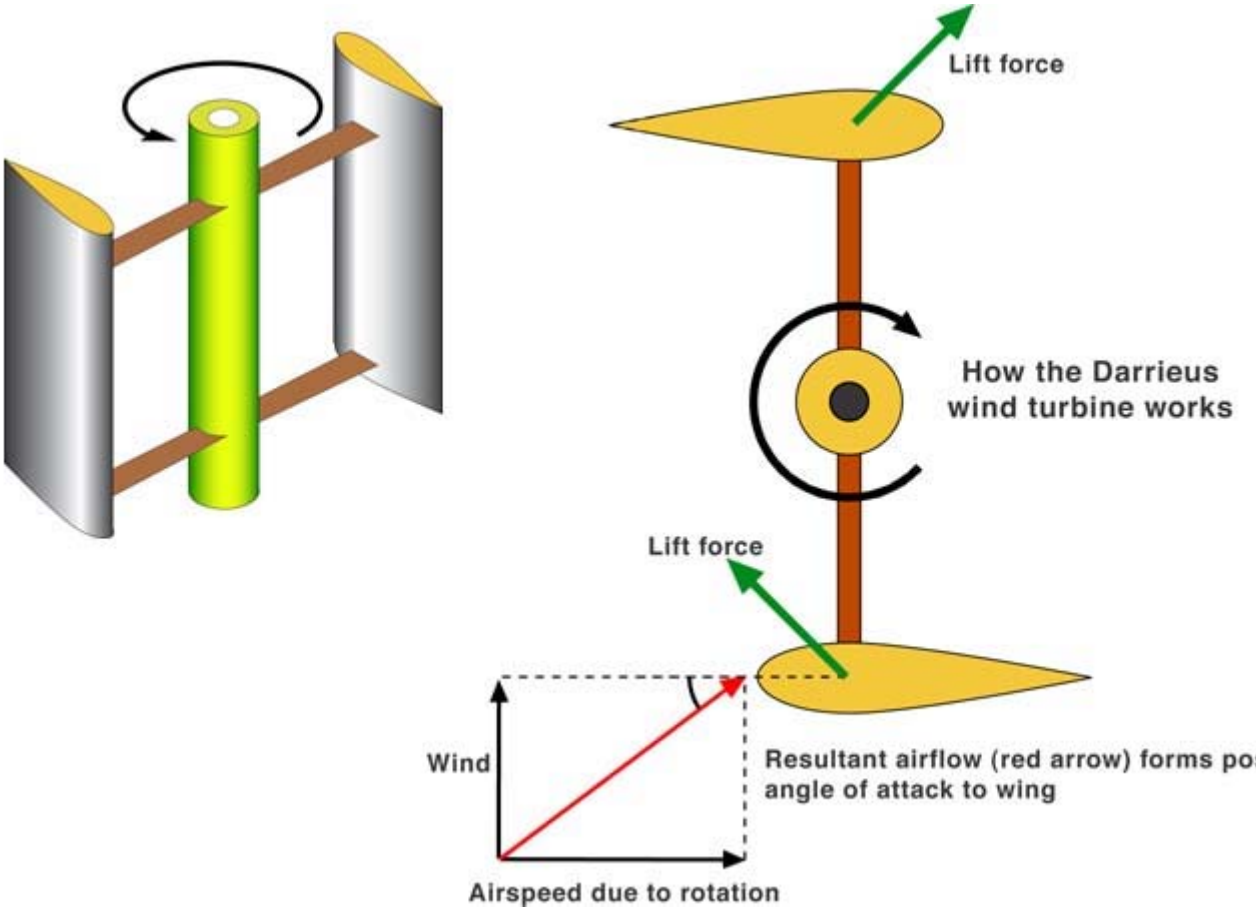
When the rotor is stationary, no net rotational force arises, even if the wind speed rises quite high -- the rotor must already be spinning to generate torque. Thus the design is not normally self-starting. It should be noted though, that under extremely rare conditions, Darrieus rotors could self-start, so some form of brake is required to hold it when stopped.

One problem with the design is that the angle of attack changes as the turbine spins, so each blade generates its maximum torque at two points on its cycle (front and back of the turbine). This leads to a sinusoidal (pulsing) power cycle that complicates design. In particular, almost all Darrieus turbines have resonant modes where, at a particular rotational speed, the pulsing is at a natural frequency of the blades that can cause them to (eventually) break. For this reason, most Darrieus turbines have mechanical brakes or other speed control devices to keep the turbine from spinning at these speeds for any lengthy period of time.

Another problem arises because the majority of the mass of the rotating mechanism is at the periphery rather than at the hub, as it is with a propeller. This leads to very high centrifugal stresses on the mechanism, which must be stronger and heavier than otherwise to withstand them. One common approach to minimise this is to curve the wings into an "egg-beater" shape (this is called a "troposkein" shape, derived from the Greek for "the shape of a spun rope") such that they are self supporting and do not require such heavy supports and mountings. See below.

In this configuration, the Darrieus design is theoretically less expensive than a conventional type, as most of the stress is in the blades which torque against the generator located at the bottom of the turbine. The only forces that need to be balanced out vertically are the compression load due to the blades flexing outward (thus attempting to "squeeze" the tower), and the wind force trying to blow the whole turbine over, half of which is transmitted to the bottom and the other half of which can easily be offset with guy wires.

By contrast, a conventional design has all of the force of the wind attempting to push the tower over at the top, where the main bearing is located. Additionally, one cannot easily use guy wires to offset this load, because the propeller spins both above and below the top of the tower. Thus the conventional design requires an extremely strong tower that grows dramatically with the size of the propeller.
In overall comparison, the Darrieus design puts much more of its weight (and cost) into components that actually generate power, the blades, and much less into supporting them. Additionally the generator and main bearings are located at the bottom, where they can be easily serviced. A final advantage to the design is that the blades typically spin at a speed near that of the wind, which birds do not have a problem avoiding. In contrast, the propeller *tips* of a conventional design spin at very high speeds, often over 100km/h, which causes serious problems with bird and bat strikes.



You can find more about VAWTs at the following websites

http://www.awea.org/faq/vawt.html
http://www.windpower.org/en/tour/design/horver.htm
http://www.windstuffnow.com/main/darrieus_type.htm
http://www.onetoremember.co.uk

For more plans, ebooks and books don't forget to visit the onetoremember website – www.onetoremember.co.uk

If you are looking to buy or sell wind turbines, or other renewable energy products please pop along to our free to use green directory and trading site – www.wxtrade.com

If you need help with these plans and want to contact other like minded people pop along to our community website and post a free message and read about other peoples' projects.

http://www.onetoremember.co.uk/community/index.php

About these plans

This plan was developed to make use a car alternator maybe not the best generator but certainly widely available. The plan was originally written Peter Hanbury in the 1970s with the rights for reproduction bought by Richard Jemmett (then Jemmett Engineering) in the 1980s. Since then many hundreds have been sold and successfully built. The plan is in its original form and may be a little difficult to read but if you have any difficulties after printing please email me plans@onetoremember.co.uk

NOTICE

The information contained in this plan has been given in good faith and is believed to be accurate at the time of writing. Whilst every effort has been made to obtain the correct information, no liability can be accepted for any information that is incorrect or misleading.

A: INTRODUCTION

The DARRIEUS WINDTURBINE was invented by the French engineer G Darrieus in 1931. However, it was never really developed as a local power source in North America, with its rapidly growing centralized power systems. Although the windmill still paved a path for itself in the continent's energy picture, these windmills in rural areas were the conventional propeller type. In spite of their intelligent and feasible design, even these eventually ceased to exist.

With our currently bleak energy forecasts, many people are now seriously considering the possibility of using ALTERNATE forms of energy. The DARRIEUS ROTATING AIRFOIL can be built from local parts and tools. Being of a vertical shaft design, it is totally symmetrical and requires no directional devices as a result. These plans are quite flexible in nature, employing a "nuts and bolts" approach to this project. Any experimentation in altering the design of the airfoil is certainly encouraged, although modifications in the design may only increase the performance marginally and the difficulty of construction substantially.

B: LEGAL WAIVER

A FULLY ASSEMBLED DARRIEUS AIRFOIL CAN WEIGH IN EXCESS OF 200 POUNDS! Poor or improper construction can result in damage to personal property or even serious injury. These plans are your guidelines only. We take no responsibility in regards to the Success or Safety of this project. Acceptance of these plans warrants this on your part.

On this note, we wish you success in coming another step closer towards SELF-SUFFICIENCY...

C: CONFIGURATION

Figure 1: The Darrieus Airfoil

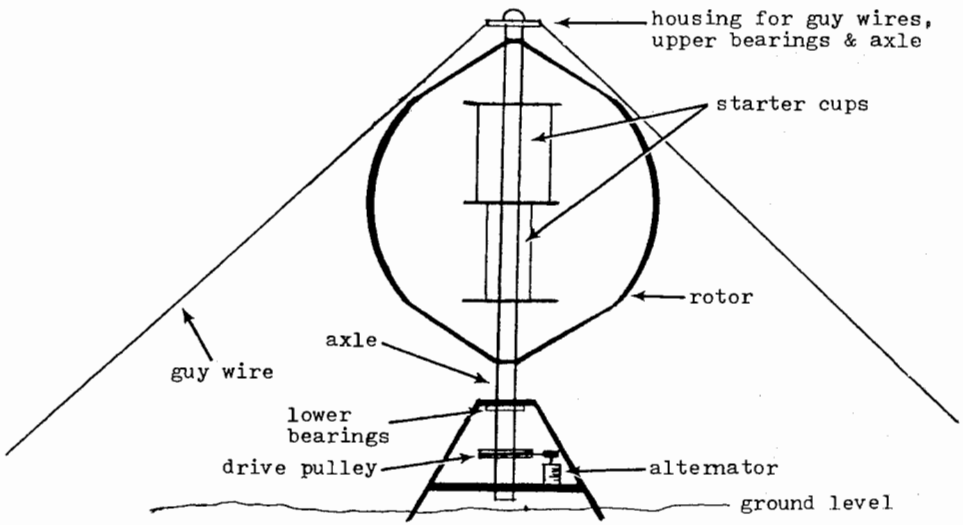
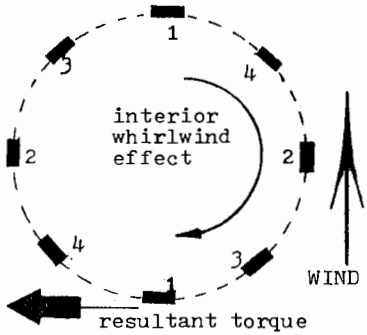


Figure 2: Principle of Operation



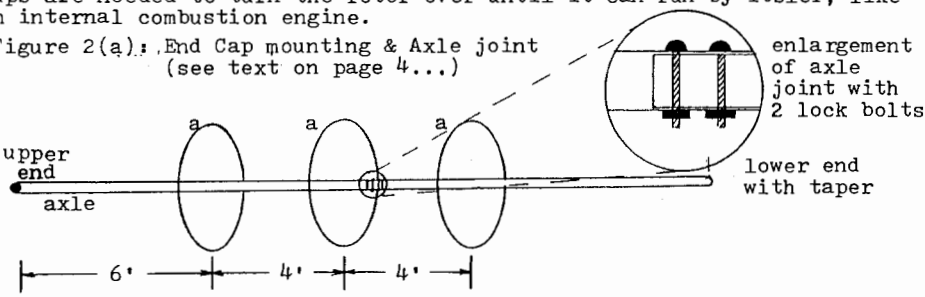
The principle of this rotational motion is a mixture of several effects. The Darrieus Airfoil is a medium speed Wind system, of a vertical axis variety. Being a medium speed system has two advantages. Firstly, it requires only moderate gearing ratios, and secondly, the maintainance required is moderate as well. The aspects in favour of this system is that its totally symmetrical, thereby eliminating the need for directional equipment. Also, it is not highly obstructive in appearance, and requires only a moderate amount of material to construct.

As mentioned earlier, the resultant torque produced by this airfoil is a result of a combination of effects brought about once this system is put into motion. In figure 2, there are always imbalances in forces (produced by the wind) acting on the two surfaces of the airfoil. In position 3 and 4, the imbalances are at a maximum. When the rotor halves are travelling downwind on the left side of the axle in this diagram (position 4) there is a high pressure area on the OUTER surface of the blade, and a lower pressure area on the INNER surface of the rotor. The lower pressure is produced by an interior whirlwind effect within the rotor as it spins, and the fact that the rotor itself obstructs the wind passing around its inner surface, thereby causing a partial vacuum as well. In position 3, same side, there is a reversal in the high and low pressure areas on the inner and outer surfaces, and on the right, the individual positions can similarly be analyzed. This principle of rotation is related to a situation called the "MAGNUS EFFECT".

The actual shape of the rotor is a compromise between a narrower width which would bring about high speeds, but less torque versus a wider arrangement that would bring about more torque but lower rotary speeds. Also, this is close to what the rotating airfoil would assume in shape, if not restricted in support while rotating naturally, due to centripetal forces. However constant distortion in the rotor would be undesireable, since energy would be expended in distorting the rotor.

In positions 1 and 2, the rotor at these brief moments experiences a balance of forces, and requires momentum within itself to carry it through these points. The Darrieus system is also a system that is not self-starting, especially at these neutral points. Consequently, four starter cups are needed to turn the rotor over until it can run by itslef, like an internal combustion engine.

Figure 2(a): End Cap mounting & Axle joint
(see text on page 4...)

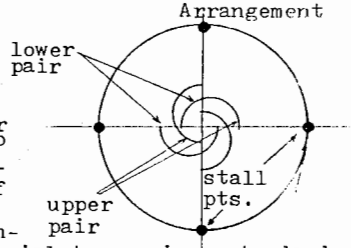


D: CONSTRUCTION

THE ROTOR ASSEMBLY

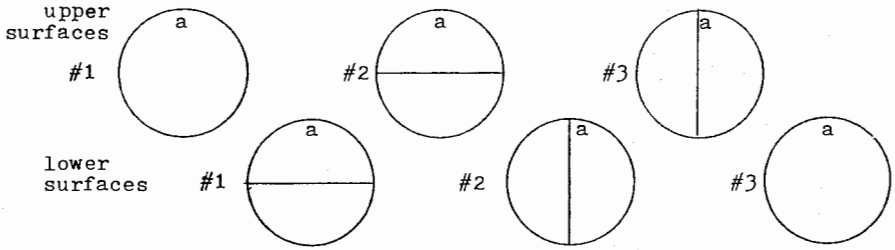
The rotor should be constructed from a flexible and weatherproof material. A good substance is the lamination that goes on top of sinks and countertops. In some areas it is sold under the trade name Arborite or Formica. If this substance cannot be found, simple masonite in a ¼" thickness can be used, provided it is coated with several layers of shellac and a weatherproof paint. It will be highly improbable that you will find any material in the lengths required to make the rotor. Therefore, joints will have to be made where you see fit. Before these are actually constructed, it will be necessary to construct and mount the starter cups first. These starter cups are specifically designed to catch the wind, even at low speeds and start the main rotor. Actually, they are a variation of the Savonius Windturbine, which is a viable system itself, but possessing somewhat different characteristics. There are two pairs of cups, resembling split cylinders, situated so that they offer maximum torque at points where the main rotor may stall. Since there are two positions, 90° apart where the rotor stall points are situated, the cups are placed similarly 90° out of phase. The first component to consider building is the axle. It is 22 feet in length, spanning the entire rotor assembly. The best material to use is a standard 1½" top running fence pipe, that are used in constructing the smaller chain link fence models. These are found in various lengths, up to 11 feet. So, two of these will be the perfect length when joined together. These pipes also facilitate joining since they have one tapered end, that fits into another length of pipe, in a consecutive succession. Once you join the two, drill two holes in the joint and install two bolts to safely secure the joint. Measure down from the top of the axle 6 feet. This will mark the upper joining point of the upper starter cups. Also, when the two axle members are joined, make sure that the one remaining tapered end faces downward. The reduced diameter at the tapered end will be useful later on in installing the lower bearings, and drive pulley.

Figure 3: Starter Cup Arrangement



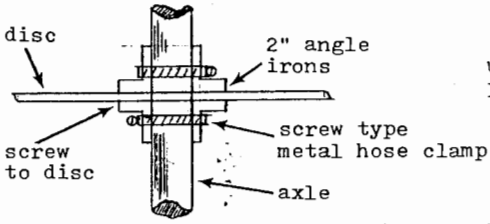
Now, construct the end caps of the starter cups. Out of 3/8" plywood cut out three 3' discs. Determine their center points and drill a 1½" hole in them, so that they shall fit snugly over the axle. The axies where the starter cups will be mounted can now be marked on the discs as well. Mark them as shown below.

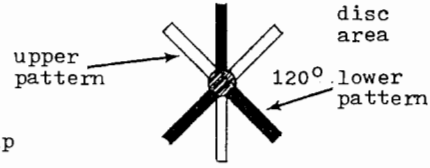
Figure 4: Marking the end caps-90° rotation of the two pairs



The end caps should be mounted in the positions on the axle as shown in figure 2(a). They may be secured with the use of 3 2" angle irons on the upper surface and lower surface of the three plywood discs. The angle irons may be fastened to the discs with screws, and to the axle with metal hose clamps. See figure 5. Make sure that the impeller mount lines drawn on the end caps are positioned correctly, as shown below.

Figure 5: Mounting end caps with angle irons & hose clamps





Use three in a triangular pattern on the upper surfaces and lower surfaces of the discs. Once this is done, the actual cups may be installed. Remember to stagger the patterns between the upper and lower surfaces, so that the screws that are installed in the individual discs do not run into each other, from top to bottom.

The starter cups may be made out of a piece of arborite (if flexible enough) or simply a piece of $\frac{1}{4}$" masonite. Four sheets, 48" high by 31" wide will be needed. Along the two opposite 48" edges, fasten a piece of wood moulding, along its entire length. Use $1\frac{1}{2}$" wood screws and white glue. If using masonite, use the rough side of the sheet for fastening, and the backside of the arborite in the other case. So, the smooth surfaces shall be curved inward to make the inside of the impellers. Place one sheet edge with mounted moulding against one of the starter cup's line of mounting and fasten in place with white glue and screws. Gently bring the other edge with mounted moulding around in a semi-circular path and fasten it to the disc along the mount line previously drawn. Small angle irons should be added for strength afterwards. The other starter cup may be added in the same manner, completing one pair. Then mount the other pair, but follow the 90° mount line for the second pair.

Figure 6: Cups and Mouldings

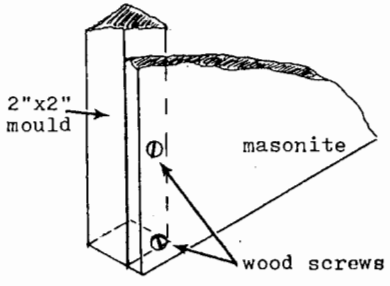
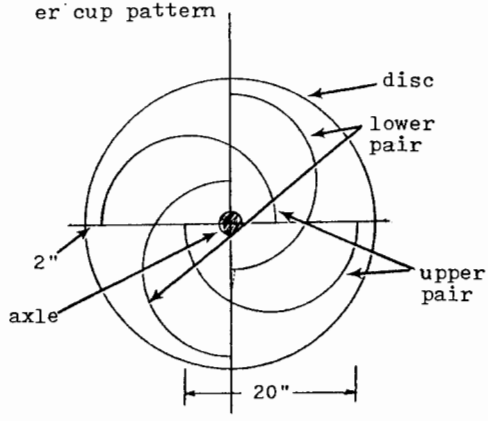
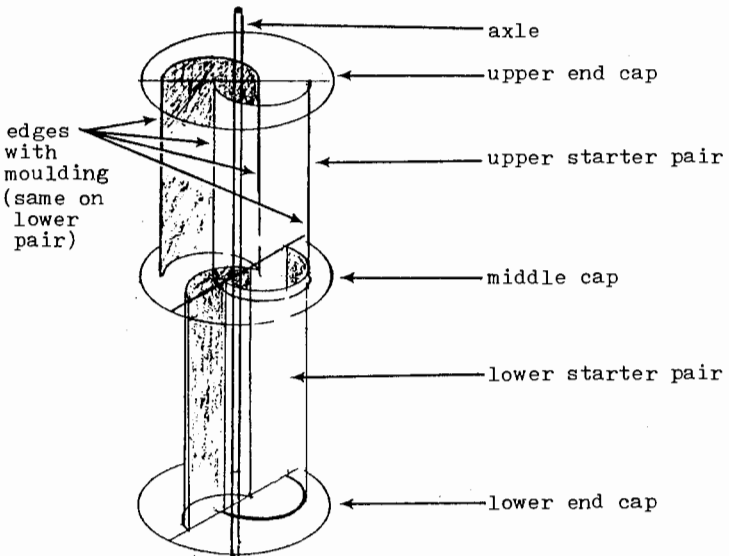


Figure 7: Top View of starter cup pattern



After the starter cups are mounted, they should appear like the set below:

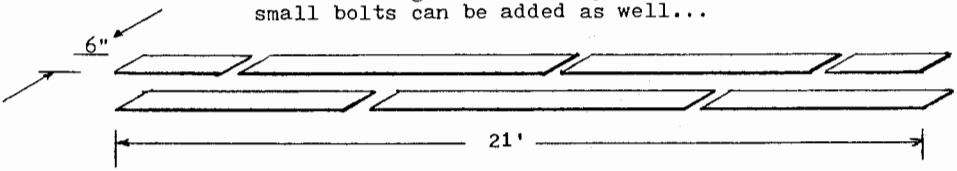
Figure 8: The Starter Cup Assembly



The rotors can now be constructed out of your selected material, as mentioned earlier. The pieces will have to be glued together, since it is highly unlikely that pieces over 8 feet will be found. Each rotor will actually be two laminations of arborite or masonite, glued together. Also, use small bolts for extra strength. Remember to stagger the joints between the two layers, like brickwork for extra strength. This will produce two solid rotor halves out of two layers of material. The rotor length is 21 feet, for each of the two rotors, and six inches wide. Once completed, we can then connect them to the axle by their ends

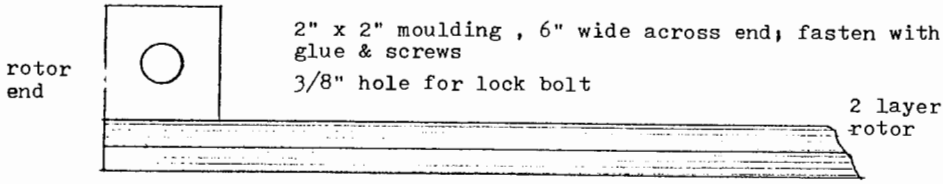
Figure 9: Rotor Blade Configuration (make two)

Glue the rougher sides of your selected laminations together small bolts can be added as well...



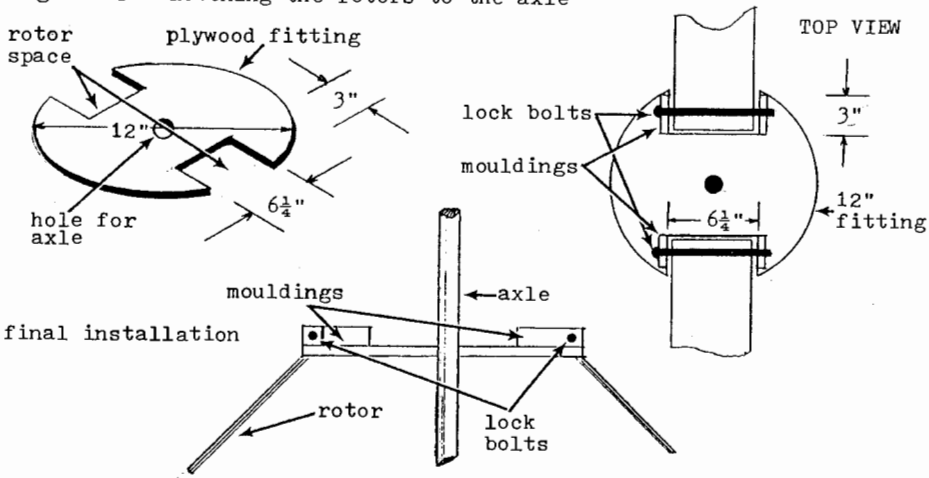
On the ends of each rotor half, fasten a 2" by 2" moulding of wood. Through these mouldings, drill a 3/8" hole to accomodate a locking bolt for fastening to the axle.

Figure 10: The Rotor Ends



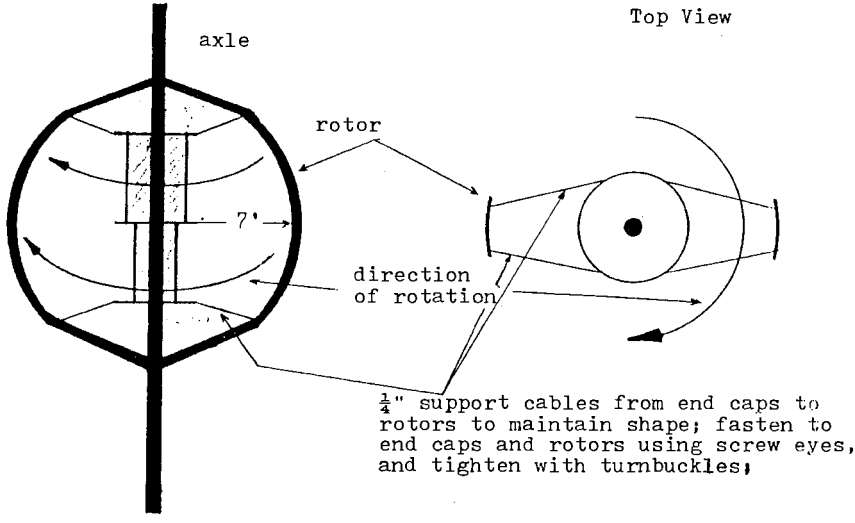
These ends should be attached to the round fittings shown below. Make these out of ½" plywood. Cut out two notches in these fittings just over 6 inches in width as shown below. Along the two edges of the notches, install similar mouldings as used on the ends of the rotors. These fittings can be fastened to the axle in the same manner as the caps used in the starter assembly. The two fittings should be installed 2½ feet from the top and 17½ feet from the top as well. Once the fittings are fastened to the axle, place the lower ends of the rotors into the lower fittings and lock them into place with the 3/8" lock bar. Then, bring each one around gently in a circular path and anchor the upper end to the upper fitting in the same manner. If the rotors lack adequate flexibility, soak the centers of them in water overnight.

Figure 11: Fastening the rotors to the axle



The rotor assembly is now essentially complete. The rotors should be fairly straight leaving the end fittings as shown directly above, but should assume a gentle curve in their centers, of about 7 feet radius. The rotor shape can be maintained with the extra support of 8 cables made of clothesline, with turnbuckles to maintain tension. By using the cables in pairs and fastening them to the upper and lower starter caps, lateral movement will also be eliminated in the rotors.

Figure 12: The Completed Rotor



It is better to construct the upper bearing housing at this point, since installation after erecting the axle will be more difficult. The upper bearing housing must be built very securely, since it will support the upper end of the airfoil, with the aid of four guy wires. A sensible angle for the guy wires is about 45 degrees, however the shallower the angle, the more groundspace required. Place this assembly at the very end of the axle to offer the most clearance between the guy wires and the upper part of the rotors as they spin. The upper bearing housing should be constructed out of two 7/8" thick plywood discs, 1 foot in diameter each. In between them will be two bearings, with mount cradles. These will be housed in 2" by 4" lumber, with four cylindrical posts around the perimeter to attach the guy wires. When selecting the bearings with matching mount cradles, they must obviously fit snugly onto the axle. However, select bearings that have as large an outside ring as possible. In other words, the actual balls in the bearings should be as large as possible, since small bearings will wear out and spin less freely.

Figure 13: The Upper Bearing Housing

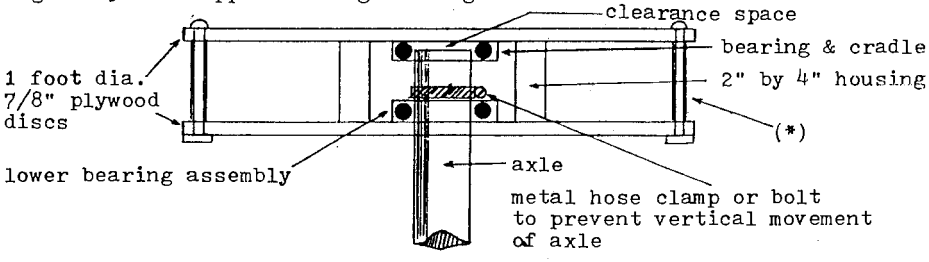
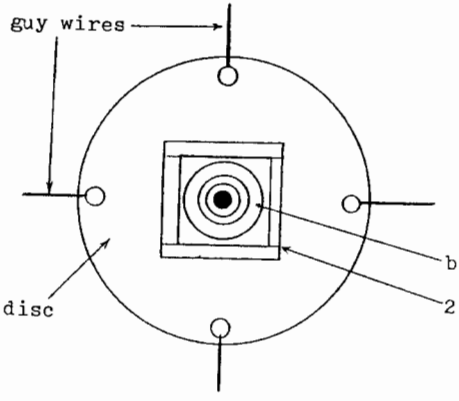


Figure 14: Top View of upper bearing housing

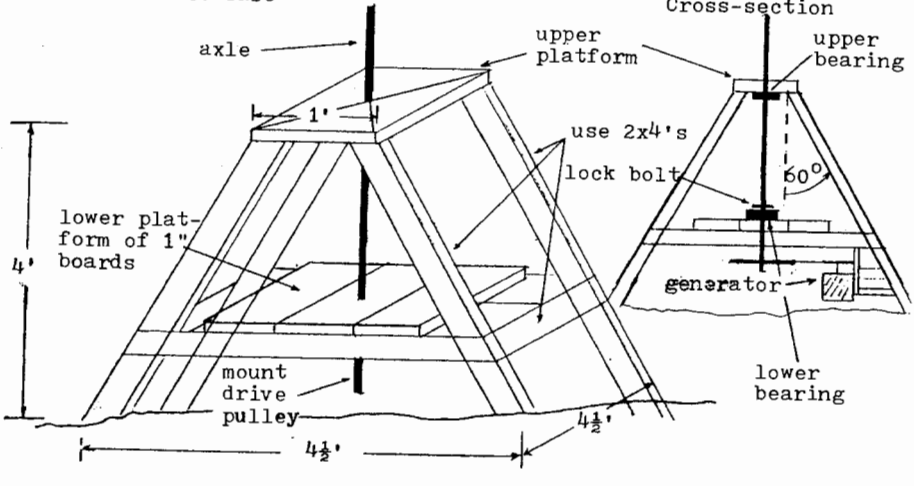


As shown in figure 13 by the symbol (*), the four vertical posts can be made out of a 3/8" bolt with a steel pipe sleeve around it. The guy wires should be ¼" or 3/8" metal cable with turnbuckles for tightening them. Secure the cables to the ground, by fastening them to four steel 1½" pipes placed two feet into the ground.

CONSTRUCTION OF THE SERVICE BASE

The service base will support the lower end of the rotor, and house the generator with its drive assembly. The base is approximately four feet high and is built simply of 2" by 4" lumber. Three feet from the TOP of the base, install a lower platform as shown below. The lowermost bearing will rest on this platform, and the second bearing set will rest underneath the upper platform. The main point to remember when building the base is to ensure that everything is "square" so that the axle will rotate with little resistance. If there are minor random errors in the base's alignment, the bearings may be correctly positioned with shims where necessary. This is likely in most cases.

Figure 15: The Service base



The upper and lower bearings in the service base are mounted in same manner is in the upper bearing housing. The two units are mounted to the upper platform and lower platfrom respectively. Again, use the same bearing size and mount cradles as in the upper case. The larger the actual ball bearings, the better. Above the lowermost bearing, pass a lock bolt, through the axle to prevent vertical slippage. Make sure that it does not rub against the bearing, other than its inside ring which moves freely with the axle. The alternator may be placed in any convenient place within the service base. Use a small bracket fastened to two legs of the base to mount the unit. The drive pulley will probably not have a mount hole that is large enough to fit over the axle. So, if mounted as shown in the cross-section, install a diameter reducing bar into the bottom of the tapered end. Since the airfoil rotates between 50 to 150 rpm, a step up of about 12 to 1 is necessary to drive the alternator. That is, the drive pulley should have a diameter of about 12 times the diameter of the pulley on the alternator. In some cases, depending on what's available in your area, it may be necessary to do this in two steps.
After the base is completed, it is a good idea to enclose the base to protect the drive system and the generator. Any wood parts should be liberally coated with shellac and then finished with a waterproof all-weather sealant. In the case of the base enclosures, mount one side like a door with hinges, so that easy access to the components for lubrication and maintaince is possible.

ASSEMBLING AND ERECTION OF THE TURBINE

Look at the site where you will be erecting your Darrieus Airfoil and try to estimate where the four guy support wires will be located. It is easiest to complete the airfoil in a horizontal position. Before erecting the entire assembly, place the airfoil on two level supports and rock the rotor back and forth to see if everything spins freely.

At the four holes where the guy wires will be fastened to the ground, dig a hole at each one about 18 inches into the ground. Insert a concrete building block and wire a 1½" pipe to it. Then bury the block to secure the post completely.

Attach the guy wires before erecting the airfoil. Then, dig a shallow hole about 6 inches for each post of the service base, right beside the Airfoil that is still resting on its side. With the help of several other people, hoist the Airfoil into a vertical position with the base inserted into the holes earlier made.

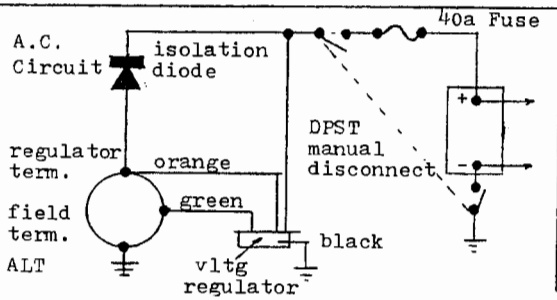
Once in a vertical position, fasten the guy wires to the ground support posts and tighten them to secure the system.

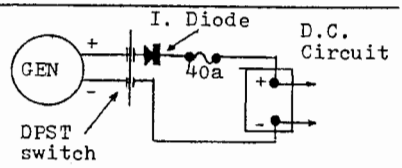
Fill in the holes around the legs of the service base.

The electrical system is on the next page. It delivers 12 volts of DC current. Conversion of the power to household current is possible with an inverter, but somewhat complex and unnecessary, since there are quite a few appliances designed to run on 12 VDC power. Also, DC current may be stored in batteries for delivery during periods of higher demand. Conversely, current generated during slower periods will be stored in order to provide power during these peak periods. This facilitates current output of up to 3000 watts (peak power rating).

E: CHARGING CIRCUIT

There are two basic charging curcuits, one using a PM DC generator, and one using an automotive alternator. In this case, we shall assume that the alternator is a newer model that has internally mounted rectifying diodes. In the alternator case, you can see that the field terminal requires current from the battery to create a surrounding field around the armature to facilitate charging. The PM DC generator is a much simpler system, and is recommended if one can be found in your area.





F: PARTS INVENTORY

2 11 foot running fence members, with tapered ends for axle
4 bearings with matched mount cradles to fit axle snugly (get the biggest ball bearings available)
2 4 by 8 7/8" sheets of plywood
supply of small turnbuckles and clothesline or similar steel cable for support wires, rotor to starter caps
4 4 by 8 ¼" masonite sheets
supply of arborite, formica or masonite for rotor
supply of 2" angle irons for fastening members together
supply of 2 by 4 lumber
supply of 3/8" steel cable for support wires to ground
4 concrete blocks
4 15" by 1½" steel pipes for support pipes
4 long 3/8" bolts and steel sleeves for attaching guy wires to upper bearing housing
supply of metal hose clamps
supply of 2" by 2" moulding
supply of misc. hardware