BUILDING A VERTICAL AXIS DRAG PROPULSION INVOLUTE SPIRAL WIND TURBINE

Congratulations! Your purchase of these plans will launch you into a major alternative energy project, with a new wind turbine design that has many exciting advantages over other approaches. These plans are for a 4ft diameter prototype, which is undersized for most energy needs. Dimensions are also given to increase the size for greater power output.

BACKGROUND:

The drawing on the left was first built with sailcloth vanes (see picture below), which proved to be too flexible for optimum performance.

The aluminum-vaned model pictured right was then built. It is a great improvement! I call her “Wendy”

Wind power has the potential to supply much of the energy demands of the world, and is one of the most rapidly expanding sector of current alternative energy technology. Most existing wind turbines are of the familiar horizontal axis configuration, with spinning propellers directed into the wind by a “tail” or, for larger systems, electronically controlled motors. These “lift” propulsion blades are typically of airfoil shape, like airplane wings or propellers, which rely on the low-pressure lift from the momentum of the wind passing over the airfoil shape. The vertical axis Darrius rotor is also a “lift” device, with its airfoil-shaped “eggbeater” blades. The vertical axis wind turbine (VAWT) pictured above is primarily a “drag” propulsion device (along with “lift” components that allow the rim speed to be faster than the wind speed), which continually diverts the mass of the wind to perform work on the sail. Results from only a few tests indicate that we can increase the low-speed power significantly over the horizontal axis rotating blade wind turbine, largely because we are utilizing “drag” propulsion of a much greater surface area sail instead of just “lift” propulsion from a thin airfoil-shaped blade. According to a Gruman Aerospace research paper on the subject (Tornado-Type Wind Energy System, James T. Yen, Research Department Grumman Aerospace Corporation, published in IECEC ‘75 Record)*, the increase in power of drag propulsion over lift propulsion can theoretically be thousands of times greater! This fact is little known but extremely important for designing wind energy technology.

* “Thus, in contrast to conventional wind turbines that use only the wind kinetic energy V²/2, we will
additionally use the wind pressure energy \( P/\rho \) which in magnitude is more than 3000 times larger than the wind kinetic energy for a wind of 15 mph (and more than 750 times larger for 30mph winds).”

This concept could also revolutionize sailing, for which I have designed a unique drag-propulsion mechanism that could get us quickly around Puget Sound, fastest into the wind! This VAWT can also be mounted on the top of a tree, with 3 additional cables holding the triangular stand vertical. Any swaying of the tree in the wind should also increase the velocity of the spinning gyroscope/turbine (as a gyroscope resists being moved out of its plane of rotation), thus amplifying the power imparted to the generator! This hypothesis of course needs to be tested.

A vertical axis wind turbine has several advantages over the more traditional horizontal wind turbine, especially in uneven wind conditions where a horizontal wind turbine has to change directions, which puts stresses on the bearings and tower and dissipates energy. In contrast, the VAWT is propelled by wind from any direction, and gravitational stresses on the vertical axis turbine are even, allowing lighter and larger construction. This vertical-axis wind turbine incorporates 3 involute spiral sails in a configuration that utilizes the mass momentum of the wind to spin the sails around a central mast. Force is applied to the sails by the wind both entering and leaving the turbine, allowing maximum extraction of energy from the wind.

The unique nature of the involute spiral is that the wind is increasingly diverted into and out of a central vortex with no constriction in the path, only pushing the surfaces around. Other advantages to this particular design will be covered below. This project began in the early 70’s with a fascination for the Savonius rotor, a cut-in-half and shifted oil drum wind generator spinning around a vertical axis. I wondered what the optimum offset and if the half-circle curves could be streamlined better, so I built a series of vertical axis wind turbine prototypes, with thin aluminum printing plate vanes glued between 78-rpm phonograph records. I filmed them on Super-8 next to a wind speed anemometer, and counted revolutions. I found the Savonius weak and stalling in its worst aerodynamic position, and found several new and faster vane configurations. The clear winner of them all was the 3-vane involute spiral. A 6-vane involute configuration was slightly more responsive in slower winds.

This circle of Radius 1 unwinds its circumference to trace out an involute spiral, which could continue spiraling around in a path exactly 2 \( \pi \) away from the next inner spiral. In other words, a non-constricting path is traced out, which is ideal for applying all of the wind mass to push on the vanes. As the 3-vane drawing above right shows, segments of the same involute can be duplicated around the central circle,
creating multiple non-constricting wind paths. Dimensions in the drawing on the right are of the prototype pictured.

This 3-sailed prototype was built by participants in a Community School class, “Testing a Vertical-Axis Wind Turbine”

We utilized a bicycle frame for the drive train and as part of the support framework. The mast is connected to a variable-speed bicycle chain-drive mechanism that drives an electrical generator. We experimented first with both a bicycle headlight generator and a Zap bicycle motor being driven as a generator by the bicycle tire on the drive mechanism. We are looking into the details of building our own low-speed generator from a Volvo disk brake, with imbedded super-magnets and heavy copper wire windings. This would be a direct-drive replacement for the high-speed automobile alternator.

The sails, first made of Dacron sailcloth, later replaced with aluminum vanes, are held rigidly in position with an involute-curved stiffener halfway above the 4’ diameter base disc, which is further aligned with tension cables to the base of the mast. Three tension cables keep the top bearing centered over the triangular base support and tension the leading edge. The first testing of the aluminum vanes was done without the lower tension cables, since the curved vanes offer considerable stiffness just from their shape. (After several accidents, the leading edge of the vanes became crimped and would be spun outward in high winds, compromising the shape and touching the guy cables, so we recommend using the tension cables, which improves balance and performance in high winds.)

The 48” diameter base disk, with 53” tall sails, will give 9.5 sq.ft. cross-sectional area exposed to the wind, or the equivalent in swept propeller area of a 3.5ft. dia circle. Comparing this to the popular “Hornet” horizontal wind turbine (http://www.survivalunlimited.com/eagleturbine.htm), which has a (6) blade diameter of 59” to 144”. The smallest 59” dia blade sweeps an area of 19 sq.ft, or twice that of our prototype model. Even when we consider the sum of the curved area of the three sails (10.2 sq.ft x 3 = 30.7 sq.ft.), equivalent to a 9.8’ (117”) dia circle, we are still under the larger Hornet blade-sweep-area. The 59” diameter Hornet will give 300 Watts in a 15 mph wind, 150 Watts in a 10 mph wind, which is closer to what
we might expect here on a windy day. Ideally, we would like to take advantage of even a 5 mph wind, which will only give 25-30 Watts with the Hornet specially-designed fat blades on their Ospray ultra-low wind speed model. For serious power generation, we recommend one twice as large (8ft diameter base)

We finally got our first prototype built and out in the wind, and what a perfect day for it! We averaged 20 mph winds, which spun the wind turbine at 120 to 130 rpm, which translates to speed of circumference of the 4 ft dia. sail-disk of 17 - 18 mph, which is 85-90% of the wind speed, spinning the bicycle wheel on high gear at 52/14 = 3.7 x 130 = 481 rpm x 27" = 47 mph. There was not enough torque to turn the powerful bicycle motor (with it’s 1.25” roller and much magnetic and frictional resistance) at that speed – when we geared down it could almost balance the friction of the motor, but we didn’t generate much power. Those of us taking part in the test (Larry, Blaine, Bill & Ebey) nevertheless considered it a successful test and exciting beginning, for the following reasons:

The cloth sails were too loose for the high winds, and the leading edge bowed in and out 3 or 4 inches as it spun, adding vibration & slowing it down considerably. The sails luffed badly on the upwind side, caving in and rippling the surface coming into the wind. This seemed to be the most severe dampening to the smooth spinning of the sails and their aerodynamic properties.

The sails/disk/booms were quite imbalanced, especially as we tightened the tension lines, which shook the truck it was mounted on, dissipating considerable power and prevented higher speeds.

We have replaced the cloth sails with stiff aluminum sheets that keep their smooth profile throughout their spin and are easier to tune the tension members and balance the rig.

Another observation from our truck-roof mounting platform ~ While getting the turbine up in position certainly wasn’t a breeze in this 20 mph wind, once it was up and spinning, we were able to unstrap it and stand there talking for a while without having to hold it down. Very little energy was offered in resistance by the turbine vanes, and the gyroscopic stabilization got us talking again about how easy it would be to mount it on top of a tree (as pictured above).

What about adding more sails? Remember, this is drag propulsion, achieving most of its power from the impact of air molecules on the continuously-spiraling-inward turbine vanes. If we have 3 more vanes, we have doubled the molecular impacts from the air, and because the geometry of the passageways between the sails is non-constricting, all impacts are moving the vane around the mast. This proposition has been challenged by sailors and wind turbine experts alike...... only testing will tell..... What about making one with a clear lower disk, so we can watch ribbons, photograph meter readouts, meditate on the expanding spirals?
We briefly tested a wind-diverter, which seemed to add more turbulence than power to the sails, and the stiff aluminum vanes obtain considerably higher speeds without the complications of the diverter, although it may help on a cylindrical (non-tapering) design.

After we replaced the cloth sails with stiff aluminum vanes, we placed the wind turbine on the garden gate in a location surrounded by trees, which blocked most of the wind and caused turbulence. Still, we were able to generate a small amount of electricity with a bicycle generator. Then we took it to the beach and with 18-22 mph winds were briefly generating power from a Zap bicycle motor turning an electric trolling motor. With a bicycle generator, we were able to light a headlight with about 15mph winds.

At speeds above 150 rpm, the crimped aluminum vanes wanted to flare out at the top and threatened to touch the support cables, so we had to keep a drag on the turbine at wind speeds above 16mph. The turbine is not dynamically balanced and shook the truck at high speeds. Both of these conditions were aggravated by the fact that for this first test we omitted the lower tensioning cables, relying entirely on the stiffness of the vane curves, which was actually quite impressive. The bicycle frame is bent, causing misalignment of chain and sprockets. The bicycle wheel is severely out of round, requiring excessive pressure on the generator rollers, so there is considerable friction in the system. Nevertheless, the turbine rim speed was consistently faster than the wind speed, sometimes by as much as 50% more, which indicates that both lift and drag propulsion may be involved.

We have since added the lower tension cables and trued up the bicycle wheel, which allowed us to transport the turbine on a truck at 35mph, spinning very fast with considerable drag of two generators engaged tightly. It spun very smoothly and generated impressive torque. We are excited about the potential of this VAWT design and hope you are too! I am sharing this information freely with the world because I feel strongly that there is great potential for superior wind power from this design. I am only one person with limited resources and time. R&D is costly and time-consuming, and we global citizens need to be experimenting and perfecting the technology.

There are many fruitful avenues of further experimentation. A direct-drive generator that can capture power efficiently at 4 rpm would greatly simplify converting rotation to electric current. Let me know if you find such! I would like to see larger units built and tested, a configuration with 5 sails compared with one of 3 sails, experiments with wind diverters, etc. If cloth sails had two more involute-shaped battens in the middle, perhaps that would be as good as making them with stiff material to resist deformation in high winds, but deterioration of sailcloth is a major consideration.

I would like to build a 12 foot diameter version of the present 4ft dia. one. That would give nine times the sail-vane area and get power from light breezes. Scaling up to that size should not be difficult with the triangular vane/guy cable approach. The strength of that arrangement has been proven and refined in sailboats, and the rotating mechanism elsewhere. Look at the much heavier and taller crystal swing (www.stiltman.com/html/crystal_swing.html) with 3/16” cables holding it up, loaded with spinning adults, in continual use for 33 years. Old model-A front wheel bearings were originally installed top and bottom. The bottom bearing was eventually replaced by a Dodge spindle bearing, which is better for thrust. You can't beat this arrangement for lightness of construction and least stress on bearings, which is the main reason why I didn’t use a cylindrical profile with large bottom bearings on a super strong mast.
I am currently designing a 5-vaned, 8ft diameter model, which has 6.6 times the surface area of the first prototype. It will be operating in an area with average 3.5m/s (meters per second) (7.8mph). I expect it will begin producing useful power in 2m/s (4.5mph) winds. Alternators take power from the base disk through smooth ‘roller-blade’ wheels. I am optimistic about this low-friction high-speed drive mechanism.

The photos above show Wendy mounted on a 12ft (2.5” dia, 0.035 wall) aluminum mast extension, which has 3 more guy cables supporting a bearing at the top of the tube. This works very well to transmit power through a super-lightweight “tower”, which could be continued with 20ft sections to as high as required. Note the wireless transmitting weather station mounted on top. This is an excellent location.
The rest of this document will focus on details of construction.

We built the support stand to utilize the bearings and gear/chain of a bicycle frame. Our frame turned out to be bent, which was a bummer for shifting into full high gear. Make sure yours is straight. We had problems of derailing in storms, probably because of this frame misalignment, and also some gravity imbalance of the chain on its side. Proper tensioning of the derailler spring should solve that. Note in 3D CAD drawing I added an additional two frame-stiffening pipes, and still there is a very slight play. It would be much simpler to have a direct drive shaft and only 6 tetrahedral support pipes.

In place of the pedal we inserted a box-wrench socket, which is covered by an aluminum fixture and fits around a protruding bolt head, which engages the pedal shaft to the base of the turbine mast, attached securely thereto with bolts and glue.

This works great as long as there are no mishaps, which was not the case with this baby. We hit a low-hanging TV cable when we were driving Wendy, mounted high on a truck for a mobile speed test after the wind died, which violently knocked the turbine off its mounts, sending it sprawling on the pavement far below. We repaired the bent and bashed blades and re-epoxied the base fixture onto the carbon-fiber
mast. Then a violent windstorm did it again, working a double-nut guy-cable attachment loose until it pulled out and sent the turbine flying off the garden gate. This time the turbine blades, which are 0.020” thick soft aluminum sheet, were unscathed, but the mast base was ripped off again. Therefore, I recommend using a universal joint or quick-release binding at this critical joint. It would also greatly assist the raising and lowering of a larger turbine.

The base plate must be securely attached to the mast. We used a tapped aluminum insert glued into the tapered carbon-fiber sailboard mast, as pictured above left. This allowed dismantling of the turbine (which hasn’t been necessary yet). The vanes are attached to the base plate and mast-top with aluminum reinforcing plates, as shown center and right above. On this prototype, only a ¾” folded edge was used to strengthen the vane edges. For maximum strength, run a tension cable or stiff aluminum strip down the leading and trailing edge seams to connect with tension cables to the mast base.

We used right- and left-handed threaded rod with lockable turnbuckles to provide tension adjustment between mast base and outer edge of vanes. Picture at right shows similar adjustment and attachment mechanism for holding top of mast rigid to mounting platform.
A bicycle front wheel bearing was used for the top bearing. It was mounted into a plug on top of the mast. Six short tricycle spokes were used to attach the three guy cables to adjustable eye-bolts. Since there were 10 spoke holes in the bearing housing, two spokes were shortened on one side to align the cables evenly at 120 degrees.

A rain cap with wind-direction ribbon will keep the bearing dry and tell you much about the wind.
The 4ft diameter .06 6061 T-6 base plate is scribed with 3 involutes, upon which are mounted 3 48.75” aluminum extrusions (for shower-board edging?) with poprivets. The vanes are 0.02” thick soft aluminum, with thicker aluminum reinforcing at all 3 corners and the involute-shaped tempered aluminum square-channeled stiffener in between. A T-6 tempered aluminum would be better for the vanes. Use thicker gauge if making bigger turbine.

We mounted both a small bicycle generator and a large Zap bicycle motor on the frame so they could roll on the wheel. The small knurled rollers offered considerable friction. There was not enough power to start the large generator unless winds got above 18mph, although our range of gears was severely limited by the bent bike frame, so it might have started at a lower speed. Next, I am going to mount a low-speed PMG alternator with a smooth drive wheel touching the wheel tread, as pictured in the drawing on page 6. This will have much lower friction.

Good luck with your project - and do keep me informed of your development work and let me offer suggestions and coordinate efforts and information so that all will benefit. I am available as a consultant.

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COMPARING 4', 8', & 12' DIAMETER TURBINES:

- 12' dia circle Circumference = 37.7 ft.
- 8' dia circle Circumference = 25.1 ft.
- 4' dia circle Circumference = 12.6 ft.

8' dia. Involute length = 97.78''
40.8 sq.ft. / vane = 122.4 sq.ft. total sail area
10.2 sq.ft. / vane = 30.6 sq.ft. total sail area

Wendy 4ft.dia. with 9.5 sq.ft. wind shadow
Small Involute length = 48.89''

8ft.dia. with 35.2 sq.ft. (3.27 sq.m) wind shadow
12' dia Involute length = 146.7''
91.8 sq.ft. / vane = 275.4 sq.ft. total sail area
12 ft. dia. with 79.5 sq.ft. wind shadow

By conventional calculations, 8ft.dia. with 35.2 sq.ft. wind shadow has maximum potential power of 327 Watts in 10mph (4.5 m/s) wind
10.2 sq.ft/vane x 3 = 30.7 sq.ft, equivalent to a 9.8' (117") dia circle
The surface area of three vanes = 30.7 sq.ft.
The surface area of five vanes = 51 sq.ft.
double size turbine = surface area of five vanes = 204 sq.ft., 6.6x
tripple size turbine = surface area of five vanes = 459 sq.ft.
459/30.7 = 15 times the surface area of Wendy

Dimensions in inches
Cut from 0.02 - 0.03" thick aluminum sheet

ORIGINAL 4FT DIA. "WENDY" TURBINE VANE
Designed, drafted, developed by LAD ~ 2008
The surface area of three vanes of 4'dia Wendy = 30.7 sq.ft.
The surface area of five Wendy vanes = 51 sq.ft.
double size turbine = surface area of five vanes = 204 sq.ft.=6.8x
tripple size turbine = surface area of five vanes = 459 sq.ft.
= 15 times the surface area of Wendy

This 5-vaned, 8ft diameter turbine has alternators rolling on base disk with roller-blade wheels to increase RPM to optimum speed of alternators.
Base disk extends beyond vanes to create track for alternator roller and pressure roller, which are smooth-rolling in-line skate wheels, affording high generator-speed increase with little frictional loss.

THIS GENERATOR-DRIVE TECHNOLOGY HAS NOT BEEN TESTED AS OF 9/07
Dimension details of 8’ diameter, 5 vaned Involute Wind Turbine with rim-drive generators
Mount the mast on a universal joint to allow smooth raising and lowering of the mast and accommodate irregularities in alignment under high winds.
Threaded hole in top where base of wind meter or flag shaft screws in on top of 3 guy-cable attachments.

6205 RS Sealed Wheel Bearing
25mm ID, 52mm OD, 15mm wide

Top and bottom bearing housings machined from aluminum to contain 6205 RS Sealed Wheel Bearing from http://www.electricscooterparts.com/bearings.html

Dimensions in cm
Bearing and housing for top of Randy
Top Bearing Assembly  8/2/07  Designed & Drawn by Lawrence Dobson