Bird Windmill Summary

Peter Allen Sharp sharpencil@sbcglobal.net 1/19, 7/21

The Bird Windmill is potentially the best small wind pump in the world. It is an extremely inexpensive, multi-purpose, small-scale, lift-type, unbalanced, self-starting, expanding-orbit, single-blade, vertical axis, passive-pitching cycloturbine. It is not a Darrieus rotor. It is more fundamental. It is especially well suited for irrigation pumping by poor, small farmers in developing countries because it costs almost nothing. It is easy to construct, and it is so light that it is portable. The size and power of the windmill may be limited to perhaps 1 or 2 kW, except when used in arrays. Unlike conventional windmills, it does not require shafts, pump rods, shaft bearings, blade support-arms, welding, machining, metal bending, molds, or conventional fasteners. If desired, it can be entirely tied together.

Here is the original proof of concept model that was entirely tied together; it is simulating pumping by lifting weights:
http://www.youtube.com/watch?v=fFdPxrj1evk&feature=youtu.be

I now use more powerful straight blades and guyed-pole support-towers inserted into the ground instead of the tripod support towers in the video. Note that the vertical angle of the rocking tower above the (simulated) pump determines the mechanical advantage. So far, my maximum blade spans are 2 feet because larger blades are too powerful for hand testing, and I have no permanent test site. I need help to further develop the wind pump. Full-scale blades should range from 4 to 8 feet in span. A 6' span might be adequate for most applications.

Here is model-blade testing, with a vertical axis, using a 2' span, flat-surface, Coroplast I-blade (straight blade with 2 rocking arms and a counterweight arm) with a blade aspect ratio of 4. The hand-held testing poles are ½" steel conduit. The bottom shock cord is 1/8". I am using all of my strength to resist the centrifugal force on the blade:
https://www.youtube.com/watch?v=_dclvcYMbkY

The blade may be streamlined or flat. The blade has a crosswind axis aligned vertically (but it can also operate with its crosswind axis aligned horizontally). The blade has a fairly constant tip speed ratio (TSR) of 2.

The best blade aspect ratio to achieve the highest solidity and the largest swept area for a given tower height is a straight blade with an aspect ratio of 4.

If the blade orbit is vertical, the blade aspect ratio can be higher because the two support towers can be any distance apart, and a V-blade or a C-blade can be used instead of an I-blade.

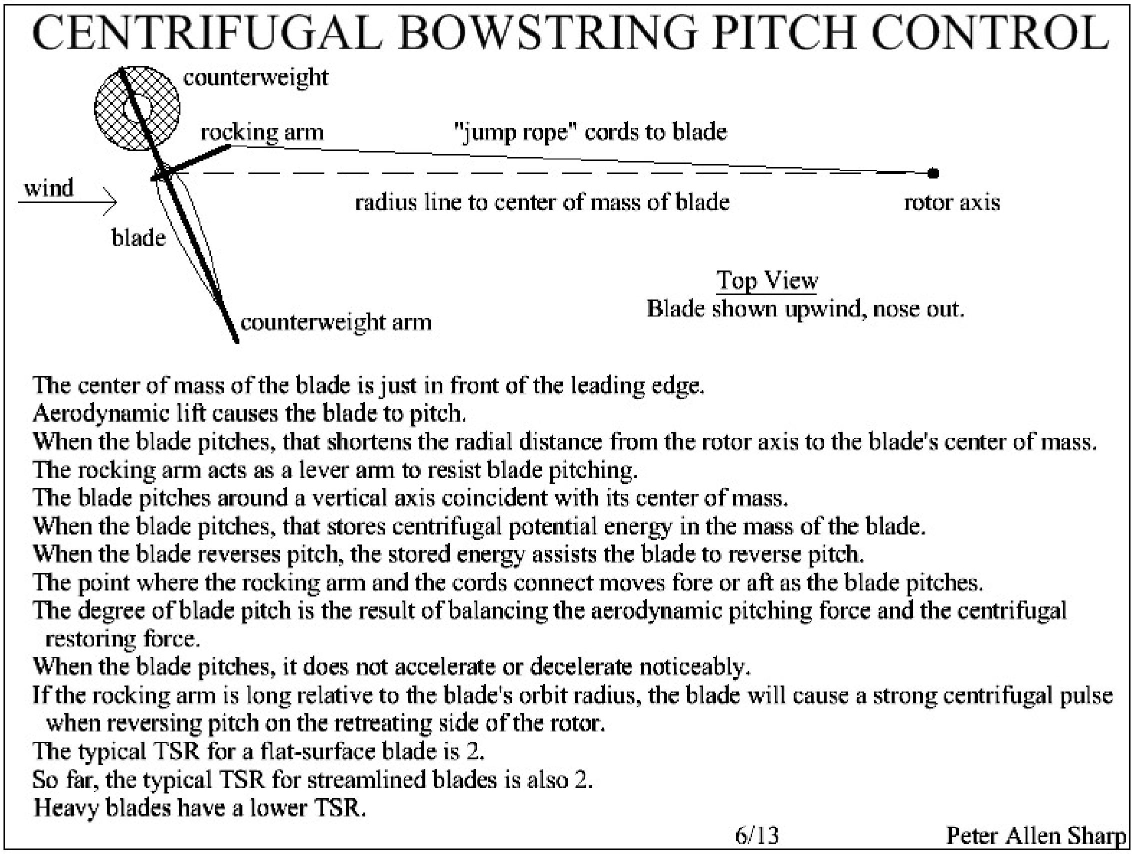
The blade orbit diameter expands as the wind speed increases in order to keep the pumping Hertz low enough for piston pumps (about 60 Hertz) and to avoid resonant shaking. Larger blades with a larger orbit diameter will lower the Hertz. To increase the Hertz by reducing the orbit diameter, increase the resistance of the shock cord below the blade.

The unique kind of passive, centrifugal-spring pitch-control is called "bowstring pitching". The blade does not suffer from dynamic stall.

The blade's pitch angle is determined by the balance of the centrifugal resisting force and the aerodynamic pitching force. Both forces increase by the square of the blade's speed (ground speed, and apparent wind speed, respectively).

The blade's horizontal orbit varies from that of a circular blade path due to the combined effects of wind velocity, gravity, and the elasticity of the blade cords. The orbit is somewhat egg shaped (flattened upwind and elongated downwind) and it is therefore offset in the leeward direction. Consequently, the orbital plane tips slightly downward toward the wind.

The blade uses centrifugal force to produce power by either creating oscillating pull-strokes of a cord (aided by an accumulator weight) or by rotating a crank arm (on a vertical shaft) located below the blade's axis of rotation.



A 2' blade should weigh between 0.5 and 1 pound per square foot, and larger blades should scale up accordingly, but this assumption has not been tested to determine the best weights for larger blades.

The blade self-starts in a wind speed of 3 to 4 MPH due to random oscillations and begins to produce useful power in a wind speed of 5 to 6 MPH. (If the blade flies in a vertical orbit perpendicular to the wind, the starting wind speed is 7 to 8 MPH. First the blade gallops and then begins to back-loop.)

Although the Bird Windmill is intended to be used primarily as a wind pump, it is cheap enough to be used to generate heat by fluid friction heating (for example, stirring BBs in a can with a little vegetable oil or silicon grease). The blade can be used alone or in combination with other blades (an array) to spin a common shaft fitted with one-way clutches (perhaps made from loops of cord around a shaft and a small weight hanging from the cord; see video below).

The blade is further stabilized (against fore and aft tilting oscillations) by using "centrifugal T-Rule stabilization" which is another type of centrifugal spring. That is done by placing the single counterweight arm at mid-span because the counterweight tries to remain in its horizontal plane of rotation.

Although the Bird Windmill is very easy to make by following a few rules, it is not easy to understand because it's principles of operation are not readily apparent. So it should not be modified. It should be sold as a complete unit. To be safe, it should probably be limited to about 1 to 2 kW using a blade span of about 8'.

The windmill can be used to charge batteries, even in low wind speeds, by using my twist-cord-accumulator-transmission (TCAT) with a magnetic release catch. It causes the generator to spin, intermittently, at a high RPM.

That completes the Summary.

What follows are a list of the unique characteristics, disadvantages, building tips, overspeed control techniques, power calculations, and drawings of related devices such as a matching pump. A more extended discussion is available in my full-length paper.

Unique Characteristics

The blade is suspended on shock cords above and below the blade, or, more often, a long, upper non-elastic cord above the blade and a shorter shock cord below the blade for easier self-starting in low wind speeds. Shock cords roughly double in length under tension.

The blade's orbit diameter increases as the wind speed increases, so the RPM remains fairly constant while the power increases and the length of the pull-stroke increases. The blade accelerates rapidly once started.

During lulls, the blade will continue to orbit down to a wind speed of about 2 MPH. It can catch more of a gust if it is already orbiting because starting requires a few seconds of random oscillations followed by orbit expansion.

The blade and its support cords function like a vertical axis jump rope. It may also be described as a wind-driven, restrained, conical pendulum.

The blade produces an unbalanced centrifugal force as it orbits so as to oscillate pull-chords that extend to a pump or other device, and to an accumulator weight opposite from the pump. The accumulator weight can also be used to help balance the weight of the water in the delivery pipe. The accumulator can double the pulling force at the pump.

Stainless steel, ball-bearing fishing swivels prevent the two blade-cords from twisting. They can be placed anywhere along their cords.

The main bearings at the upper and lower ends of the blade cords revolve but do not rotate -- like a person's shoulder joint. Outdoor testing for 6 months indicated that they are durable. They cost almost nothing to replace.

The blade is suspended between horizontal cables (above and below the blade) which are strung between the tops and bottoms of two, slender pole towers. The towers require only one guy wire each so that they are free to sway toward and away from the pump so as to allow for increases in the length of the pull strokes. If the towers are rigid, them more slack is needed in the horizontal cables.

The blade span (for straight blades) is typically ¼ the height of the pole towers. The blade starts when it is near the ground and operates most of the time at about half the height of the towers.

Straight blades with an aspect ratio of 4 serve to maximize both the swept area and the solidity ratio. Higher aspect ratio blades do not increase the TSR.

An I-blade, as opposed to a V-blade or a C-blade, allows for longer blade cords and larger orbit diameters. That is because the span of straight blades is twice the distance between the attachment points of the blade-cords to the blade's rocking arms, whereas V-blades and C-blades have their attachment points at the tips of the blade, thus reducing the length of the blade-cords.

The maximum horizontal orbit diameter is about the same as the height of the pole support towers.

The diameter of a vertical orbit can be about 1.5 times the height of the support towers. The distance between the support towers is chosen to prevent the blade from hitting the ground when the two shock cords are fully extended. But hitting sand, water, or dirt can be used as a backup method of overspeed control because the counterweight takes the impact. Then the blade restarts.

An expanding horizontal orbit limits the RPM to avoid resonant shaking, and keeps the RPM low enough for piston pumps (about 1 Hertz or less).

The high-wind orbit diameter (about 4 blade spans in diameter) is roughly 2 times the low-wind orbit diameter (about 2 blade spans in diameter).

The estimated coefficient of performance (Cp) ranges from .10 in light winds (at a small orbit diameter with a solidity ratio of about 0.125) to .05 in strong winds (at a large orbit diameter with a solidity ratio of about 0.063).

Typically, using a single shock cord, the orbit diameter doubles as the blade span doubles. A 2' blade has a maximum orbit diameter of about 8' when using 8' towers. So a 4' blade should have a maximum orbit diameter of about 16', and an 8' blade should have a maximum orbit diameter of about 32' using 32' towers. Taller towers could be used. A stronger shock cord will increase the RPM.

If shock cord is not available, the same orbit expansion can be achieved by using pulleys on one tower to gradually lift a heavy chain, or the equivalent.

The blade produces a much stronger pulling force when downwind because blade lift adds to the centrifugal force, and less when upwind because blade lift subtracts from the centrifugal force. The blade pitches less when downwind than when upwind and so operates at a higher angle of attack when downwind.

Therefore, the downwind blade pass captures much more wind energy than the upwind blade pass. (In contrast, other lift-type VAWT capture 66% to 80% of their wind energy during the upwind blade-pass.)

Here is a slow motion video showing the pitching of a straight, flat, 2' span, Coroplast blade-unit that weighs a total of about 0.5 pounds per square foot:
https://www.youtube.com/watch?v=c5rlJYD82gM&t=7s

An energy accumulator (a lifted weight), located opposite from the pump, smooths out the operation to allow the wind to come from any direction.

Since there are no rigid connections between the blade and the pump, the windmill has an inherent clutch-action for easy starting. Pumping begins gradually as centrifugal force increases the pumping force and the pump stroke.

The variable pump stroke become longer as the wind speed increases.

The windmill includes an easily adjustable mechanical advantage -- by selecting the vertical angle of the rocking tower above the piston pump. A more vertical angle produces a higher mechanical advantage and a shorter pump stroke.

The pump or other driven device can be located a long distance from the blade, and at a different elevation. Here is an example of how to transmit energy a long distance (probably 100 to 200 yards) using a "jerker line" (an old, proven technology):
https://www.youtube.com/watch?v=4x0CNNKuSSE

The blade material may be Coroplast, 1/8” plywood, folded sheet aluminum, folded sheet plastic, or some type of fabric in a rectangular frame.

Here is a straight, flat, 1/8” plywood blade being tested, with a weight of about 1 pound per square foot:
https://www.youtube.com/watch?v=QVZ0PUKrrs4
This heavier, 1/8” thick blade lowered the tip speed ratio a little but considerably increased the centrifugal force. That is the reason for using the stiff, vertical. Volleyball-net-pole for extra support during testing.

Streamlined blades can be made from folded sheet plastic or folded aluminum flashing. A tube spar is placed inside of the leading edge. The blade skin, the rocking arms, and the counterweight arm all attach to the tube spar. Streamlined blades and flat blades seem to perform equally well. Here is a streamlined, plastic blade being tested. It has an aspect ratio of 6:
https://www.youtube.com/watch?v=LwjptI096Qg
The wind was too strong, so my assistant had to stop the blade by repeatedly moving the upper pole toward the blade to reduce the load. If the blade loses its load completely, it stalls and acts as an airbrake to stop quickly.

Consequently, the blade typically stops immediately if something breaks. If balanced normally, the counterweight will swing outward, turning the blade sideways to its relative wind.

Triangulating blade bracing can be added by anchoring bracing cords (or wires) to the inward end of the rocking arms. Then extend those cords to the other rocking arm, to the tips of the blade at the leading edge, and to both ends of the counterweight arm.

There are a number of simple overspeed control and shutdown options (see below for some of them).

If necessary, the windmill can be constructed using recycled materials. For example, strips of inner tubes can be used instead of a shock cord. The support poles and the rocking towers can be made of locally harvested bamboo. Used ball-bearings can be used instead of the ball-bearing fishing swivels as long as they still rotate smoothly.

The upper blade cord can be replaced with a twist-cord-accumulator-transmission (TCAT) plus a bicycle dynamo to charge small batteries intermittently in very low wind speeds, even while driving its primary mechanical device (such as a pump). The torque of the twist cords does not significantly inhibit the pitching of the blade. In that case, the dynamo bearings replace the fishing swivel. The blade briefly slows when the twist cords rapidly unwind because that suddenly reduces the load on the blade, which increases their pitch angle.

Here is a tiny Bird Windmill, streamlined V-blade (made from a plastic water bottle) operating a TCAT in a wind speed of 3 to 4 mph.
https://www.youtube.com/watch?v=6ZHsJ5wdWHo&index=9&list=UUhYQYjRwGq2ija4KuNs7xbw

Here is a Bird blade with a TCAT operating in a wind speed of 5 mph:
https://www.youtube.com/watch?v=W85Yr1BwIsw&list=UUhYQYjRwGq2ija4KuNs7xbw

Here is a demonstration of a TCAT with a magnetic release catch. A longer twist cord would take longer to wind but light the LED for a longer time:
https://www.youtube.com/watch?v=JsUUES--QGc&list=UUhYQYjRwGq2ija4KuNs7xbw&index=3

Here is a demonstration of a slowly wound twist-cord spinning a 12 volt bicycle bottle dynamo at a high RPM:

https://www.youtube.com/watch?v=GJl6qeSAAxY&list=UUhYQYjRwGq2ija4KuNs7xbw&index=7 In this case, I am using my fingers in place of a magnetic release catch. The release catch requires 4 magnets. Any number or size of magnets could be used to increase the resistance of the catch.

Like poles create the most resistance to rotation. Once the magnets release the alternator shaft, they create no further resistance until the shaft stops again because the approaching and receding repulsion forces cancel each other.

To match the Bird Windmill, I designed a simple differential piston pump (not yet built, but I had it verified by a windmill-pump expert). It uses a rope instead of a piston rod. The water above the piston pushes it back down. It can be treadled when there is no wind. It can reach far deeper than conventional treadle pumps (which are suction pumps), and it costs much less. (See drawing below.) The entire windmill should cost about the same as a treadle pump, or even less ($20 to $100) depending upon the build quality, size and materials.

When the wind is not blowing, the blade-unit can alternatively be manually rotated by one or more people to pump water using a long pole attached to the bottom blade-cord. The pole functions as a crank rod. The blade-unit functions as an unbalanced flywheel for both the push and pull strokes of the long pole.

This particular type of centrifugal pitch control is too inefficient to use on a conventional cycloturbine. But in this case, it works well.

If the blade's top cord is non-elastic, the blade rises as the blade's orbit diameter increases. This arrangement is used for piston pumping. If the top cord is elastic, and the bottom cord is not, the blade's altitude reduces as the orbit diameter expands. This arrangement is useful for turning a crank arm below the blade or for oscillating a vertical pump arm below the blade, as for a Chinese vane pump with a vertical, oscillating pump arm. (See drawing.)

When rotating a crank arm below the blade, the non-rigid connection functions as a clutch to allow starting under a heavy load. The crank arm first oscillates and then begins to rotate when the centrifugal force becomes high enough:
https://www.youtube.com/watch?v=EdDaRMr4dwg

The blade starts more easily in lower wind speeds if the cord above the blade is longer. A non-elastic cord above the blade can be longer -- about twice as long as the shock cord below the blade.

But greater orbit expansion is possible if both blade cords are shock cords. The upper shock cord should be a little stronger to support the weight of the blade.

Shock cords can be constructed with thin sections and thick sections (or double cords) tied end to end so as to allow for easy expansion when starting, and slower expansion as the wind speed increases. A loose limit-line can be added to a thin section to make it stronger when fully extended.

For light-wind areas, easier self-starting is preferable. In strong wind areas, greater orbit diameter expansion is preferable.

Many tower options are possible. If the windmill must operate in a confined space, it can be constructed using this single "K" tower:
http://www.youtube.com/watch?v=VqKJlu9dXK4&feature=youtu.be

It may be possible to use the Bird Windmill to drill its own bore-hole water well using percussion and/or rotary drilling. Here is a simple way to lift and drop a percussion drill using an oscillating pull-cord from the windmill, and a manual release to drop the percussion drill:
https://www.youtube.com/watch?v=sq_6iljEr9U&feature=em-upload_owner

The blade can fly in a vertical orbit for special applications: http://www.youtube.com/watch?v=cxEdUlbqwsg

Using two, equal-length shock cords, the maximum vertical orbit diameter is about 1.5 times the height of the 2 pole towers, as shown here with a C-blade: https://www.youtube.com/watch?v=UKvRsBgeLQc

A vertical orbit cannot orient to the wind unless the blade is suspended between pivoting V-poles located on a yaw bearing at the pump. The V-poles then function as long lever arms to create a very high mechanical advantage for the pump. (See drawing of "Y"-tower pump.) On water, vertical support poles on floats can be made to orient to the wind around a buoy.

The windmill can also be used for pond aeration

The windmill can be erected in large arrays where many vertical blades are suspended between the same two pole support towers. They can all transmit their pull-strokes to a single rotary shaft (horizontal or vertical) on a generator, water pump, air compressor, or fluid-friction heater. Here is an example of how one or more variable-length pull-cords can rotate a shaft: http://www.youtube.com/watch?v=1UxgYOB20QE
To further simplify, one-way clutches made from loops of cord can be used, as shown previously. In wet weather, Dacron cord around an aluminum shaft should provide good traction which increases when wet.

Disadvantages

The Bird Windmill's main limitation is that it is almost impossible for engineers to analyze mathematically or to simulate on a computer due to so many interacting variables, including natural pitching and swinging frequencies that must match reasonably well for easy self-starting in light winds. It also breaks many of the standard engineering rules for good windmill design, such as being deliberately unbalanced, so engineers may reject it before understanding it.

As conventionally measured, the windmill is inefficient because the single blade sweeps a very large area for its size. That creates a low solidity ratio combined with a moderately low tip speed ratio (2). However, the simple blade can produce a lot of power for its size and cost.

Why the tip speed ratio is limited to 2 is only partially understood. The partial explanation is called "paradoxical pitching": When the blade is upwind, a stronger resistance to pitching creates higher lift. But that higher lift flies the upwind blade more inward, thus reducing the centrifugal force acting on the blade to create the resistance to pitching, and thus reducing the angle of attack, the lift, and thrust. So beyond a TSR of 2, more lift upwind produces less lift; a paradox. The result is a limit on the TSR. So far, my attempts to increase the TSR have not been successful.

The blade's resistance to pitching (its resisting force) may be influenced by the changing angle of the blade cords from vertical to roughly 45 degrees as the orbit expands. But that influence has not yet been evaluated.

Some blades self-start more easily than others, which seems to be determined by the matching of the natural pitching and conical-pendulum frequencies of the blade. So designers must rely on rules of thumb and trial and error rather than on mathematical rules. I have a blade that starts very easily.

The placement of the counterweight closer or further from the blade affects the natural pitching frequency. I typically mount the counterweight ½ chord length in front of the leading edge of the blade. I choose the weight of the counterweight to match that placement.

The blade starts more easily when the blade is a little nose heavy. For correct balancing, a hanging, horizontal blade should point downward at a 2 degree angle. That blade balancing also give the blade a neutral pitch angle because it makes the blade chord tangent to the blade path at the center of pressure (the center of lift at the quarter chord point).

Because the windmill looks so simple, amateurs may try to "improve" it without understanding the effects of those changes. The result is usually reduced performance. So it should be sold as a complete unit. And replacement parts should be pre-measured and made to clip in place.

Scaling-up introduces new natural frequency ratios, so a new series of trial-and-error experiments is required to optimize performance at each size. However, only two blade sizes (4' and 8') should be adequate to meet most pumping requirements. Or, to simplify further, only a 6' blade span could be produced. The blade could be made to fold for shipping, and to store easily to avoid theft.

Estimates of Power

We will assume the following based on observations (not measurements):

The Cp is proportional to the solidity ratio and so it is inversely proportional to the orbit diameter.

The solidity ratio ranges from about 0.12 at low wind speeds (when the orbit diameter is about twice the blade span), to about .06 at the maximum orbit diameter (when the orbit diameter is about four times the blade span).

At low wind speeds, when the solidity ratio is 0.12, the estimated Cp is .10.

At higher wind speeds, when the solidity ratio is .06, the estimated Cp is .05.

Example:

For a 4 foot blade span, at low wind speeds (6 mph), the orbit diameter equals the 2 times the blade span, which is 8 feet. (The support poles would be about 16 feet tall.)

Assume the blade is an I-blade with an aspect ratio of 4.

For a 4 foot blade span, at high wind speeds (16 mph), the maximum orbit diameter about equals the tower height, which is 16 feet, when the shock cords are fully extended.

Power in kW = (conversion factor of .000133)(Cp)(.5)(density of air at 1.2)(swept area in square feet)(wind speed in mph, cubed)

Consequently, for a **4 foot blade span**, in a wind speed of **6 mph**, an orbit diameter of 8 feet, a swept area of 32 square feet, a Cp of .1, wind speed of 6 cubed (216), the power would be:
P = (.000133)(.1)(.5)(1.2)(32)(216) = **55 Watts**

And for a **4 foot blade span** in a wind speed of **16 mph**, with a Cp of .05, an orbit diameter of 16 feet, and a swept area of 64 square feet, and the wind speed of 16 cubed (4096), the power would be:
P = (.000133)(.05)(.5)(1.2)(64)(4096) = **1.05 kW**

Another Example:

If the blade span is 8 feet, the chord length is 2 feet, and the tower height is 32 feet, the swept area will have twice the height and twice the diameter, so the swept area will increase 4 times, and the power will increase 4 times. At each wind speed, the solidity ratios, the estimated Cp, and the energy in the wind will remain the same.

So the power of an **8 foot blade span** would be:

At **6 mph**, **P** = (.000133)(.1)(.5)(1.2)(128)(216) = **220W**

At **16 mph, P** = (.000133)(.05)(.5)(1.2)(256)(4096)= **4.18kW**

However, it might be wise to adjust the overspeed control (see drawing below) to limit the power to 1 to 2 kW so as to not over-stress any of the parts.

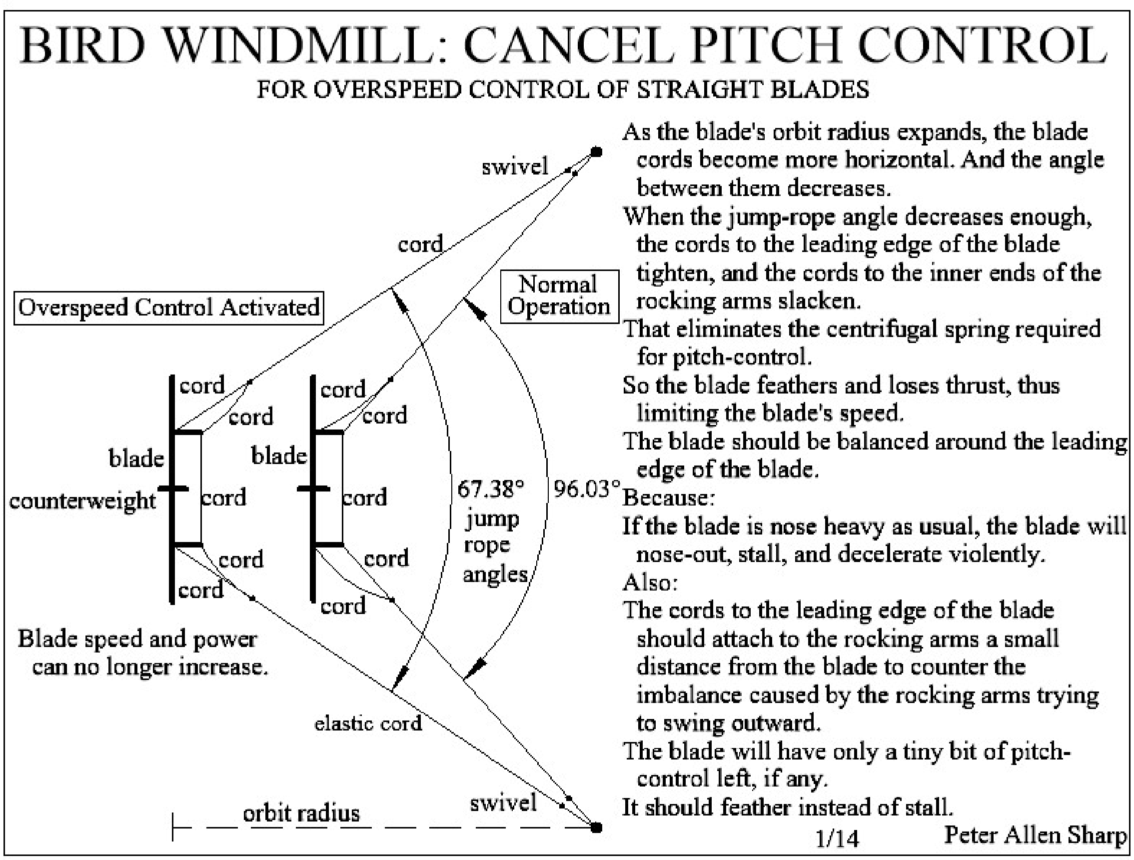
The flexing, stretching, and oscillations of the various parts, plus aerodynamic drag, might limit the power transmission efficiency to roughly 75%.

If the orbit diameter is reduced to increase the Hertz, overspeed control will need to begin at a lower wind speed so as to avoid shaking and to not overspeed the pump. However, the differential pump I show in a drawing below should be able to operate at a higher Hertz than a conventional pump with a pump rod.

Overspeed Control for a Straight Blade

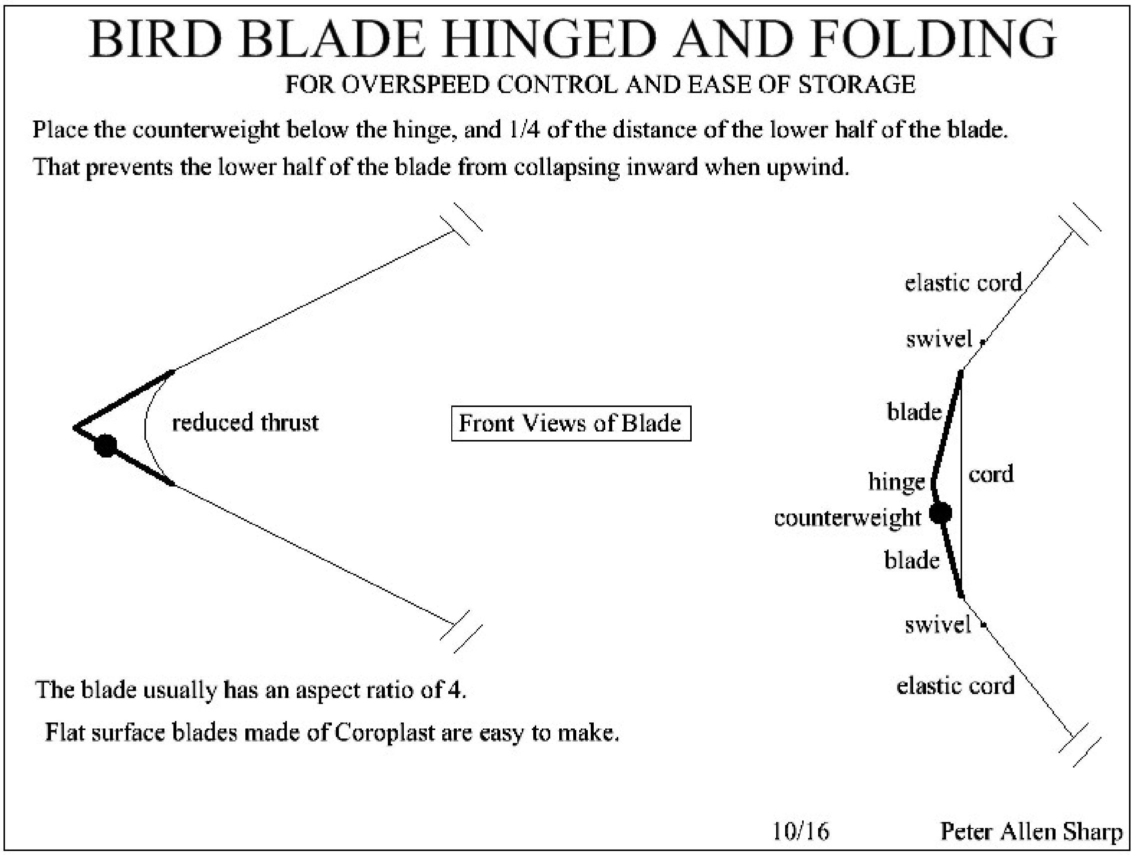
To limit the absolute speed of the blade and the centrifugal force, use the cord arrangement shown in the drawing. It eliminates the blade's centrifugal resistance to aerodynamic pitching, so the blade pitches too much to maintain an efficient angle of attack. It costs essentially nothing. Make sure to adjust it so that it works before the blade's orbit diameter reaches maximum. For this overspeed control, the blade must be evenly balanced when horizontal (no nose down). It must not be nose heavy (as usual) or it will stop abruptly by acting as an air brake. That will not hurt the blade, but it will keep stopping and starting.

It is best to tie the overspeed cords to the rocking arms a short distance inward from the blade so that the weight of the rocking arms does not cause them to swing outward and stop the blade abruptly.



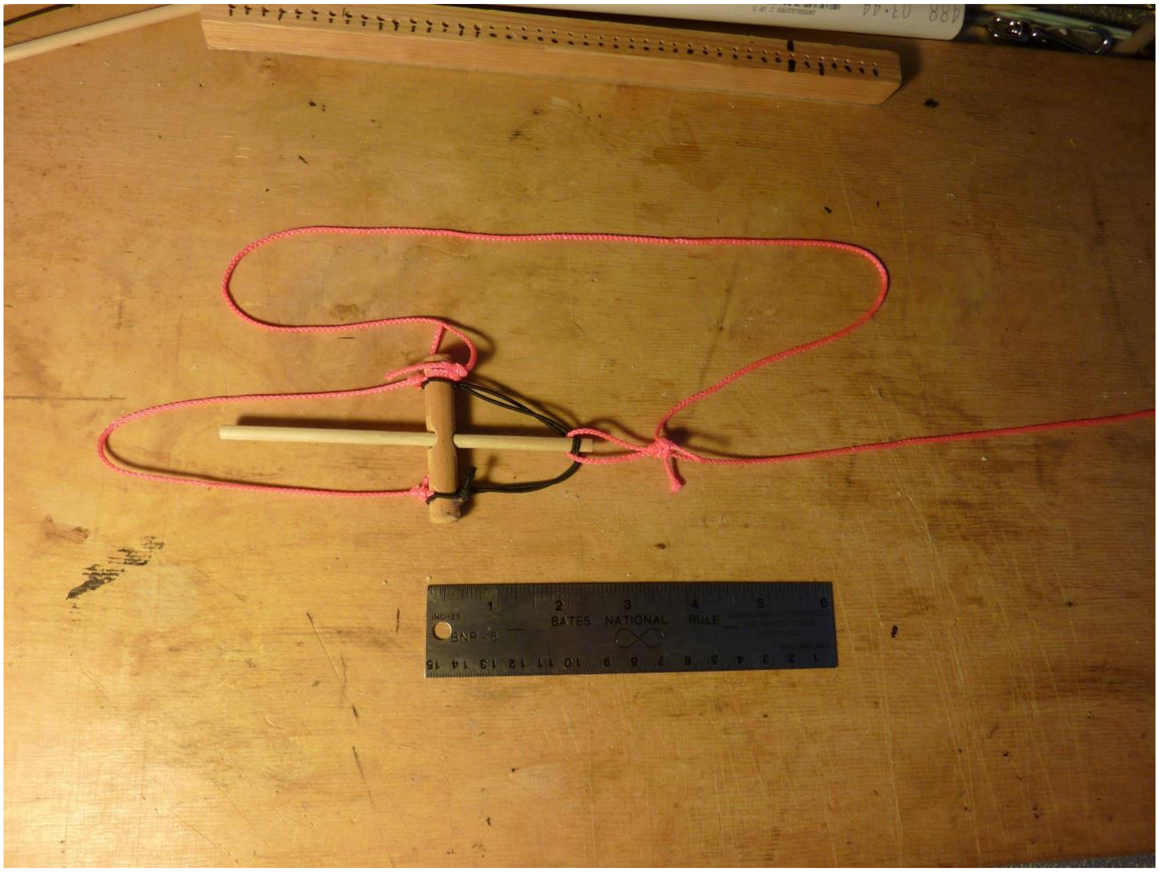
Overspeed Control for V-blade

A V-blade requires taller towers or a smaller maximum orbit, but it can be even simpler to make than an I-blade because it requires no rocking arms. To create overspeed control, place the counterweight below a hinge at the middle of the V-blade. A hinge can be made, for example, by cutting Coroplast but leaving one side intact. Placing the counterweight arm 1/8 span below the hinge ensures that the bottom half of the blade will not collapse inward when upwind As the orbit diameter becomes excessive, the blade begins to fold (increase its bend angle). That limits its swept area and thrust.



Shutdown in High Winds

To provide a safety back-up for both I-blades and V-blades, and to shut down the windmill in excessive wind speeds, use a release catch at ground level , as shown in the photograph below (must be manually reset). It is triggered by excessive centrifugal force which is preset by the resistance of the black shock cord to stretching.



The black cord loop is a shock cord. The orange cords are non-elastic paracord. The lower half-loop of orange cord, to the left, is fastened to the ground or to the middle of a horizontal cord connecting the bottom of the support towers. The bottom, right orange cord attaches to the shock cord below the blade. It can be short so that the release catch requires only a little vertical space (so as to keep the blade's bottom shock cord as long as possible).

When the blade's centrifugal force pulls the bottom, right orange cord strongly enough to pull the thin dowel all the way out of the thick dowel, the thin dowel flips to release the bottom, right orange cord, thus greatly elongating the blade's bottom cord. That serves to eliminate the load on the blade. The blade quickly stops and it cannot restart. It will safely flop around in the wind. Reset the release catch after the wind speed decreases.

To make the release catch:

Drill a hole in the thicker dowel such that the thinner dowel slides easily in that hole.

Drill parallel holes in the ends of the thicker dowel so that cords can be tied to it.

Attach the left orange loop to the middle of the bottom horizontal cord.

Adjust the release tension of the black shock cord loop as needed.

Attach the right orange cord to the bottom of the blade's bottom shock cords.

Adjust the length of the safety line (the top, orange loop) as needed. Make sure that the safety cord is not long enough to allow the blade to swing up to contact the upper horizontal cord strung between the tops of the two support towers.

Rules for Constructing a Bird Windmill

Use a straight blade with an aspect ratio of 4.

Locate the rocking arms at ¼ span from the tips, and as close as practical to the leading edge of the blade.

The length of the rocking arms should be ½ the blade chord.

The counterweight arm should be located at mid span.

The center of mass of the counterweight (metal disc or washer) should be about ½ chord length ahead of the blade. The placement and weight of the counterweight can be used, to some extent, to adjust the total weight of the blade-unit.

The blade should be made as light as possible because additional weight can be added if needed.

Balance the blade such that, when it is horizontal and suspended by its blade cords, the counterweight arm points downward 2 degrees from horizontal. However, if the overspeed control shown in the drawing above is used, balance the blade so that the counterweight arm is horizontal.

The blade's bottom shock cord will about double its length in response to centrifugal force.

Make the upper blade cord non-elastic and twice as long as the elastic lower cord. That facilitates easy self-starting, and the blade stays vertical as the orbit expands.

Choose the strength (thickness) of the elastic bottom cord so as to allow full expansion of the blade's orbit diameter at the cut-out wind speed, such as 16 mph. Also choose the strength of the shock cord such that the expansion rate produces the desirable, constant RPM to best match the driven device.

Place the stainless-steel ball-bearing fishing swivels on the blade cords, and near the attachment points of the blade cords to the horizontal cords, or far enough from the blade to accommodate the overspeed control method shown in the drawing. Oil the ball bearings periodically. If necessary place a cone shield made of tape over the bearings to deflect rain.

When the blade is hanging vertically before starting, there should be a little slack in the lower elastic cord for easy self-starting.

The lower tip of a straight blade will sometimes touch the bottom shock cord during self-starting. Cover that point on the cord with a bit of tape as needed.

The blade span of a straight blade should be ¼ the height of the support towers.

Place the two support pole towers more than one tower height apart to give the blade room to clear the towers.

The top horizontal cord connecting the tops of the two towers should have a little slack.

Allow the tops of the support towers to bend or sway sideways (toward and away from the pump). So only one guy wire per tower is required. That allows the stroke length of the pump to increase.

The top cord of the blade should attach to the middle of the overhead horizontal cord strung between the tops of the two towers..

A second horizontal cord, near ground level, should extend between the two towers, and it should also have a little slack.

The bottom elastic blade cord attaches to the middle of the bottom horizontal cord.

Attach pull cords to the junction of the blade cords to the horizonbtal cords. Extend the pull cords to the tops of the rocking towers above the pump and the accumulator weight, with the rocking towers set at their desired angles from vertical.

The rocking tower for the pump can be more than a hundred yards away from the windmill. It has an inverted V-shape. Place the feet of the towers in small pits, or in half-buried tin cans, to keep them from sliding (after their vertical angle has been chosen). They lean away from the windmill.

Adjust the vertical angle of the rocking tower above the pump to determine the mechanical advantage. Adjust the pull cord accordingly. A more vertical angle produces a higher advantage and a shorter pump stroke.

Place the other rocking tower on the opposite side of the windmill, but near the windmill. Use a hanging weight (such as a sack of stones) for the energy accumulator. Adjust the amount of the weight and the angle of the tower to what works best. Or, using a cord, let that rocking tower lift one end of a stick or board, and locate that weight along the board to determine the board's resistance to being lifted.

The support guyed pole towers and the rocking inverted-V-towers can be made of any light but stiff material, such as metal conduit or bamboo. PVC tubing may be too flexible unless the diameter is large enough.

When splicing poles to make them longer, overlap them and place a short section of the same pole diameter over the overlap region, thus creating a prism-like section. Then bind, tape, clamp, or bolt the overlap area to create a very strong splice.

DIFFERENTIAL PISTON PUMP; NO SEALS

The goal here is easy maintenance and cheap parts. Both the check valves and the filter are part of the main piston. So they can all be withdrawn from the well by just pulling up the pump cord.

Also, there is a seal to prevent back leaking so that the delivery pipe will stay full of water. For hand pumping, the seal would be used; for wind pumping, the seal would probably be ommitted.

Everything attaches to the main rod, which is threaded.

There are no piston seals. Instead, close fitting tubes are used for the two pistons. The water will lubricate them. There may be some leaking, but that will occur only during pumping, not when idle.

During the recovery stroke, the internal volume between the two pistons decreases and water is forced out of the upper flap valve.

During the pump stroke, the internal volume between the two pistons increases, thus sucking water in through the lower flap valve.

When the pump is idle, the leak back seal is lowered to sit tightly against the top of the inner pipe.

The bottom of the sliding filter is pointed to enable it to easily enter the inner pipe when the piston unit is lowered down the outer pipe.

The pressure of the water above the piston unit will force it downward during the recovery stroke. So rapid pumping is possible.

Attach the ring for the rope with a nut; don't weld it.

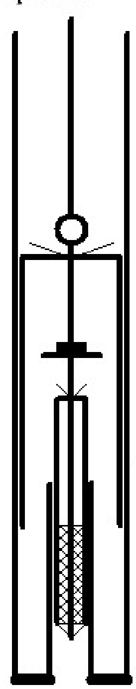
The cap holds the inner pipe in place relative to the outer pipe.

The flap valves are rubber circles cut from inner tubes.

The rod should be threaded stainless steel; the nuts too.

The sliding tubes can be brass or bronze or PVC.

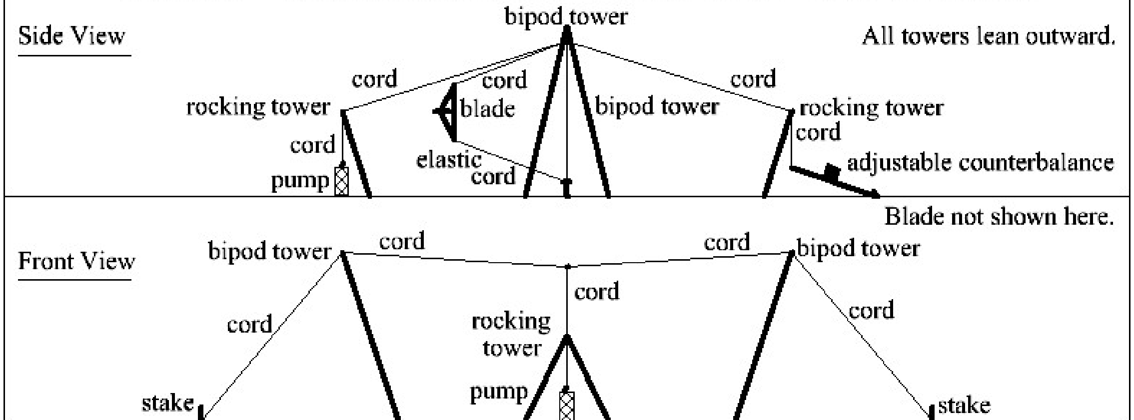
The filter material might be plastic scouring pads for dish washing cut into discs and stacked inside of the filter tube; very cheap.



3/20/11 Peter Allen Sharp

A note regarding the differential piston pump shown above: A wind pump engineer informed me that to reach greater depths, the flap valves should be changed to solid sliding valves mounted on the main rod. The pistons and filter can be easily pulled out of the well for maintenance.

BIRD WINDMILL 4 BIPOD TOWERS



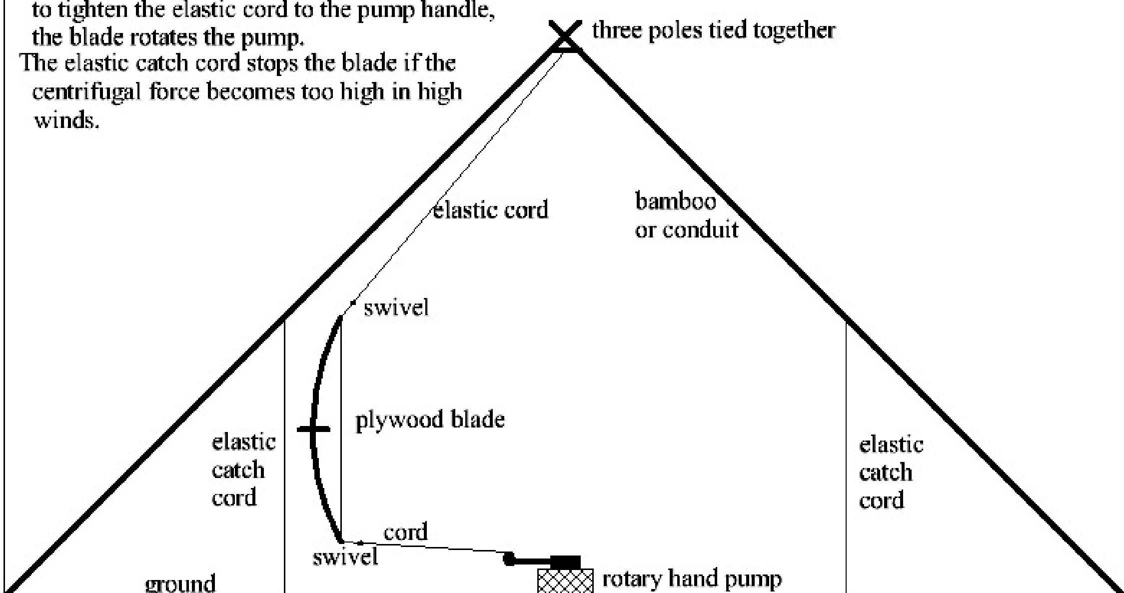
This is for a lift pump. Add a small weight to the pump handle to push the pump down. 12/13

The adjustable counterbalance is just a stick or a board with a weight tied to it, such as a bag of rocks.
The bipod towers next to the pump and adjustable counterbalance rock back and forth.
The closer they are to vertical, the higher their mechanical advantage for lifting.
A cord is tied between the bottoms of the two poles of each bipod tower to limit their spread.
The stakes are "T" shaped to make tying and adjustments fast and easy.
To minimize wear at the bottoms of the rocking towers, place their feet in tin cans partially buried.
The tops of the poles of the bipod towers are joined using a hinge binding similar to bamboo joints.
The tower tubes may be bamboo, metal conduit, or metal pipes. They need to be stiff and light.
The elastic cord from the blade may be tied to a stake in the ground. Or, it can be tied to the middle of a cord extending between the bottoms of the two fixed towers. Two more cords attach that point to the tops of the two rocking towers -- to maximize the pulling force of the blade.

Peter Allen Sharp

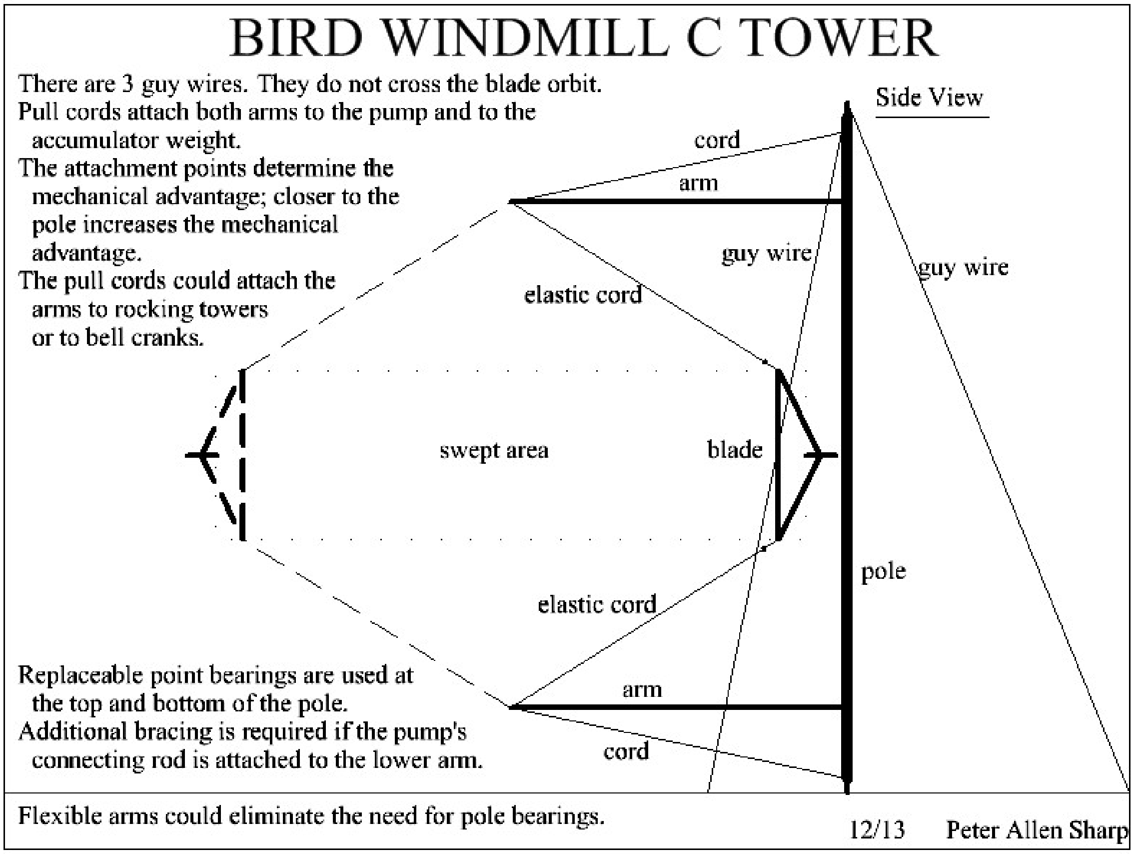
BIRD WINDMILL ROTARY HAND PUMP

The blade begins to orbit before the pump begins to rotate.
When the centrifugal force on the blade is sufficient to tighten the elastic cord to the pump handle, the blade rotates the pump.
The elastic catch cord stops the blade if the centrifugal force becomes too high in high winds.



7/12

Peter Allen Sharp


BIRD WINDMILL C TOWER
There are 3 guy wires. They do not cross the blade orbit.
Pull cords attach both arms to the pump and to the accumulator weight.
The attachment points determine the mechanical advantage; closer to the pole increases the mechanical advantage.
The pull cords could attach the arms to rocking towers or to bell cranks.
Side View
cord
arm
guy wire
guy wire
elastic cord
swept area
blade
pole
elastic cord
arm
cord
Replaceable point bearings are used at the top and bottom of the pole.
Additional bracing is required if the pump's connecting rod is attached to the lower arm.
Flexible arms could eliminate the need for pole bearings.
12/13
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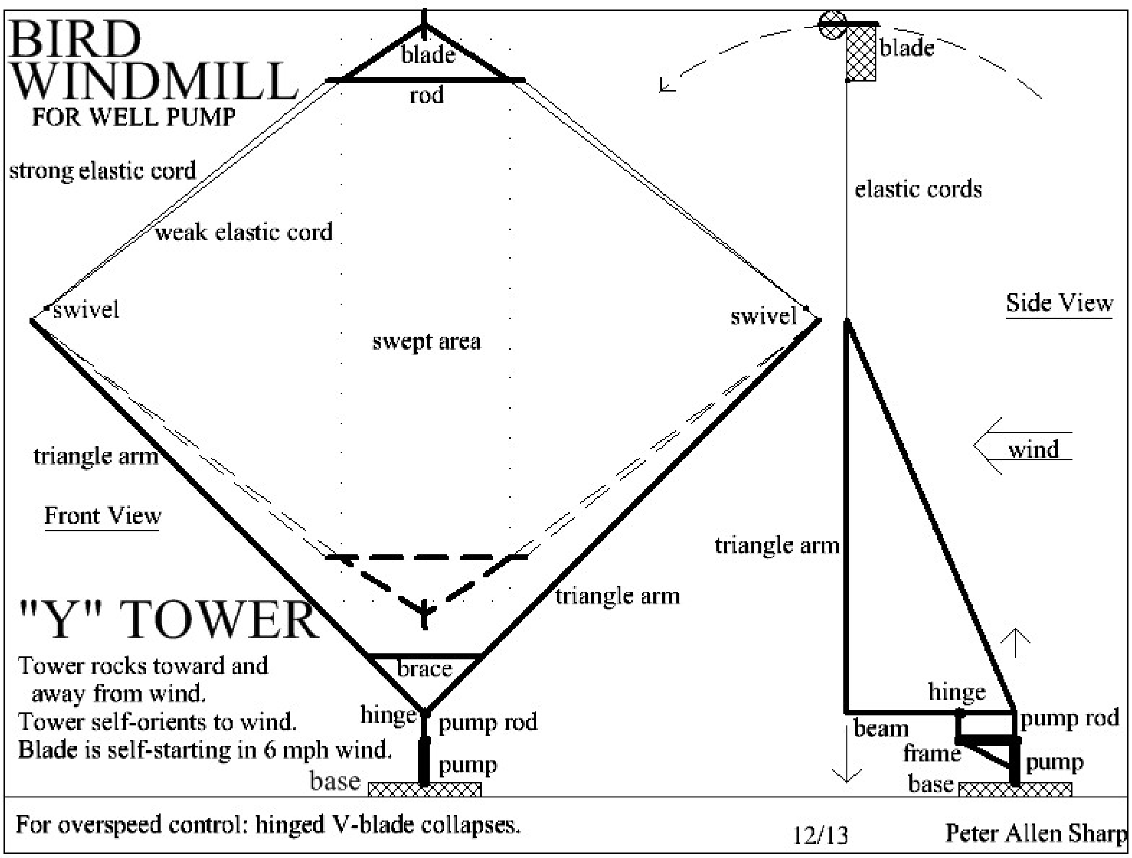
BIRD WINDMILL
FOR WELL PUMP
blade
rod
blade
strong elastic cord
weak elastic cord
elastic cords
swivel
swept area
swivel
Side View
triangle arm
wind
Front View
triangle arm
triangle arm
"Y" TOWER
brace
Tower rocks toward and away from wind.
Tower self-orients to wind.
Blade is self-starting in 6 mph wind.
hinge
pump rod
pump
base
hinge
beam
pump rod
frame
pump
base
For overspeed control: hinged V-blade collapses.
12/13
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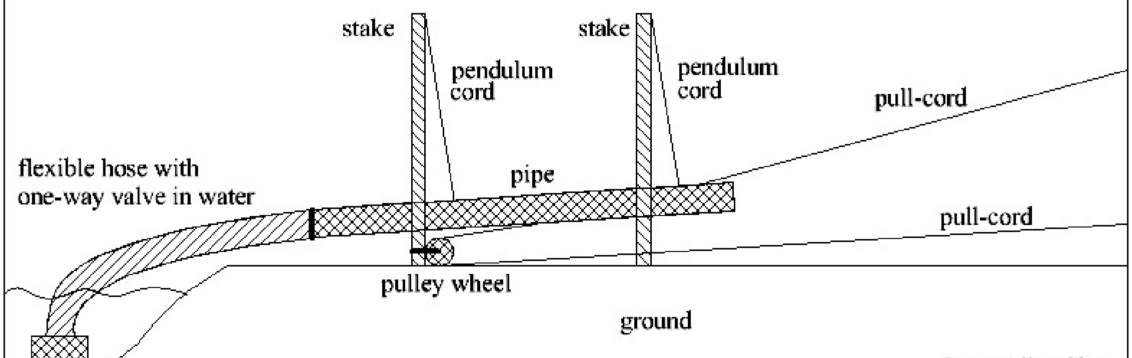
INERTIAL PUMP FOR LOW LIFT IRRIGATION

The pull-cords from the Bird Windmill alternate to cause the pipe to swing fore and aft longitudinally.
The pipe must be primed.
When the pipe swings forward, it imparts momentum to the water inside of it.
Water is sucked up through the one-way valve to refil the pipe during the discharge stroke.
During he recovery stroke, some additional water flows out of the pipe, and the hose flexes.
The pump can also be operated manually.
There are two pairs of stakes.
Adjust the natural pendulum frequency of the pipe to be higher than the rpm of the Bird Windmill.
We tested this concept using a 1' by 1/4" brass tube and it worked when oscillated manually.



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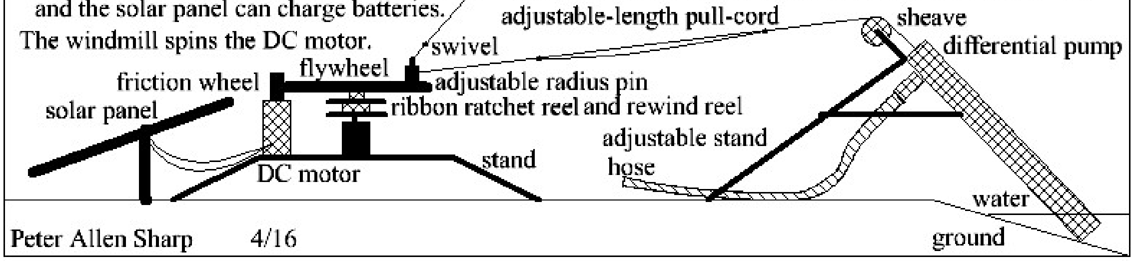
BIRD WINDMILL\SOLAR HYBRID PUMP

Three, guyed pole towers support the shock cord.
The blade orbit expands as the wind speed increases.
The blade has a built-in clutch action.
Both the blade and the motor spin the flywheel.
Water above the differential piston pushes it down.
The pump can be a long way from the windmill and the solar panel.
The pump legs detach so the pump can be lowered into a pit or well.
The sheave is then placed at the lip of the well.
The adjustable radius pin determines the stroke length of the pump.
The top of the pump is closed except for a small hole for the pull-cord, so the pump can force the water upward from the pump.
When not pumping water, both the windmill and the solar panel can charge batteries.
The windmill spins the DC motor.

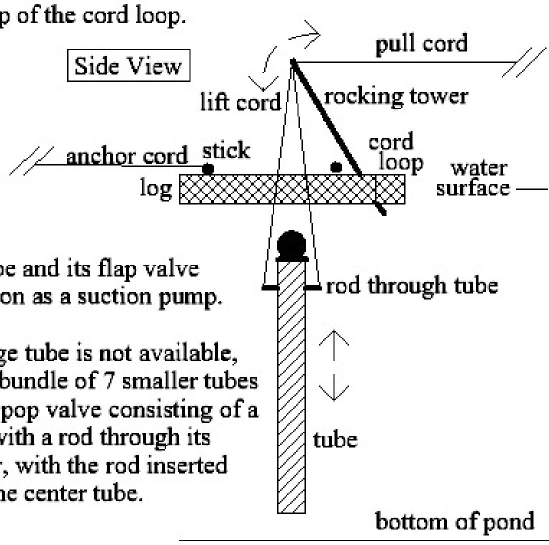
All of the parts are light and portable.
The solar panel can pivot and tilt.
The pump cord attaches to a bearing on the adjustable radius pin.
The ribbon ratchet reel enables a distant Bird Windmill to spin the flywheel.
The blade expands outward and downward as the rpm increases.
Two wheels can be added to the stand so that all of the parts can be easily carried together.
The blade can be equipped with an aero-dynamic transmission to provide lighting for night pumping and security.
For night pumping, store the panel and motor.
When no wind, spin blade manually with stick tied at X.

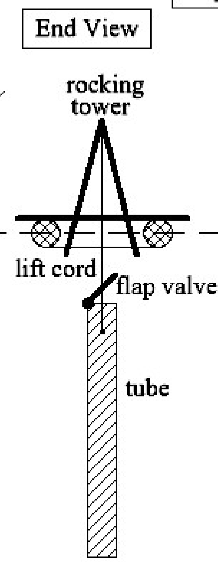


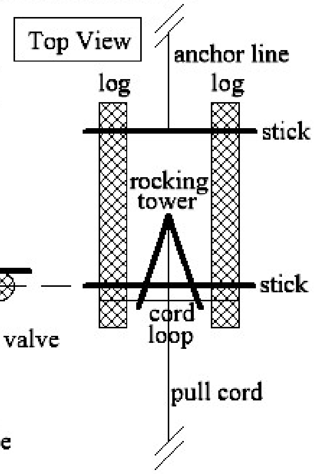
Peter Allen Sharp 4/16

BIRD WINDMILL POND AERATION

The bearing for the rocking tower is the bottom of the cord loop.
It twists back and forth.
The angle limits of the rocking tower are the stick and the top of the cord loop.







The tube and its flap valve function as a suction pump.

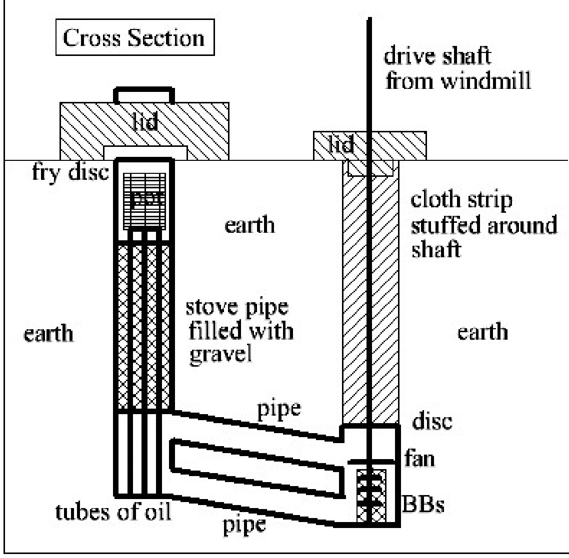
If a large tube is not available, use a bundle of 7 smaller tubes and a pop valve consisting of a disk with a rod through its center, with the rod inserted into the center tube.

The sticks are tied to the logs to create the float structure.
The anchor cord attaches to a peg on the shore opposite the Bird Windmill.
The angle of the rocking tower is adjusted to determine its mechanical advantage.

7/21 Peter Allen Sharp

WIND-OVEN/STOVE-TOP

Cooking can be done using only the stored heat once the heat storage is charged.
There are two parallel holes in the ground; one for the heat storage and one for the heat generator.
The heat storage is a stove pipe with caps, filled with gravel.
The heat generator is a can of BBs in vegetable oil stirred by metal rods on the shaft.
The depth of the rod in the can determines the resistance. A fan on the shaft circulates the hot air.
The cooking pot is placed on top of the stove pipe until the water boils for 5 minutes, then the pot is placed in an insulated container to continue cooking.



A removable disc with a hole for a frying pan fits into the top of the stove pipe.
The cloth strip around the drive shaft can be easily removed and replaced when servicing the BBs.

This wind stoves uses the earth itself as the insulation around the heat storage to minimize the total cost of the stove.

If any of the cloth insulation burns, it will consume the oxygen down in the holes and leave carbon dioxide, which is heavier than air.

The disc above the BBs slides out with the shaft.
It supports the cloth insulation above it.

A vegetable oil with a high smoke point is used in the can of BBs and in the tubes of oil.
The tubes (conduit) filled with oil insure rapid heat transfer required for frying.
A roof keeps the ground dry.
Add ash insulation around all hot areas.

4/16 Peter Allen Sharp

BIRD WINDMILL MONOHULL DRONE

The orbiting blade oscillates the masts, torque tube, and vertical fins.
The limit-lines are elastic; they allow the masts to heel while oscillating.
The orbiting blade also causes the horizontal fins to alternately rise and fall. So does wave motion.
The keels are weighted enough to resist the pull of the limit-lines, and to provide self-righting.
The drone is driven by both wind and wave simultaneously. The blade can also provide electricity.
The drone can sail in all directions, including directly upwind.
The bow keel/rudder steers. The fins and keels may be slanted aft to avoid snagging debree or weeds.
In a high wind, the masts will heel until the blade hits the water and stops, then restarts.
Since no tacking is required, and both wind and wave energy are used, the drone should have a relatively high average speed point to point. This drone should be extremely inexpensive and versatile.