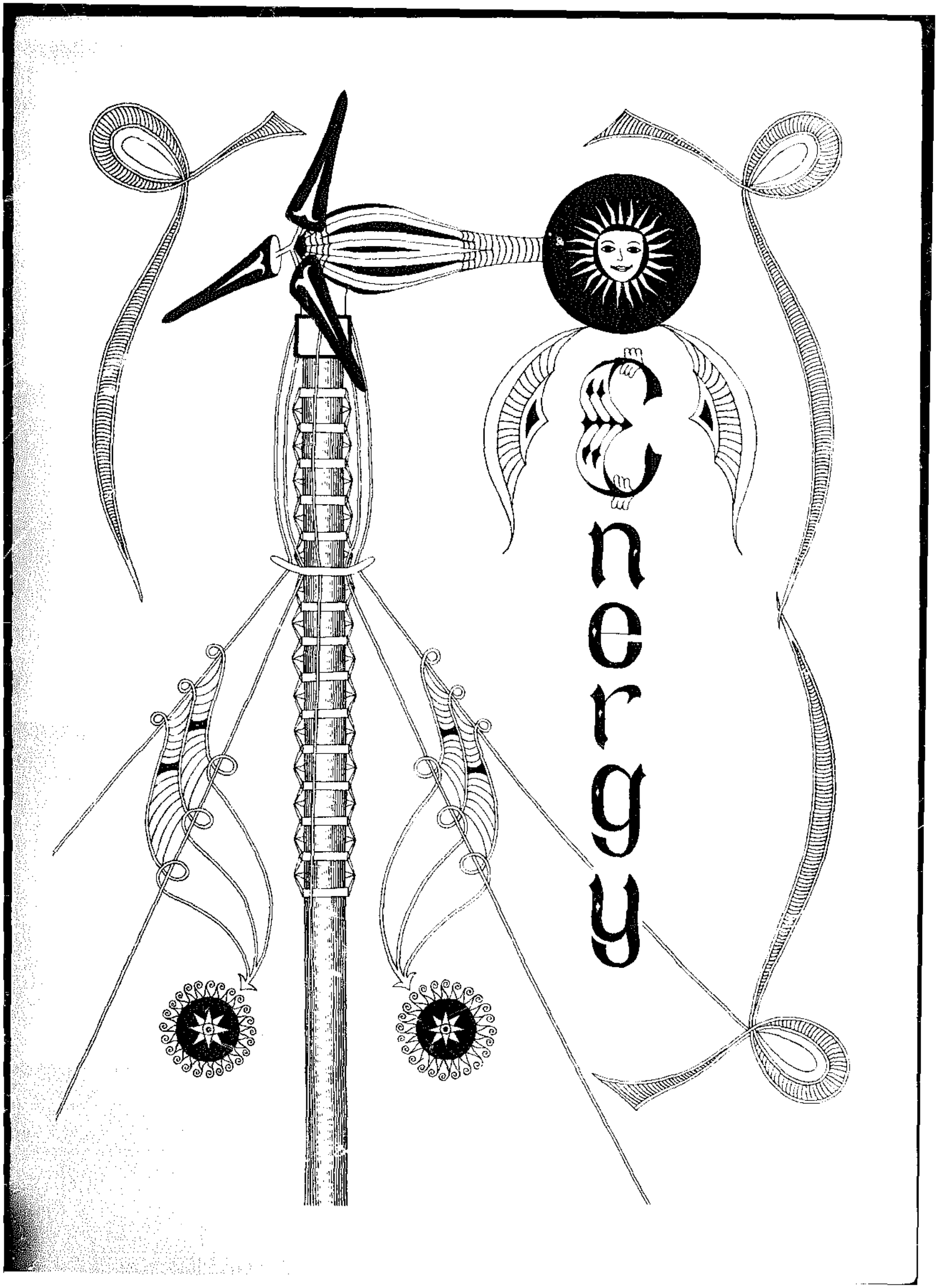
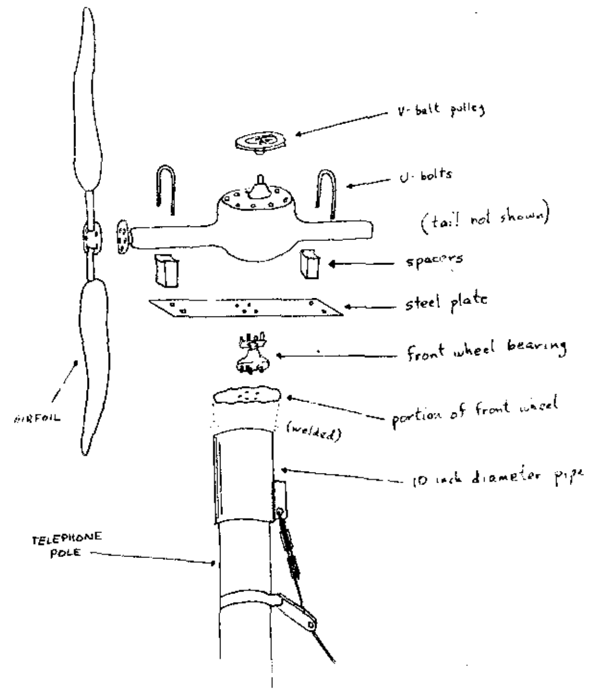

Energy

Wind Power



There are three windmills now on the brink of the hill overlooking the gardens though to someone unfamiliar with this peculiar form of ingenuity, they might as likely appear to be experiments in mobile sculpture. From the tails of two of them enigmatic suns smile down at us as they turn. The third, like a dislocated cylinder, consists of two canary yellow oil drums spinning around each other.

A good deal of our time and thought is spent on working with non-polluting energy sources, and on Cape Cod this has led to concentration on capturing the energy of the wind. Earle Barnhart and Marcus Sherman are our inventor-engineer-mechanic-tinkers in residence. As last fall wore on we would often find them thawing in the kitchen after being buffeted about on the windmill tower for as long as they could bear.

Their work is not without its moments of glory. Last November we were contacted by Peter Jones of the B. B. C. who planned to make a film about dissident scientists. We said that he might do any filming he thought appropriate at the farm. He arrived with his crew one blustering morning. Marc and Earle as usual were at their post at the top of the forty-foot tower. Windblown and heroic, they swayed on the high pole. After several hours of work, they sawed off the working platform, climbed down, then released the restraining ropes. The cameras whirred as we watched. After agonizing moments, for the first time, slowly, the blades began to turn.

But then it's not always like that.

Several experimental windmills are turning now to take advantage of one of the Cape's major energy sources. One is a large wind generator to produce electricity for tools and pumps, another a small wind charger to supply lesser amounts of electricity for radios or for a single storage battery, and a third is a Savonius rotor to produce mechanical energy for water pumping. All are designed to be low-cost and simple to make or to repair.

WIND TURBINE-GENERATOR

Tower: The tower is a 42-foot telephone pole, guyed by five cables to buried phone pole segments.

Mounting: The windmill's main pivot is the bearing and axle from the front wheel of a Rambler automobile welded to a thirty-inch section of 10-inch diameter pipe which fits over the top of the pole.

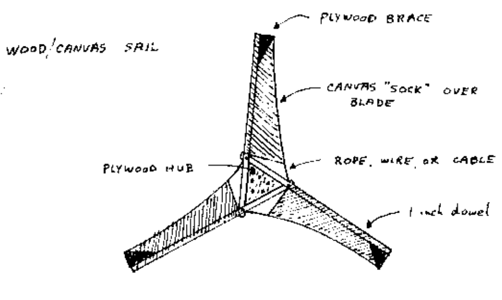
Power transmission: The rear differential and drive shaft unit from a discarded Rambler is the body of the windmill. It is U-bolted to a steel plate which in turn is bolted to the pivot bearing. (The drive shaft stub should not point downward or it will leak oil.)

Blades: The hub with attached blades is bolted to one end of the differential on the 5 original wheel-mounting bolts. Our first set of blades was designed and built by Bill Smith of Hull Cove, Rhode Island. They were 10 feet diameter, 2-bladed, fiberglass, high-speed airfoils, designed for 12 mph winds. Their starting torque was rather low for our 9 mph average winds, but they worked well and gave very high rpms. We also tried a 3-bladed medium-speed canvas sail prop which worked quite well until an ice-storm got it.

Electrical system: We put a belt-pulley on the drive shaft stub of the differential, and V-belted a 12 volt auto alternator to it. The differential is geared up 4:1 and the pulleys 3:1, giving us a 12:1 step-up in rpm from the blades to the alternator. With the turbine blade, this was enough; with the sail blades, more gearing is necessary. A 12 volt battery and a regulator are mounted on the differential to charge the field coils; electricity is then transferred to the ground via a cable.

Tail: A plywood tail is U-bolted on the differential opposite the blade end from which the axle has been removed.

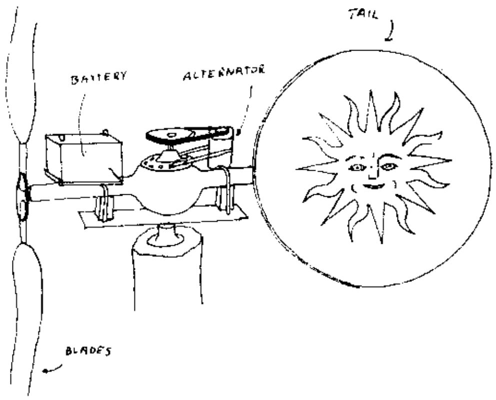
Changes: We are switching from high-speed fiberglass air-foils to medium-speed sail wing blades, adapted from the Princeton sail wing studies.[1] We'll have three blades instead of two, using aluminum shafts as the leading edge, taut cable as the trailing edge, and dacron wing surfaces. They will trail downwind



of the tower, probably at a slight dihedral angle for added stability. Higher gearing will be necessary (about 20:1), but we feel that a larger blade diameter (15 feet), simple construction, and less centrifugal stress will make the test worthwhile.

We are not ready to report on the electronics until the mechanics are completely worked out. From most reports in *Alternative Sources of Energy*[2], a simple cord running down from the generator is an acceptable alternative for slip-rings, needing only to be unwound periodically. We are still debating between a 12 volt or a 120 volt generator; in either case, golf-cart batteries will be used for storage because of their ability to take complete charge-discharge cycles and their relatively long life.

If you plan to use an auto differential, leave the brake drum on the hub end with which to stop the blades for inspection and maintenance. It is possible to let the emergency brake cable hang down within reach.

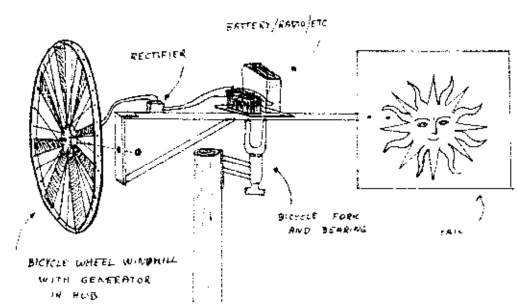


SMALL BICYCLE WHEEL GENERATOR

This windmill is useful where small amounts of electricity are needed as in running radios, cartridge players, or in charging storage batteries. It is made from a Sturmey-Archer Dyno-Hub bicycle wheel minus the tube and tire and has a small generator built directly into the hub. Eight blades are formed on the spokes by attaching sheet metal strips between adjacent spokes from the rim to the hub. The proper spokes are those which form slightly twisting blades nearly parallel with respect to the wheel at the rim and gradually turn to about 45° to the wheel at the hub. This shape is favorable aerodynamically to produce the high rpms for which the generator was designed.

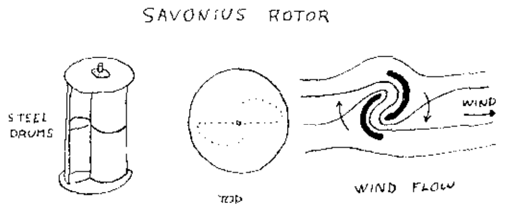
The wheel is mounted by one of the original hub bolts to a simple metal body made up of 1 inch of water pipe with a sheet metal tail on the other end. This is assembled and welded to a cut-off bicycle fork and steering bearing and attached to a fence post.

Output of the generator is 6 volt AC, and is changed to 6 volt DC by a diode and a resistor. A detailed circuit diagram and variations of bike generator windmills are in the U. N. energy conference, Volume 7[3].



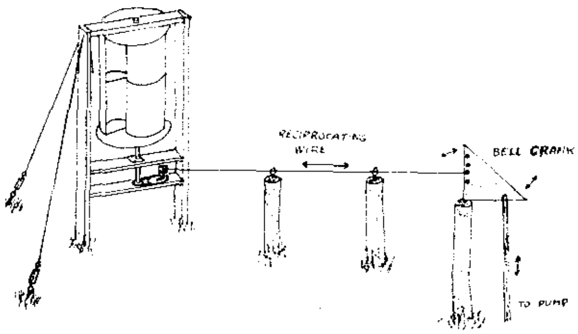
SAVONIUS ROTOR

The Savonius rotor, although only about half as efficient as a multi-bladed windmill of the same wind-sweep area, has several advantages that make it appropriate for home construction and use. It spins on a stationary, vertical axis regardless of wind direction and it is therefore a simple matter to take power directly from the rotor shaft. It is very simple and cheap to construct. Adjusting the diameter of the rotor wings varies the rate of spin in identical areas and wind-speeds.



Our present Savonius rotor is a variation of the Brace Research Institute's design[5], using 55-gallon steel drums cut lengthwise and welded into two off-set cup-shaped blades. Bearings at top and bottom in a guyed wooden frame complete the rotor. (A few hints: Use 4x4 inch lumber for the frame; balance the rotor carefully; and wire the turnbuckles when tight as they can vibrate loose.)

We coupled this system to a reciprocating wire power transmission, which was originally used by the Pennsylvania Amish to transfer power from a waterwheel[6], in order to pump water from our hand-dug well. A reciprocating wire transmits the energy from a bicycle crank below the windmill to a lever above the well. Each horizontal wire stroke is converted to a vertical pump stroke.



Using the Brace plans an optimum pump stroke can be calculated from the average windspeed, pump diameter, and height of lift. By choosing various ratios of the lever, we can set the windmill for different windspeeds. Experience has shown that a large crank with a long wire stroke will produce serious wire vibration problems as will a fast reciprocating frequency. We geared the windmill to the crank at a 2½:1 ratio and settled on a six-inch wire stroke. The wire supporting poles are 15 feet apart. we have our pumping system set to start in an 8 mph wind and pump between windspeeds of 6 and 30 mph. It pumps water into a storage pond at a head of 17 feet.

— *Earle Barnhart*

NOTES

1) *Popular Science*, November 1972.
   Aviation Week and Space Technology, November 13, 1972, p. 47

2) *Alternative Sources of Energy*, bi-monthly magazine, 2/year from Don Marier, Rt. 1, Box 36B, Minong, Wisconsin 54859

3) *Proceedings of the U. N. Conference of New Sources of Energy*, Volume 7, pp. 340-345.

4) *Mechanical Engineering*, Volume 53, No. 5, May 1931, "The Savonius Rotor and Its Applications" by J. Savonius.
   Mechanical Engineering, Volume 47, No. 11, pp. 911-912, "The Savonius Wing Rotor" by Alexander Klemin.

5) "How to Construct a Cheap Wind Machine for Pumping Water" (pamphlet) – A. Bodek.
   "Performance Test of a Savonius Rotor" (pamphlet) M. Simonds and A. Bodek.
   Both from: Brace Research Institute, MacDonald College of McGill Univ. St. Anne de Bellevue 800 Quebec, Canada

6) "Reciprocating Wire Power Transmission for Small Water Wheels"
   From the *Village Technology Handbook*, pp. 117-122 VITA, College Campus, Schenectady, New York.

A Windmill in India

While other members of the New Alchemy family were deciding to spend the winter in France, Costa Rica, California and good ole wind-swept Cape Cod, I chose to return to the nine acre peanut farm of my friend Tim Heineman in South India. Tim's farm is located outside of a small village among some rolling hills near Madurai, Tamilnadu state. During my previous stay at the farm in 1971 we had talked about installing a well and a water pump near Tim's mud hut so that we would not have to haul water manually in buckets up from the stream for drinking and cooking. At that time the only supply of water was a small stream flowing through the farm that goes completely dry during the winter drought and floods during the monsoon in the spring. Tim wanted the new pumping system to be able to irrigate a one acre vegetable garden all year round in addition to watering the cattle and supplying the hut. We realized that there were many problems to overcome if we were to install an independent, cheap and reliable water supply system.

In many parts of India including Tim's farm there are adequate supplies of ground water which are unavailable to farmers during the dry season because of inadequate power sources for pumping. Three to eight horsepower diesel pumps are frequently used but are expensive to operate because of the high cost of imported oil and often must be taken out of service for costly and time-consuming repairs. Efficient five horsepower electric pumps are being used more and more as rural electrification proceeds, but only well-to-do farmers can afford to buy and maintain them. This winter in South India there was a 75% power cut to the rural areas due to heavy consumption in the cities and to overexpansion of the power grid without a corresponding increase in supply. This power shortage means that there are only four hours of electric pumping per day. This situation is expected to worsen for the next four to five years until the Indian Government begins operation of atomic power plants in South India. At the present time bullock operated pumps remain the most common and reliable source of irrigation water for subsistence farming. Water for domestic use is usually hand-lifted with a rope and bucket from open wells.

During the early 1960's the Wind Power Division of the National Aeronautical Laboratory in Bangalore, Mysore, developed, tested and produced two hundred 12-bladed fan-type windmills which demonstrate the feasibility of using wind power to pump water to South India. Several types of imported European and American multibladed windmills have also been used to harness India's abundant wind energy resources. However, due to lack of public awareness and the unavailability of simple and inexpensive devices, wind power is only occasionally exploited.

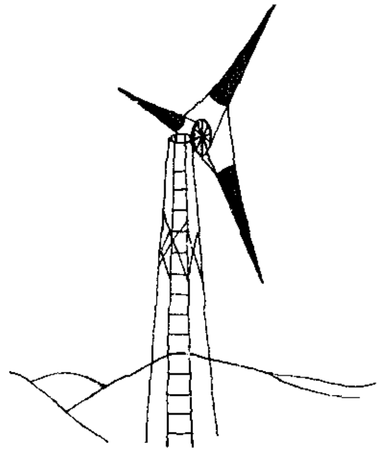
With these thoughts in mind I returned to the States for one year. While working at the New Alchemy farm on Cape Cod, Earle Barnhart and I built and tested a three-bladed cloth sail windmill which appeared to be simple and efficient enough for practical use on Tim's farm.

Cloth sails with a wooden framework have been used for hundreds of years for transforming the useful energy of the wind into labor-saving mechanical work, especially for grinding grain and pumping water. The use of windmills spread from Iran in the seventh century A. D. to coastal China where the application of the art of sailmaking significantly improved the sophistication of windmill construction. Heavy rigid wood windmill blades surfaced with cloth were used increasingly throughout northwestern Europe and by the seventeenth century the Netherlands had become one of the world's richest and most industrialized nations largely as a result of extensive exploitation of windpower with ships and windmills. Cloth was a natural choice for windmill sails because of its acceptance and wide use in sailing ships. It is lightweight, easy to handle, readily and cheaply available, and most important, it forms a strong uniform surface for catching the wind when firmly supported at three or more points.

In the Mediterranean region flour-grinding and oil-pressing mills were rigged with six to twelve triangular cloth sails set on simple radial spars. A three dimensional array of guy ropes radiating from a central spar projecting out along the axis of the main shaft, suspended the sails in position, rather than the heavy grid of wood used in the traditional Dutch-type windmills. This sailboat jib type of rigging was a significant improvement in windmill design which encouraged the spread of windmills throughout the deforested Mediterranean countries. The wind capturing area of these windmills was controlled by wrapping each cloth sail around its spar. Though requiring daily rigging adjustments and occasional replacement of tattered sails, the efficiency and simplicity of these windmills resulted in their widespread use in Rhodes, the Black Sea coast, the Aegean Islands and Greece. In Portugal their use was accompanied by the sound of whistles attached to the rigging, an audible indicator of the wind at work. In the West Indies large sailwing windmills were commonly used for crushing sugar cane. Many handcrafted windmills with eight triangular jib sails are presently pumping irrigation water in the Plain of Lassithi, Crete. In Japan four-bladed jib sail windmills are used to operate reciprocating pumps which supply water to vegetable gardens. A high-speed aerodynamic two-bladed sail wing is being developed at Princeton University. Further construction simplifications may make it applicable to use in less developed countries.

A windmill with four self-adjusting cloth sails has been developed by Mr. H. Stam for rural markets in less industrialized regions. Its relatively complex design is limited because of the difficulty in connecting it to a deep well pump. Unfortunately, it cannot be manufactured by hand using local materials. Those people who are in a situation to most benefit from a windmill are also those least able to pay for it. If the critical moving parts were separately available, a small farmer could purchase the remaining materials needed and assemble the windmill in his own village using local skills and labor. This way a major portion of the money spent would remain in the village.

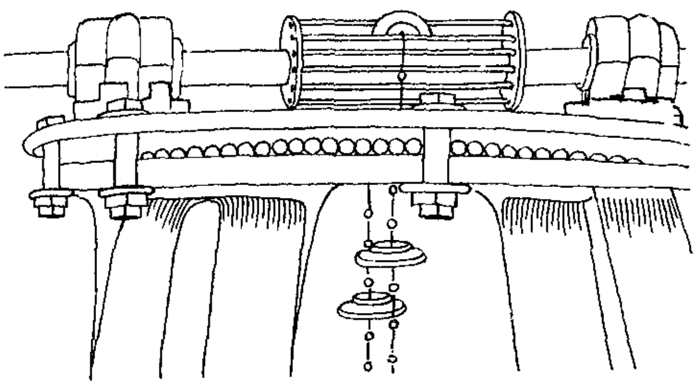
Upon returning to India this winter I discussed some of the problems of building a small practical windpowered pump with scientists at the Indian Institute of Agricultural Research in New Delhi. It was suggested that I



set up the windmill that I was planning for Tim's farm with a modified paternoster pump like those used to drain mines in England many years ago. I was given a working demonstration of some chain pumps at the I. A. R. I. and was told that a chain pump is easily and cheaply built and has the advantage of being more efficient than most other types of pump. Unlike some other pumps it operates well with a low speed variable power source like a windmill. Recently chain pumps have been replacing the traditional square pallet pump and the Noria water lifting wheel throughout China.

My friends in Delhi wished me good luck and I merrily proceeded on a delightful three day train ride by third class coach to the southern tip of the Indian subcontinent. I arrived at Tim's farm and we soon began construction of the windmill.

This sail wing windmill is made of a one-meter diameter bullock cart wheel to which three bamboo poles are lashed in a triangular pattern with overlapping ends. Each bamboo pole forms the leading edge of a wing, and a nylon cord stretched from the outer tip of the pole to the rim of the wheel forms the trailing edge. A stable and lightweight airfoil results from stretching a long narrow triangular cloth sail over that bamboo-nylon frame. This wing configuration, a hybrid of low-speed eight-bladed Cretan sail wings and high-speed two-bladed aerodynamic sail wings, produces high starting torque at low wind speeds. The bullock cart wheel is attached at the hub to the end of an automobile axle shaft which rotates in two sets of ball bearings. The shaft and bearing assembly is mounted horizontally on top of a turntable. The turntable consists of two circular steel plates separated with a raceway of ball bearings and held together with a ring of eight bolts which encircle the bottom plate. A one-foot diameter hole through the center



of the turntable will allow the chain and gaskets of the chain pump to go up and around the "squirrel cage" which is mounted at the center of the auto axle. If a reciprocating deep well piston pump were desired, the reciprocating rod, rather than a chain, would go through this hole and the crankshaft rather than an axle shaft would be mounted on top of the turntable. Since the blades have a slight built-in coning effect and the axle or crankshaft is mounted slightly off center from the center line of the turntable, the blades act as their own tail, trailing in the wind. Because the blades are downwind from the tower, there is no danger of the bamboo poles bending in a monsoon wind and hitting the tower. The tower is made of five 25-foot-long teak poles set in concrete at the base and bolted at the top to five angle irons welded at a slight flaring angle to the bottom of the turntable. The tower tapers in towards the turntable at the top from a seven-foot diameter at the base. It has cross bracing and a ladder.

This eight-meter diameter windmill lifts three hundred pounds to a height of twenty feet in one minute in a ten mph wind. This is accomplished by a rope passing over a six-inch pulley on the main drive shaft. This lift is now being used to raise soil and rock from the 20-foot deep well which is being dug below the windmill. When the well is finished the pulley will be replaced by the "squirrel cage" of the chain pump.

I hope that other people will continue to refine and adapt this windmill to their own needs and materials. If you have any inquiries or suggestions for improvement, I will be pleased to reply.

— Marcus M. Sherman