Energy

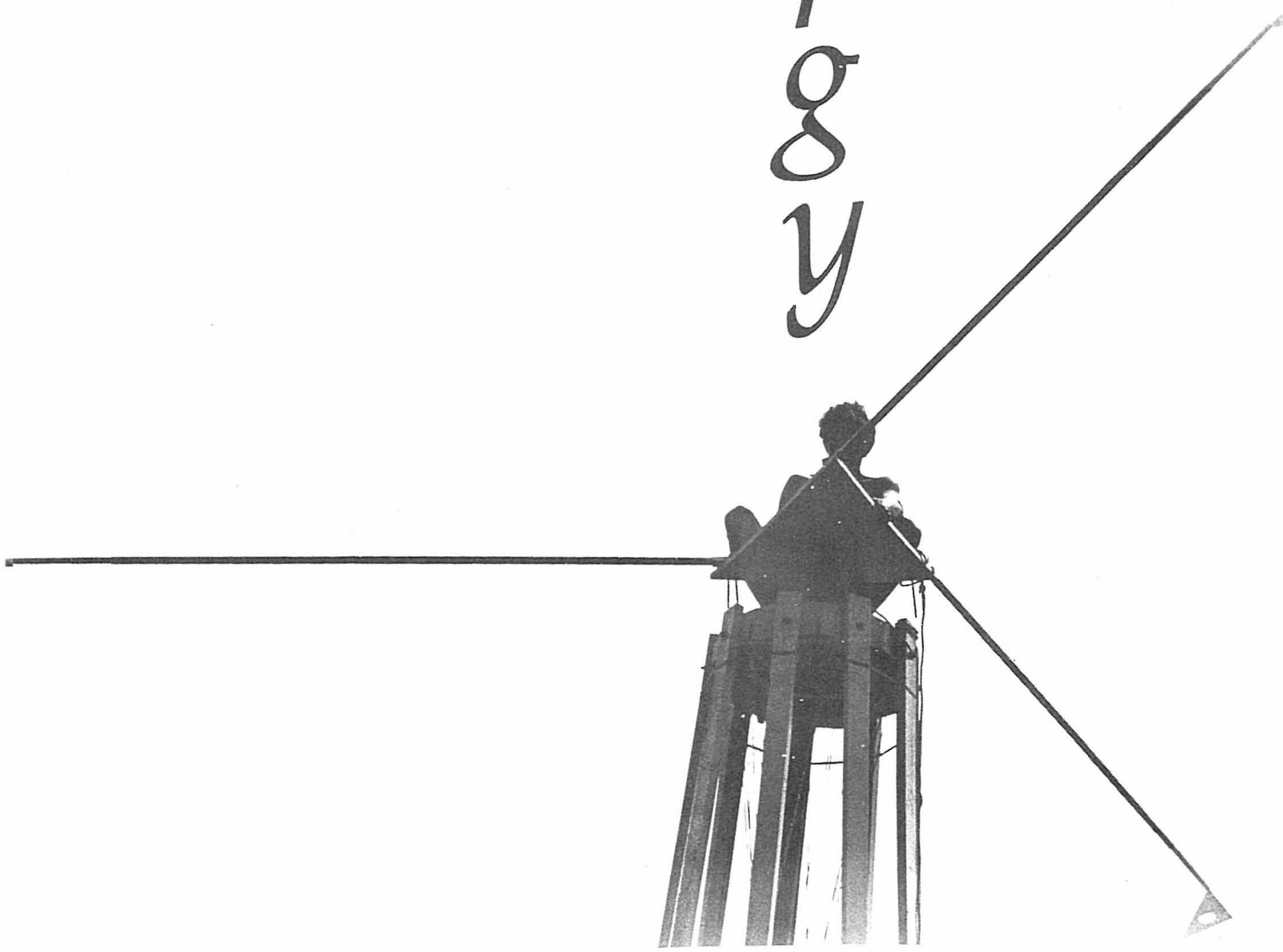
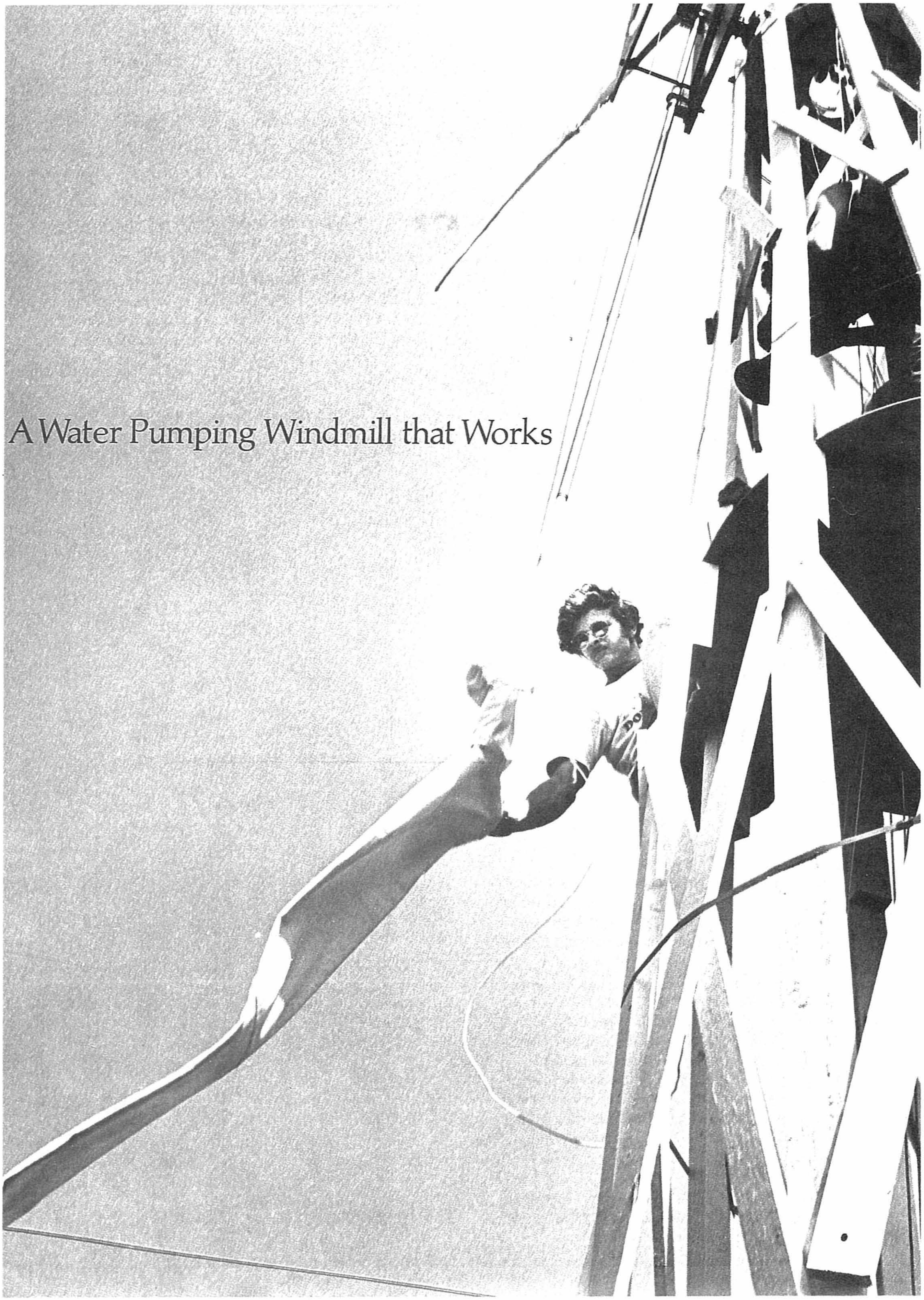


Photo by Alan L. Pearlman

We little thought, when we chose the title "Energy" for this section of the Journal, of how many shadings of meaning the word could be understood to have. I have seen it used to describe the positive force that believers in a New Age feel is growing swiftly now and will take us forward in an Aquarian Era of serenity and heightened awareness. Energy is spoken of to describe the impact of a personality or a group; of one's power to influence the people and events around one. It is still an apt term for what children have limitless amounts of.

We are still using it, in this section of the Journal, in a more traditional sense of the capacity to do work. At the same time, in doing so, we are deeply committed to working with as opposed to taking from nature, and, as this implies a contemplative approach of learning to listen to the wind and the sun and to growing things, then, perhaps when we chose "Energy" to describe our work, we half-intended some of the more subtle meanings to be understood as well.

— NJT



A Water Pumping Windmill that Works

Photo by Alan L. Pearlman

This windmill consists of three cloth sails attached to three tubular steel masts which are fastened to a triangular plywood hub. The center of the hub is bolted to the end of an automobile crankshaft which spins in bearings mounted on top of a steel ball-bearing turntable. The bearing turntable unit, which allows the windmill to rotate so that the sails are always perpendicular to the wind, is mounted at the top of an eight-legged tower which is firmly guyed and braced. A piston rod connected to the crankshaft transfers power through a reciprocating vertical steel pipe which runs from the top to the bottom of the tower where it operates a high capacity piston-type water pump.

The tower legs are bolted at the base to eight telephone pole sections which are firmly buried in the ground to prevent the tower from blowing over in heavy winds. This windmill is designed to remain operational and to withstand storm conditions. Ideally the cloth sails should be removed if severe wind conditions are anticipated. Our windmill was built to supply circulating water to a series of twenty experimental aquaculture ponds. It was required that the water in each pool be replaced once each day. Water pumping trials showed a yield of 250 gallons per hour in a 6 mph wind with 18' diameter blades applying power to a 3" diameter pump through a 3½" stroke.

7.481 gallons/ft^3

$$\frac{250 \text{ gph}}{7.5 \text{ g/ft}^3} = 33.3 \text{ ft}^3\text{/hr}$$

$33.3 \text{ ft}^3\text{/hr} \times 8 \text{ hr} = 266.4 \text{ ft}^3$ in 8 hr.

This figure is lower than the calculated pumping capacity of the windmill.

Because of this we recommend that a crankshaft with a greater stroke or a pump of a larger diameter piston be used. A new mill that we have just completed uses 2 No. 350 cast iron pumps mounted in tandem (Mid-West Well Supply Co., Huntley, Illinois).

Parts

PARTS SHOWN ARE NOT DRAWN TO SCALE

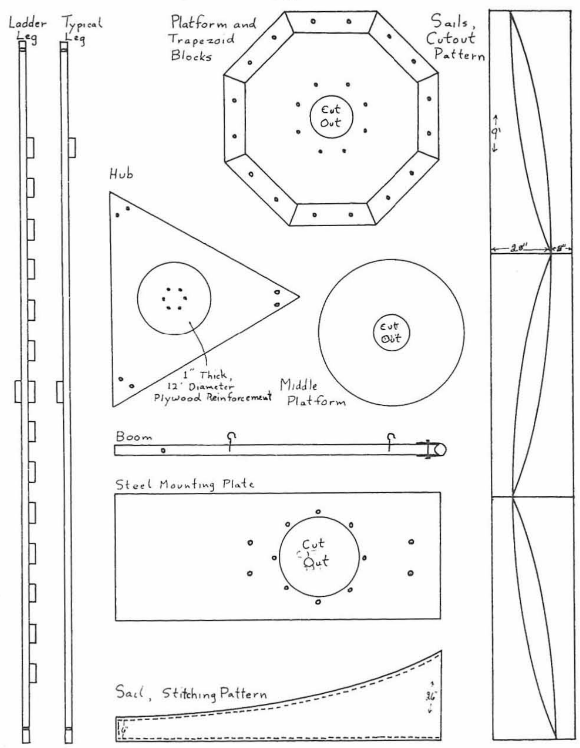
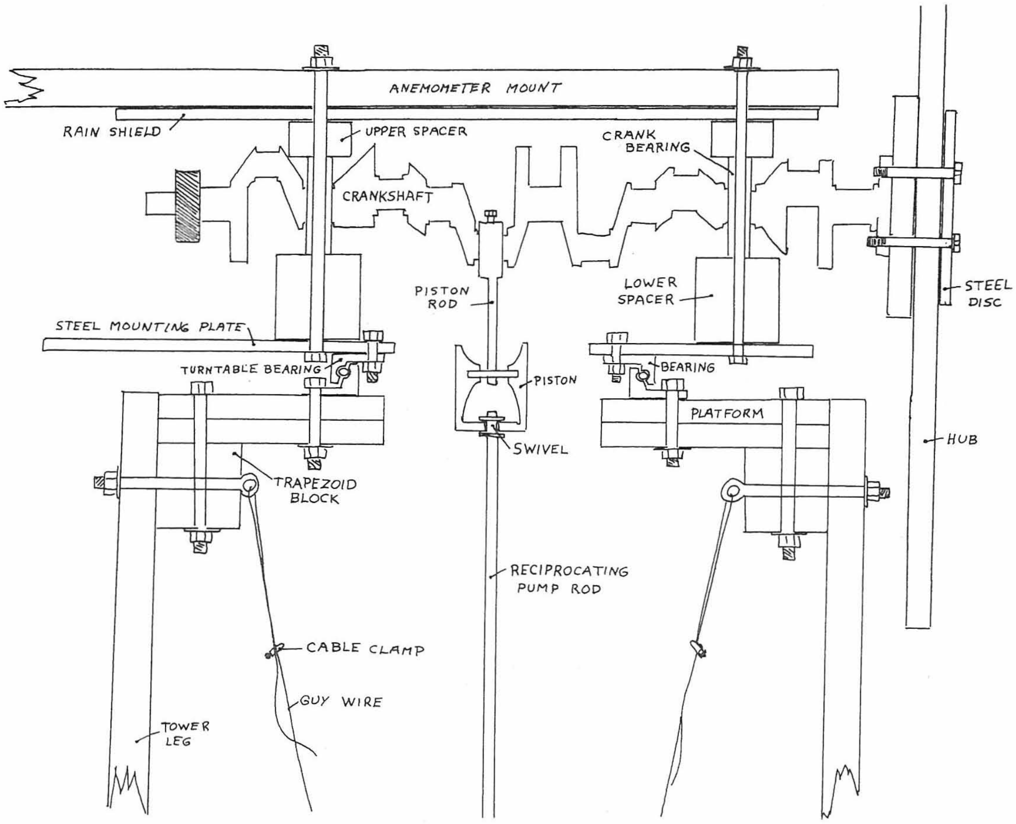
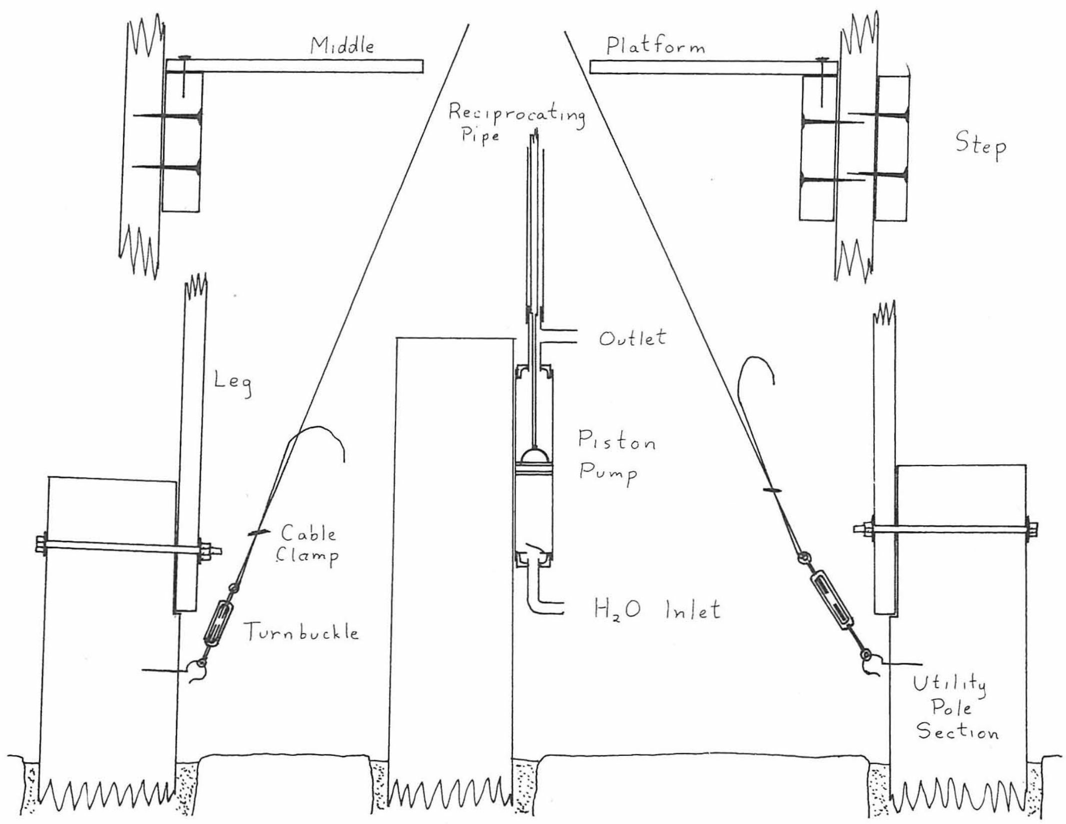


Photo by Alan L. Pearlman


ANEMOMETER MOUNT
RAIN SHIELD
UPPER SPACER
CRANK BEARING
CRANKSHAFT
STEEL DISC
PISTON ROD
LOWER SPACER
STEEL MOUNTING PLATE
TURNTABLE BEARING
BEARING
PISTON
PLATFORM
SWIVEL
HUB
TRAPEZOID BLOCK
RECIPROCATING PUMP ROD
CABLE CLAMP
GUY WIRE
TOWER LEG


Middle
Platform
Reciprocating Pipe
Step
Outlet
Leg
Piston Pump
Cable Clamp
H_2O Inlet
Turnbuckle
Utility Pole Section

Materials in Order of Assembly:

BASE

8 - 6' sections utility pole (or railroad ties), concrete optional depending on hole depth

8 - 12"x ½" galvanized machine bolts, 8 nuts, 16 washers

8 heavy galvanized screw hooks to secure turnbuckles to base

TOWER AND TOP PLATFORM

8 - 26' x 2" x 4" spruce for tower legs

8 - 8" pieces 2" x 4" spruce to secure middle platform to inside of legs

16 - 8" pieces 2" x 4" spruce for ladder steps on outside of one leg

8 - 8" pieces 2" x 4" spruce for foot holds around top of tower

½ gross 2½" No. 10 galvanized wood screws

2 - 1" thick, 28" wide plywood octagons for top platform

1 - 10' x 3½" x 3½" spruce for making 8 wooden trapezoid blocks to secure platform to legs

16 - 7" x ½" galvanized machine bolts, 16 nuts, 32 washers, to secure trapezoid blocks to platform

8 - 6" x ½" galvanized eye bolts, 8 nuts, 16 washers, to secure top of tower legs to trapezoid blocks and to provide attachment for top of guy wires

16 - 27' lengths of t-v antennae guy wire for internal guying of tower

32 cable clamps to form loops at ends of guy wires

Several strong persons and 100' strong rope required to set tower in place, gin pole helpful

1 - 48" diameter ½" plywood disc for middle platform

16 guy wire turnbuckles

16 - 56" pieces 1" x 3" spruce for lower bracing of tower

1 - 8' piece ½" nylon rope with eye splices and safety clips (for safety line)

At least one capable person who is not afraid of heights

16 - 40" pieces 1" x 3" spruce for upper bracing of tower

1 gross 12 penny galvanized screw nails to fasten bracing to tower legs

TURNTABLE AND DRIVELINE UNIT

1 - Model No. M4-12P4 series 1000 Econotrak bearing (9" inside diameter) from Rotek Inc., 220 West Main Street, Ravenna, Ohio 44266 (about $129.00) with 6 holes (½" diameter) bored equidistantly in both top and bottom bearing ring segments

1 - 36" x 14" x ½" steel plate for mounting crankshaft on top of turntable bearing. A hole approximately 9" in diameter must be made in this plate through which the piston rod extends to connect with reciprocating rod

6 - 1¼" x ½" galvanized machine bolts, 6 nuts, 6 spring lock washers to secure steel mounting plate to top of turntable bearing

1 large stroke auto or truck crankshaft with 4 of its bearing retainers. An 8 cylinder crankshaft is preferable.

2 - 6" x 3½" x 3½" spruce blocks for lower bearing spacers

2 - 8" x 1½" x 3½" spruce blocks for upper spacers

1 - 36" x 14" x ½" plywood for rain shield

1 - 8' x 1½" x 3½" spruce for anemometer mount

4 - 12" x ½" galvanized machine bolts to secure anemometer mount, rain shield, upper spacer crankshaft, bearings and lower spacer to the steel mounting plate, 4 nuts, 4 washers and 4 lock washers

6 - 3" x ½" galvanized machine bolts to secure bottom of bearing to platform, 6 nuts, 6 washers, 6 spring lock washers

1 piston and piston rod unit to connect crankshaft to vertically-reciprocating pipe

1 - 20' length ½" galvanized pipe to connect piston at top to pump at bottom

4 - ½" pipe thread screw collars and 2 - ½" inside diameter heavy polyethylene washers to secure top of pipe in hole in head of piston for swivel mount

1 adaptor to connect ½" pipe threads to 3/8" machine threads on pump rod

PUMP UNIT

1 - 8' section utility pole (or railroad tie) set in ground off center of line of travel of vertically-reciprocating pipe (pump cylinder is mounted on this)

1 Model No. 81 brass-lined pump cylinder No. 380-1-3021 from Demster Industries Inc., P. O. Box 848, Beatrice, Nebraska 68310 (about $45.00), or any large diameter piston pump or Model No. 350 Shallow Well Cast Iron Cylinder from Mid-West Well Supply Co., Huntley, Illinois (about $18.50).

1 "T" joint for outlet of pump

1 - 1¼" check valve for bottom of intake pipe

Adequate 1¼" plastic piping for inlet and outlet of water

HUB-BLADE UNIT

1 - 1" thick plywood equilateral triangle 30" on each edge for hub

1 - 12" diameter 1" thick plywood circle to reinforce center of hub

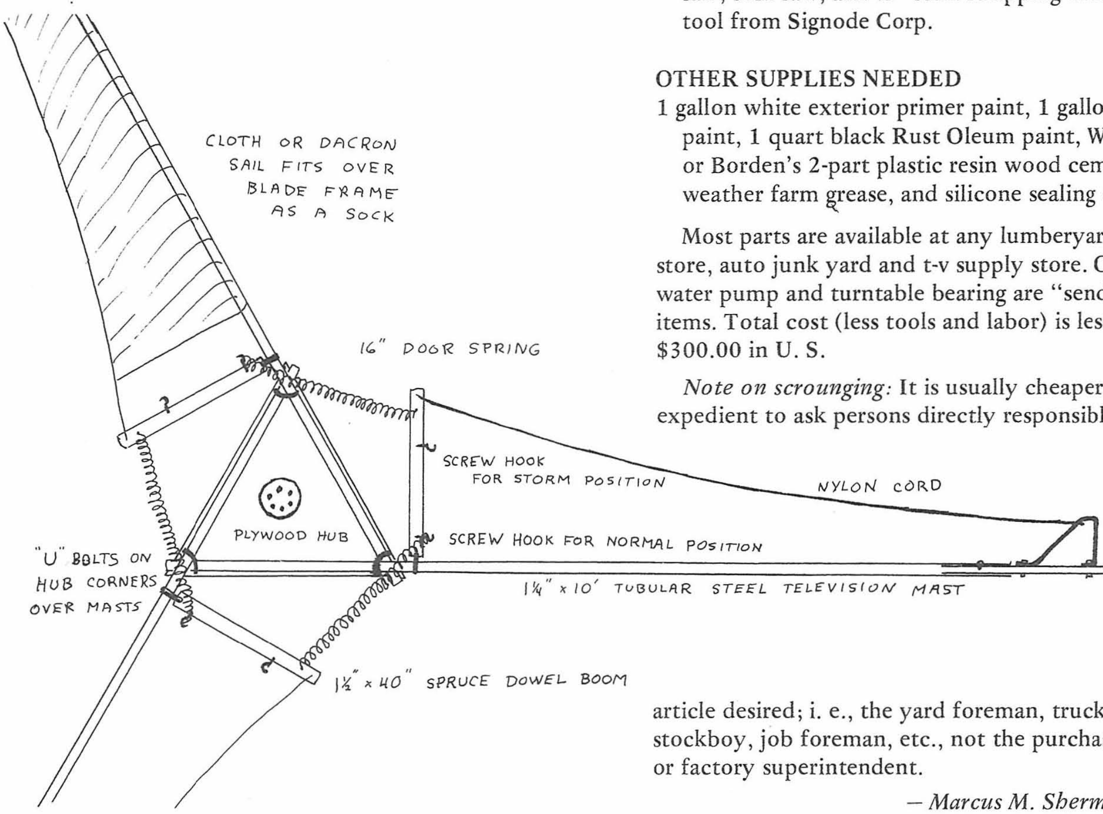
1 - 9" diameter ½" thick steel disc to reinforce center of hub (from hole in steel mounting plate)

3 - 10' long 1¼" tubular steel t-v antennae masts for windmill masts (arms)

3 - 1½" spread "U" bolts made from 3/8" threaded rod to secure masts at hub corners

3 - 1½" inside diameter galvanized steel pipe sections 6" long to prevent "U" bolts from crushing masts

6 wooden wedges 12" long, 1½" wide, 1" thick at fat end to adjust coning angle of masts to prevent collision with tower
3 - 2' x 1" steel tubing for mast extensions
3 - ¼" thick, 1" wide 21" steel straps for tip of mast extensions



12 - 1½" x 3/8" machine bolts to attach steel straps to tip of mast extensions, 12 nuts, 12 spring lock washers
3 - 2" cotter pins to secure mast extensions within masts
3 - 32" pieces 1" spruce dowel for booms at base of masts
3 - 1" x 8" medium gauge galvanized sheet metal strips to secure booms to masts
3 - 16" door springs for automatic pitch control
9 medium screw hooks to secure door springs to booms
3 - 12' long pieces nylon cord to form trailing edges of sail blade frames
9 yards muslin, cotton or dacron sail material

OPTIONAL ITEMS
1 anemometer (recording)
1 water meter
Water storage tank(s)

TOOLS NEEDED
Bit brace, chisel, cross-cut wood saw, hammer, level, open-end wrench set, paint brushes, post-hole digger, screwdrivers, sewing machine, shovel, socket wrench set, 9/16" wood bit, and wood clamps; *Optional:* electric drill (heavy duty), high speed drill set, jig saw, skill saw, and ½" steel strapping and tensioning tool from Signode Corp.

OTHER SUPPLIES NEEDED
1 gallon white exterior primer paint, 1 gallon exterior paint, 1 quart black Rust Oleum paint, Weldwood or Borden's 2-part plastic resin wood cement, all-weather farm grease, and silicone sealing compound

Most parts are available at any lumberyard, hardware store, auto junk yard and t-v supply store. Only the water pump and turntable bearing are "send away for" items. Total cost (less tools and labor) is less than $300.00 in U. S.

Note on scrounging: It is usually cheaper and more expedient to ask persons directly responsible for the article desired; i. e., the yard foreman, truckdriver, stockboy, job foreman, etc., not the purchasing agent or factory superintendent.

— Marcus M. Sherman

POSTSCRIPT

Testing of the mill: Since the article was prepared we have had an opportunity to test the sailwing windmill for ruggedness and pumping ability.

The windmill, with the cotton sail blades of 18' diameter, did indeed pump 250 gallons per hour in 6 mph winds. The water was pumped up 14' from a lake below the windmill. Our calculations and direct observations indicated that our pump was considerably undersized for the windmill. A larger stroke or a larger diameter piston pump would have been desirable. Our latest sailwing windmill, with sails designed by Merrill Hall, has two pumps mounted side by side (see drawing of advanced backyard fish farm mill) and we may yet add additional pumps.

Cotton versus dacron sails: During the winter trials the cotton sails did not stand up to continuous operation through storms and high winds. We decided to try dacron sails as dacron is a much longer-lived material, holds its shape better, does not absorb water during rains and is much stronger and lighter than cotton.

Photo by Alan L. Pearlman

These are important factors when it comes to the design of large sailwings.

Merrill Hall made us a set of 3.8 oz. dacron sails to Marcus Sherman's design. From visual observations they seem to perform better than the cotton sails did. They are steadier and have a better configuration while driving in heavy winds.

It was not long before we had a chance to test the dacron sails. With the feathering springs set in their storm position (see sailwing diagram) the mill came through a force nine gale (40 knots-plus winds) and continued to pump throughout the storm. The next gale arrived a few days later accompanied by freezing rain. This time we decided to leave the feathering springs in their full working position. The mill, to our great pleasure, was still pumping when the storm abated. The strong sails and Marc's spring feathering system have vindicated themselves, and since the last gale, a number of severe storms have been weathered.

Post Postscript

We have recently learned that dacron is not superior to cotton for use in tropical areas, although coloured dacron has proved more durable than white.

Problems: During high winds, bolts and screws, including those on the end of the crankshaft, shake themselves loose. We replaced the hub bolts with longer ones so that lock washers and nuts could be placed on the crankshaft side of the hub. If you plan to have your windmill operate during high winds, we advise that you do not skimp; get quality materials and build it to last a long time, perhaps even a lifetime.

The windmill as accomplice and ally: Our sailwing windmill with its bright red sails has brought us an immense amount of satisfaction. Having it around makes us feel better, and there is something almost magic about working with the wind. At the bottom of the tower with the wind passing through the rigging, one is carried off to the plains of Crete and to distant shores where men first used the wind to drive their vessels and embark upon the unknown.

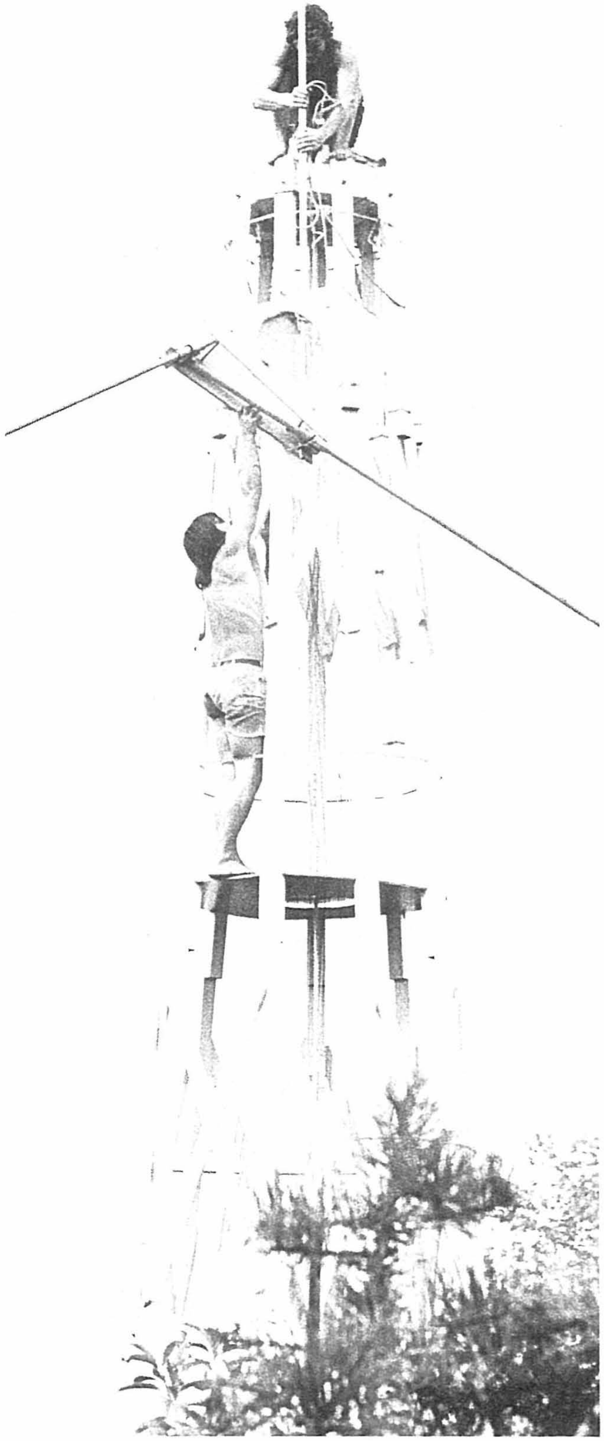
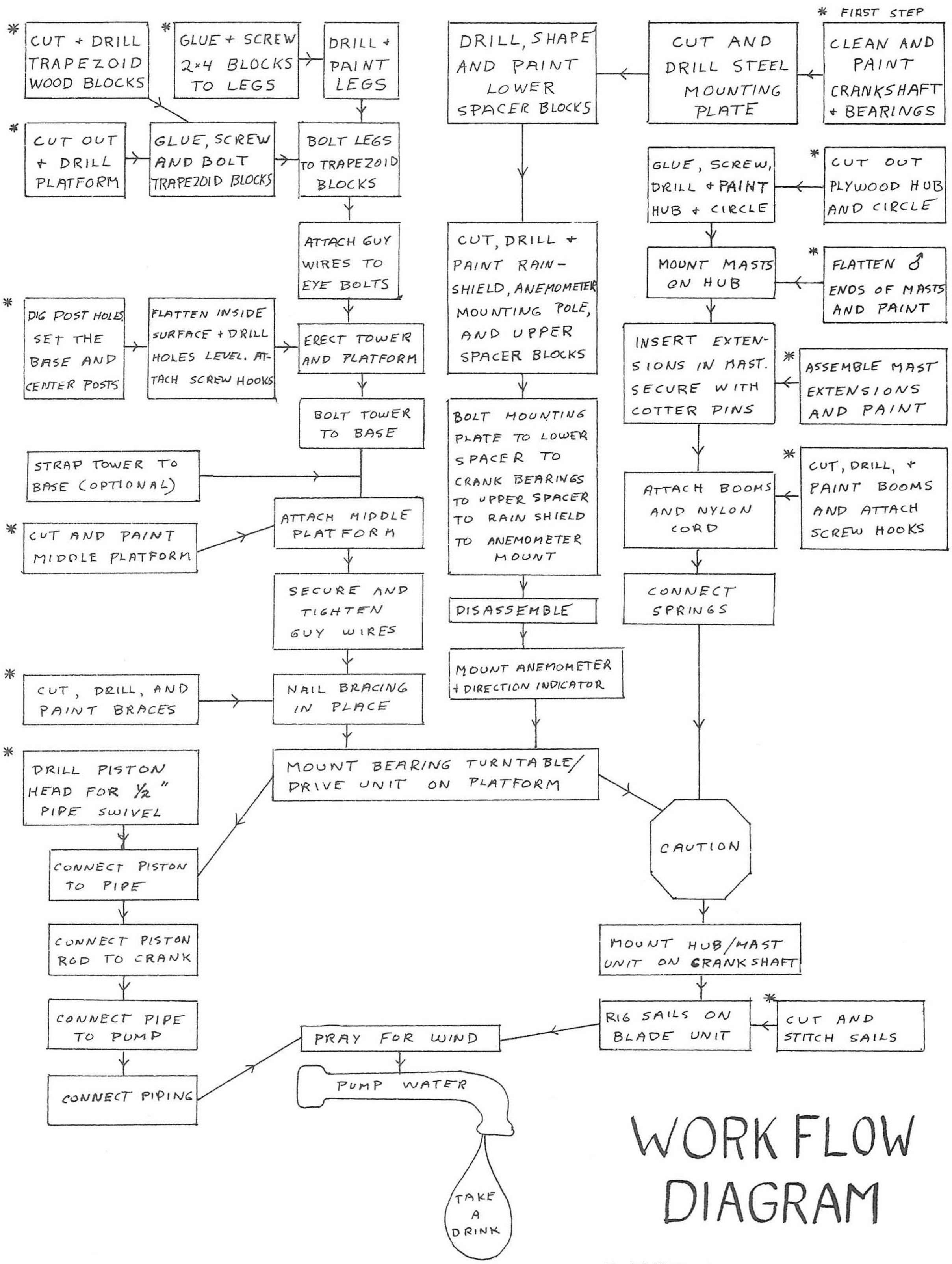
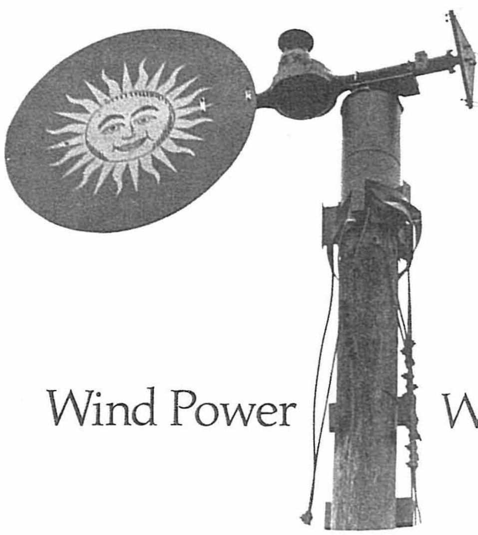


Photo by Alan L. Pearlman



WORK FLOW DIAGRAM

* JOBS ARE FIRST IN SEQUENCE



Wind Power

Windmill Electronics

Photo by Alan L. Pearlman

In Journal 1, we introduced the design of a home-built windgenerator made of recycled automobile parts, with details of the tower, swivel, transmission, and other mechanical parts. In the following article by Fred Archibald, we continue the development of the windmill by discussing the electrical system. The following diagrams and excellent technical advice allow the basic mechanical windmill to be adapted to several power ranges to suit the needs and situations of the builder. Equally valuable information is given concerning batteries and storage.

January 6, 1974

Dear New Alchemists:

I have been following your work with interest, and a little sense of participation, as I came up with the idea for the automotive differential-wheel spindle basis for a wind generator. Marc Sherman and I spent a long time discussing the system, both in the fall of '72 when the thing was started and this last Christmas. I have investigated the problem a bit further and hope that the following information, mainly on the electrics of the thing, will be of some use to you or your readers.

There are a number of problems associated with producing useful amounts of electric power from the wind for any length of time, if money is a consideration.

1. A constant voltage must be produced from a mechanical energy source (the propeller) varying from a few RPM to several hundred RPM.

2. A constant AC frequency of 60 CPS must also be produced from this variable speed source if standard appliances are to be used, and AC power frequency depends on AC generator speed.

3. The system must be able to withstand extremes of vibration, temperature, water and ice, corrosive salt spray and hundreds of thousands of revolutions with little maintenance.

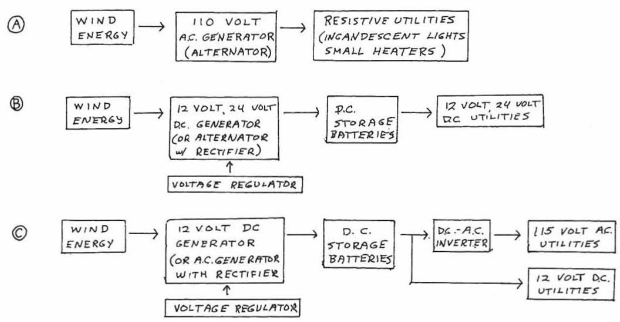
4. It must be designed to extract as much energy from the wind as possible and transfer it efficiently to the utilities to be run.

5. As wind conditions, terrain, facilities, and power requirements will be different with nearly every installation, blade size and design, tower height, and the generator:propeller mechanical ratio will be more or less specific for the site.

6. The components must be fairly cheap, very rugged, and widely available.

Cutting corners on Nos. 3, 4 and 5 will make the whole project a great waste of effort. Really, if you don't have the time or facilities to do this thing right, it will only be a toy.

There are many possible generation systems, but the three thought most practical for a small home-type system are:



System (A) is the simplest, but an AC generator run off the wind will have widely varying frequency and voltage which would damage most appliances. Only resistive heaters and incandescent bulbs would be usable, and these would flicker on and off with the wind.

System (B) is the simplest system with storage capacity. A number of commercial wind systems use this. DC power is available at a regulated level, usually 12 or 24 V, even when the wind isn't blowing, and can be used for a wide variety of lights, motors, small heaters, and radios. Many of these things can be bought or scrounged from old cars (12 V) or ordered from automotive or marine supply houses. A small 12V DC refrigerator is even made for marine use. However, the low voltage means high currents and therefore very heavy wire is needed. For instance, Edison calculated that it would take several *tons* of copper to light the houses in a city block using 10-volt bulbs in a 10-volt system. Therefore unless a great deal of heavy cable (like auto starter or 200 AMP arc-welder cable) is available, only small devices (< 50 watts) or ones very near the generator are feasible.

System (C), while the most complex, is the only one providing reliable power compatible with all the utilities in use commonly. The DC storage provides constant power whether the wind is blowing or not, and in turn allows the capture of wind energy when the electrical devices are not being used, which in a system without storage ability would go to waste. Both 12V DC and 115V AC utilities can be run directly and even European 230V AC ones with the simple addition of a transformer. The only limitations on this system are the *amount* of power produced daily, and the current or wattage rating of the inverter. Such a 115V AC system could be plugged directly into a house by pulling out the main circuit breaker or block of cartridge fuses and connecting the inverter directly to the house side of the circuit.

There are infinite variations on these three, depending on what's available, like 28V DC surplus aircraft generators, arc-welding generators, etc., but these are the basic alternatives open.

I won't discuss System (A), because it is the simplest to construct (electrically anyway) and is fairly useless except for heat production, and as even small heat-producing appliances like an iron or toaster use 750-1500 watts each, a very large generator and propeller would be needed to heat even a small building or fish pool.

The 115V AC system is just the 12V DC system with the inverters added, so it might be feasible to start with the 12 V system and later add the inverters. The solid state ones are around 70% efficient, i. e., 1000 watts of 12-volt DC power (83 AMPS) will produce 700 watts of 115V AC (about 6 AMPS).

The reliability needed in a fairly complex system like this is only possible with a really rugged well-designed generating system, and unless you have considerable engineering and technical facilities available to you, the best thing to do is adopt an entire system from another application. The only such system available and meeting the ruggedness, cheapness, and availability requirements is the modern automotive one. Only the automotive one is temperature-compensated to work from -40° to 260°F, go thousands of hours maintenance-free, and resist water, dirt, grease and exposure. If this doesn't sound like the generating system in your old car, it's because there have been some very significant improvements in the system since 1969, mainly the integrated circuit (IC) regulator.

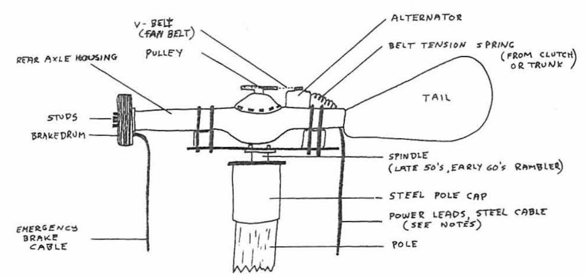
These new systems employ an alternator (AC generator) with an internal rectifier bridge to produce DC and an IC regulator, often also within the alternator unit itself (on '72–'74 units). These alternators come in a number of power (wattage or amperage) ratings, and for the wind generator, the higher the better. Sixty AMPS is the largest common size on big American cars and the best for this application. Sixty AMPS at a nominal 12 volts is 720 watts (generators actually put out 13-14 volts). This is the peak continuous output of 1 unit. As can be seen in the accompanying diagrams, 1, 2, 3 or 4 of these can be accommodated by the design, giving peak outputs of <u>720</u>, <u>1440</u>, <u>2160</u> and <u>2880</u> watts. In assessing the amount of power you need, it is very important *not* to compare directly the wattage ratings of the utilities to be used to these peak output values. The important figure is the *average* power output of the wind generator through 24 hours of the day. If optimal propeller and generator design will only produce 400 watts average (actually quite a good figure), then whether the peak potential power is 2160 or 2880 watts is not very significant, unless your area alternates between calm and very strong winds to get this average. To obtain a good average output, proper blade design, gear ratio, tower, and generator cut-in speed are all-important. The power capability of the system depends on the *length of time* used, at least as much as amperes consumed by utilities, and the storage capacity of the batteries. Even the average power produced is wasted if there is not sufficient storage capacity to hold it and few utilities are being used. In other words, a system producing only 100 watts average output would have stored 2.4 kilowatt-hours a day, if the battery system is adequate, easily enough to run a stove once or twice a day. Actually this would take a large DC-AC inverter, and so such large heating jobs should better be left to DC or other energy sources. The principle, though, is important; a small, continuous power input to a good set of batteries will provide adequate power for high consumption occasionally, say for morning pumping, coffee percolating and evening lights, radio, etc. Perhaps it would make us more aware of electricity's value to us also.

The accompanying diagrams will explain the outline of a feasible electrical system for a wind generator. It doesn't include blade design (which I know very little about) or the over-all ratio between the blade speed and the alternator rotor speed. A high-speed 2-bladed propeller might have an over-all ratio of 8-10 revolutions of the rotor to one of the propeller, and a slower sail type or 3 or 4-bladed type perhaps 20-25:1 ratio. The ratio is determined by selecting an auto rear end with a proper ratio. They vary from about 2.7:1 in big cars with automatics to 4.6:1 for trucks and many small standard shift cars (Datsun, Toyota, British cars, etc.) On top of this, the ratio of the diameters of the pulleys on the pinion shaft and alternators is added; i. e., 2" alternator pulley to 10" pinion pulley. A wide selection of these aluminum pulleys can be found at any hardware store.

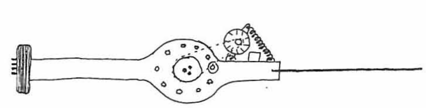
You'll probably read in the other papers about wind systems that pulleys, belts and gears all waste some of the wind's power. It's quite true, but the only way around it is to get a very slow-speed generator directly driven. It must have a very heavy shaft, heavy case and super bearings to take the propeller directly; and the only ones I know of are the ones custom-made for wind generators; and if you're willing to get into such expense, you might as well get an entire Quirk or Wincharger system. The auto rear end, of course, is a very long-lived and maintenance-free unit carrying a ton and with several-hundred horsepower flowing through it. So in a few-horsepower wind generator, it should last a tremendous length of time and consume relatively little power, if it is broken in and lighter oil is used.

Notes on Mechanical Aspects

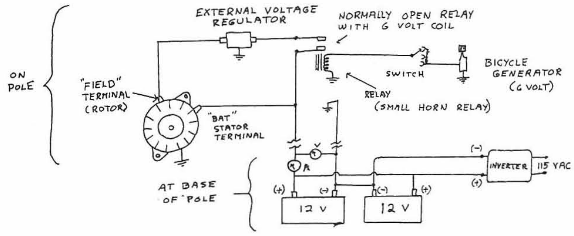
- for best efficiency, remove original oil and put in 20 W motor oil and *new oil seals*
- spider gears in differential may have to be welded together ("spiked")
- tail axle tube must be welded shut
- assembly should be balanced on pivot (spindle)
- a wheel center can be conveniently bolted to the original studs and the steel or fiberglass of the blades affixed to it by welding, bonding or clamping
- a fiberglass or sheet-metal shroud should at least partially protect the alternators and pulleys (not shown)
- ideally a commutator would transfer power from the generator to the ground (to permit free turning of the generator with the wind). This would be very difficult to build as 12 volts would be impeded by even a slight resistance and the generator rendered ineffective. The cables are allowed to hang free with enough length for 2 or 3 revolutions. A steel cable slightly shorter than the power cables, firmly fastened to the base of the pole and the differential housing, would provide a "stop" and prevent the power cables from being ripped off.
- a heavy marine or military type plug in the power cables at the base of the pole will allow their being unwound if they become twisted around the pole.
- stays from the pole cap to the ground will give the whole unit more stability
- the bicycle generator can be of the common type that is spring-loaded against the tire, and in the same way pushes against the alternator belt. In case this is too fast, a suitable surface of rubber on the rim of the brake drum would provide a surface for the generator to run against. A section of an inner tube could be stretched around the outside of the drum like a large rubber band
- all welding should be arc, if possible
- bolts you expect to get loose again should be at least galvanized, preferably brass or stainless steel
- if the belts are kept tight and the pulley ratio not too tight, belt drive will work quite well with 1-2 generators. If 3 or 4 are to be used, a second pinion pulley and belt must be used. Also auto belt drive isn't good with larger generators (greater than 1 KW).



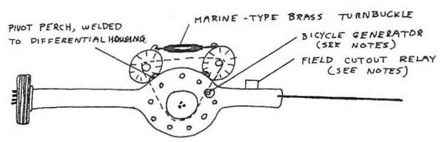
SIDE VIEW SINGLE ALTERNATOR UNIT



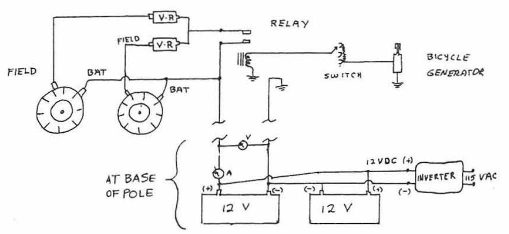
TOP VIEW SINGLE ALTERNATOR UNIT



SINGLE ALTERNATOR SYSTEM



TOP VIEW 2 ALTERNATOR UNIT



2 ALTERNATOR SYSTEM

Electrical Notes

- the bicycle generator-relay system cuts off the rotor current flowing from the (+) side of the battery when the speed of the wind is too low to produce power. In addition when the relay opens, the rotors free wheel, greatly reducing the drag on the propeller, allowing it to get up speed more easily. This is especially important in low-starting torque, high efficiency 2-bladed types.

- a 3-position switch is shown in the generator line. This will control the cut-in speed of the alternators. It may be desirable to change this according to the seasons or wind conditions. This could be replaced by a rheostat, or left out completely if desired.

- a good anemometer is a nearly indispensable aid in setting up and monitoring the machine, as is a $15 "VOM" or electrical multitester.

- the number of batteries needed will vary with the size of the system and how steadily the wind blows in your area, but remember that the batteries represent the only way to capture the wind's energy when utilities are off or using less power than is being generated. Therefore the more AMP-HOURS of battery capacity you have, the more efficient the system will be in using wind energy.

- the batteries will be one of the major expenses of the system so all the standard precautions should be taken to insure efficiency and long life.

1. Add only distilled water.
2. Keep them clean and dry.
3. Check them with a hydrometer frequently (1.230-1.280 corrected for temperature)
4. Have heavy wires and good connectors (covered with grease to prevent corrosion).
5. Don't completely discharge them, especially in winter.

- an integral alternator-regulator unit is wired just as units with a separate regulator (see sketches and schematics) with the low speed cutout relay taking the place of the ignition switch.

- these wires grounded securely to differential housing

- the more batteries are paralleled, the more wind energy you can store and the more will be available for peak use periods.

- the 2 alternator is almost identical to the single. Three or four can be paralleled in the same way. Make sure the relay has adequate capacity (current handling ability) if several units are used.

- all wires should be *soldered*, not clipped, clamped or screwed on the wind generator unit and the joints protected with acrylic, silicone or some other protective material.

- field and bicycle generator leads can be 16 or 18 gauge copper insulated, but (+) and (-) power leads from the stators to the batteries and inverter *must* be very heavy copper like arc-welding or auto "jumper" cables or most of the power generated will be used up in heating the power leads, and the voltage regulator won't work properly.

- wires on the wind generator should be tied down to prevent flexing in the wind .

- the external voltage regulator (if present) and cutout relay should be sealed as well as possible against the weather.

- be sure all electrical units (alternators, bike generator, relay, voltage regulator) are well grounded to the differential housing. Small pieces of braided grounding strap brazed to the housing are good.

- once installed, the solid state rectifiers (in the alternator) and voltage regulator are rugged and reliable, but if their polarity or battery polarity is reversed (the battery is hooked up backwards), they can be permanently damaged in a few seconds.

- the 1969 and later alternators with "IC" regulators are by far the best ones to get, but in any case it's probably not worth using the older DC generators (pre-1960 approximately) as they have much less power output and more maintenance, wiring, and poorer regulation and reliability.

- a spark-gap (¼" or so, obtainable as a TV-antenna accessory, or home-made) should be put between the (+) cable at the base of the pole, and the (-) terminal grounded by a steel stake, to protect against lightning. Unless you really need the power, it's probably best to disconnect the batteries and inverter during thunder and lightning storms.

- at least a DC volt meter and ammeter to monitor generator output should be mounted in the battery box, and preferably an AC ammeter and volt meter in the house, barn, etc., to monitor inverter output.

- never completely discharge the batteries as this shortens their life.

- lock the blade with the emergency brake whenever disconnecting the power leads between the batteries and the alternators. To disconnect the alternator from the batteries while it is charging could damage it.

- the excellent regulation provided by the IC regulator should significantly increase battery life.

- an alternator has brushes, but the slip ring has no breaks like the generator's commutator, eliminating nearly all the wear and sparking. Also an alternator's brushes only carry the field (rotor) current (1-3 AMPS) while a generator's must carry the full output (20-40 AMPS). Therefore alternator brushes generally last many times the life of generator brushes.

- if you stick to 12 V DC power, remember that every auto has two very useful large motors, the starter and the generator (the DC type, not an alternator). The starter is a series-type motor, with tremendous starting torque, good for low speed, heavy jobs, but takes lots of power and the generator is a shunt-type motor. This is really a versatile unit that can produce up to about 1/3 horsepower at a variety of speeds and can be picked up in any junkyard from 1955-1963 American cars. These units can be rewired or rewound if you are really a do-it-yourself type, but can be used directly and the speed controlled by a rheostat between the fields and the armature (about 10-15 ohms at 25 watts).

- actually if you wanted only a small amount of AC, one of these units driving an alternator from a later car with the diodes bypassed for AC and the DC motor (generator) adjusted to the right speed with the field rheostat to the proper speed will produce 115V AC at 60 cycles at a fraction of the cost of an inverter.

- for a really cheap auxiliary power supply, in case the wind doesn't blow, a 2½-3 horsepower horizontal crankshaft lawnmower engine will run an auto alternator, which can produce 12 V to charge the batteries or 115V AC 60 CPS if the engine speed is adjusted properly, usually 1800 or 3600 RPM.

- actually, in obtaining old alternators and generators, I stopped at a number of service stations and asked to look through their trash and got more old units than I knew what to do with for nothing, and most of them, after cleaning, were either perfectly usable or needed only a bearing, diode, or set of brushes!

- Chrysler specifies regulation (charging) of their IC-alternator from 50-5000 RPM; Ford and GM, I couldn't find.

Costs

- it's impossible to give a figure, as this depends on scrounging, but quality parts in some areas are a must.

- look at the ampere-hour capacity of batteries. A \$35 battery often has twice the capacity of a \$25 one as well as better materials and construction.

- rebuilt alternators (\$25-\$60) are usually just as good as new ones, if they come from a reputable firm and much cheaper. J. C. Whitney Co. of Chicago, a mail-order auto-parts firm, has good prices on these items. If you're handy, junkyard ones can be renovated for even less.

- the inverter(s) are another major cost, and as the solid state "multivibrator" type are quite new, there isn't much chance of finding a used one. The older mechanical reed type is rarely found, and anyway is very inefficient. A 500 watt continuous, 550 watt intermittent unit costs about \$110 from such places as Lafayette Radio or J. C. Whitney. If more power is needed, two or more units can be bought. It's possible to make one from parts, if you are handy, but considering the time and effort and the cost of the parts, it's not practical unless you can "scrounge" the parts.

I guess all this makes pretty dull reading, but for the person serious about such a project, I hope it is of some use. Good luck in your various ventures!

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POSTSCRIPT

The last major hurdle of a low-cost wind generator is the blade technology and construction. Currently the only dependable blade design is a high-speed airfoil blade made of wood or fiberglass. This type of blade can be handmade, but becomes more difficult in larger sizes. We are presently investigating nautical sail design to determine if the long tradition and recent advances in that art can be turned toward low-cost wind generators. Progress toward that end is the success of the self-regulating sail-blades of Marc Sherman's water-pumping windmill described in this Journal.