HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

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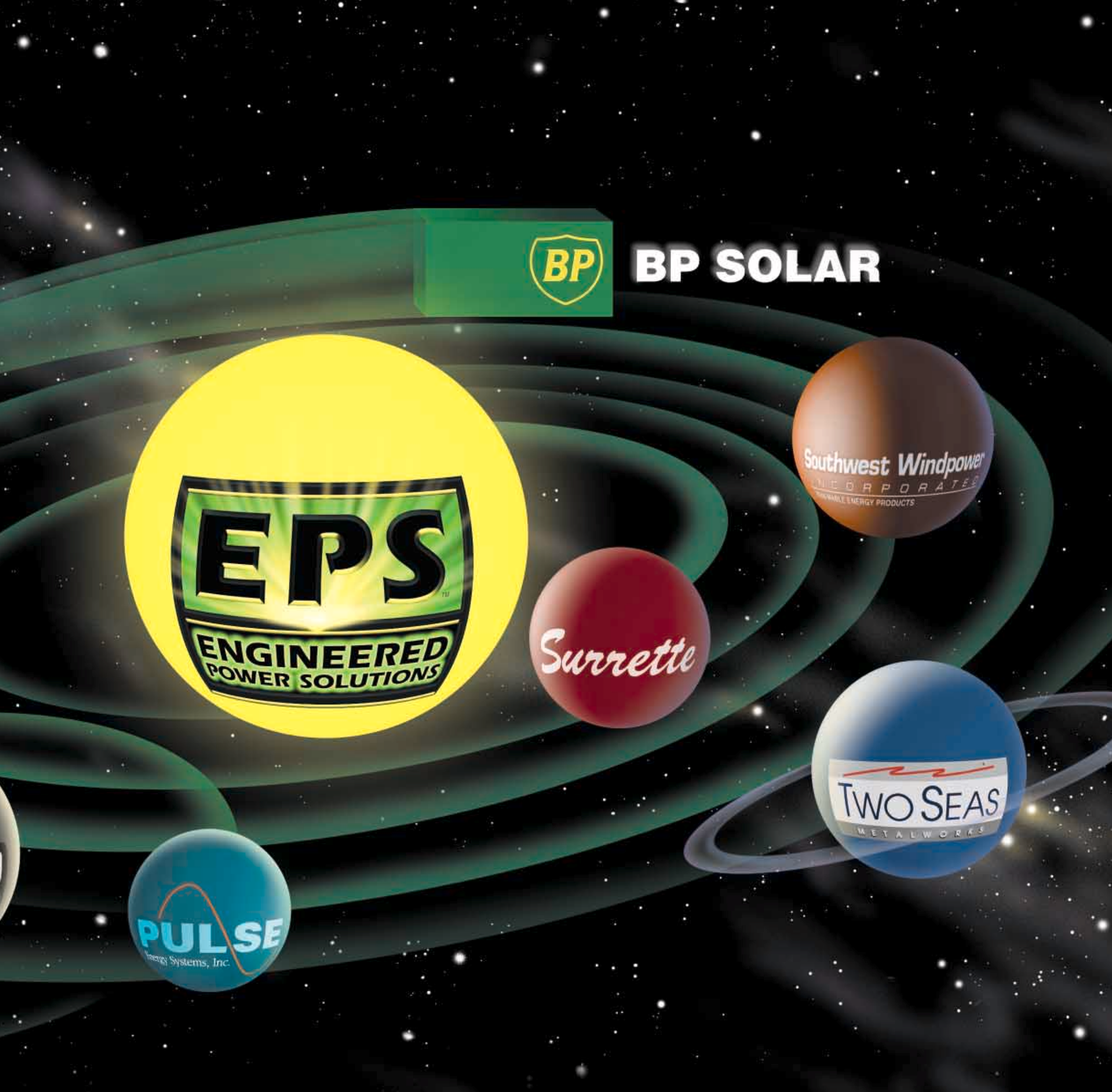

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Cover: A waterfall cascades off the Coast Mountains in British Columbia, Canada. At the base of the falls is the intake for Malibu Club youth camp's 12.6 KWp hydro system.

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Home Power
PO Box 520
Ashland, OR 97520 USA

Editorial and Advertising:
Phone: 530-475-3179
Fax: 530-475-0836

Subscriptions and Back Issues:
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Internet Email:
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Taking Renewable Energy On-Grid

We have been publishing *Home Power* for over twelve years now. During this time, we've seen home renewable energy (RE) use grow from a few thousand early adopters to well over a quarter of a million folks worldwide. Almost all of these people are not connected to a utility grid. Photovoltaics, wind generators, and microhydro turbines have become the most reliable and least expensive way of providing electricity off-grid. RE has fought the off-grid power battle with the engine generator, and RE has won.

We are now turning our attention to grid-connected folks. After all, over half the people on this planet are connected to a utility grid. If we are serious about spreading the environmental benefits of RE, then the grid is the next frontier.

On-grid, we have two basic ways to spread RE use. The first is to encourage utilities to produce their electric power using RE resources. But the utilities are very slow to change—they remain locked into the centralized fossil fuel and nuclear mentalities. Besides, I personally find it silly to buy RE from a utility when I can make it myself at home.

The second way to spread RE on-grid is for individuals to establish their own RE systems, either stand-alone or utility intertied. Here are three reasons why a grid-connected household might wish to establish its own RE system.

For the health of the planet and future generations

For the benefits of a reliable electric power source

For the benefits of a high-quality electric power source

RE offers us relief from the pollution associated with utility-generated electricity. RE offers us electricity with no blackouts or brownouts. RE offers us electricity that is of higher quality than the grid can deliver. All these reasons make RE as big a winner on-grid as off-grid.

One reason not to install RE on-grid is to save money on electric bills. Currently, RE cannot compete financially with heavily-subsidized utility power. It's not that RE is really more expensive; it's that the true cost of utility power doesn't show up on our monthly electricity bills. About half the cost of utility power is concealed in our taxes.

Our tax dollars subsidize utility operation, pay for much of the environmental and health damage caused by fossil fuel burning and nuclear waste, and pay for wars to secure our energy supplies. If the true cost of energy showed up on that monthly power bill, it would become instantly apparent that RE is cheaper than utility-produced power.

On-grid RE is now at about the same place as off-grid RE was twenty years ago. It is limited to folks with a vision for the future and the courage to make changes—even if these changes don't instantly save them money. I urge you to look ahead and take that courageous leap into a cleaner and saner future.

–Richard Perez for the *Home Power* crew

People

Joy Anderson
Mike Brown
Sam Coleman
Windy Dankoff
Chris Greacen
Jo Hamilton
Stewart Hay
Arne Jacobson
Dr. A. Jagadeesh
Anita Jarmann
Kathleen Jarschke-Schultze
Jon Kenneke
Stan Krute
Don Kulha
Scott Lee
Don Loweburg
Harry Martin
Glynn Morris
Mark Patton
Karen Perez
Richard Perez
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Shari Prange
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-J Rubin

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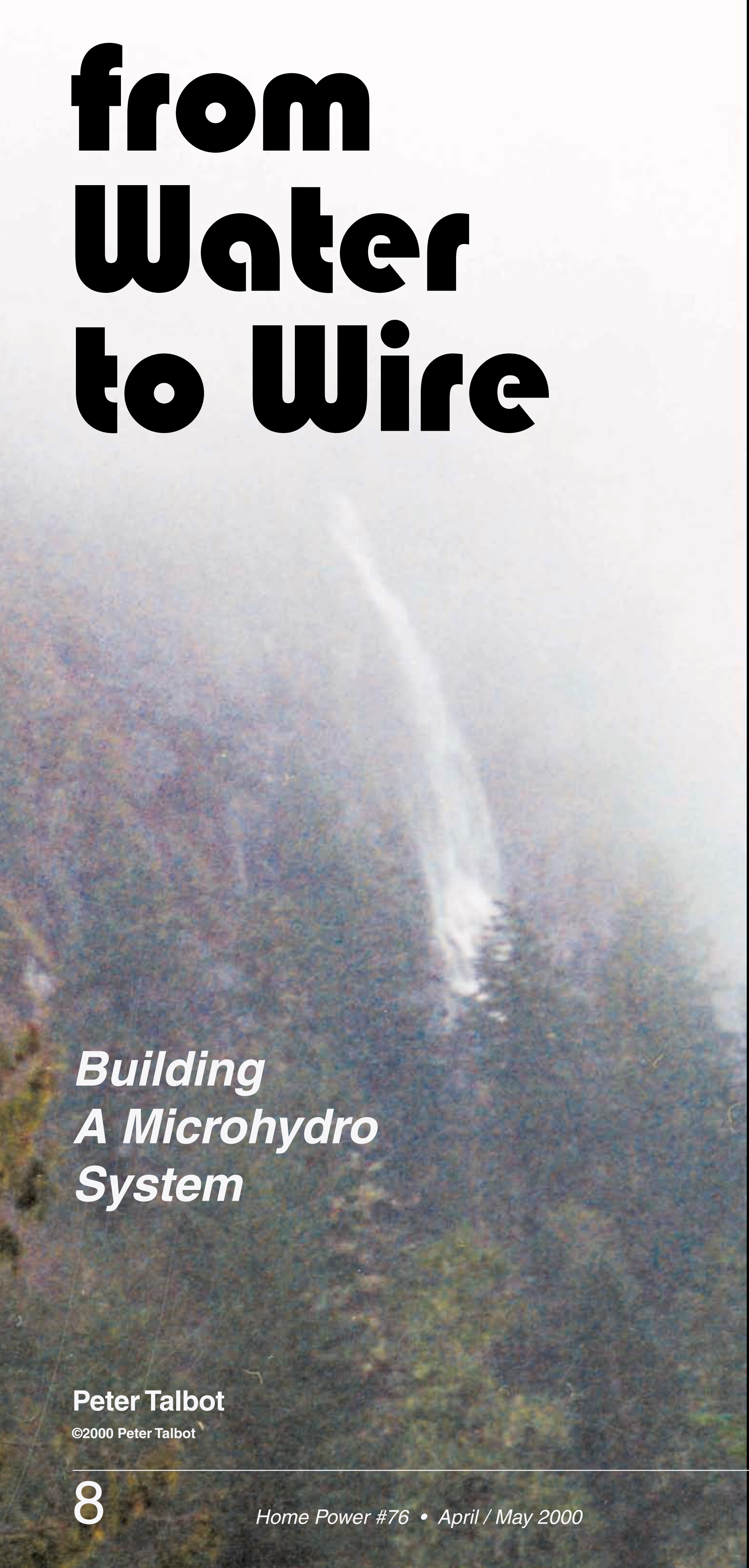


Building A Microhydro System

Peter Talbot

For 500 miles, the remote and storm-battered coast of British Columbia, Canada winds its way north in a torture of craggy cliffs and isolated fjords.

It is drenched by the wettest climate in North America, and situated at the foot of the ice-covered Coast Mountains.

This wild isolation provides a perfect setting for tapping into the endless supply of energy produced by falling water.

Remote Camp
Tucked among these mountainous wilds, 100 miles (160 km) north of Vancouver lies the picturesque resort camp of Malibu Landing. Forty-five years ago, a wealthy entrepreneur built the Malibu Club as a private resort for the stars of the California film industry. Boasting all the modern conveniences of the time, and situated in a beautiful location, the resort operated for a few brief years before being abandoned due to unpredictable, cool Canadian summers and fierce winter storms. Following the closure, the camp was converted into a summer camp for teenagers, and has functioned in that capacity for over forty years.

Since its early beginnings, this isolated site has been subject to the relentless roar of diesel-powered generators and the high cost of barged-in fuel. It is surrounded by snow-covered mountains up to 8,500 feet (2,600 m) high, and blessed with steep, flowing creeks. The site was a natural for a microhydro power plant, yet in all these years, one had never been developed.

I had been visiting the area and volunteering at the camp for a number of years and saw the potential for a development that could reduce their dependence on diesel fuel. For most of the winter, a thin waterfall cascades over cliffs 1,000 feet (300 m) above the camp. Though dry for most of the summer, this was a potential source of hydro power for the winter months.

Since the camp is closed in the winter, the power requirement for the year-round caretaker is small, averaging under 10 KW, and might just be handled by a small hydro plant fed from this seasonal flow. A decision was made to conduct a rough survey of the terrain, and then collect stream flow data over the course of the following winter. If the flow proved to be sufficient, we would begin construction the following summer.

The Survey
One of the first steps in the design of a hydro plant is to determine if there is sufficient flow available to make the project worthwhile. Fortunately, the wet winter season corresponded with the demand that would be placed on the system, and long-term casual observations suggested that there would be adequate flow for most of the winter.

The caretaker had been keeping an unofficial visual record for almost ten years and could compare the estimated flow on any given day with seasonal norms. This proved to be a great advantage when we installed an accurate measuring device at the falls, since we could then compare actual flows with past observations.

Measuring Head
The second key ingredient to a successful hydro project is the total available change in elevation over which the water can develop pressure in the pipeline. We first measured this “head,” or elevation drop, by means of a sensitive altimeter, and then with a handheld clinometer level and a 15 foot (4.6 m) survey rod.

The route the pipeline would take was more or less obvious, so we followed this as we carefully took each reading off the rod. As we leapfrogged up the hill, the exact elevation was marked on prominent landmarks as a permanent record. The use of the rod and level gave considerable accuracy over the distance, which traverses some really rough terrain. Two elevation surveys were made to check for error and the results tied within a foot—close enough considering the method used.

When all the surveyed elevation steps were added up, the total to the base of the falls came to 639 feet (195 m) above the proposed powerhouse floor. The altimeter reading agreed within 10 feet (3 m), and provided a good check against any gross errors. This elevation is

The survey team at the base of the falls, ready to measure total head.

The intake box is used for filtering and settling of debris. The V-notch was used for determining flow during system planning.

on the high side for the typical microhydro installation, but it allowed us some margin for locating an open filter box and starting the pressure penstock.

Increasing height raises the operating pressure, and hence the power output. However, it also causes the turbine to spin faster, increasing with the square root of the height. This affects the turbine diameter used, the desired output frequency, and the pressure rating of the piping.

Sizing Pipe

To measure the overall distance, we used a 100 foot survey tape, and again marked the distance along the route. The total came to 2,200 feet (670 m), of which about 2,000 feet (610 m) would form the pressure penstock. Determining the distance was much easier than measuring the exact head, but it too had to be done carefully, since we planned to use pre-cut steel pipe lengths in the lower section.

We planned to use high-density polyethylene pipe (HDPE) for most of the pipeline. Since the static water pressure would be increasing as the pipeline descended the slope, we had to decide where we would change to the next greater pressure-rated pipe. We did this by dividing the slope into six pressure zones, and selecting the appropriate pipe thickness for each zone.

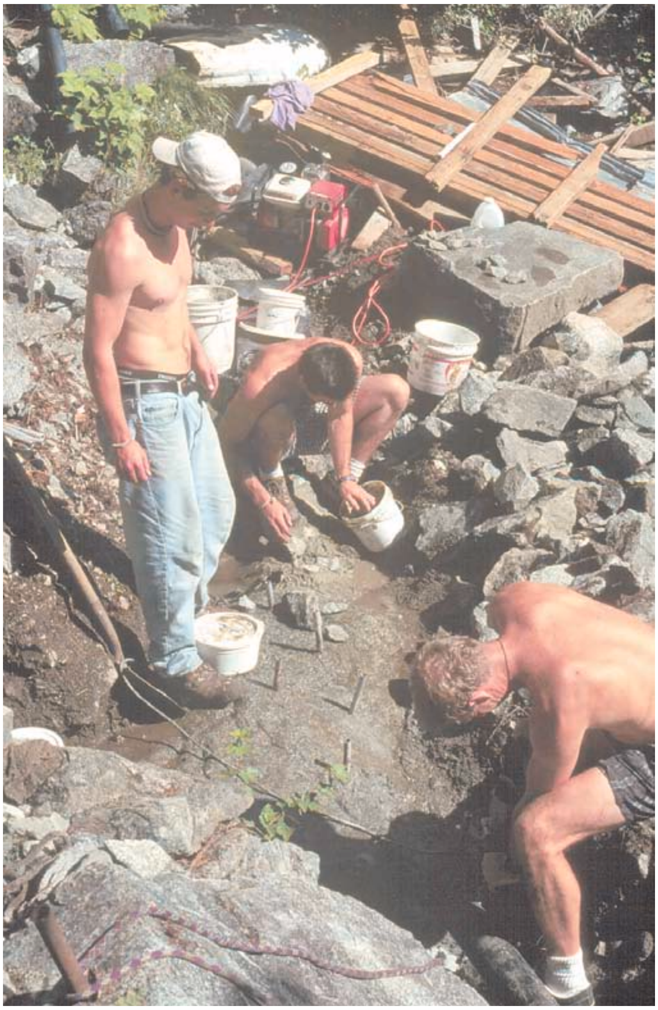
This HDPE pipe is extruded in various thicknesses. Often the pipe is rated by a series number, giving its safe sustained working pressure. Another common system rates the pipe by its dimension ratio (DR), which compares the pipe's wall thickness to its diameter.

We planned to use DR26 in the low pressure section, which is the same as series 60, all the way up to DR9, which is equivalent to series 200. Beyond that, the wall thickness increased enough to significantly reduce the inside diameter. This would cause the water flow velocity to increase, resulting in greater friction and hence losses, so a strong, thin-walled steel pipe became a better choice, and cost less.

Determining the Required Flow

Since the survey was done in summer when there was just a trickle of water flowing, we didn't have the actual flow data. As a result, we couldn't calculate the exact power output, efficiency, and payback time. However, having a fixed budget to work with and knowing the

Building the intake basin, which was then covered with large rocks for protection from falling debris.



Flow Rates through a Calibrated 90° V-Notch Weir

Notch depth (inches)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00	7.50
US gallons per second	0.04	0.10	0.21	0.36	0.57	0.86	1.20	1.60	2.10	2.70	3.30	4.00	4.80	5.70

head, distance, penstock profile, and power requirement, it was possible to design a system based on a minimum anticipated winter flow. Calculations showed that half a cubic foot per second, or about 225 US gallons per minute, over a net head of 500 feet (150 m) would produce an output of 12 KW and make the project well worthwhile.

A simple formula to estimate electrical power produced from falling water in an AC hydro plant of this size is as follows:

Power in KW = Q x H ÷11.8 x N

where Q is flow in cubic feet per second, H is head in feet, and N is overall efficiency, typically 60 percent (0.6) in a small, well-designed system.

Several years of use has proven the intake basin's covering of rock a worthy armour and a coarse filter.

Another version of the power output formula is:

Power in watts = net head in ft. x flow in US gpm ÷ 9

This formula already takes the efficiency into consideration. For this site, the result is: 500 feet x 225 US gpm ÷ 9 = 12,500 watts (or 12.5 KW).

Measuring the Actual Flow

In order to get an accurate record of the flow profile over the winter, we constructed a wooden tank equipped with a V-notch weir, and placed it below and to the side of the falls. A length of 6 inch diameter plastic pipe was secured in the channel to catch the majority of the runoff and direct it into the box. The depth of the water flowing through the calibrated V-notch weir gave an accurate measure of the flow available.

Details on building various weirs are outlined in most textbooks dealing with fluid flow. These are available in many libraries. We used a 90 degree V-notch weir cut out of a piece of sheet metal. The table above shows the flow in gallons per second per inch of depth through a small V-notch weir.

A sensitive water-level monitor was installed in the box, coupled to a radio transmitter which would relay the flow conditions down to the camp every few hours. A modified receiver and some additional electronics show the level on a numeric display, which can be read and recorded by the caretaker. He can then compare this accurate flow reading to what he observed flowing over the falls, and relate this to his ten years of casual observations.

As the long, wet winter set in, it soon became clear that there would be more than enough flow to make the project viable, so we began to design the system.

Shopping List

Once we had the approvals to build the project, and had established a preliminary budget of $15,000 (all prices in Canadian dollars), the next phase was to order the necessary hardware. We were fortunate in that most of the suppliers were willing to give us jobber prices, since Malibu operates as a non-profit organization.

Since we had done an accurate survey, we could order the pipe to the exact length and pressure rating that we required. We went to the suppliers before ordering the materials to check out the quality of the steel pipe, and

John Smoczyk, a regular volunteer at Malibu, shows off the fusion welding equipment for the polyethylene pipe.

to be sure that we would be able to handle the weight during construction. Pipe lengths of 20 feet (6 m) weighed 180 pounds (80 kg), and would have to be carried by hand over very rough terrain.

The four-inch diameter polyethylene plastic pipe was ordered in 40 foot (12 m) lengths. The pressure ratings varied from 60 pounds up to 200 pounds with a safety margin of 25 percent. Transporting the pipe was expensive since it required a 40 foot truck to get it to a suitable waterfront dock where a landing barge could be loaded. The long lengths did, however, cut down on the number of joints we had to make.

One of the advantages of using polyethylene pipe over PVC is that the working pressure can be close to the pressure rating of the pipe itself. This is due in part to the elasticity of the plastic used, which will absorb the shock wave (water hammer) generated if the water flow is forced to change velocity abruptly. This effect causes a momentary pressure rise which travels up the pipe, and has the potential to do permanent damage, even bursting a more rigid pipe.

To further reduce possible damage to the pipe when shutting off the flow, we obtained a slow-acting 4 inch gate valve. This was picked up at a scrap yard for $50! With a pressure rating of 500 pounds, this valve would have cost many times that if purchased new.

Pelton Wheel

The high head and relatively low flow rate of our site would be best handled by a Pelton-type of turbine. Since our operating head would be somewhere between 500 and 550 feet (150–170 m), and we wanted the rotational speed to be 1,800 rpm—suitable for direct coupling to a generator—we needed a turbine with a diameter of approximately 10 inches (25 cm). When under load, this diameter wheel would rotate at the correct speed, and the direct coupling would afford the maximum efficiency.

We looked at three different turbines and got firm quotes. Each machine had its own merits, and costs were roughly equal. We settled on a unit made by Dependable Turbines, a local manufacturer, because of their proximity to, and familiarity with, our site. They also had a turbine runner with the correct pitch diameter and bucket size to exactly match our site characteristics. The turbine was ordered as a package, together with a 14 KW, three-phase Lima brand generator.

Floating 400 feet of poly pipe across the bay to the base of the hill.

Intake

Intakes are usually the most difficult aspect to design on a microhydro project. Seasonal variations in flow can range from a trickle in late summer to a raging torrent in winter. On the steep mountainous terrain of the west coast, many a concrete intake structure has vanished following a heavy downpour.

With this in mind, we thought about ways we could minimize the construction required, and work with the natural form of the land. It was obvious that ice and rock falling from the frozen lip of the falls high overhead would destroy any structure we built.

What was needed was an intake that was formed as much as possible from the bedrock buried beneath the boulders and gravel below the falls. Following some excavation, we were able to take advantage of the sloping granite bedrock down the hill from the base of the falls, and out of the direct line of fire of falling ice and rock. We built a low wall of reinforced concrete there to divert the flow into a small pool, enabling us to pick up even the smallest flows. The pool and wall were then backfilled with large rocks. Falling rock and ice would then pass over the low wall, leaving it undamaged.

From the pool at the 600 foot (180 m) elevation, we ran 4 inch plastic pipe for 200 feet (60 m) across and down to a level spot at the 550 foot (170 m) elevation. We moved the 5 foot (1.5 m) long wooden box that was used to measure the flow to this spot. Then we equipped the box with three sizes of filter screens and a valve in the bottom to allow for the flushing of any sand and gravel. Excess water passes through a narrow 1 inch (25 mm) slot cut into the top 12 inches (30 cm) of the tank which forms the overflow. This replaced the V-notch weir and increased sensitivity for the level sensor.

A crew of up to 25 volunteers haul 400 foot sections of polypropylene pipe up 550 vertical feet to the intake.

The superhuman strength of volunteers John Smoczyk and Robin Millar is put to good use hauling heavy steel pipe.

A pressure transducer and microprocessor circuit relays the level of overflow to various locations in camp by a radio link and phone wires. This allows the operator to monitor the flow and to throttle back on the water passing through the turbine as the falls dry up. When there isn't enough water to make it worth running the turbine, he can switch over to diesel. From the filter box, the pressure penstock runs 2,200 feet (670 m) down to the powerhouse, dropping 550 feet (170 m).

Down through the trees, the bottom sections of steel pipe reach for the powerhouse.

A hugger clamp joins poly pipe to steel pipe.

Laying Pipe

The great advantage of polyethylene plastic pipe is that it is almost indestructible. It is not affected by UV exposure, can be squashed nearly flat and recover, and can freeze solid under pressure and not split. The major disadvantage is that it can not be glued, but must be either fusion welded or connected with expensive “hugger clamps.” We opted to rent the welder and join the 40 foot (12 m) lengths into long sections at the bottom of the hill where there was the necessary 1,500 watts of 117 volt power to run the fusion welding equipment. It was quite a sight to see the first section of pipe stretch for 400 feet (120 m) down the dock and float halfway across the bay as more sections were welded on!

The “welding” process is really a form of hot “fusion melting.” This involves placing the pipe ends in a special holding jig, and squaring the ends with a motorized cutter which is inserted between the pipe ends. The pipes are brought together in the jig and contact the cutting wheel which planes off a bit of plastic. The cutter is then removed, and a flat heated plate inserted.

The pipe ends are lightly pressed against the hot plate for a minute or so to soften the plastic. Then the plate is removed and the pipe ends are brought together under light pressure. A bead of plastic forms as the melted plastic fuses together. After cooling for five minutes, the joint is complete, and is said to be stronger than the rest of the pipe. Despite some very rough handling, we have never had a leak.

When ready, we got another 20 volunteer grunts to help haul the pipe up the hill following a carefully surveyed path. This was a lot of fun, but also an amazing amount of work. We were fortunate to have the willing bodies.

Most of the plastic pipe was laid directly on the ground and secured to solid trees and rock anchors with half inch (13 mm) white nylon rope. We found that yellow poly rope would not last long in the sun.

Pipe destined for the lower sections of the route was much heavier, so we welded these into lengths of 160

Pipe anchors were drilled into solid rock.

feet (50 m), intending to join the long sections with hugger clamps. These clamps are made of two halves that bolt together and compress sharp ridges into the pipe wall. A rubber gasket makes them watertight. Although expensive, with enough of these clamps, the entire penstock installation could have been done by two people.

We soon found that our small 1 KW Honda generator would run the welder if we momentarily unplugged the hot plate when we needed to use the cutter. So we decided to haul the equipment up the rough route and weld the plastic pipe into one 1,700 foot (518 m) long piece. This gave us a slightly smoother pipeline, and it allowed us to keep the expensive hugger clamps for future repairs to the line.

Steel Section

The 20 foot (6 m) lengths of steel pipe were muscled up the hill one piece at time by three bush apes, and connected together by victaulic clamps. This is a two-piece cast fitting that is bolted together and grips into grooves cut into the pipe ends. A rubber gasket prevents any leaks. This method of coupling allows a few degrees of flex at each joint, while avoiding the need for an arc welder.

Each twenty foot length of steel pipe weighed 180 pounds (80 kg), and we put in 550 feet (170 m) of it. As the line was extended, we supported it on rock and timber cribbing at regular intervals. Half inch (13 mm) wire cable was wrapped around the pipeline just below a coupling, then clamped together forming a small loop. We attached the cable to one inch (25 mm) diameter anchor rods drilled into rock outcrops, and tensioned it using a come-along (hand winch).

Volunteers Dave Wheeler and John Smoczyk build scaffolding to support the 180 lb. sections of steel pipe.

Bends were kept to a minimum, and where necessary we used short 22.5 degree pre-formed sections. By planning the route carefully and aiming for solid anchor points, we were able to obtain a perfect fit with just four bends. Our main anchors and thrust blocks were drilled into solid bedrock. We used a portable electric rock drill, which worked very well. It was able to cut a one inch (25 mm) diameter hole, 4 inches deep, in under five minutes.

The steel pipe comes out of the woods and across the bay to the powerhouse.

Just in front of the powerhouse, the penstock crossed a small bay. Here we built up log scaffolding to hold the pipe as we maneuvered it into the most direct route while correcting the slope so it would be self draining. Once the position was established, we waited for low tide, then placed forms directly below the pipeline. Pilings were set vertically in the forms, and the forms were filled with underwater-setting concrete.

The thrust block at the powerhouse keeps the tremendous weight of pipe and water from sliding downhill and crashing through the building.

Camp caretaker Frank Poirier, on the powerhouse concrete foundation, with framing for the tailrace visible. The building was built around the turbine and generator.

After three days, the penstock was slid over on the pilings and secured, and all the scaffolding was removed. Once the penstock was secured in place and the main valve attached, we began the pressure test by slowly filling the pipe from the trickle coming over the falls. It sagged in places and pulled against the cable anchors, but there were no leaks. When it was full, the static pressure read 239 pounds, which was within a pound of what had been calculated. A static pressure penstock will develop 0.433 pounds of pressure for every foot of vertical drop. In our case, the measured 550 feet (170 m) of head should then give 238.1 psi (550 ft x 0.433 pounds/foot = 238.1 psi).

Powerhouse

The site for the powerhouse was selected to minimize the overall penstock length and the number of pipe bends required. We wanted easy access and a location safe from ocean swell and any freak high tides. The machinery and related controls required a space of about 9 by 11 feet (2.7 x 3.4 m). This would give access to all sides of the turbine for maintenance and installation, which later proved invaluable.

In order to get a solid anchor, the bedrock was cleaned with a fire hose and then drilled for steel reinforcing bar. A wood frame was built on three sides of the sloping bedrock, and backfilled with concrete and broken rock.

Mechanical drawings of the turbine showed how large to make the tailrace, or discharge pit, so this was formed with a bit more framing. A notch for the generator power conduit and other control and monitoring wires was formed before the final surface was smoothed.

Installing the turbine was simply a matter of placing it over the tailrace pit and drilling the concrete to line up with the holes in the steel flange forming the turbine base. The generator bolted directly to the same base and required a few shims for correct alignment. A semi-flexible coupling joined the 2 inch (5 cm) turbine shaft to the generator shaft.

The pressure penstock terminated at the main valve just inside the powerhouse walls. Right outside, the penstock was securely anchored to a huge rock outcropping. This formed the final thrust block, and restrained the downward force the weight of water and pipe imposed against the valve body. Over the 4 inch (10 cm) diameter, the total force was close to 3,000 pounds, so a solid anchor was essential.

From the valve, we connected the intake manifold to the nozzle flanges which were part of the turbine housing. A couple of 4 inch sections joined by victaulic clamps were added between the valve and the main thrust block to give a little flexibility and expansion relief. This is important, and prevents possible cracking as expansion and contraction vary the dimensions of the steel.

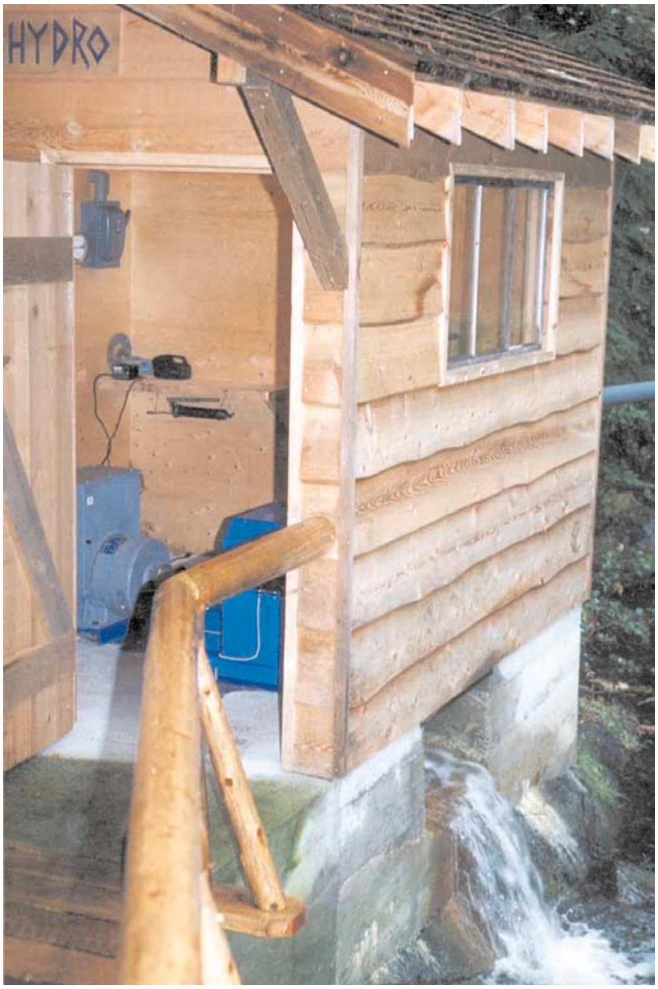
The powerhouse was framed up and the roof built over the installed machinery. A requirement was that it had to blend in with the other old log and cedar building on the site. We were fortunate to have a skilled carpenter who was familiar with building to exact specifications.

The powerhouse blends in with the forest and the traditional buildings on site. The penstock enters the rear of the building.

Controls—How It Works

The Pelton turbine is equipped with two nozzles, each with a maximum diameter of 0.5 inches (13 mm). One of these is equipped with a spear control (similar to a needle valve in a carburetor, but much larger). This allows the flow rate to vary. This is necessary when the flow is lower than what a single 0.5 inch nozzle would require. With this adjustable spear, we can run the turbine with very little water, and still get useable power.

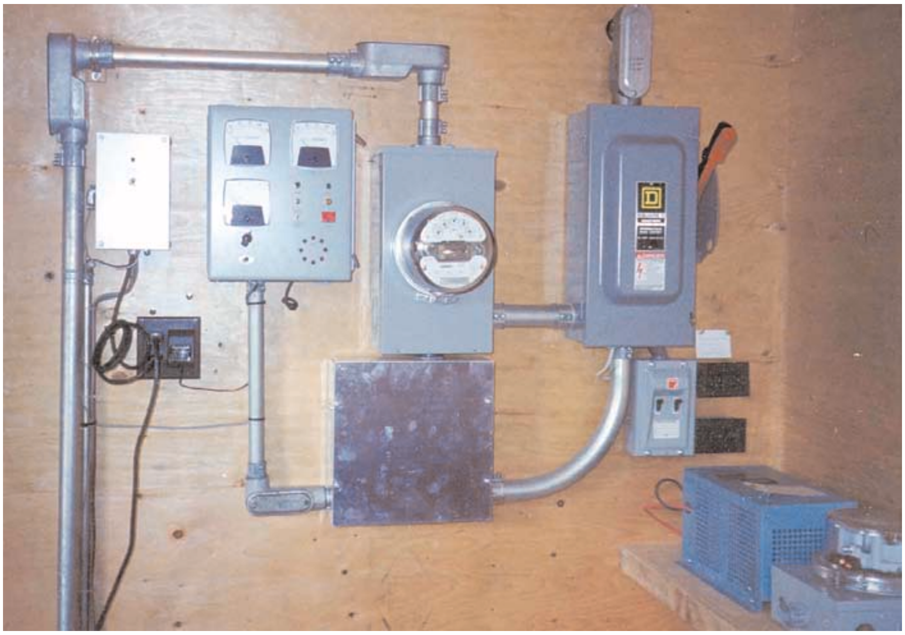
The generator and turbine visible in the powerhouse. The tailrace dumps out the side of the foundation.



The generator was chosen for the best efficiency rating at the mid-range of our power demand. When there is too little flow, the diesel is used. In times of high flow, there is more than enough water, so efficiency is not as important. This same principle can apply to any small “run of the river” system.

Most synchronous generators come equipped with twelve output leads. They can be hooked up to produce single phase or three-phase current. This usually depends on the application. A typical home situation would most likely require single-phase power, at 120 and 240 volts.

Larger installations and any site with big industrial motors usually require three-phase power. This was the situation we were faced with. The 125 KW diesels used in summer fed the camp’s three-phase grid, so to avoid very complex rewiring, we wired the hydro generator accordingly. The major load was the caretaker’s house, and this was wired like any conventional home, drawing juice from only two of the three phases. Other loads could be connected to the third phase to maintain a better balance on the generator. Three-phase generators can be damaged if they are run with all the load on just two of the three phases.

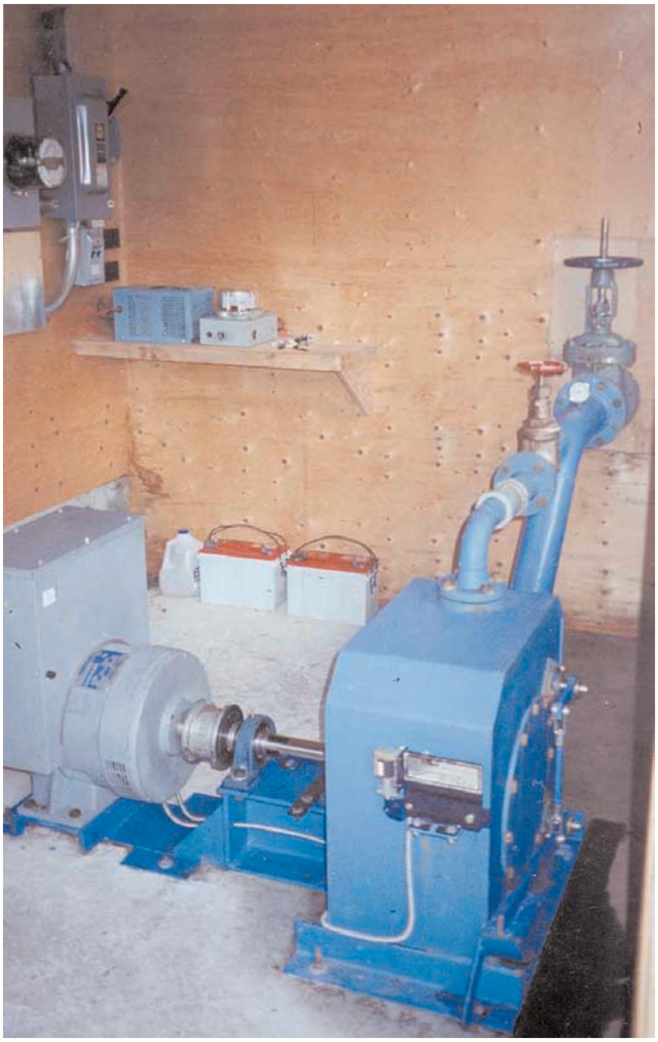


The controls and metering on the powerhouse wall.

Protection: Shaft Speed & Frequency
The frequency of the system is monitored by two independent systems. Should the generator begin to slow down due to excess load, or possibly overspeed due to insufficient dump load or a broken power line, the protection circuitry will sense the condition and shut the machine off. This is accomplished by optically sensing the shaft speed as well as line frequency and voltage. The frequency limits are user adjustable.

Without this protection, motors and transformers would be subject to lower than normal line frequency which can cause damage. As the

The 14 KW Lima generator is direct coupled to the Dependable Turbines Pelton runner.



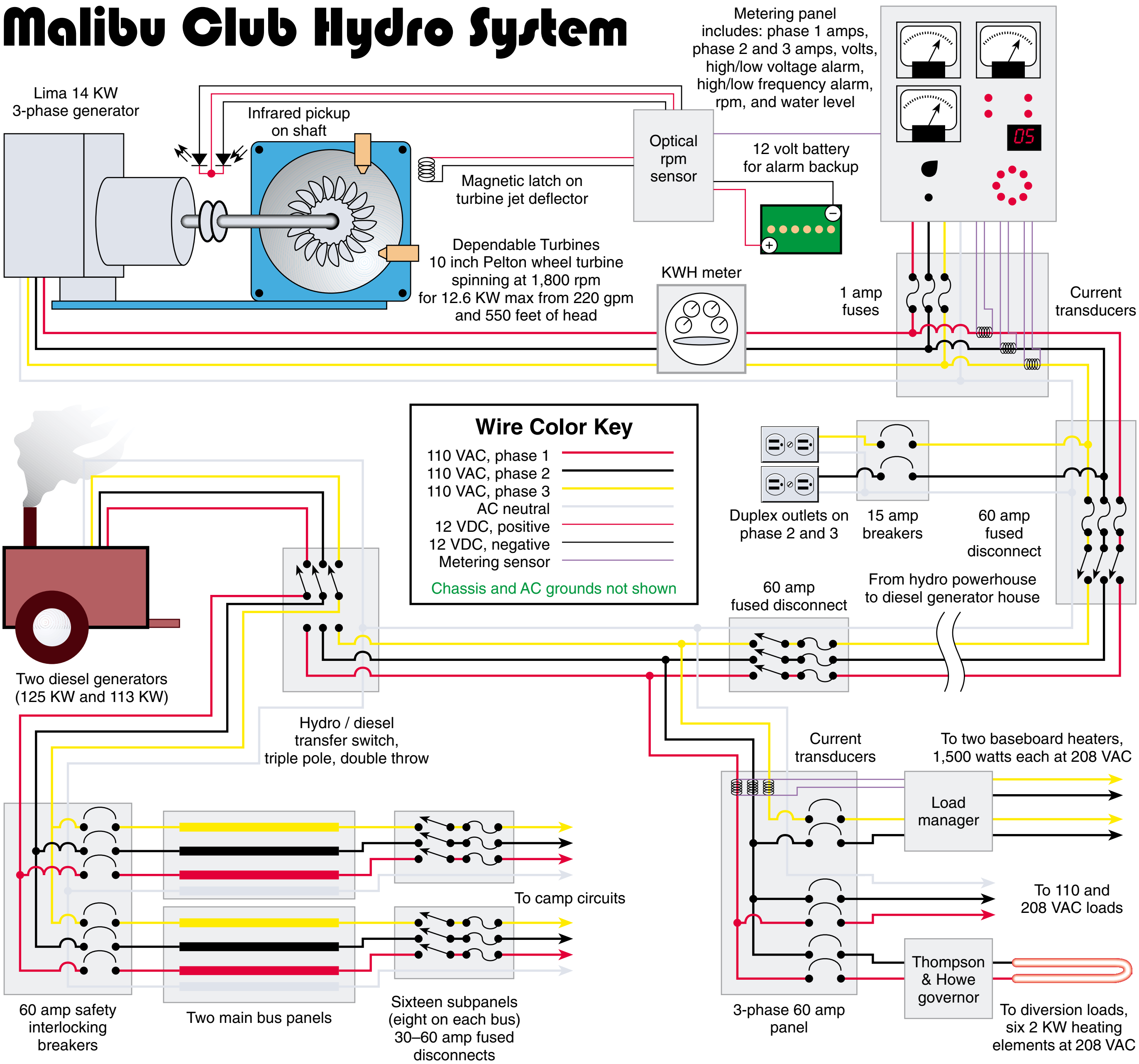
60 Hz Governor & Load Dump
The generator is directly coupled to the turbine through a semi-flexible coupling. So in order to produce standard 60 Hz, the turbine must spin at exactly 1,800 rpm. This is accomplished by using a Thomson and Howe electronic governor, which works by keeping a precise but constantly varying load on the generator. In essence, it "puts the brakes" on the generator and turbine if it deviates from 60 Hz.

The governor works by sensing the generated power line frequency and comparing this nominal 60 Hz to a crystal reference. An internal microprocessor then controls the phase firing angle of high power triacs which shunt excess power to low priority, but useful, dump loads.

These loads do not necessarily see the full sine wave generated since they are being fed with rapidly switching and varying width pulses. Because of this, only purely resistive loads can be used; motors or electronics would soon self destruct. We used baseboard heaters located in a large woodworking shop. Immersion elements in hot water tanks are another useful dump load.

Frequency stability is excellent with this method of control, and it avoids the much more complex method of mechanically controlling the flow of water to precisely match the electrical load. This was traditionally done with centrifugal weights acting on an oil-based servo control, which in turn controlled a deflector in front of the nozzle or a spear valve.

Malibu Club Hydro System



generator slows, the frequency falls in direct proportion to the rpm, while the generator's voltage regulator tries to hold the voltage constant. This can cause large currents to flow in the regulator and field windings as the regulator tries to maintain the output voltage. Generally, resistive loads like incandescent lighting and heating elements are not damaged by low voltage or frequency, but reactive loads, such as devices with windings like motors and transformers, are at risk.

These frequency, speed, and voltage sensor outputs are connected to a weighted mechanical jet deflector which will divert the water away from the turbine runner. A magnetic latch holds the deflector in the open position in the absence of an alarm. An adjustable time delay will release the latch in the presence of an alarm condition, shutting the system down. This requires a manual restart which is a bit awkward if it happens in the middle of the night. But the consequences of the turbine lugging or running away at high speed can be very bad.

Metering

Voltage and current are displayed on a homebrew metering panel, together with alarm status, water level indication, and shaft rpm. The water level is also displayed at other locations in the camp, and the displays are equipped with an adjustable low water

Just part of the volunteer crew—thanks guys!

alarm setpoint. This keeps the operator informed of the flow situation up the mountain, and provides advance warning of when to switch over to the diesel generator.

We also installed a three-phase KWH meter to monitor the total energy produced. This added feature has enabled us to keep track of the savings in diesel operating costs, and to determine how the project payback is proceeding. It is really satisfying to see the meter whiz around, and to know that the small creek is powering all our needs. The best part is that for the first time in 40-odd years, there is complete silence throughout the camp, yet all the lights are on!

Breakers & Switch

A 60 amp fused disconnect feeds into 300 feet (90 m) of #4 (21 mm^2) Tec cable (outdoor armored cable) which runs from the hydro site to the diesel powerhouse. The hydro output can then be fed into the main bus system, and distributed throughout the camp as required. We had to install a triple-pole double-throw transfer switch so either the hydro or a small 15 KW diesel generator could feed into the camp grid. One, but never both of these, is always supplying power.

The transfer switch then feeds a 60 amp circuit breaker which in turn feeds into the camp's grid. This last panel is has two keys which must be turned before it can be put on line. Both of the two main diesel generators (125 KW and 113 KW) also feed into the grid through separate breaker panels. The same key must be used in both of these panels before they can be switched on. This eliminates any danger of backfeeding one generator into another.

Life With Hydro

As the winter rains returned, the falls once again began to pick up force. On a rainy day in late October, the telemetry system indicated a flow through the catchment weir sufficient to test the system. The penstock pressure gauge read 239 pounds under the static head of 550 feet (170 m).

Once the pipeline was purged of debris, the spear valve was cracked open, and the Pelton wheel immediately started to rev up. At first we set it to produce just a few amps, letting the governor dump load absorb the output. The effort we had made to align the shafts with the correct thickness of shims during the installation phase was rewarded by quiet operation with virtually no vibration. Once it checked out, we opened the spear valve, and the output quickly increased to 20 amps per phase. As predicted, we were getting close to 6 KW using one nozzle!

Other than the silent operation, there is no way to tell that the camp is running on renewable energy. Under wet conditions it will run for weeks without stopping. We were accustomed to shutting the diesel down every day and adding oil, so this took some getting used to!

A fixed amount of water flowing through the turbine sets the limit on power production. Unlike the diesel, there is no throttle which will automatically open up as the load increases. To attempt to draw more energy out than is being supplied by the water jets will result in the system slowing down. Drawing even a few extra watts slows the shaft speed and hence frequency, and the turbine will shut down.

A system that will trip itself off on overload is a minor inconvenience of a small run-of-the-river system like this, but is something one learns to live with. The protection it affords is definitely worthwhile. It doesn't take long to approximate the electrical load on the system. If a load largerer than the governor reserve is switched on, the line frequency begins to fall. If you are quick, you can switch it off again and the turbine will recover.

Over time, the KWH meter began counting up in the thousands of kilowatt-hours. It was obvious that the payback would take just a few winters at this rate!

Lessons
The two factors which produce the only notable trouble are the intake clogging up and the variable flow of the water source. The clogging can be minimized by using effective screening (see the article on Coanda screens in *HP71).* We have not tried this approach yet, but rely instead on several large wire mesh baskets and regular cleaning by hand. The problem is only bad in late fall; throughout the winter there is little debris in the water.

Times of low flow still produce a useful output which provides additional heat even when the small diesel is running. In fact, we can leave the turbine unattended under this condition. The plant will keep on running, feeding into the dump loads, producing heat for the workshop. When it gets down to the last few hundred watts, it will quickly shut itself off when the water probe signals that the intake box is low on water. At this point we close the valve so the penstock doesn't drain. The only exception is if a hard freeze is expected. Under this condition, the line is drained.

One big lesson we learned quickly was that it is one thing to design a system based on summer conditions, and quite another to implement it and expect it to withstand the ravages of a winter storm. Rock fall and sheets of ice falling from high above will destroy just about any structure. We had to adjust our intake piping several times to prevent it from being swept away. We finally buried it, and it has been safe since then.

The catchment weir has been a big success. There is evidence of some really large rocks having rolled over it, and it has been buried under a mound of ice several feet thick. The only minor trouble is the 4 inch outlet pipe clogging with gravel and vegetation. We plan to replace this with a short length of 6 inch pipe and screen out the major debris with a coarse screen, followed by a Coanda screen.

Work or Play?
By far the hardest part of this project was the installation of the 2,200 foot (670 m) long penstock. We chose to haul long sections of pipe up the hill by hand, and at times we had 25 bodies spaced along the section, all straining away. When we found that the fusion welder could be run off the small generator, we packed it up the hill.

It took a crew of four guys to pack all the welding equipment, and several more to assist in aligning the pipe prior to fusing the ends. It's not backbreaking work, but it does demand a coordinated effort. Despite the complexity of working with this polyethylene pipe over PVC pipe, I would do the same thing again. Poly pipe is so amazingly strong and flexible; it's the only material that could stand up in our situation.

Malibu Club System Costs

Item	*Canadian Dollars*
Turbine and generator	8,500
1,800 feet of plastic pipe	2,400
Governor	1,145
350 feet of 4 inch steel pipe	740
8 hugger clamps	350
Switch gear (some reconditioned)	325
Metering and level sensing panel	300
Welder rental for five days	250
Dump loads	250
20 victaulic clamps	240
Rock anchors and cable	225
Additional wire	145
Intake box and screen	100
4 inch gate valve (scrap)	50
Pressure gauge	42
Concrete dam	20
Subtotal	$15,082
Other	
Powerhouse *	1,300
600 feet of #4, 4-conductor Tec wire **	1,200
Total	$17,582

* Built with materials on hand, not included in original budget.
** Tec cable was a later addition.

The steel section went together surprisingly quickly; it took just two days to place all 550 feet (170 m). Having a ready supply of blocking material and having pre-drilled the anchor points allowed us to connect the sections as fast as they could be carried up the hill.

The scaffolding we had set up over part of the bay enabled a crew of just three to connect the sections. Constructing the scaffolding took extra time, but it was worth the effort. Working with heavy pipe overhead is risky enough, so it was worth taking the time to do it safely. Having a volunteer labor force available at the camp was the biggest saving. Without this, the project would have taken much longer, and the construction cost would have been considerably higher.

Efficiency
At the maximum flow of half a cubic foot per second, we are able to produce 35 amps per phase. This works out to 12.6 KW, spread between our main loads and the governor's resistive dump load. With a flow of 225 gpm over the falls, and a gross static head of 550 feet (170 m), there is 23 KW of potential energy available. Our 12.6 KW represents about 55 percent of that total.

An efficiency figure of 60 percent is about average for a small system such as this. Our turbine is rated at 76 percent, and the generator 79 percent. We lose about 10 percent of the gross head due to friction in the penstock at full output. Totalling this (79% x 76% x 90%), we have 54 percent, and 54 percent times 23 KW equals 12.4 KW, roughly our measured output.

On average, the system is set with only the adjustable nozzle open. This will produce just under 7 KW. The reduced flow velocity results in slightly less pipe friction. This in turn results in higher net pressure at the turbine, and the more efficient spear nozzle appears to account for the increase in overall efficiency under this condition.

Payback

The 15 KW diesel generator would go through an average of two gallons (7.6 l) of fuel per hour. At 53 cents per litre ($2 gallon), the cost to run the diesel works out to $4 per hour, or $96 per day. That comes out to 27 cents a kilowatt-hour for fuel costs only.

We used this figure to calculate the payback time of the hydro plant. On average, we produce 6 KW, and can run for about 100 days a year. If we price the hydro power at the same rate as diesel-produced power, our hydro is earning $39 per day (6 KWH x $0.27/KWH = $1.62 per hour = $39/day). That's $3,900 per season, so it will pay for itself in just under four years. Not a bad investment!

As mentioned earlier, we were able to keep the total project cost down by doing some scrounging, and by purchasing new equipment at a slight discount. Other items were available on site (such as building materials), and all the labor was donated. The electronic water level sensor and optical frequency control were built at cost.

With the great success of this project, we are now planning to construct a larger plant on a year-round creek two miles (3 km) from the camp. This would take care of the needs of the entire camp throughout the year, and would result in significant cost savings.

On behalf of the Malibu Club, I wish to extend my thanks to all those volunteers who helped make this project a reality. In particular, thanks to Ron Kinders, Malibu's representative. Without his continual dedication and assistance in some very demanding conditions, this project would never have gone ahead.

Access

Author: Peter Talbot, 18875 124 A Ave., Pitt Meadows, BC, V3Y 2G9 Canada • Phone/Fax: 604-465-0927
ptalbot@rptelectronics.com • www.rptelectronics.com

Malibu Club, PO Box 49, Egmont, BC, V0N 1N0 Canada • 604-883-2582 • Fax: 604-883-2082
info@malibuclub.com • www.malibuclub.com

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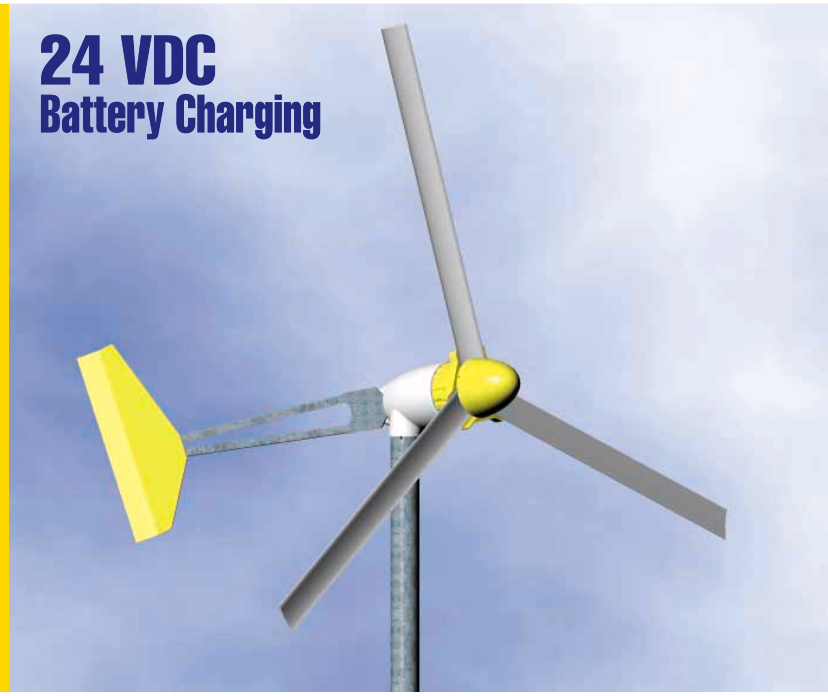

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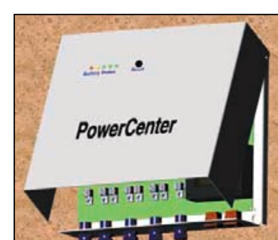

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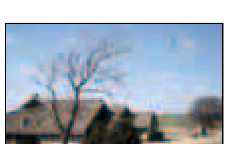

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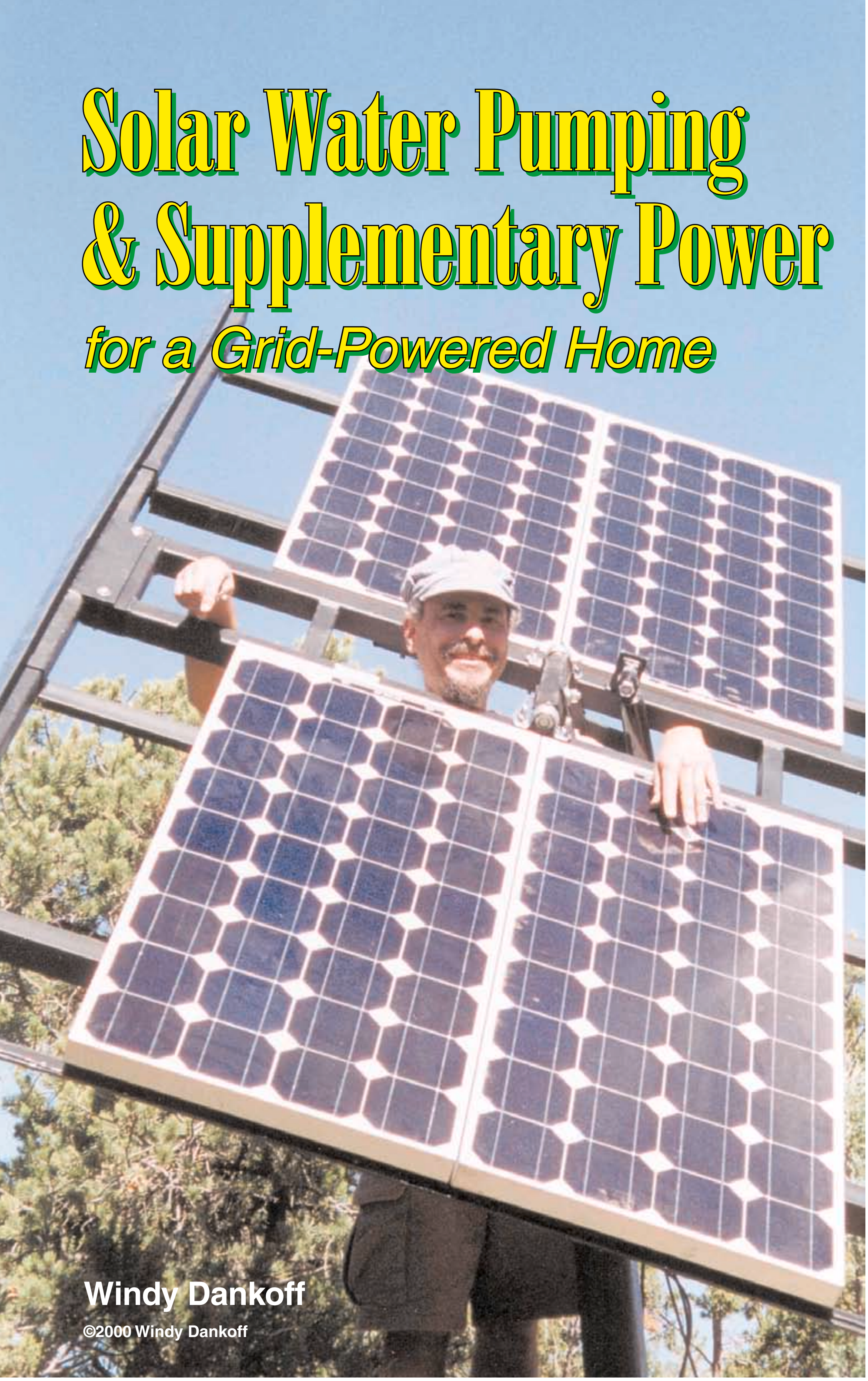


Author Windy Dankoff peers between his BP-585 PV panels on the Zomeworks Universal tracker.

My wife Anne and I found our perfect home in the woods, except for one thing—it already had electricity from the grid. Half of the staff at Dankoff Solar lives with photovoltaic power so the Dankoffs certainly should!

This article describes the system that we installed in late 1999. It uses solar power to pump our well water, and to power some of the circuits in our house. It also gives me a way to test new products and ideas. I will describe the power and water supply systems so you can learn from my experience. I will also describe how the solar-electric power is tied into the house.

Design Goals

I wanted my system to pump all of our water, to power a few of the circuits in our home, and to keep most circuits alive during power failures. I wanted a PV array of minimal size, so it wouldn't cost a fortune and would not impose on the aesthetics of our natural setting. Therefore, energy efficiency was a priority. I also wanted a battery bank to carry us through a power failure of several winter days.

System Location

I installed the PV array and power system near the water well, 140 feet (43 m) from the house. Our wellhead is located at the bottom of a covered pit that also contains the pressure tank and water filters. The pit is 6 feet deep and 7 feet in diameter (1.8 x 2.1 m). It is made of galvanized steel culvert material. I called the well driller and had him install a similar pit to contain the power center, batteries, and inverter.

The "power pit" can be a real problem solver. Some of our customers have installed systems this way even before the house is built. It gives protection from temperature extremes, is unobtrusive, and cheap. A pit installation is feasible at any site that doesn't have a high water table or flood potential, and isn't solid rock. I added some shelves to ours for storing food, making it even more useful. The PV array is installed nearby, on a pole-top tracker.

PV Array & Tracker

To size the PV array, I did a load calculation for summer drought conditions. I wanted to supply 500 gallons (1,900 l) of water per day in a worst case scenario. Working from the pump specifications, I determined the daily watt-hours to be about 1,000. I chose 85 watt, BP-585 modules because their extra quality and embedded-grid cell construction makes them more efficient, and thus more compact, than others. I figured on a nine hour peak solar day, assuming the use of a solar tracker during the driest summer weather. Calculation indicated that just two 85 watt modules would produce more than enough energy for water lift and pressurizing—surprising, isn't it?

I decided to go with four of the BP modules. This gives us enough surplus energy to run my home office and some compact fluorescent lights in the house. In case of a long power failure, the battery bank would have good capacity to run our Conserv refrigerator, our gas heating system, and the blower that distributes heat from our wood stove for about four winter days. Our heating systems consist of a wood stove with a 50 watt blower that blows hot air into an adjacent room, and an LP-gas hydronic system for in-floor heat. The hydronic system uses about 0.8 KWH per day in the winter, as measured on a Brand Power Meter (see *TtW! HP67).*

The solar tracker gives the array a 40 percent average energy gain during the warm half of the year, when we need the most water. I chose the Zomeworks Track Rack™ because it is simple and cost-effective. The only moving parts are the rack axis, a shock absorber, and the refrigerant fluid that flows from one side to the other to tip the balance.

I used the new "Universal" tracker that accommodates various sizes and brands of PV modules. It took about two extra hours to measure and place the parts to fit my modules, but it worked out fine. I installed an 11 foot (3.3 m) pole to be clear of nearby vegetation. The tracker requires a 3 inch pipe for its pole. But that's not strong enough to handle the extra height, so I had 5 feet (1.5 m) of 3 inch pipe welded to a 4 inch pipe. After we did the assembly and wiring on the ground, a neighbor came over with his backhoe to lift the finished array onto the pole. It tracks beautifully, even on windy days.

System Voltage

DC voltage standards are 12, 24, and 48 volts. We decided on 24 volts, as it's a happy medium, and is most common for a system of this size. A 12 volt system would require four times the wire size in all DC circuits, and would necessitate wiring battery sets in parallel, which is not ideal (see *Batteries: How to Keep Them Alive for Years and Years, HP69).* A 48 volt system was not an option because 48 volt charge controllers and inverters are only available in sizes much larger than we need.

Windy does the final wiring of the PV array.

Charge Controller

I'm testing a new RV Power Products' Solar Boost™ 50 charge controller with maximum power point tracking. I have observed over 20 percent gain in charge current during cold weather, compared to a traditional controller. I'm also happy with the way it regulates when there is excess energy (see *Solar Boost TtW! in HP73).*

Storage Battery

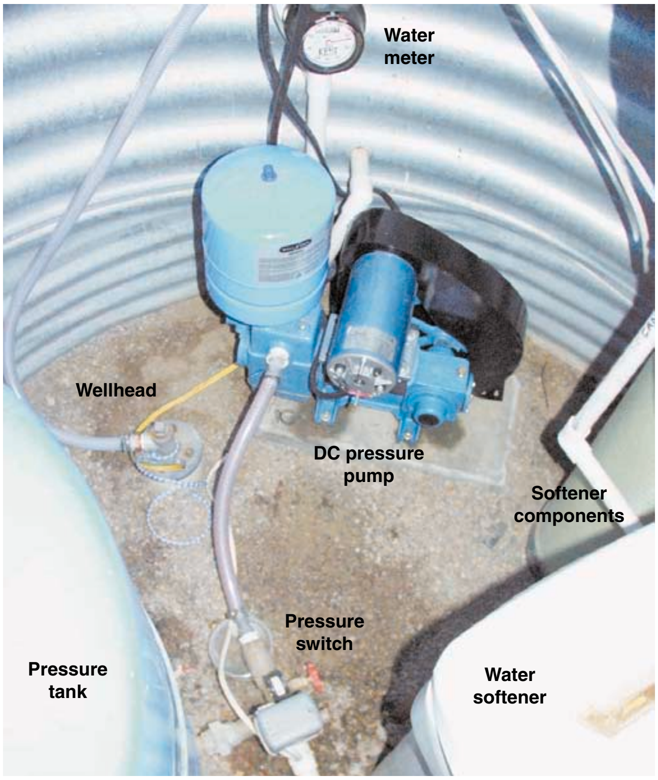
I selected a battery bank with 970 amp-hours of capacity. This is relatively large for the array and the load on the system. I wanted a large battery bank because it gives us a good reserve during power failures, and allows future expansion of my system. I chose batteries of the conventional wet cell lead-acid variety, made by Surrette/Rolls. They have a good reputation for quality and reliability (see *Surrette TtW!* in *HP75).* I expect these batteries to last for at least 15 years in our relatively light service.

Lowering the batteries into the pit was easy. The Rolls dual container batteries allow you to unbolt and remove individual 2 volt cells. It is then safe to suspend them by their terminals. We used a 4-to-1 rope and pulley system suspended from a stepladder to lower the twelve 95 pound (43 kg) cells one at a time.

Pump & Storage Tank

I installed the most energy-efficient pumping system available, using two DC pumps and a storage tank. This system uses less than half the energy (watt-hours per gallon) of a conventional AC pump powered by an inverter (see *Adding a Solar Deep Well Pump to a PV Home, HP61).*

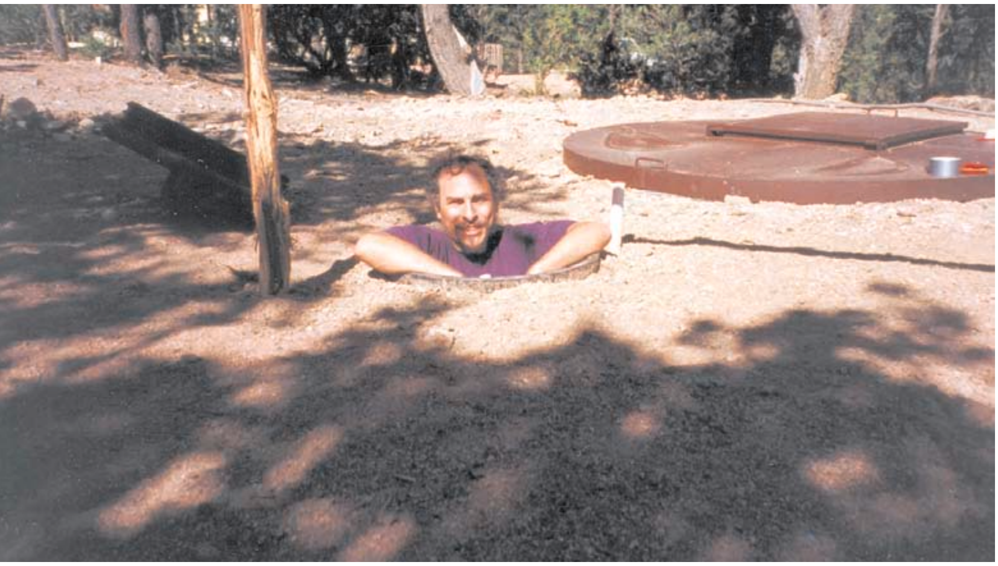
By utilizing a storage tank, the well pump can be set to run only during daylight hours, to eliminate the 15 to 20 percent loss that occurs when energy is stored and then later withdrawn from the battery. The tank provides a safety buffer in case of pump or system failure. The additional cost of DC pumps and a storage tank is balanced out by the savings in the power system, which would have to be doubled in size to run our original AC pump. The storage tank is made of drinking water grade polyethylene, designed for burial. It stores 1,200 gallons (4,500 l), which is sufficient for a four to ten day supply, depending on the season.



Water system components in the well pit.

Our water well is 285 feet (87 m) deep, and had a 230 V, 1 hp submersible pump. After I got the power system, storage tank, and pressure pump working, I used the AC pump one last time to fill the tank before our well driller pulled the pump out. Discoloration on the drop pipe indicated our static water level to be around 125 feet (38 m), so I chose to set a SunRise Submersible pump at 150 feet (46 m). Five days later (still with a half-full tank of water), a friend and I lowered the SunRise pump by hand, using 3/4 inch flexible polyethylene pipe.

The author emerges from the water tank after wiring the float switches and cleaning the dirt out. Behind him is the lid of the electrical pit.



Well Pump Controls

To power the SunRise pump, I use the SunRise SC-1B battery system controller. It contains a voltage converter that runs the pump at the full 60 V from our 24 V battery. It has a variety of safety features, including a low voltage disconnect (LVD) with two modes of operation. Mode 1 is normal LVD, which shuts off the pump if the battery voltage falls below 22 V to prevent malfunction or battery damage. Mode 2 raises the shut-off to 25 V so that the pump only runs when the battery is receiving a charge.

I selected mode 2 so that the pump doesn't draw from the battery at night. When the float switch in the storage tank calls for water at midnight or on a cloudy day, the controller waits until the battery is receiving a good charge. This eliminates battery loss. Normally we can wait a few days for the voltage to rise because our tank stores plenty of water.

The storage tank has two float switches in it. One is near the top. It turns the pump on when the tank is about 90 percent full, and off when it's full. I added a manual override switch so I can let the tank overflow when I want to. An overflow pipe leads to a low spot on our land where we will plant some trees. When there is excess energy during dry summer weather, it will support a beautiful little forest.

The second float switch is located low in the tank. If the tank gets down to the last 20 percent, this switch causes the LVD in the controller to switch to mode 1 to run the pump even if the battery voltage is not high. This is easy to do because the LVD mode 2 is selected by adding a jumper wire between two terminals. Simply wire a float switch to the terminals, instead of the jumper. I used an ordinary sump pump switch.

Pressurizing System

Our storage tank could not be located higher than the house, so we use a pressurizing pump to deliver the water. Our two-story house requires around 50 psi (4 bar) pressure. To supply pressure by gravity flow would require a tank to be elevated to a height of 115 feet (35 m)! Our pressurizing pump does the same thing with ease, using less than one quarter of the energy produced by our solar array.

We often run a small sprinkler or a drip irrigation system. Either one draws about 6 gallons (23 l) per minute. I installed a 24 V Solar Force™ Piston Pump. It pumps 9 gpm at 60 psi into our 85 gallon (320 l) pressure tank. The pressure tank was there from the original AC system. The Solar Force is a heavy, quiet, slow-speed pump that is durable and extremely energy efficient. The DC motor eliminates yet another load on the inverter.

Battery Monitoring—The TriMetric

I consider it extremely important for system users to have easy indicators of system performance, especially battery state-of-charge (SOC). I want this to be easy to read not only for my wife and me, but for any future housesitter or renter. I chose the TriMetric™ TM-2020 battery system monitor (see *TriMetric TtW!* in *HP45,* page 37). Its display of "Percent Battery Full" is as easy to understand as a car's fuel gauge.

Inside the well pit is this sight tube. The orange float indicates the level of water in the storage tank. The well pit is also used for food storage.

The TriMetric accomplishes this by counting amp-hours flowing to and from the battery. (A mere voltage reading cannot give battery SOC without the user also knowing the current flow, and understanding basic battery dynamics.) It also shows voltage, current, and additional data to facilitate system management and troubleshooting.

At a list price of US$185 (with current-measuring shunt), this type of meter belongs in all but the least expensive battery-based energy systems. I installed my TriMetric in the laundry/utility room in our house. This way we can monitor the system conveniently, and see the warning indicators that may show if there is a problem with the system.

The TriMetric can be located hundreds of feet from the power system, if the appropriate cable is used. I used shielded cable with twisted pairs, similar to underground telephone cable. When we buried the power cable from the pit to the house, it was no extra trouble to run the signal cable inside the same conduit as the AC power wires. I twisted the AC wires together. This suppresses the electromagnetic field to reduce any possible interference with the TriMetric's sensitive measuring functions.

Anne flips a switch in the transfer box—
part of the house is now running on solar power.
The label identifies the loads carried by each switch.

Our original water well drop pipe had been 1 inch PVC. We replaced it with 3/4 inch flexible polyethylene to facilitate hand installation of our solar pump. I recycled the PVC pipe by using it as the buried conduit. I ran the ground wire outside of the conduit so that it contacts the soil. This adds to the quality of our grounding system. Good grounding helps reduce the risk of lightning damage by draining off accumulated electrical charges before lightning strikes.

Water Tank Monitoring
I also wanted an easy way to observe the water level in our buried storage tank. The well pit is adjacent to the tank and at the same level. I rigged a sight tube in the pit where it is easy to see by opening the lid. The sight tube looks like a big thermometer with level marks.

I tapped a small fitting into the pipe that feeds the pressure pump, and connected a piece of 3/4 inch clear vinyl tubing that extends upward just higher than the top of the tank. I made a little plastic float to go inside the tubing, to make the water level more visible. You can see it when you lift the access lid of the pit.

As a side note, my power pit and well pit have steel lids. I've also seen them with poured concrete lids. I recommend the concrete because it provides much better insulation from outside temperature extremes. I'm still trying to figure out how to insulate my steel lids.

Inverter
My power system is for supplement and backup, so I don't need a giant inverter. I did however want high quality "true sine wave" power so that I wouldn't hear a buzz in the stereo, or risk damage to my computer (I have have heard that some Macintosh computers can be damaged by "modified sine wave" power).

I determined that an inverter with a 2,000 watt capacity would be sufficient to run our AC essentials during a power failure. I chose the Statpower ProSine 1800. Other sine wave inverters on the market are either too small, or larger than I need. The ProSine has all of the basic features needed for a home system inverter and works as specified.

Transfer Switch
To make the best use of my modestly-sized system, I need the choice of switching various circuits in the house from grid to solar, at will. During a long power failure, I want to solar-power the essentials for safety and comfort. During very sunny weather, I want to power as many circuits as I can. During the short days of winter, I can power my office and the water supply, but little else.

I found a device that lets me make this choice—the Reliance GenTran™. It's a manual transfer panel, designed to interface a backup generator with an ordinary AC load center (breaker box). Various models are available, to transfer as many as 10 circuits. It's intended to take 240 V power from a generator, so I had

Dankoff System Costs

Item	*Cost (US$)*
12 Surrette 2 V cells, 970 AH	5,000
4 BP-585 85 watt PV modules	2,100
SunRise Submersible DC well pump	1,850
Statpower ProSine 1800 inverter	1,300
Solar Force piston pump 3040-24B	1,250
Pit materials & construction	950
Zomeworks Universal Track Rack UTR-040	860
Tank excavation and installation	850
Power center, custom made	800
Wiring and misc. components	800
Water storage tank	750
Solar Boost 50 charge controller	380
SunRise SC-1B converter/controller	365
GenTran transfer switch	285
TriMetric amp-hour meter	165
AC pump removal	150
Total	$17,855

to open mine and tie the two hot sides together. This is normal practice in a load center that must accept a power source that puts out only 120 V.

I bought an outdoor version of the GenTran, and mounted it next to the load center on our house. I brought power underground from the power pit to the GenTran. Next, I decided which home circuits would be transferable. Wiring was very easy, following the product instructions. Inside the GenTran, I labeled which switches control which circuits and appliances in the house.

The GenTran has a receptacle that connects directly to the inverter line. I keep a 1/4 watt night light plugged into that to indicate whether the inverter is on or off. When the inverter is in its "power saver" mode and doesn't see a load, the night light flashes every 2 seconds. This indicates that the inverter is "sleeping" but checking for a load. A quick glance at the light tells me if some appliance or phantom load was left on accidentally.

Testing the System

I let my battery bank rise up to 100 percent full indication on the TriMetric, which was verified by the Solar Boost charge controller having reached its "float charge" mode. On December 21, I set the transfer switches to run our heating systems, kitchen appliances, office, and most home lights on solar.

Then I simulated a power failure by shutting off the main breaker to our load center. It was comfortable, and especially satisfying to not be totally dependent on the power company. We ran some incandescent lights, and didn't even try to conserve energy. We even baked a loaf of bread in our bread machine! Twenty-four hours later, the TriMetric indicated that the battery charge was 75 percent. That was the end of my test. Because of deep winter solar conditions, it took four days for the batteries to return to 100 percent. When we get a real power failure, we will be more energy conserving!

We Survived Y2K!

What did I do at the turn of the big 2000? I kept one eye on the solar-powered TV, and the other eye on the grid-powered light in the adjacent room. Happily, neither of them faltered. Since then, I've been running my home office on solar power (even now as I write) and occasionally some other circuits in the house, and always the water supply. When summer comes, I'll be able to run more of the home circuits on RE.

Access

Author: Windy Dankoff, Dankoff Solar Products, Inc, 2810 Industrial Rd., Santa Fe, NM 87505-3120
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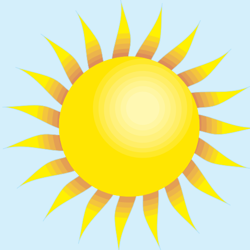

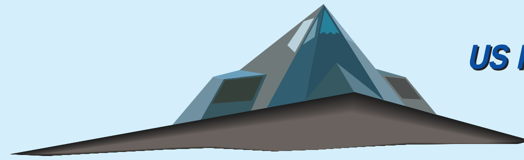

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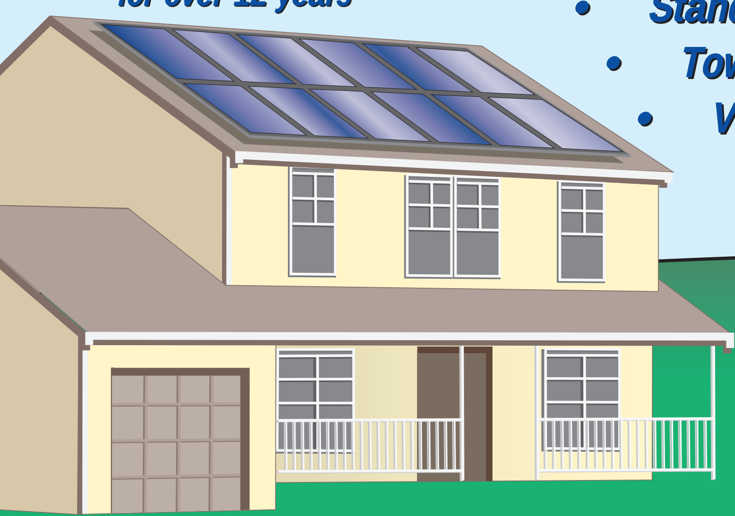

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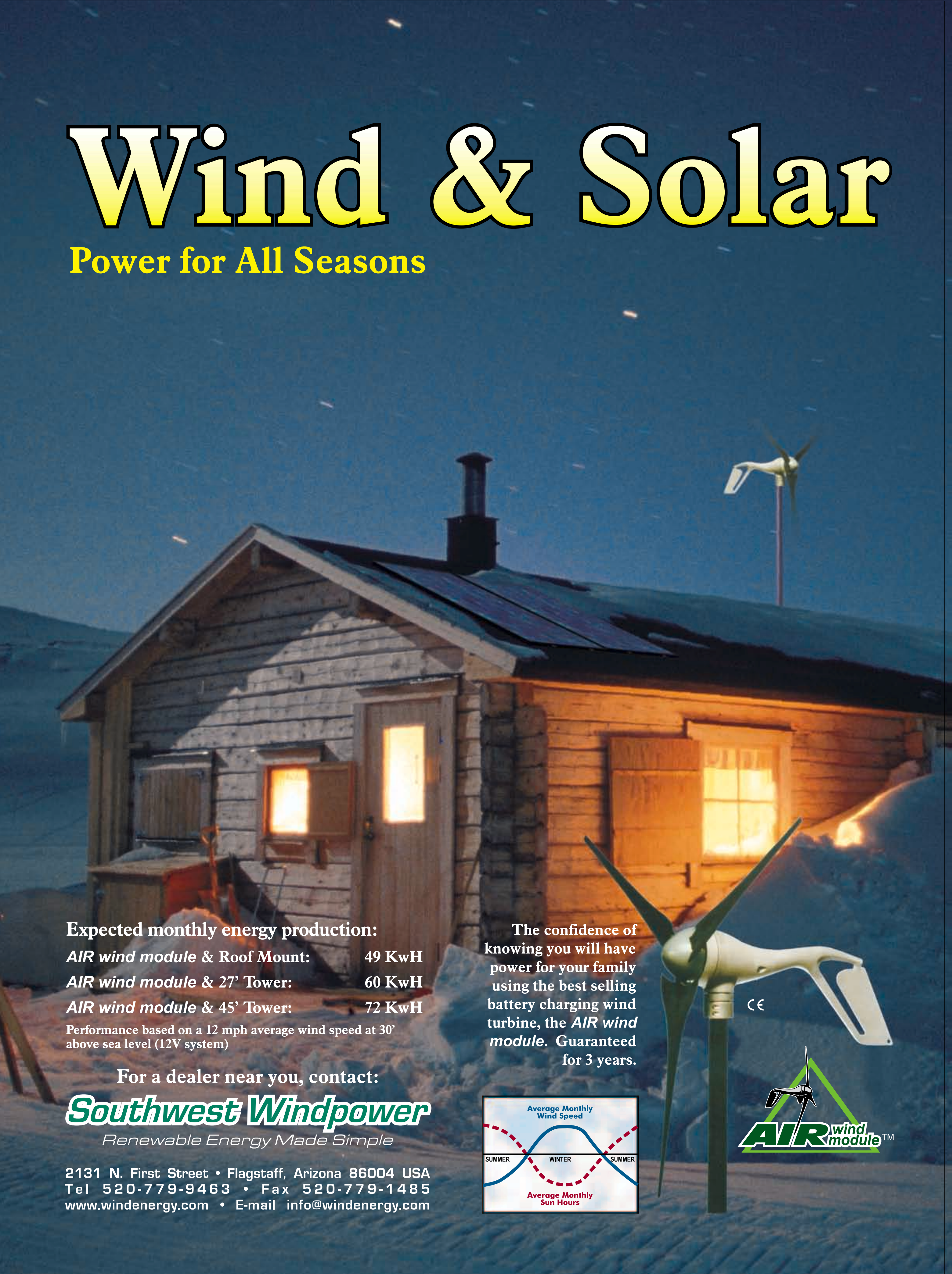
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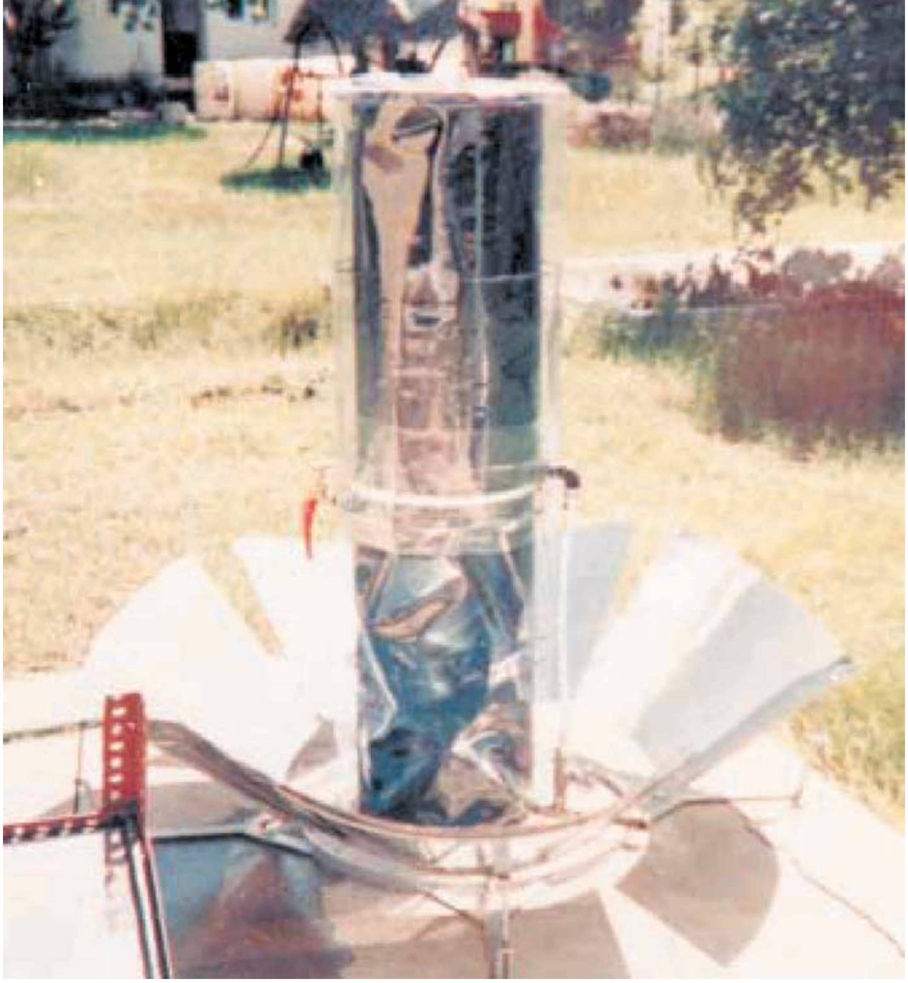


A simple solar batch water heater.

The sun is an energy source available to everyone—an energy source that can be used simply and inexpensively to reduce developing countries' dependence on imported fuels. A solar water heater is the simplest and most cost-effective solar application.

Solar water heaters are based on a common natural phenomenon: cold water in a container exposed to the sun undergoes a rise in temperature. A solar water heater is usually a flat-plate collector and an insulated storage tank. The collector is commonly a blackened metal plate with metal tubing attached, and is usually provided with a glass cover and a layer of insulation under the plate. The collector tubing is connected with pipe to a tank that stores hot water for later use.

When mounted on a roof or other suitable support, the collector absorbs solar radiation, and transfers the resulting heat to water circulating through the tubing. In this way, hot water is supplied to the storage tank. In many common designs, the storage tank is located above the top of the collector. The elevated position of the tank results in natural convection—water circulates from the collector to the tank.

Solar water heater technology is so simple. Why is it that developing countries do not use it very much? The reasons are not hard to find. The main constraint is prohibitive cost. For example, in India, a 100 litre (25 gallon) solar water heater costs around 12,000 rupees (Rs.), about US$300. Also, not many people living in towns and villages have access to overhead water storage tanks with a continuous supply of cold water. To overcome these barriers, I designed and tested a vertical, cylindrical solar water heater that does not require pressurized water or roof mounting.

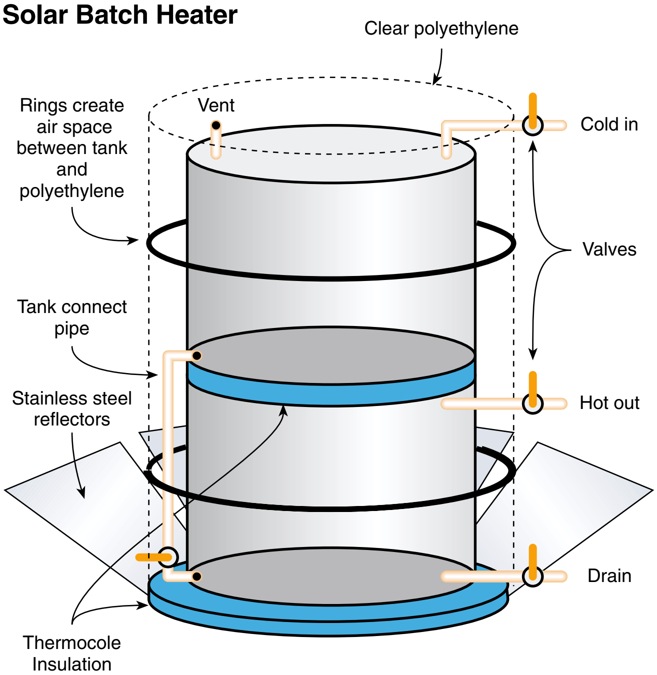
Design Details

The system consists of two stainless steel collectors (normally used in the manufacture of drinking water drums). These vertical cylinders are 0.6 m high and 32 cm in diameter (24 x 12 inches). The cylinders are placed one over the other with Thermocole insulation (made with paper) in between, as well as at the bottom, to prevent heat losses. The top tank is provided with an inlet at the top, a cap, and an opening at the bottom. This bottom opening is connected to the bottom cylinder with a pipe designed to withstand high temperatures.

There is a lever attached to this pipe to control water flow. The bottom cylinder is provided with an outlet at the top from which water is drawn. Both the cylinders have rings welded to the tanks to form a 3 cm (1 inch) gap. They are covered with high-density transparent polyethylene sheet to create a greenhouse affect.

A lotus flower shaped reflector made of stainless steel focuses sunlight on the bottom cylinder. It doesn't need

Solar Batch Heater



to be moved to follow the motion of the sun; it does its job wherever the sun is. With normal reflectors, there is a shadow in the afternoon. With this circular reflector, when one side is shaded, the other side is still working.

There is a separate insulated cover to help hold the heat overnight. It is made of a circular bamboo basket that is 1.3 m high and 45 cm (4.2 x 1.5 feet) in diameter. It is covered with 6 mm (1/4 inch) glass wool (rock wool), with a transparent polyethylene cover so that the whole setup is airtight.

Hot Design

This heater is somewhat different from the common batch water heaters you see in places with pressurized water or gravity flow systems. You might think that the lower tank is "wasted," since the hot line out is in the top of this tank. Or you might wonder why the hot line out is not where the hottest water is—at the top of the upper tank.

But consider what it takes to design a ground-mounted system with no pressurized water. Then you will see that the upper tank in this system provides a small amount of pressure and a reservoir of hot water, and the lower tank is a place for the cooler water to cycle down into.

If you put the hot line out where the drain is, you'd get the coldest water. If you put the hot line out where the hottest water is, you'd only get a little of it before you had no pressure. Tapping the hot water from the top of the bottom tank is a worthy compromise, giving you the best of both worlds. And if cold or warm water is needed, the drain from the lower tank can be tapped.

Operation

The collector is filled with potable water in the morning at 8 AM and is covered with the insulator (bamboo basket) at 4 PM. The hot water can be used either in the evening, at night or the next morning. Hot water up to 70°C (160°F) is obtainable depending on the sunshine. In fifteen hours of storage, with nighttime temperatures dropping to 25°C (77°F), I observed about 7°C (13°F) drop in the hot water temperature.

This 100 litre (25 gallon) unit costs about Rs. 6,000 (US$150) in southern India, and will be highly useful as a pre-heater for cooking, bathing, washing clothes and utensils, and for rural schools, hospitals, etc.

Advantages

- The unit is mobile, modular, and easy to install and dismantle for transporting.
- Cold water supplied through pipes is not necessary.
- There is no need for an overhead water storage tank.
- There is no need to have a separate collector; this is an integrated system.
- Since the collector is made of stainless steel, the hot water will be hygienic.
- Because of the omni-directional reflector, relatively higher water temperatures are obtained even in moderate sunshine.
- The unit occupies less space on the ground or roof, being vertical and circular.
- All the materials used in the fabrication of this simple and cost-effective solar water heater are available locally.
- The unit is durable and will last a long time, except for the polyethelene cover. It will need to be replaced about every four months, which costs just Rs. 30 (about US$0.70).
- By using pre-heated water for cooking from this unit, considerable fuel such as firewood, kerosene, gas, electricity, etc. can be conserved.

Access

Dr. A. Jagadeesh, Renewable Energy Specialist, 2/210, First Floor, Nawabpet, Nellore - 524 002, AP., India
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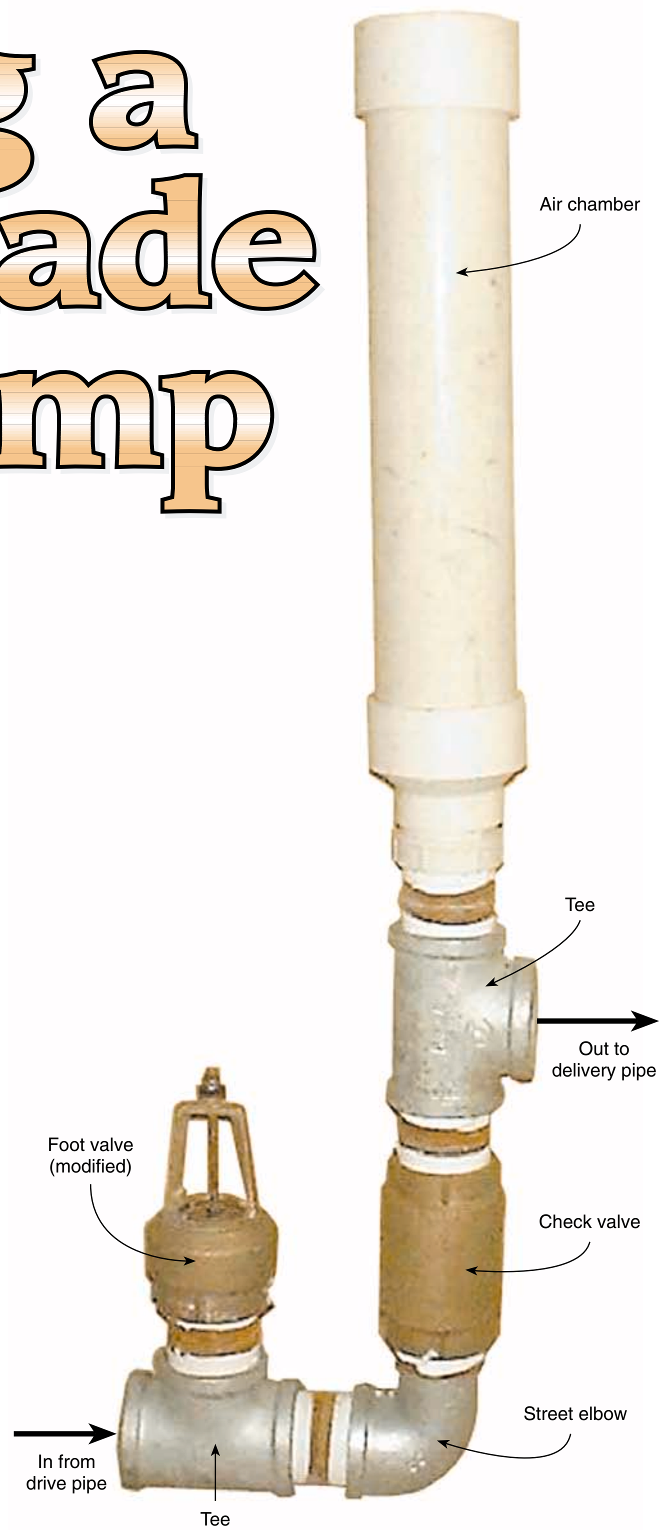
Building a Homemade Ram Pump

Scott Lee



During the mid 1970s, I first encountered the hydraulic ram water pump. A friend of mine was interested in a water pump for irrigating a garden. I had also purchased some land with a stream and a nice garden spot, but no electrical service. The combination of a stream below my garden spot and no electrical power seemed to be a perfect situation for a hydraulic ram.

Three Tries

The manufactured rams back in the '70s were fairly expensive—US$250 and up. Some publications had home-built designs. One in particular was by an organization called VITA (Volunteers in Technical Assistance). Based on the cost of the manufactured rams, I set out to construct a home-built ram pump. The first two versions of my ram were based loosely on VITA's descriptions and plans. They weren't followed exactly, due to the difficulty in obtaining some of the parts that were mentioned.

Scott Lee's ram pump in operation.

I recently went to the local hardware store to check out the cost of these parts. The 2 inch version of my homebrew ram will cost about US$130 (see parts list). A 1 inch ram will be cheaper, and might cost a little more than half that amount. The cost of the pipes needed to hook up the ram may exceed the cost of the ram itself.

Ram Pump Parts List

Qty	*Item*
1	2 inch foot valve (brass)
1	2 inch check valve (brass)
2	2 inch tees (galvanized)
6	2 inch close nipples (galvanized)
1	2 inch street elbow (galvanized)
1	2 by 1 inch bushing (galvanized)
1	1 inch close nipple (galvanized)
1	3 inch pipe cap (PVC)
1	3 inch pipe, 18 inches long (PVC)
1	3 by 2 inch reducer (PVC)
1	2 inch PVC to IPT adapter (PVC)
1	1/4 inch threaded rod (stainless)
6	1/4 inch nuts (stainless)
2	1/4 inch washers (stainless)
1	Faucet washer
1	14 gauge copper wire, 2 inches

The first version of my ram was built entirely out of galvanized steel pipe and fittings. The waste (or impetus) valve proved to be the hardest to construct. The first version's valve was constructed from a 1 1/2 by 1 inch bushing. While this valve worked after a fashion, it was very leaky. I figured that the ram would perform better if this valve would seal tightly. My second version had a valve that was constructed from a 1 1/2 inch pipe plug. The plug was bored with a 1 inch hole, and had the inside surface of the plug machined smooth. This resulted in better ram performance.

I never used the first two versions in working applications, though I did test them. Shortly after the second one was operational, an article appeared in *The Mother Earth News* (May/June 1979, #57, page 120) with instructions on how to build a ram mainly out of PVC pipe fittings. Using this design as a guide, I developed a third version. This version was also built from galvanized steel pipe fittings, with the exception of the air chamber, which was constructed from PVC pipe and fittings. This version still required machining of a sort—cutting threads on the outside of a 1 1/2 inch hose barb, so that it would thread into a 2 by 1 inch bushing.

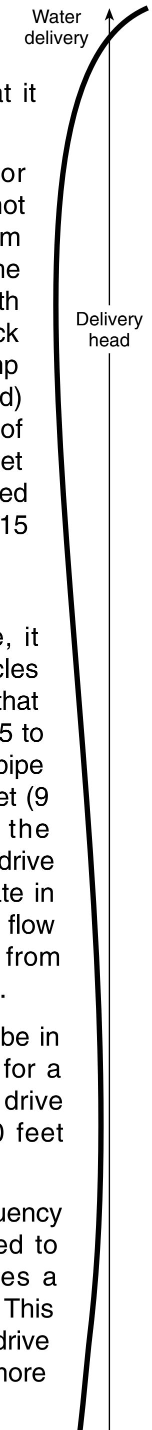
Although this was a workable system for constructing the waste valve, it still was not as simple as I wanted. For a time, this ram was used to pump water to my garden. The water was also used to provide showers, with the use of 200 feet (60 m) of 3/4 inch black poly pipe for a solar water heater. This pump was installed with a 4 foot (1.2 m) fall (head) to the ram, developed over the distance of 100 feet (30 m). It had a delivery lift of 30 feet (9 m) to a 3 by 12 foot (0.9 x 3.7 m) pool used as a storage tank. The point of use was 15 feet (4.5 m) lower than this storage pool.

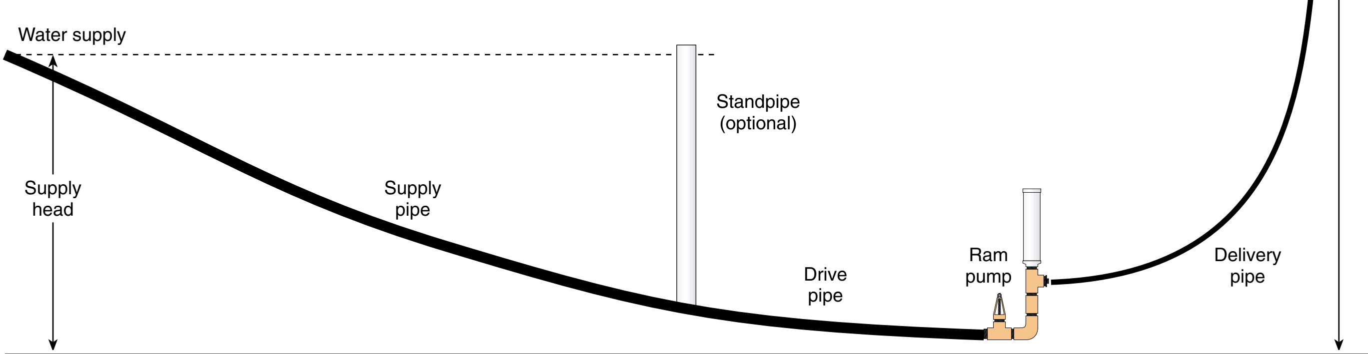
Standpipe

When the ram was first put into service, it operated very slowly—about 15 to 20 cycles per minute. Everything that I'd read stated that rams of this size should operate at about 45 to 60 cycles per minute. I fabricated a standpipe and inserted it in the drive line about 30 feet (9 m) from the ram. This is within the recommended 5–10 times ratio of head to drive pipe length. This allowed the ram to operate in the 45 to 60 cycles per minute range. The flow of water delivered to the tank increased from 0.25 to 0.75 gallons (0.9 to 2.8 l) per minute.

Ideally, the length of the drive pipe should be in the range of 5 to 10 times the head. So for a head of 3 feet (0.9 m), the length of the drive pipe should be in the range of 15 to 30 feet (4.5–9 m).

If the drive pipe is too long, the cycle frequency that the ram can operate at will be limited to some low value. The standpipe provides a closer location for the ram pump's supply. This means that there is less resistance in the drive pipe, and the flow can reach full velocity more





How a Ram Pump Works

The energy required to make a ram lift water to a higher elevation comes from water falling downhill due to gravity, as in all other water-powered devices. But unlike a water wheel or turbine, the ram uses the inertia of moving water rather than water pressure, and operates in a cycle.

1. When the waste valve is opened, water flows from the source, through the water inlet (drive) pipe, and out the waste valve.

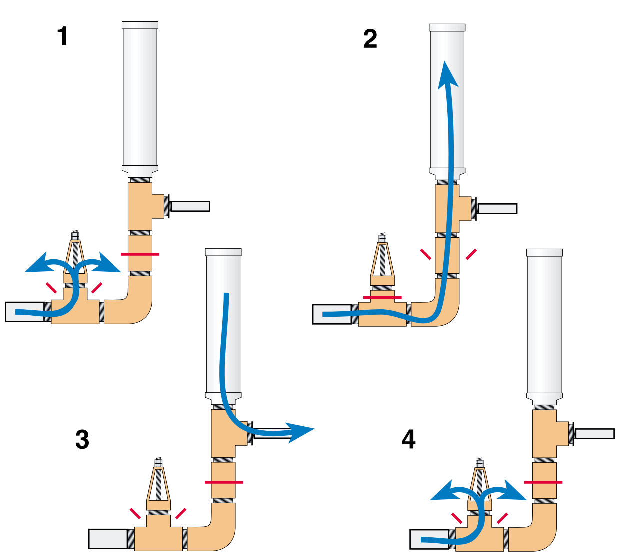
2. After a short time, the velocity of the flow is high enough to force the waste valve closed. The water, due to its inertia, wants to continue moving past the valve. The pressure inside the ram will rapidly increase enough to force the check valve open. This forces some water into the air chamber, compressing the chamber's air bubble. The pressurized bubble forces that water through the delivery pipe to the point of use.

For a ram pumping one gallon (3.8 l) per minute, and cycling 60 times per minute, each cycle pumps one-sixtieth of a gallon—about two ounces (60 ml). The compressed air in the air chamber helps smooth out the flow on the delivery side of the ram, so the flow tends to be more continuous, rather than a small spurt during each cycle of the ram.

3. Soon after the check valve has opened, the pressure surge (generated by the waste valve closing) is spent. Flow will try to start backwards, but the check valve will close, preventing this from happening.

4. At about this time, the pressure in the drive pipe will be low enough so that the waste valve can open, allowing water to start flowing from the source to the ram, beginning a new cycle.

The cycle that the ram goes through can occur 30 to 120 times per minute, depending upon conditions such as head, flow, and the size of the ram.



quickly than without the standpipe. Basically, a standpipe allows the ram to operate as if it had a shorter drive pipe.

The diagram on page 43 shows a standpipe inserted between the supply pipe and the drive pipe. The critical distance is now only the distance between the standpipe and the ram, not the total distance to the source of supply.

A standpipe can easily be constructed out of PVC pipe and fittings. The pipe needs to be long enough so that it is a few inches higher, in its installed location, than the elevation of the water source. Consider screening the top of the standpipe to keep out birds, insects, and detritus if you are pumping potable water.

The standpipe is usually inserted at a distance from the ram that is 5 to 10 times the supply head. This will vary from installation to installation. Since my installation had 3 feet (0.9 m) of supply head, I inserted the standpipe 30 feet (9 m) from the ram. This allows the ram to cycle properly, which results in more water pumped.

It's also important to consider the diameter of pipe on long drive runs, to minimize flow loss due to pipe friction. When in doubt, go up in size. It's recommended that the standpipe be at least two full pipe sizes larger than the drive pipe. I've used 4 inch standpipes with 2 inch rams, and 2 inch standpipes with 1 inch rams. It's also recommended that the pipe from the supply to the standpipe be one full pipe size larger than the drive pipe. This will insure that the flow to the standpipe will be able to keep up with the ram pump's usage.

Drive Pipe

This configuration operated for about six months, after which it was dismantled for the winter. It was later installed at a new location with 3 feet (0.9 m) of head and 12 feet (3.7 m) of lift. Most of the time it supplied garden soaker hoses, with an old 52 gallon (200 l) hot water tank being used for a small storage volume, operated as a pressure tank.

One day, we were operating the ram with the discharge valve shut, and we noticed that the 2 inch black poly drive pipe was actually expanding visibly with each closing of the waste valve. We concluded that a portion of the energy was being wasted expanding the drive pipe, rather than pumping water. We also noticed that the max discharge pressure was 21 psi.

So I replaced the 30 feet (9 m) of black poly pipe between the standpipe and the ram with schedule 40 PVC pipe. With this pipe in place, I noted that the maximum discharge pressure was now 57 psi. This meant an almost threefold increase in the amount of water delivered. With a 12 foot (3.7 m) lift, we measured the flow at 2 gpm after the installation of the PVC drive pipe.

Based on these observations, I suggest that you don't use black poly pipe or other flexible pipe for the drive pipe. If you are using a standpipe, the pipe from the standpipe to the ram is the only section that needs to be rigid. The supply pipe from the source to the standpipe can be flexible. If your drive head is higher than a few feet, steel drive pipe is recommended, since high pressures can blow out plastic pipe joints.

The foot valve on its way to becoming the waste valve—the stem is cut off the valve disc and the lower crosspiece has been cut away from the casting.

Versions Four & Five

Although this ram was successful, it still was not completely satisfactory. The waste valve needed a lot of maintenance, and also required a pipe threading machine to make it. In light of these shortcomings, a fourth version was built using a standard plumbing check valve for the basis of the waste valve. This worked well, but required a lot of work to cut discharge ports into the check valve.

In a matter of days after version four was put in operation, it was discovered that a foot valve would serve the purpose as well as a check valve, with very little work required to convert. This valve was built and put into operation successfully and performed well. The fifth version is still in use. I think that it was first used in 1980 or '81. This ram continues to provide irrigation for a garden, and water for keeping a compost pile moist enough for proper decomposition.

It should be noted that this is not a year-round installation. Before winter weather starts, the ram and standpipe are removed from the stream to prevent freezing. They are reinstalled the following spring. This has worked well, since there is no demand for the water during the winter.

I built and installed another ram of this size for a neighbor, to supply water from a spring to two houses. This ram was a slightly improved version. The main differences were that I used a larger check valve and foot valve, which improved the performance slightly. This ram was supplied by 4 feet (1.2 m) of head and lifted the water 30 feet (9 m) to a 1,500 gallon (5,700 l) storage tank about 1,400 feet (425 m) away.

At the storage tank, separate centrifugal pumps and pressure tanks were used to supply water to both houses. The ram delivers almost 1 gpm to the storage tank, which has proved to be plenty of water for all normal household uses. This ram installation is freeze-proof, with the delivery line buried and the ram in an enclosure. The ram has proved to be superior to trekking to the spring and running a gasoline engine-driven pump every two to three days to fill the storage tank.

How to Build The Ram

All of the parts for the ram were obtained from a local hardware store's plumbing section. The foot and check valves were Simmons brand, but any other good quality valves should work as long as they are of the same general configuration.

Begin the fabrication of the waste valve by removing the screen that is supplied as part of the foot valve. Then use wrenches to remove the valve disc from the foot valve, and cut off the supplied stem from the valve.

Now take the disc and drill a 1/4 inch (6 mm) hole in the center of it.

Use extreme care in drilling this hole to make sure that it is straight and centered. Use a drill press if you can. It is possible to get this right by hand if you are careful.

Now cut a 6 inch (15 cm) piece of 1/4 inch (6 mm) threaded stainless steel rod for the new valve stem. Thread on one of the 1/4 inch nuts, far enough to allow the valve disc to be placed on the threaded rod with room for another 1/4 inch nut. Lock the disc to the threaded rod by tightening both nuts against the disc.

The valve disc is reassembled with a 6 inch long piece of 0.25 inch stainless steel threaded rod, and locked in place with nuts top and bottom.

Now take the valve body and enlarge the threaded hole in the top crosspiece to 1/4 inch with a drill. Again, use care to get this hole straight. Using a hacksaw, remove the lower crosspiece.

After these modifications have been made, take the modified valve disc and insert it up through the valve body. After you have inserted it, put on a 1/4 inch washer, a faucet washer with its hole enlarged to 1/4 inch, and another 1/4 inch washer. The faucet washer provides some cushion to help quiet the waste valve when it falls open. Then thread on two 1/4 inch nuts, adjusting them so that they allow about 1/2 inch (13 mm) of movement of the valve disc and stem within the body. This is a good starting point—further adjustments can be made later, after the ram is operating. Your assembled valve should look like the diagram at right.

Air Sniffer

The next step is to modify the 2 inch check valve by adding an air sniffer hole. This hole will allow a little air to be taken in on each stroke of the ram, replacing air in the air chamber that has dissolved in the water and gone up the delivery pipe. Loss of all the air in the air chamber can result in something breaking. I once saw the bonnet of a 2 inch PVC valve blow off. This valve was used to isolate the ram from the drive pipe. If you choose not to use an air sniffer, you must shut down the ram every few days and drain some water from the air chamber.

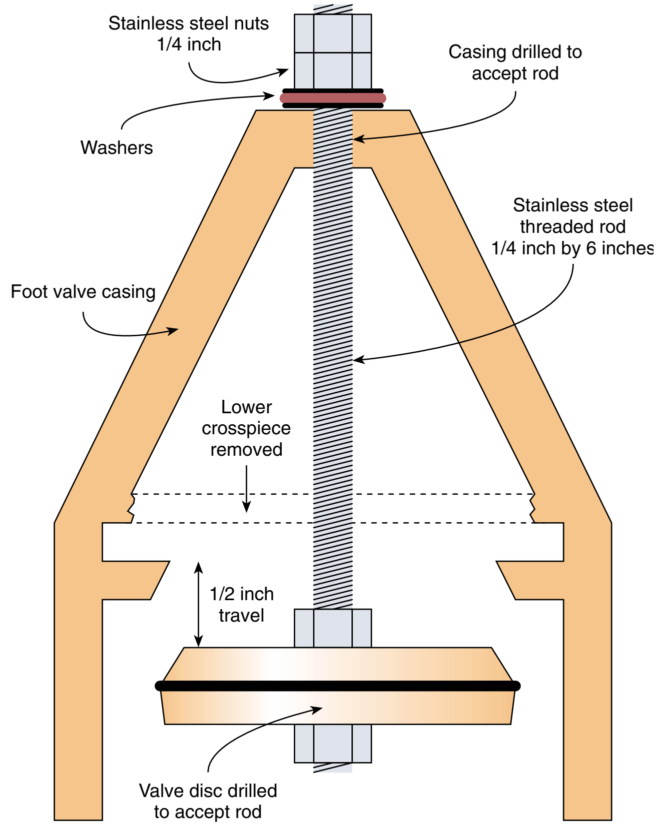
Begin the construction of the air sniffer by stripping the insulation from a piece of #14 (2 mm^2) copper wire. Select a drill bit that is just slightly larger than this wire. Use this bit to drill a hole in the check valve as shown in the next sketch.

Make sure that you drill this hole on the correct side of the valve seat, as shown on page 47. After you have drilled this hole, twist a small loop in one end of the wire you have stripped. Insert the straight end of this wire into the hole, and twist another small loop in the wire on the inside of the check valve. If you are building the ram for a low-head installation, you may want to remove the spring from the check valve at this time. Otherwise it can be left in place.

Air Chamber

The air chamber is the last piece you will need to assemble before the ram can be completely finished. A 4 inch diameter air chamber should be okay for up to 10 feet (3 m), while a 6 inch chamber should work for about 15 feet (4.5 m). When in doubt, it's probably better to err on the large side. The air chambers are usually about 18 inches (46 cm) plus the length of the fittings, but could be made longer if necessary.

Assembled Waste Valve Detail



The modified foot valve ready to assemble onto the ram.

To assemble the air chamber, glue a cap to one end of the 3 inch PVC pipe. Then glue the 3 by 2 inch reducer to the other end of the pipe. After these are complete, glue in the PVC to IPT adapter. The air chamber should now be complete, and the final assembly of the ram can proceed.

Assembly
Screw a 2 inch close nipple into one of the end branches, and another into the side branch, of a 2 inch tee. Teflon tape should be used on all of the threaded connections. This will aid in any disassembly that may be required in the future. Screw your waste valve onto the nipple on the tee's side branch.

Screw the street bend onto the nipple on the end branch. Screw the check valve onto the end of the street bend. The flow directional arrow should point away from the street bend. Screw a 2 inch close nipple into the check valve. Screw an end branch of the other 2 inch tee onto the close nipple.

Screw another close nipple into the other end branch of the 2 inch tee. Screw your air chamber onto this nipple. Screw the 2 by 1 inch bushing into the side branch of the tee. Screw the 1 inch close nipple into this bushing. Go back to the first 2 inch tee and screw in the last 2 inch close nipple.

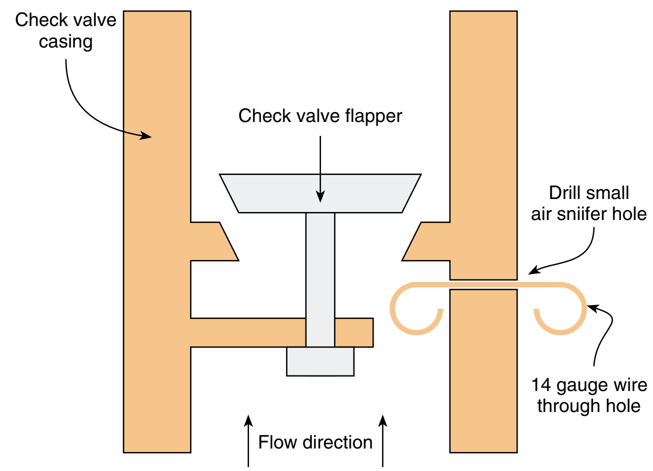
Your completed ram should look approximately like the photo on page 42. The 3 inch air chamber size on this ram should be adequate for supply heads of up to 5 feet (1.5 m). If the head is greater than this, the air chamber should be larger.

Installation
This completes the ram pump construction, but you may find that this is the easiest part of the job. As much or more depends on a good installation. I recommend that you use a union on either end of the ram. A gate valve on both the drive and discharge lines will also facilitate any maintenance that is required on the ram itself. The diagram on page 43 is a typical ram installation, showing head, lift, supply, delivery, and the length of the drive pipe.

To calculate how much a ram will deliver, divide the head by the lift, multiply by the flow, and finally multiply by 0.6. It takes at least 5 gpm to run this ram, with at least 2 feet (0.6 m) of head. In general it is easier to pump more water with more head, so run more drive pipe to get the head you need.

The check valve with the wire poking out of the air sniffer hole.

Check Valve Cutaway



Using this equation, a site with 3 feet (0.9 m) of head, 20 feet (6 m) of lift, and a supply flow of 10 gpm would deliver 0.9 gpm. The same flow and lift, with 4 feet (1.2 m) of head, would result in 1.2 gpm delivered to the point of use. Or the same delivery could be accomplished with less supply flow. The delivered flow of 0.9 gpm could be achieved with 7.5 gpm of supply flow, using 4 feet (1.2 m) of head.

Maintenance on this ram is not very demanding. I've had to replace the faucet washer a couple of times per year. Otherwise the ram is noisy, and tends to wear the metal parts more. The O-rings on the valves will have to be replaced about every five years. The wire in the air sniffer will last two to four years.

Consider a Ram

Hydraulic rams can be very useful in providing a supply of water from a lower to a higher elevation. They can pump in a remote location, with no other energy required besides the falling water. Don't be discouraged about the small flow of water delivered by a ram, since they can pump 24 hours a day. Remember that one gallon per minute times 1,440 minutes per day will be 1,440 gallons per day delivered to wherever it is needed. It can also be used year-round if the ram and piping are protected from freezing.

The most important step in deciding if a ram is for you is a site survey. This will ensure that you have the flow and head required to operate a ram. Once this has been determined, build a ram to supply the water. Rams are inexpensive, easy to construct, and dependable, so there's no reason not to use one, if you have a location that meets the requirements.

Access

Scott Lee, 708 White Rock Gap Rd., Covington, VA 24426 • 540-862-4377 • slee529282@aol.com

Other *Home Power* articles on ram pumps:

Hydraulic Ram Pump, by Kurt Janke & Louise Finger, *HP41,* page 74.

Things that Work! on the Folk Ram Pump, by Michael Welch, *HP40,* page 44.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Zimbabwean Wind Energy Spins at Redhill

The African Windpower bird above the telecomms array.

Glynn Morris

Feather Energy has erected a small wind turbine as part of a hybrid wind/PV/genset electricity supply system for a home and office at the Redhill Mountain Reserve, a private addition to the newly established Cape Peninsula National Park, above Simon's Town, South Africa.

The property has a passive solar home and office, with a PV-powered water pump and microwave telephone exchange, and a wind energy system for house and office loads. The system includes a 1 KW wind generator, a 1 KWp PV array, and a 5 KVA petrol genset supplying a 1,000 AH 24 V battery and a 2 KVA sine wave inverter.

The energy demand is roughly 3.5 KWH per day during the week—for the office and domestic needs—and 800 WH per day on weekends. In addition to lights, the office equipment includes two desktop PCs, a notebook PC, laser printer, deskjet printer, scanner, network hub, fax machine, PABX, and an answering machine. The domestic loads include a washing machine, TV and VCR, small kitchen appliances, and power tools.

The system is a joint initiative between Feather Energy, owner and operator of the site; African Windpower (AWP), the wind turbine manufacturer; Siemens Solar, who supplied the PVs and batteries; Photovoltaic Design and Installation (PDI), controller manufacturer and system designer; and MLT Power, who supplied the inverter and battery charger.

The passive solar home and offices at Redhill Mountain Reserve.

Wind Generator

The wind generator is manufactured by African Windpower in Harare, Zimbabwe. It is specifically designed for lower wind speed regimes which are typical of the inland areas of southern Africa. But it can also perform well in high winds found in coastal areas.

The AWP36 is keeping the Redhill system's battery bank fully charged, with the ammeter often showing up to 35 amps at 29 volts—over 1,000 watts. It often supplies between 20 and 30 amps in furled mode due to the high wind speeds encountered at Redhill. The machine looks and feels substantial, and yet it is very elegant, with good aesthetics.

Heavy Metal

The machine's rotor diameter (3.6 m; 12 feet) is large compared to its maximum power output (1 KW). This gives it the torque to deliver good power in lower windspeeds, when other machines are unable to catch as much wind. AWP believes it is more important to have a steady, day to day supply of amp-hours into the battery than to have a high peak-power rating. This is a "heavy metal" wind turbine, built for low speed and long life.

The turbine uses a direct-drive permanent magnet alternator, but with skewed windings to eliminate cogging. The alternator is heavy because it has many magnets and coils in it. Lighter alternators generally run at higher speeds. These lighter, high-speed wind turbines are noisier and wear themselves out sooner.

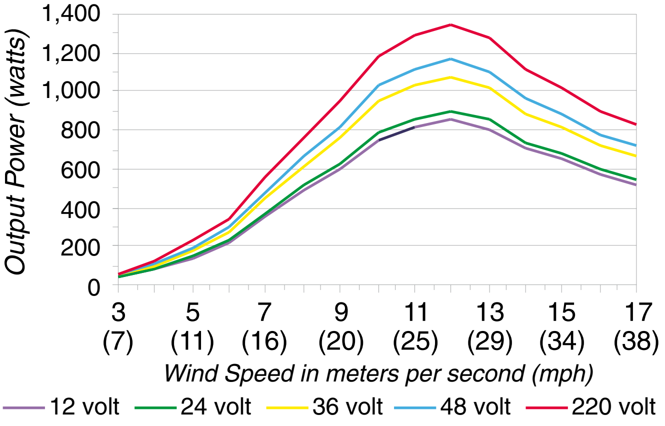
Power comes from a 3.6 m diameter rotor with three GRP blades (glass reinforced plastic—fibreglass). The wind turbine is protected against high winds by a simple, passive system which has been tested in winds exceeding 160 kph (100 mph), without incident. As the wind grows stronger, and maximum power is reached, the turbine "yaws" sideways from the wind. This prevents the blades from overspeeding. There are a minimum of moving parts involved—no springs, and no highly stressed components.

Wind Power for Africa

The machine is the direct result of a development project initiated through the Zimbabwe Energy Research Organisation (ZERO) in Harare. It has been designed by world leaders in small turbine and machine design. These include Geoff Watson (Manx Wind Energy), Hugh Piggott (Scoraig Wind Electric), and Oloff Smyth and Duncan Kerridge of African Windpower, among others.

The initial objective was to investigate the feasibility of a locally-manufactured, simple battery charging wind turbine capable of producing the equivalent power of an array of six 85 Wp PV modules in mean windspeeds of 3 meters per second (6.7 mph). The principal attraction was that almost all the value added in the production of the machine would be in local currency, hence protecting against the foreign exchange variations that affect imported PV modules.

AWP36 Power Curves



AWP's large diameter, low rpm wind turbine.

The turbine has operated to specification at the Redhill site. It is also useful in many different locations due to its ability to operate effectively in low-wind regimes. Its robust construction is highly suited to low-maintenance sites. The machine was installed on a guyed 7.5 m (25 foot) steel tower on the open, treeless Redhill site. It was erected over three days by Duncan Kerridge and two inexperienced helpers. It's encouraging to see this quality product come out of a "developing" country.

The wind turbine installation required an environmental impact assessment (EIA) to comply with the environmental management requirements of the Cape Peninsula National Park. The EIA concluded that the turbine was by far the most cost-effective and environmentally acceptable electricity option for the park.

Access

Author: Glynn Morris, Feather Energy, PO Box 576, Simon's Town, 7995, South Africa • +27 21 780 9024
Fax: +27 21 780 9019 • glynn@feather.co.za

Oloff Smyth, African Windpower, Box 4533, Harare, Zimbabwe • 2634-771581/4 • Fax: 2634-771580
power@harare.iafrica.com
http://homepages.enterprise.net/hugh0piggott/african36

Duncan Kerridge, 135 Airport Rd, Hatfield, Harare, Zimbabwe
+263 4 570804
dragon@mango.zw (text only)

Jon Adams, Siemens Solar, Private Bag X71, Halfway House, 1685, South Africa • +27 11 652 3655
Fax: +27 11 652 2959
jona@siemens.co.za

Noel Smith, Photovoltaic Design and Installations (PDI), PO Box 2086, Parklands, 2121, South Africa
+27 11 880 2283
Fax: +27 11 880 9646
pdi@pv.co.za

Michel Malengret, MLT Power, 11 Harris Dr., Sunset Park, Cape Town, South Africa • +27 21 704 2710
Fax: +27 21 73 9278
mltdrive@global.co.za

Hugh Piggott, Scoraig Wind Electric, Scoraig, Dundonnell, Ross shire, IV23 2RE, UK
+44 1854 633 286
Fax: +44 1854 633 233
hugh.piggott@enterprise.net
http://homepages.enterprise.net/hugh0piggott

Dr. Geoff Watson, Manx Wind Energy Services Ltd,
1 Church Rd., Port Erin, Isle of Man, IM9 6AH British Isles • +441624 832021 • Fax: +441624 832 176
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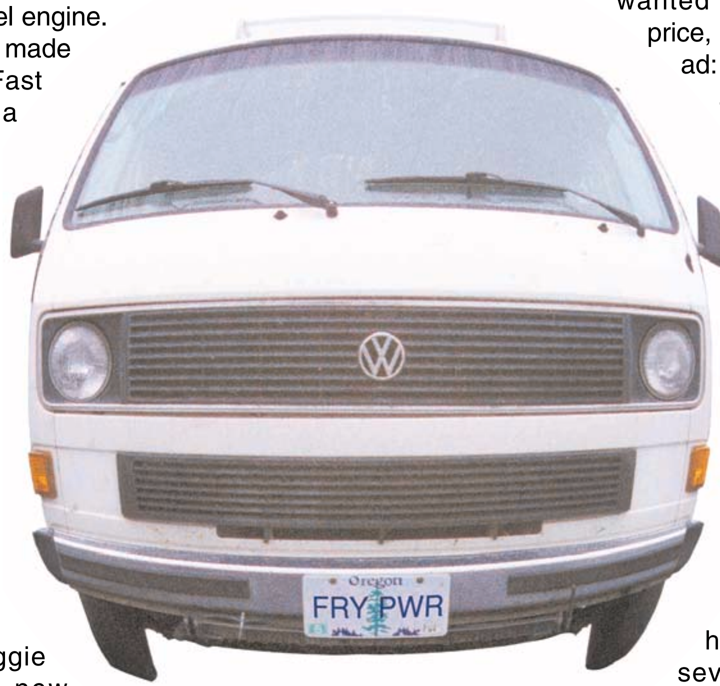
The SlugBus
A Biodiesel-Powered Vehicle

Jon Kenneke

I've always been interested in alternative transportation, such as electric vehicles and methanol-powered engines. In my continuing search for more knowledge, I bumped into a different technology: biodiesel. I read and learned, and as a result I now own a VW diesel, and make my own biodiesel fuel.

What Started This Mess?

One evening, I was surfing the net, looking around at various types of alternative-fuel vehicles. After reviewing several Web sites, I came across www.veggievan.org, a biodiesel-oriented site. I quickly discovered that biodiesel is a product made from vegetable oil that can be used as fuel in an unmodified diesel engine. Further, biodiesel can be made from used cooking oil. Fast food restaurants are a great source of used oil. That caught my interest.



Studies by major universities say that biodiesel has fewer emissions than fossil diesel. Also, biodiesel does not put more net carbon into the atmosphere, since it uses carbon that plants captured from atmospheric carbon dioxide. It is a "green" fuel.

The creators of the Veggie Van Web site have a new, second edition of their book available—*From the Fryer to the Fuel Tank: The Complete Guide to Using Vegetable Oil as an Alternative Fuel.* This book was written by Joshua and Kaia Tickell. I purchased the book from their Web site, and read it cover to cover when I received it. That was not enough—I had to try it. I had one problem, though; I didn't have a diesel vehicle.

Vehicle Search

Since the authors of the book mentioned a Volkswagen (VW), and since I have had previous experience with VWs, that was the make for me. Parts are reasonably easy to find, and they are generally inexpensive.

To find a suitable vehicle, I searched the classifieds in the local newspaper, and the Web. That search turned up nothing affordable. I read the classifieds some more, and saw that the paper offered free "wanted" ads. Free is a very good price, so I wrote a quick classified ad: "Wanted: VW diesel."

The classified ad generated several calls, most of them being for diesel Volkswagen Rabbits and Dashers that did not run, had blown head gaskets, or other problems. I wanted a running vehicle. It didn't need to look good, but it needed an operating engine, so I could try out biodiesel.

One of the last calls I got was from a fellow who had a Volkswagen Vanagon that had been stored in a barn for several years. It didn't sound good at first, but the idea of a Vanagon was appealing, so I went out and took a look. Well, that was the vehicle for me: It ran, looked decent, and the price was right. I gave the guy six hundred dollars, and the 1983 Vanagon was mine.

Fuel Tribulations

Keep in mind that biodiesel is not straight vegetable oil. It is filtered and chemically processed. Not to get into a technical discussion, but the basic idea is that something needs to be done to break apart the really long used cooking oil molecules into something smaller

L to R: storage drum, mixing drum, and sodium methoxide mixing drum.

The trolling motor mounted to a board and held by a concrete block.

A solar-charged 12 volt battery powers the mixing process.

that a standard diesel engine fuel system can deal with. See Josh and Kaia's article in *HP72,* page 84, for the details.

The biodiesel recipe calls for some nasty chemicals: lye and methanol. So I took all the precautions—gloves, a well ventilated area, eye protection, and all that. For my first batch, I used Red Devil lye, new Crisco oil, and SLX paint thinner/stove alcohol, since the back of the alcohol container read "Contains Methanol." More on this mistake later. The mixture of lye and methanol creates a very skin-corrosive compound called sodium methoxide. This is the magic that breaks the cooking oil apart.

As the Tickells suggested, I started with a small batch. The book recommends sacrificing a blender, but I used a glass jar. My method just takes lots and lots of shaking the jar. It's sort of like making butter, I would say. But all I could come up with was sludge. I tried several times, and only got sludge.

So I started suspecting that one or more of my nasty chemicals was not quite right. I checked, and verified that Red Devil lye was the right thing to use. That left one suspect: the alcohol. After some research, I found out that the SLX paint thinner/stove alcohol is mostly ethanol. It is clear in the book that ethanol is difficult or impossible to use.

OK, so I knew what was wrong. But I couldn't find methanol anywhere, until I was driving around town and saw a gas station that sold racing fuel. Those folks had several types of racing fuel, one of them being methanol. I purchased several gallons for US$3 a gallon, and went to try a small batch again. This time it worked!

I dumped this approximately one quart of biodiesel into the Vanagon. It continued to run. No anti-matter explosions, and the sun came up the next day. I was pleased.

The Big Batch

After mastering the small batch, I was ready for used cooking oil, and a larger batch. I went to the local rancid oil well behind a greasy spoon restaurant and filled several four gallon plastic buckets with foul smelling oil. I first explained to the manager what I was up to, and she was more than happy to help. Away I went, covered with oil, with twelve gallons (45 l) in the trunk.

Back at home, I poured the oil into a 55 gallon drum. I then created the sodium methoxide (from lye and methanol) in a separate container. Once ready, the two were combined in the drum, and an old 12 volt trolling motor mounted on a board was used as a mixer. I did this when the outside temperature was 55°F (13°C). After running the trolling

Like any diesel Vanagon, the SlugBus may be a bit slow, but this one runs on greenery, just like its namesake.

motor for an hour (from a PV-charged deep cycle battery), I let the mixture settle for 24 hours.

I checked the biodiesel the next day, and it was sludge *again!* I was getting tired of this. So I went back to the research. What I found out was that for the chemical reaction to take place, the temperature of the mixture needs to be around 80°F (27°C). No problem—the next day was in the 80s. I simply ran the mixer motor again, and this time—success!

After 24 hours, the fuel was on top, and food chunks and glycerin were on the bottom of the drum. Approximately 15 percent of the volume was not biodiesel.

Getting Rid of the Junk

To get the biodiesel off the top of the glycerin/food chunks, I used a marine oil change pump to transfer the biodiesel into another plastic 55 gallon drum. On the output end of the pump, I put a filter/water separator. According to the book, the waste can be composted, which is what I did. It didn't kill the Jerusalem Artichokes growing in my compost pit, so it seems to be pretty safe.

Some Web resources that I came across in my various research missions suggest spraying water on the top of the separated biodiesel to remove excess alcohol from the fuel. I think it's a good idea, so I did it using a plant sprayer. Some folks spray with vinegar, which supposedly gets rid of more impurities.

Since alcohol mixes readily with water and with vinegar, and the mixture settles to the bottom, it has a cleansing effect. The water and vinegar flow from top to bottom, pulling impurities along with them. Vinegar has the added benefit of being slightly acidic, so it attracts the impurities.

In my first batch of biodiesel, I did not adequately remove the remaining alcohol. The alcohol attacked the van's already old fuel hoses, causing them to leak. Alcohol in diesel fuel will ruin various fuel system seals. On a Volkswagen diesel, bad seals in the injection pump will result in costly repairs. So I would highly recommend getting as much alcohol out of the biodiesel as possible. I got lucky on this one.

I routinely add automatic transmission fluid (ATF) to my fuel. I use half a quart when I think about it. ATF is designed to keep seals from drying in an automatic transmission, and works well for fuel system seals.

The First Test

After creating just over 10 gallons (40 l) of biodiesel, I wanted to see how the van would run on the stuff. Since I had to replace fuel hoses on the van, I drained all the fossil diesel from the tank. I then pumped all 10+ gallons of biodiesel into the van. This was the test.

I climbed into the van, and it started right up, and kept on running. I went around to the tailpipe, and experienced an interesting smell that I can best describe as a mixture of french fries and burning marshmallows. Then it was time for a drive.

A diesel Volkswagen Vanagon is a slow creature. Running on the biodiesel, it was as slow as normal. Sources say biodiesel has a little less power than fossil diesel, and that might be true. It was hard to tell, but it ran smoothly, and with little smoke.

So I went for a drive. The van performed well with 100 percent biodiesel. The cost per gallon for this batch was 50 cents, not counting my time. Not bad. Fossil diesel was well over US$1.30 per gallon then. The Vanagon, now named "SlugBus," gets around 30 miles (48 km) to the gallon.

The Big Test

Burning less than a gallon in the test, there was still 270 miles (435 km) of range with the first big batch of straight biodiesel in the tank. So we took a 160 mile (260 km) round-trip excursion on pure biodiesel. Again, we completed this trip without a hitch. Even in the SlugBus, we could attain freeway speeds of 65 mph (105 kph). The remainder of the fuel was consumed around town.

Given this success, the next test was a 500 mile (800 km) round trip, with the outbound leg running on the second batch of biodiesel. On this trip, we were headed to the SolWest Renewable Energy Fair in John Day, Oregon. A full tank gives the SlugBus a range of around 300 miles (480 km). So the drive home was mostly fossil diesel.

The only problem on the John Day trip was a near overheating situation on the long grade heading east out of Mitchell, Oregon. It was a 95 degree day, with a 65 horsepower motor trying to push 3,500 pounds (1,600 kg). A quick stop into a turnout to cool the engine was enough to make the rest of the trip "cool."

Performance SlugBus

The biodiesel works well in the SlugBus. I've done some further improvements to increase the life of the vehicle and reduce the amount of pollutants. Probably the biggest performance improvement came when I switched to synthetic lubricants in the motor and transmission. This subject has been the topic of a recent *Home Power* article *(HP69,* page 50). Synthetics have worked for me.

With synthetics, the vehicle runs noticeably cooler. This means less energy is being wasted as heat, so fewer pollutants are being generated. I use Amsoil, but there are many other great synthetic lubricants on the market.

I also use a magnetic algae reducing system. Believe it or not, algae can live (and thrive) in diesel, and especially in biodiesel. These critters can clog your fuel system, and do other nasty things. There are toxic chemical biocides, but the magnetics seem to work. According to the manufacturer of the system, the magnetic fields disrupt the clumps of micro-organisms. The critters have no chance to form colonies, and will not clog the filter. They are often small enough to pass through the filter, and are safely burned in the engine.

Tire pressures also makes a big difference. Keep those tires inflated to proper pressure for safety and better fuel economy.

Earth-Friendly Fuel

Based on my experiences with biodiesel, I believe it is a low-cost, earth-friendly alternative fuel. Experimenting with biodiesel just takes some careful chemical handling techniques, and very little money. There are commercial sources of biodiesel in some places, but making the fuel yourself really gives you do-it-yourself satisfaction.

Access

Author: Jon Kenneke, 1217 29th St. SE, Albany, OR 97321 • 541-928-4552 • Fax: 541-928-3543
jon@bitblaster.com • www.bitblaster.com/~jon

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800-266-5564 or 419-281-1802 • biofuel@best.com
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Fuel Dynamics, PO Box 523, Cape Canaveral, FL 32920 • 888-825-4239 or 321-784-4227
Fax: 321-784-5663 • fuelmag@fueldyn.com
www.fueldyn.com • Magnetic algae reducing devices for diesel fuel systems

Web biodiesel resources:

www.biodiesel.com • Commercial biodiesel

www.biodiesel.org • National Biodiesel Board

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A new biodiesel email discussion group has been formed. To join, send a message to
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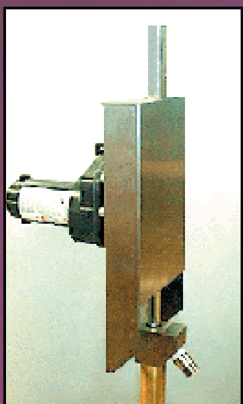


12v motor option

A Microhydro Learning Experience

Louis Woofenden,
with Jo Hamilton and Rose Woofenden

The potential for microhydroelectric power can't be beat the way it rains in the North Cascade mountains of Washington State. The climate in the foothills is wet, and many trees are covered with thick moss. It is cloudy much of the year, and though solar and wind are options, hydro is more cost-effective for those with a good stream. At Floyd and Frasia Omstead's property in the Skagit River valley, hydro is the best renewable solution. Although grid power is close, the Omsteads prefer to have the independence and reliability of a hydroelectric system.

Ian Woofenden (my dad), Solar Energy International's (SEI) Northwest coordinator, approached Floyd with the idea of installing a hydroelectric system as part of an SEI workshop. They had met two years earlier when Floyd attended an SEI PV workshop. After considering the pros and cons, Floyd agreed to provide the installation site for the SEI microhydro workshop.

The workshop was held in October of 1999. A class of students spent five days learning about microhydro. They came from the Northwest and beyond, including Montana, Pennsylvania, and California. There were students planning to work in the renewable energy industry, others who wanted to build their own hydro systems, and one student who had concerns about the Y2K computer bug. There were also those who wanted to learn more about the systems they were already living with.

Hydro Education & Experience

The first two days were dedicated to classroom instruction taught by Bob Mathews from Energy Alternatives of British Columbia, Canada. Bob is very knowledgeable about microhydro, and has designed many systems in Canada and in the U.S. His organized and detailed approach gave the students a real grounding in microhydro theory and design principles.

On the third day of the workshop, we toured a couple of hydro systems, led by SEI instructor Johnny Weiss. First we stopped to see Chris Soler, who has a small homebrew system with a Harris Pelton wheel coupled to a salvaged car alternator. His system showed students what you can do with a very limited budget and a tiny stream. We also toured the Canyon Industries manufacturing plant in Deming, Washington. Dan New, owner of Canyon Industries, showed us around their production shop. We saw turbines of various sizes that were going to be shipped all over the world—one was going to Honduras, another to Montana.

Dan has a 25 KW AC system that provides some of the power for the facility. We toured the system from intake to tailrace, and talked with him about the special problems of AC systems. It was fun to see a larger system in action.

Down to Business

Thursday morning, the SEI class carpooled to the Omstead property. After everyone arrived, introductions were made, and the class toured the site. We found that Floyd was not as ready as he had agreed to be. The ditch was not completely finished. The power shed was full of stuff. The platform for the turbine wasn't painted. We also later found that there wasn't enough pipe, or enough fittings.

Above: Dan New (center) discusses hydro with SEI workshop students.

Left: Author Louis Woofenden monitoring the flow at the diversion during turbine testing.

We had to work hard just to finish on time. This was good in some ways, because it showed the students how to do an installation quickly. After finding out how much there was to do, we broke into three groups and began installing the system. The intake, penstock, and electrical system were all tackled by different work crews. We did finish, with the group's hard work, and a truck full of tools and parts brought by SEI alumnus John Klemmedson who came to help out.

We Capture the Water

The intake was designed as an in-stream diversion—a small dam in effect. This means that the intake blocks the whole stream, and creates a small pond. The intake structure was made of pressure-treated 2 by 12 lumber, with black plastic sealing most of the cracks. The diversion was divided into two sections, the intake section, which was screened, and the spillway section, where the extra water spills over and returns to the stream.

We used the small dam because local residents said that not much silt or debris comes down the stream in winter. Just above this system is a system with three overshot waterwheels, and we expected that it might

The penstock, still propped over the ditch for ease of gluing, snakes its way down to the turbine.

filter out whatever did come down. Now that the system has been in operation for a few months, it's obvious that we were all mistaken. Floyd reports that the impoundment area fills with silt and rocks, and he has to clean the screen quite frequently. He is now in the middle of designing a better intake system to deal with the actual stream conditions.

The penstock was attached by first cutting four inch (10 cm) holes in the pressure treated 2 by 12 lumber. Then a short piece of pipe was glued to two couplings, one on each side of the wood. We then had a "coupling sandwich," and it was secure. Next we glued on a tee, to which we later attached an air vent.

The air vent prevents the penstock from damage if the intake is suddenly clogged. If there were no air inlet and the intake was clogged, the force of the water rushing down the penstock could cause a vacuum that might collapse the penstock. We also added two cleanouts low in the dam wall.

Penstock

When we arrived at the site, the 450 foot (140 m) long ditch to bury the penstock was mostly completed. It was dug by a backhoe, and it needed to be evened out, and dug a bit deeper in a few places. While some of us worked on the intake and other projects, a few of the students and staff did the required ditch digging. After the ditch was finished, it was about eighteen inches (45 cm) deep.

The crew then laid sticks across the ditch about every five feet (1.5 m) to hold up the penstock, so that it was easier to glue the pipe together. We removed the sticks and lowered the pipe into the ditch before we pressure tested the penstock. The penstock was constructed of ten and twenty foot (3 and 6 m) sections of 4 inch ABS pipe.

Manifold & Turbine

The manifold was built from 4 inch ABS pipe. At the bottom of the penstock, there is a tee. We connected one side of the tee to a 2 inch ball valve. Ball valves were not the best choice, but gate valves in this size are expensive. A ball valve can be closed very quickly. When you close any valve too quickly in a hydro system, you create a surge of pressure at the bottom of the penstock. This is called water hammer.

Water hammer occurs because the water rushing down in the pipe has a lot of force. If you suddenly cut off an outlet for the water to escape, then the water that is moving pushes the water in front of it. Because water isn't very compressible, a lot of pressure builds up. This

Floyd and Frasia's cabin (left) and power shed (right).

can burst joints of pipes, or pipes themselves. If Floyd had bought gate valves instead of ball valves, the potential for water hammer would have been reduced, because a gate valve takes more time to close than a ball valve.

After the ball valve came a nozzle. We cut the four nozzles to different diameters, so that Floyd has more options for how much water to use. The other side of the first tee went to a 90 degree fitting. After the fitting came a short section of pipe, which was connected to another tee. One side of this tee went to a valve and nozzle, and the other side continued to another 90 degree fitting. The manifold continued in the same way to the other nozzles. It was quite a puzzle to get it together properly, and we had to do some cutting and refitting.

Stream Engine
Floyd chose the Energy Systems & Design (ES&D) Stream Engine, which is made in New Brunswick, Canada. The ES&D turbine is a bronze turgo wheel coupled to a permanent magnet alternator. The permanent magnet alternator requires less maintenance than an alternator with brushes, but it is harder to adjust for maximum output.

Turgos can handle more water than Pelton wheels. At Floyd's site, this is a definite advantage, because of his high flow in the rainy season. The head (vertical distance from the intake to the turbine) is only about 30 feet (9 m), and the lowest flow is around 40 gallons per minute. But in the winter, this flow can more than quadruple. Floyd wanted to be able to handle as much water as possible, so he chose the Turgo runner.

Electrical System
The electrical system was installed in one side of a small shed about 20 feet (6 m) from Floyd and Frasia's cabin. The shed was partitioned, with one side for the electrical equipment, and the other side to be used as a wash house. Floyd chose to have only AC loads, so he will be running all his loads through his Trace inverter. Because he is not running any DC loads, his choice of a 48 volt system makes good sense. A higher voltage allowed us to use smaller wire in between the turbine and the power shed, because of the lower line losses.

Omstead System Loads

Item	*Watts*	*Avg. Hrs/day*	*KWH/ day*	*%*
22 incandescent lights	1,320	2.00	2.64	35%
Fridge/freezer, 11 cu ft	400	3.00	1.20	16%
Ceiling fan	50	24.00	1.20	16%
Chest freezer, 9 cu ft	500	2.00	1.00	13%
Computer	300	2.00	0.60	8%
Toaster oven	1,500	0.25	0.38	5%
2 TVs and VCR	180	2.00	0.36	5%
Microwave oven	1,100	0.25	0.28	4%
		Total average KWH/day	7.65	

The completed manifold with the ES&D turbine.

John Heil from Dyno Battery headed up the electrical crew. He provided expert instruction and design assistance even while under the stress of working with his competitor's batteries. By the end of the first day, the inverter and batteries were wired, and the inverter was providing AC power from the energy stored in the batteries. The batteries are eight Trojan L-16s, and are connected in series to provide 350 amp-hours at 48 volts DC.

We used 3/4 inch (19 mm) plywood for a backboard to mount the gear on the wall of the power shed. The crew mounted the Trace 5548 sine wave inverter, DC disconnect box, and Trace C-40 charge controller on the wall. The AC output from the Trace was connected to a multi-plug outlet mounted on the wall of the power house, since Floyd wasn't ready to run it to the cabin.

The inside of the power shed, showing inverter, DC disconnect box, charge controller, and dump load.

We also installed a Cruising Equipment E-Meter to monitor the system.

The C-40 prevents the batteries from being damaged by overcharging. We ran the output of the turbine through a 20 amp disconnect. This prevents the system from damage if a short or other fault occurs. We then wired the C-40 to dump any excess power into a heating element attached to the wall. The heating element will provide some heat to the battery room and wash house.

Earlier, some of the class had dug a trench between the power shed and the turbine site. The electrical crew laid PVC conduit in the trench. Then they pulled the wires through the conduit, and we were almost ready to test the system.

Putting It All Together

Most of the separate parts of the system were now complete. The electrical system was ready to accept the power from the turbine. The intake was all prepared, and the manifold was assembled. All we had to do to send water down the penstock was to put in the clean-out plugs in the dam. But down at the turbine site, there was still work to do. We needed to connect the manifold to the turbine, install a pressure gauge, test for and fix any leaks, and wire the output of the turbine.

It was quite a job to attach the manifold to the turbine, and not without its problems. To get the manifold on, we had to flex the pipe slightly. After attaching most of the nozzles to the manifold, we tried to bend it too much in an attempt to get it all together, and we broke a nozzle. Luckily, ES&D provides six nozzles with their turbines, so we just replaced the broken nozzle and began again. This time we put it all together with no mishaps.

We added a wye to the end of the penstock above the manifold. From the bottom of the wye we continued the pipe in a ditch, all the way to where the water from the turbine runs back into the stream. On the end we attached a clean-out. Floyd can periodically open the clean-out and let any residue from the bottom of the pipe wash back into the stream. We connected a short piece of pipe to the top of the wye, and connected a tee to it. We glued an adapter and valve to one side of the tee. This is so Floyd and Frasia can tap water from the penstock for irrigation and fire protection.

We glued a 22 1/2 degree fitting on the other end of the tee, and a piece of pipe about three feet (1 m) long. This brought us almost to the manifold. We added one more 22 1/2 degree fitting, and glued it all together. We then drilled a small hole in one of the fittings and threaded the pressure gauge in.

Ready to Rumble!

Then...the time we'd been waiting for. We were ready to pressure test the system. Someone ran up to the intake of the penstock and closed the clean-outs. We left the irrigation water valve open for a while to let the air escape. In a couple of minutes, the penstock was full of water, and the pressure gauge read 16.5 psi. We wired the output of the turbine to the wires running through conduit to the power shed.

Now we were ready to test run the turbine. One of the students held a multimeter, which was set up to measure how much electricity was being produced. The Stream Engine doesn't have an ammeter included. Instead, inside the connection box is a shunt and two test points. It's set up to show you the output amperage by measuring DC millivolts at the test points.

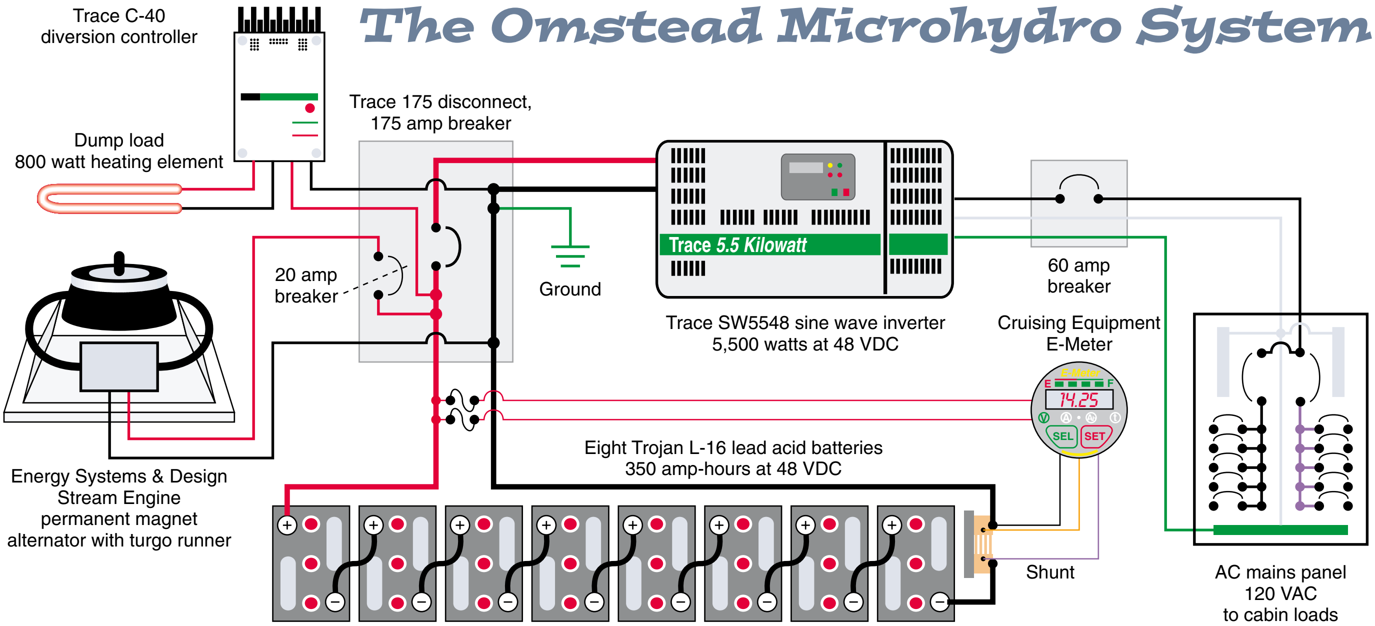
Someone opened the valve. The turbine spun up to speed. It was making power! The meter read 5.8 amps, which is about 280 watts at 48 volts. At this point we all had big smiles on our faces, and we were gathered around, looking at the meter and listening to the hum of the turbine.

We weren't done yet though. We had started the turbine using the largest nozzle, but that soon brought the water level at the diversion down. If we continued to use the water at that rate, pretty soon we'd end up with air in the pipe. If any air is in the penstock, the turbine will still run, but you lose head, and therefore power.

Adjusting Flow

One of the students had a pair of FRS transceivers. So while the turbine crew turned on a nozzle, I watched the

The Omstead Microhydro System



water level at the diversion and reported back to them on the radio. If the water level went down, that meant that we were using too much water, so we tried the next smaller nozzle.

We installed the system in the season with the minimum flow it will see. In the winter, spring, and early summer, there will be much more water, and Floyd will be able to use more nozzles and have more power output. We found that even using the smallest nozzle, the water level was still going down, so we replaced one of the nozzles with a new nozzle cut to a smaller diameter. That did the trick. The water level didn't fall. It actually spilled over the top of the dam a bit, which is just what we wanted.

Adjusting Output

We started working on adjusting the Stream Engine for maximum output power with the smallest nozzle. The Stream Engine has magnets that spin, and fixed coils. The magnets can be moved up and down, nearer and farther from the coils. For any rpm, the closer the magnets are to the coils, the more power is produced. But if the magnets are moved closer, the turbine slows down. To produce power, the turbine has to spin above a certain rpm. The trick is to find a balance between having it too slow and not producing any power, and having it too fast (magnets too far away from the coils) to produce much power.

We didn't have time to do the process thoroughly, but we got the magnets adjusted to approximately the right distance. Just doing it roughly took a long time. First we had to close the valve, and wait for the turbine to stop.

SEI instructor Johnny Weiss holds the meter while system owner Floyd Omstead (left) and students share the excitement of making power.

After two long days of work, remaining SEI students, staff, family, and friends gather for a group photo with the running turbine.

Then we had to loosen a nut that locked the magnets at whatever distance they were from the coils. Then we screwed the magnets closer to the coils. Then we had to tighten the nut that locked it. Finally, we opened the valve and let the turbine spin up.

Then we checked what the power output was. If the power had increased from the last test, we repeated the process all over again, and moved the magnets even closer to the coils. If the power had decreased, we back-tracked and moved the magnets farther away. After everything was adjusted, the turbine put out 2.1 amps at 48 volts, or about 100 watts.

Useful Energy

By this time, it was dusk. We finished up the last minute details, and headed up to the power shed. We plugged in a light, and looked around at our handiwork. We looked at the E-Meter, and saw what the voltage and amperage where. The class went outside, and gathered around. Goodbyes were said, and addresses exchanged. The students drove off into the darkness, tired, but satisfied to know that the job was done, and that they had a good working knowledge of how a microhydro-electric system works.

This system will make a big difference for Floyd, Frasia, and their two children. Floyd reports that for the past two months, he's been running the turbine on three nozzles with an output of 11 amps at 48 volts, or over 525 watts continuous. This gives the Omsteads a significant energy surplus, so they don't have to worry much about what loads they use during the winter.

The hydro system has allowed them to move into their cabin and stop paying rent. It will provide them with ample power year-round. When wind storms take out grid power, it will keep their lights shining when others are lighting candles. If efficient loads are used, it will provide power for them to eventually build and electrify a larger house. The system will help *people,* which after all, is what renewable energy is all about.

Access

Authors: Louis Woofenden, Rose Woofenden, PO Box 1001, Anacortes, WA 98221
Fax: 360-293-7034
kc7hdc@arrl.net

Jo Hamilton, Solar Plexus, 130 W. Front St., Missoula, MT 59802 • Phone/Fax: 406-721-1130
solplex@montana.com • www.montana.com/solplex

Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866
sei@solarenergy.org • www.solarenergy.org

Omstead Hydro System Costs

Item	*US$*
Trace 5548 inverter	4,000
ES&D Stream Engine	1,900
8 Trojan L-16 batteries	1,600
ABS pipe & connections	1,000
Misc. (fuses, wire, breakers, switches, etc.)	500
Electrical conduit & wire, 160 feet	400
E-Meter with prescaler for 48 V system	375
DC disconnect, 175 amp	310
Trace C-40 charge controller	185
Turbine base & enclosure	125
Battery interconnect cables	125
Lumber, 2 x 12 pressure treated	80
Hardware cloth	20
Visqueen plastic sheeting, 6 mil	20
Pressure gauge	20
Dump load (heating coils)	20
Total	$10,680

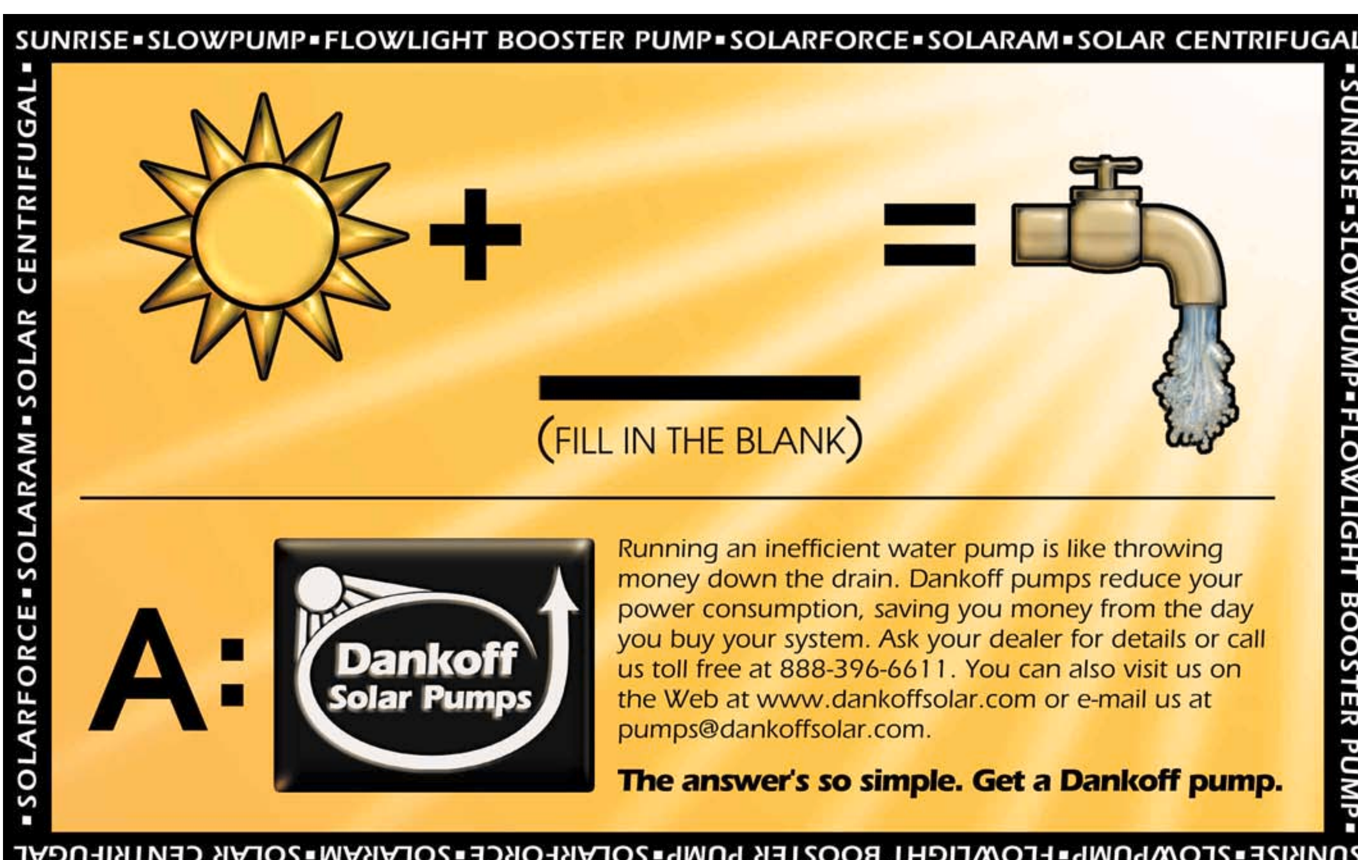
Bob Mathews, Energy Alternatives, Box 1270, Chase, BC, V0E 1M0 Canada • 800- 265-8898 or 250-679-8589 • Fax: 250-679-2953

John Heil, Dyno Battery, 4248 23rd Ave. W., Seattle, WA 98199 • 877-DYNO-BAT or 206-283-7450 Fax: 206-283-7498 • dyno01@aol.com www.dynobattery.com

Energy Systems & Design, PO Box 4557, Sussex, NB, E4E 5L7 Canada • 506-433-3151 • Fax: 506-433-6151 hydropow@nbnet.nb.ca • www.microhydropower.com

Dan New, Canyon Industries, 5500 Blue Heron Ln., Deming, WA 98244 • 360-592-5552 Fax: 360-592-2235 • CITurbine@aol.com www.canyonindustriesinc.com

Chris Soler, Soler Hydro-Electric, 18067 Colony Rd., Bow, WA 98232 • 360-724-5111



Solar Power in Papua New Guinea

Stewart Hay

Solar panels as originally mounted on the classroom roof. All the existing mounts were reused.

Kerina Evangelist's College is in the village of Tsendiap, which is in the Jimi Valley in north central Papua New Guinea. Situated at 1,600 feet (490 m) above sea level and in a river valley, the area is very hot and has almost no wind. The one renewable energy resource that Tsendiap has in abundance is sunshine, and this is what I intended to harness.

In February 1999, I accepted a position with Missionary Aviation Fellowship (MAF) as a regional manager. MAF is an ecumenical Christian organisation committed to serving isolated communities, churches, and missions using aircraft. Papua New Guinea (PNG) has extremely rugged terrain, and many of its communities have access to the outside world only by aircraft or along walking tracks. My job involves dealing with the aircraft operations as well as customers, employees, and forward planning.

My wife Debbie, our three children, and I moved to Mt. Hagen, a major centre in the PNG Highlands, to take up this new challenge. We were introduced to the residents of the Tsendiap area when MAF sent us as a family from our home in Mt. Hagen to Tsendiap for a week-long bush orientation as part of our introduction to PNG.

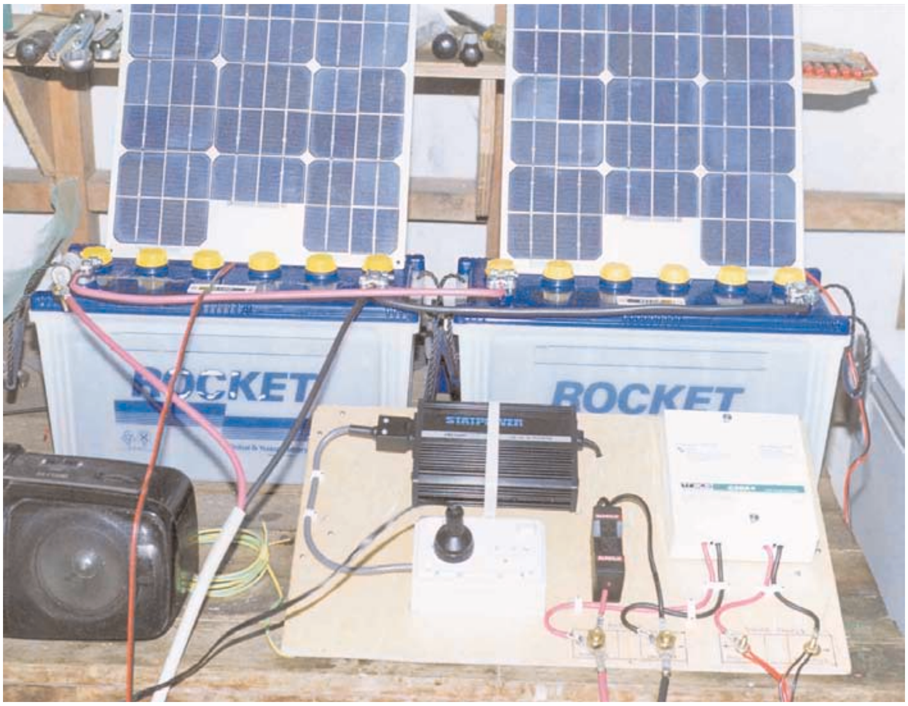
Orphaned PVs

It was during this visit that we saw the solar-electric panels on the roofs of two of the college classrooms, and asked some questions about the solar-electric system there. We discovered that time had taken its toll on the batteries and other parts of the system. The only

MAF pilot Karl, and Nicola, the author's daughter, arriving at Tsendiap.

viable components left were the solar panels sitting happily on the roof doing their thing day by day. But because the rest of the system was not working, the people of the college could get no benefit from them.

Kerina Evangelist's College is an Anglican training college that opened in mid-1985. It consists of two classrooms and enough housing for the fourteen student evangelists and four staff. The staff and students all have their own gardens and grow enough food for themselves and their families during the two year course. The main reason for this is the isolation of the college and the expense of bringing food in by plane. It is a three day walk through very mountainous jungle into Mt. Hagen.



The system as bench tested at Mt. Hagen (the small solar panels were only used to test the charge controller).

Another thing that spurred me to revive the system was when the principal of the college showed us the TV and VCR that had been donated for teaching purposes. The college had the power source and the end use on site, but some important components in the middle were missing. When our week finished and we were flown back to Mt. Hagen, we set about the task of designing a system for Tsendiap, and locating the necessary bits to do the job.

Designing an Appropriate System

Because of its remoteness, Tsendiap has no electrical power or gas supplies. The only readily available fuel is kerosene, which is used to power the refrigerator at the health clinic and a few kerosene lamps in the village and college. Because all this has to be flown in (usually by MAF), the cost is high, so its use is restricted. The only other solar-electric system in the area is also at Tsendiap, and is owned and operated by a trade store owner who is the MAF agent at the remote airstrip. The system consists of one panel and a battery, and provides power for an HF radio, which is the only method of outside communication for the Tsendiap community.

Kerina Evangelist's College has six solar panels that are seven to eight years old. The panels have been out in the tropical sun all that time, so the only information that I could glean from the very deteriorated labels was that they were made by Solarex. Their physical size suggests that they are approximately 30 watts each. We decided to use four of these panels to power the inverter and lights in the classroom and leave the other two on staff housing to provide solar lighting in the near future, when funds allow.

Analysis of Anticipated Loads

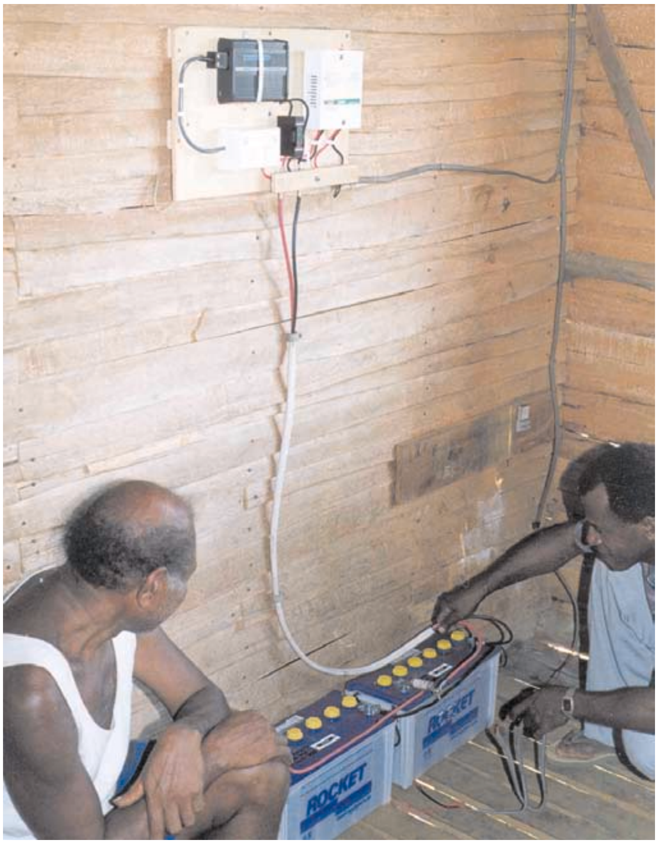
The only electrical loads at the college are fluorescent lights (20 watt tubes), a JVC 14 inch TV and video player, and the occasional use of a laptop computer (once a month for approximately four hours). Sizing the system was not critical because there were no large loads like freezers and refrigerators that had to run over periods of low or no sun. Having said that, we still had to make sure there was enough power to give the college a useful, reliable system.

Batteries

After calculating that the expected daily load would be approximately 35 amp-hours at 12 volts DC, we

Kerina College System Loads

Item	*Watts*	*Hours per day*	*Watt-hrs per day*
Three 20 W fluorescents	60	3.0	180.00
TV & VCR	115	1.5	172.50
Laptop computer	50	0.3	12.50
		Total	365.00
		Total including 15% inefficiency	419.75
		Amp-hours (WH ÷ 12 V)	34.98



Installing batteries and inverter. Ventilation won't be a problem because there is no glass in the windows, and there are gaps in the floor to keep people cool.

decided to size the battery bank at 200 amp-hours. This was achieved with two 100 amp-hour batteries, and meant that the batteries were only being discharged to 25 percent of their rated capacity.

The climate in Tsendiap has plentiful sunlight every day, even though it can sometimes get fogged in all morning, and has a wet season from October to April which increases the cloud cover. Using four solar panels, each delivering about 2.5 amps, gave a charging current of 10 amps. Assuming an average of five hours of sunlight per day, we theoretically have 50 amp-hours of charge going into the batteries each day.

This rate of charge should insure that the batteries are fully replenished each day. If the system is only used for lighting, which is quite possible, it would go for days with no sun. However, if the TV and VCR are used, someone will need to monitor the power usage to some degree.

Charge Controller

To allow for future expansion of the system and years of reliable service, the Trace C30A was selected as a charge controller. The Trace seemed a safe bet to put in the bush and forget about. The LED indicator will also enable the people at the college to observe the state of charge of the battery by observing the function of the LED (off, flashing, or constant).

Inverter

There was nothing scientific about the choice of inverter. I had in mind a 300 watt unit, as this would drive the TV and VCR, plus a full size computer system in the future. In the end, we had no choice, since the only reasonably priced inverter we could find in PNG was a Statpower Prowatt 250. I have no complaints about the Statpower inverter; it seems to run perfectly. Before putting the inverter in the bush, we ran our home computer on it to be sure it was up to the task.

Assembling the System

The system was assembled at our home in Mt. Hagen, and tested there to make sure that we would not have any disappointments in the bush. We knew that once we were dropped off at the airstrip, we would have no way of just slipping down to the hardware store for the odd bit that was needed.

We designed the system so that all the components were mounted on one board in advance. This served two purposes. First, it meant all the wiring and mounting work was done with access to tools, and nothing would get left behind. Second, it would be laid out in a clear fashion, so we could use it as an educational tool.

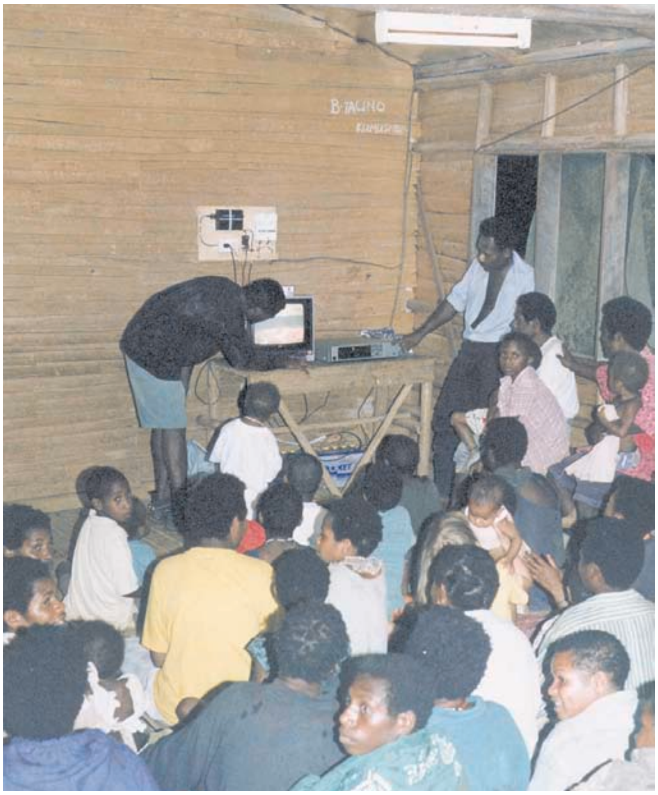
A few compromises had to be made on the selection of fusing and other accessories, due to availability. But with some shopping around and consultation, we managed to get all the safety features we needed in the system. Some parts aren't as compact or pretty as we would have liked, but spares can be found locally, and this is important for future system maintenance.

System Performance

After hooking up all the parts of the system, the moment of truth was upon us. Because I'm a white man, and because I was a visitor with lots of interesting hardware, it was very difficult to have a trial run in private. By the time the TV and VCR were set up, there were about 30 expectant onlookers.

I'm pleased to report that they weren't disappointed. The excitement of these people was amazing. The whole room started to clap when the TV sprang into life with grey mist on the screen and static noise. There was complete silence from the crowd when the tape started with pictures and sound. It just emphasized how much we take for granted all we have in the west. We don't always appreciate the ease of access we have to technology.

This project must rate as one of the most worthwhile things I have done for some time. The college can now



The first night's entertainment. There were 80 men, women, and children watching the video.

play the educational tapes it has access to, and students can now study at night without straining their eyes.

Part of the installation process included a ninety minute lecture on battery maintenance. The batteries will be the weakest part of any system like this, since they can be abused by overdischarging or lack of attention to electrolyte levels. The education was well received by the people at the college, and the chances are good that the system will give many years of trouble-free service.

System Cost

The breakdown of cost to complete the system is shown in the cost table. The existing solar panels would have cost approximately K2,600 to replace (K650 each). So to replicate a system like this on another site would cost around K4,000, allowing for materials to mount the panels and wire them in. At the time of this project, one PNG Kina was worth 36 U.S. cents.

Economic Viability of Solar

If we compare the cost of using 20 watt fluorescent tubes with using a pressure kerosene Coleman lantern, and assume that each gives a similar light output (in reality the fluorescents are much better), the figures favour solar. The Coleman will use approximately K1.00 of kerosene per night, which equals K350 per year.

Kerina College System Costs

Item	*Papua Kinas**
Statpower Prowatt 250 inverter	368.40
Two 12 V, 100 AH batteries	352.00
Trace C30A charge controller	218.73
Battery clamps, lugs, wires, etc.	60.00
HPM combination outlet with mount	30.00
Fuse assemblies	25.00
Total	K1054.13

* At the time of publishing, a PNG Kina was worth about US$0.36.

In comparison, the initial outlay for the solar system to do the same job (lighting only) would be about K1,000, with no running costs. The quality of light is far better, as is the convenience. The system will break even in three years with plenty of life still left in the battery bank (assuming proper care).

Acknowledgements

I am a mechanical guy by trade, and solar energy systems are mainly electrical. So I have had a learning curve to climb, and I'd like to acknowledge those who helped me construct this system.

- Christian Radio Missionary Fellowship (CRMF) for advice on batteries and solar panels.
- Summer Institute of Linguistics (SIL) for supplying the inverter and charge controller.
- Gerald Wade for checking my electrical work and for his encouragement.
- Karl Anderson (MAF) for flying us and our equipment to Tsendiap.
- Nicola Hay, my eight-year-old daughter, who was my travelling companion and helper.
- The students at Kerina Evangelist's College, who helped us move solar panels and mount various items for the system.
- The people of Tsendiap, whose hospitality was superb; we were very well looked after for the three days at the college.
- Last but not least, *Home Power* magazine has been a great source of information and encouragement with the many articles on systems, and tips for design.

Development of Electrical Power in Papua New Guinea

Due to the rugged terrain and the uneasy and sometimes unstable relationships between neighbouring tribes and provinces, I doubt the wisdom of pushing ahead with widespread development of a

Father Paulus (front right), the Principal of Kerina Evangelist's College, and college Chaplain, Father Irenaeus (front center), and some of the students, with their new system.

traditional western-style grid system. The present limited grid system has reliability problems. These are caused by inadequate maintenance and continuing demands for compensation claims, since the poles and lines must be situated on locally-owned land.

Renewable energy systems are an economically viable alternative to traditional methods of electrical power supply. If you are comparing the capital cost of setting up a new grid system with the cost of several stand-alone solar-electric sites, the latter may be cheaper. It also gives the end-users a lot more control over the cost and reliability of their electrical supply.

We must also look at the type of appliances we run from our power supplies. The "whiteware" (refrigerators, freezers, and washing machines) routinely available through many appliance outlets are very wasteful of electrical power. Minimising the demand for power reduces the capital cost of the renewable energy system, which makes it even more financially attractive. We have a big responsibility to think laterally and not conventionally when guiding these people on future power projects.

Energy & Chickens

Introducing too much technology into the bush puts a financial burden on the community due to the purchase price and the ongoing operating costs. Technology should be appropriate to the people, culture, economy, and climate of the area. As an example, look at chickens. In many "developed" cultures, they sit in an energy-gobbling deep freezer for two months waiting to be eaten. In the jungles of Papua New Guinea, they run around the village while waiting to be eaten.

This is a much more sustainable and appropriate approach. The addition of solar lighting to communities can make a significant improvement in quality of life with a moderate level of investment. Instead of relying on inappropriate and environmentally destructive energy from an expensive and intrusive grid, it uses renewable energy that is available locally. That's about as appropriate and sustainable as the chickens running around in Tsendiap….

Access

Author: Stewart Hay, c/o MAF-PNG, PO Box 273, Mt. Hagen, PNG
675-545-1362 • Fax: 675-545-1485
stewart_hay@maf.org.au

Kerina Evangelist's College, MAF-PNG, PO Box 273, Mt. Hagen, PNG

Christian Radio Missionary Fellowship (CRMF), PO Box 1307, Goroka, PNG • 675-732-2670
Fax: 675-732-2413 • crmfpng@online.net.pg

Gerald Wade, Regional Manager, c/o MAF-PNG, PO Box 1080, Goroka, PNG • 675-732-2814
Fax: 675-732-1167 • gerald_wade@maf.org.au

Karl Anderson, c/o MAF-PNG, PO Box 273, Mt. Hagen, WHP, PNG • 675-545-1358 • Fax: 675-545-1485
karl_anderson@maf.org.au

Summer Institute of Linguistics (SIL), PO Box 413, Ukarumpa, EHP, PNG • 675-737-3544
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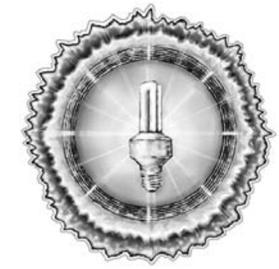

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Sir Thomas Lipton — 1870

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TOP SECRET

GUERRILLA SOLAR: the unauthorized placement of renewable energy on a utility grid.

PROFILE: 0009

DATE: March, 2000

LOCATION: Somewhere in the USA

INSTALLER NAME: Classified

OWNER NAME: Classified

INTERTIED UTILITY: Classified

SYSTEM SIZE: 1,600 watts of PV

PERCENT OF ANNUAL LOAD: 25%

TIME IN SERVICE: 8 months

I have thirty-two 50 watt Photowatt panels wired in series and parallel for 48 volts. This is fed through a Trace 4048 UPV inverter directly to the grid, with no battery backup. The panels are quite old, but still will deliver up to 6 amps of smog-free juice to the grid at 240 V. Though I can't measure the monthly production, my electric consumption is down by about a quarter. This adds up to about 200 KWH per month for my house, shop, and an apartment, all on the same meter. The system was installed in June of 1999.

Why??? After living off the grid for four years, I moved to my present farm and felt I had to do something for the environment. I installed a solar DHW system and supplemental space heating. This wasn't enough. The local IOU was hyping grid-intertie systems and some federal and state rebate programs. After requesting info several times and not getting anything back, I talked to their "renewable energy expert" who gave me the runaround some more.

The utility then contracted with a local company who was supposed to do the installations and all the paperwork to get the rebates. When I told them I wanted to use some used panels I already owned and do the installation myself, they weren't interested. So I installed the system myself, and let the meter run backwards. I plan to install more panels and a wind genny as my budget allows, and continue to lower my load. As long as I don't have a negative reading for the month, the utility will never know. Until the utilities pull their heads out of the sand, I'm proud to be a solar guerrilla, or is that gorilla…


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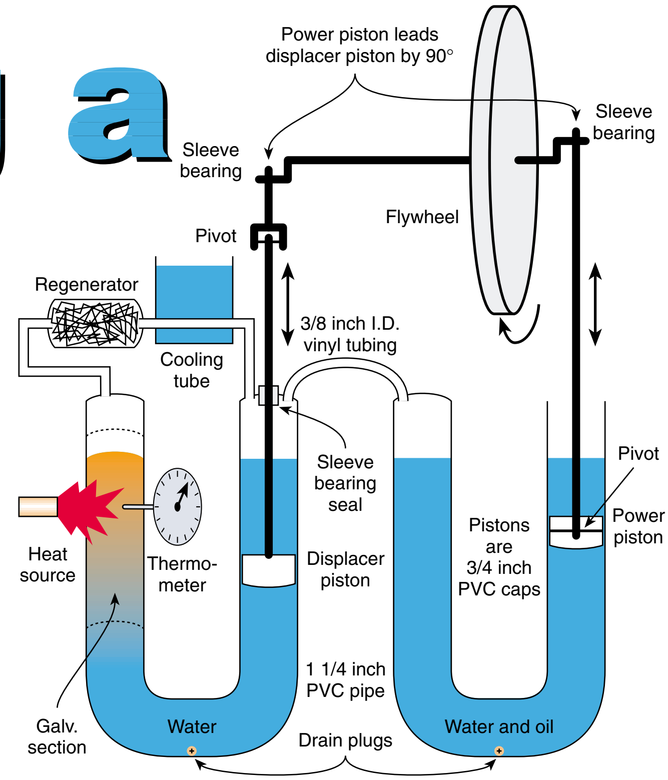
Building a Simple Stirling Engine

Jay Wilson



It's a common misconception that Stirling engines are some sort of high-tech invention, belonging more in NASA research labs than in the basements of home tinkerers. This perception perhaps comes from the many attempts to make Stirling engine-powered cars during the "energy crisis" era of the '70s. Making a Stirling engine that matches the performance of a typical auto engine is indeed a daunting task. But lower performance Stirling engines can be simpler to build than even steam engines, which seem simple, but actually have a lot of hidden complexity.

Photo 1: Jay's wet-cycle Stirling engine.

The Stirling engine, also known as the hot air engine, is actually an old concept. It was invented by Robert Stirling, a Scottish minister, in 1816. He invented it largely in reaction to the frequent horrible accidents that occurred with the primitive steam engines of that era, whose boilers tended to explode without warning. His new type of engine was filled with relatively low pressure hot air, which is much less dangerous when something breaks.

Stirling engines are safer than steam engines because they can operate at low pressures and lack the dangerous, explosive mix of pressurized water and steam that is found in steam boilers. Stirling engines are also mechanically simpler than steam engines, because no valves are required.

Like steam engines, Stirling engines are externally heated devices that can produce mechanical power from any source of heat, from nuclear reactors to burning cow chips. Basement tinkerers and RE enthusiasts will find the Stirling engine a rich area for study, as well as a potentially ideal means of utilizing renewable energy sources.

Model Stirling

This article discusses how to build a simple Stirling engine. Better hardware stores will have all the components needed for this project. This engine is too small to provide serious power, although it can run a fan or tiny one watt generator. Mostly, building this engine is for education and fun. Of course, if the components are scaled up, you will get more power. Perhaps a quarter horsepower is possible without components becoming too large or needing too much deep design engineering.

This engine design requires no precision machining at all, only normal household tools such as a power drill, hand saws, and such. For neat work, I recommend a miter box and drill press, but if you're careful, even these may not be necessary. The entire engine can be built out of common hardware store materials such as wood, plastic and copper tubing, and PVC pipe. Construction of my prototype engine took about twenty hours of work and a very limited amount of craftsmanship.

"Wet-Cycle" Stirling Engine

There's no need to cover the theory of Stirling engines in detail, as this subject is covered in depth in many places (see Access). I'll just mention some of the peculiarities of my design. It is what I call (for lack of a better name) a "wet-cycle" Stirling engine.

Mechanically, a wet-cycle Stirling engine is the same as any other Stirling engine. However, unlike a normal Stirling engine, a wet-cycle engine uses the evaporation and condensation of steam to enhance its power output. Thus it shares some characteristics of steam engines, including a relatively low operating temperature and lower thermal efficiency.

Of course, efficiency is only one consideration determining the usefulness of an engine. A wet-cycle Stirling engine can be run from all sorts of heat sources because of its modest temperature requirements. My prototype engine runs when it is heated to as little as 160°F (70°C). Such temperatures are easily achieved by non-tracking flat-plate solar collectors or wood stoves.

Also, because of the low temperature, most components of this engine can be built of wood and plastic. In contrast, normal Stirling engines typically operate red-hot, requiring expensive materials to withstand the heat. As for safety, my engine cannot build up any sustained internal pressure, making it explosion-proof.

The other unique feature of this engine design is the use of liquid-flooded displacer and power pistons. Liquid flooding eliminates the need for precision machining, yet provides a good, low-friction seal around the pistons. I'll discuss the design details later in this article.

My Model Engine—General Info

A schematic of my Stirling engine design is shown at left. Photo 1 shows a picture of the whole engine. The power piston displaces about 2.5 cubic inches (40 cm^3), and the displacer about 3.5 cubic inches (57 cm^3). The engine is heated by a propane torch. When the water in the hot side of the displacer is heated to about 160°F (70°C), the engine will begin to run (the flywheel has to be pushed to get it going).

As the water gets hotter than 160°F, the engine will run faster. However, adding more heat after the water reaches the boiling point does not increase the engine speed, and just wastes energy. The maximum speed I have achieved is about 180 rpm. Engine speed could certainly be made faster with a more optimized design. Uncontrolled sloshing of the liquid in the piston and displacer cylinders may impose an unknown upper limit on speed.

The Power Piston & Cylinder

See Photo 2 for a picture of the power cylinder assembly. The piston is set up for a stroke of two inches (5 cm), although this can be easily varied by changing crankshaft components. The piston is made from a

Photo 2: Power cylinder assembly.

Photo 3: Displacer cylinder assembly.

standard 3/4 inch PVC cap (Nibco brand, schedule 40, 1.32” O.D.). It fits snugly into one side of the U-shaped cylinder assembly, which is made of 1 1/4 inch PVC pipe (Apache brand, schedule 40, 1.35” I.D.). A metal pin stuck sideways through the cap attaches the piston to the connecting rod, which is made out of 1/4 inch (6 mm) diameter aluminum bar and 3/4 inch (19 mm) square wood.

The U-shaped cylinder is filled with light vegetable or motor oil, which lubricates and seals the piston. Some water may also be added to reduce the amount and cost of the oil. The piston must be completely covered with the oil or it will not seal sufficiently. This flooded piston design works surprisingly well and develops a lot of compression even with a fairly sloppy fit between the piston and the cylinder wall. Plain water will not work as the flooding agent; it lacks the required viscosity to seal the piston.

The power cylinder is connected to the displacer cylinder by a length of 3/8 inch inside diameter vinyl tubing. The tubing is attached to a standard brass barbed hose fitting, which is screwed into the top of each cylinder. Most tubing connections in the engine use similar hose fittings. Air pressure variations developed in the displacer during engine operation are transmitted to the power cylinder through the tubing. Air pressure alternately pushes and pulls on the oil, which pushes and pulls on the piston, which drives the crankshaft, which converts the forces into the desired rotary motion.

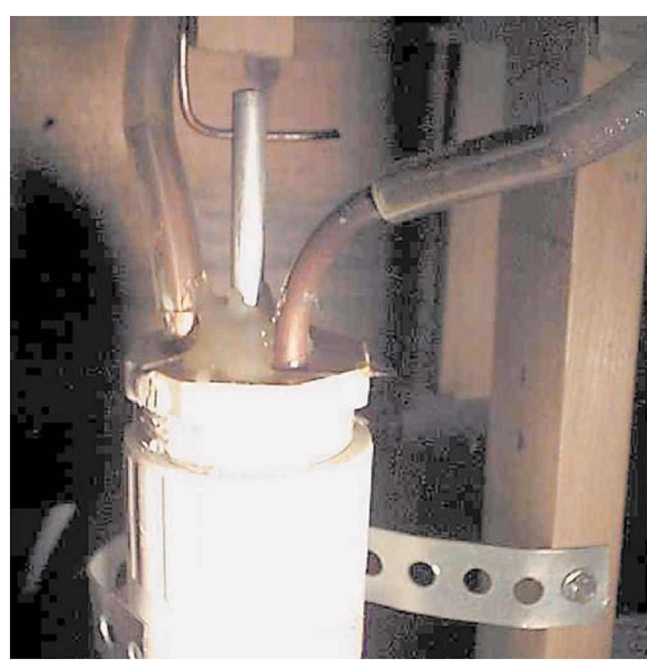
Displacer

See Photo 3 for a view of the displacer cylinder assembly. The displacer cylinder is a U-shaped piece of 1 1/4 inch PVC pipe similar to the power cylinder, except that it is filled with water, not oil. To better withstand the heat, the area contacted by the torch flame is made out of a standard galvanized iron pipe nipple, which is threaded into the rest of the PVC displacer cylinder. The nipple is 6 inches (15 cm) long, and the threads are sealed with a generous amount of silicone sealant.

The water heated by the torch floats on the top of the hot side of the displacer cylinder and does not appreciably heat the cold side. It is important to maintain the temperature differential between the hot and cold sides of the displacer cylinder, since this drives the Stirling engine.

A piston made out of a 3/4 inch PVC cap (similar to the power piston) provides the force that oscillates the water in the displacer. The stroke of the piston is 3 inches (7.6 cm). The 1/4 inch (6 mm) diameter aluminum connecting rod slides through the PVC cap

Photo 4: Pivot in displacer rod.



on the cold side of the displacer cylinder through a 17/64 inch (7 mm) hole. Because this rod cannot pivot, a hinged joint and second rod section is needed to connect the displacer piston to the crankshaft. See Photo 4 for a detailed picture of this.

Maintaining a good air seal at the point where the piston rod penetrates into the displacer cylinder is important. I improved the sealing around the connecting rod by squirting a good sized pile of hot-melt glue around the the top of the 17/64 inch hole, with the connecting rod in place. If the connecting rod is oiled, the hot-melt glue will not stick to the rod.

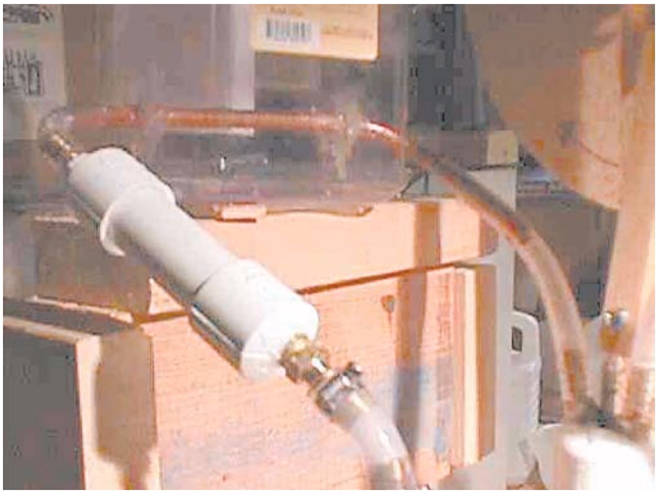
After creating this hot-melt glue "bushing," I applied a liberal amount of grease to the connecting rod to provide even more sealing and lubrication. Using a sleeve bearing along with a precision-ground connecting rod would provide a more durable method of sealing the penetration.

To maximize compression of the steam and air in the displacer cylinder, the water level in the cylinder should be adjusted so that the water comes close to hitting the cylinder caps when the piston oscillates. Drilling a drain hole into the displacer cylinder at the desired height is a good way to assure the right water level. Once the displacer is correctly filled, the drain hole may be plugged by twisting a machine screw into the hole. Since the water and steam are always contained within the engine, refills are only needed infrequently.

Regenerator & Cooler

The hot and cold ends of the displacer cylinder are connected by 3/8 inch vinyl tubing and two important performance-enhancing components, the regenerator and cooler. Hot air and steam pushed out of the hot end of the displacer cylinder first flows through a regenerator (see Photo 5), which is a simple device with a complicated sounding name.

Photo 5: Regenerator and cooler.



In my engine, the regenerator consists of a 4 inch (10 cm) long, 3/4 inch I.D. piece of PVC pipe with a cap on each end. It is thoroughly stuffed with ordinary aluminum window screen. The fine mesh of the screen efficiently removes heat from the air leaving the hot space, and recycles it back to the cold air flowing from the cold end of the displacer. An excellent material to use in regenerators is stainless steel wool, if you can find it.

A Stirling engine can run without a regenerator, but is it a good idea to include one. When I installed a regenerator in my engine, I observed a remarkable increase in its performance and efficiency. The regenerator is the secret of why Stirling engines can be so efficient.

After the regenerator comes the cooler (see Photo 5), which removes heat and condenses steam left in the air that has passed through the regenerator. In my engine, the air is cooled by passing it through a 6 inch (15 cm) length of 1/4 inch I.D. copper tubing immersed in a bath of cold water.

Crankshaft & Other Mechanical Components

See Photo 6 for a view of the crankshaft assembly. The crankshaft is made of 1/2 inch (13 mm) threaded steel rod, on which all the other rotating components can be easily bolted. Two ball bearings support the threaded rod. The flywheel is a one foot (30 cm) diameter disc of particle board. The crank arms are made out of wood. Standard 3/8 inch (9 mm) bolts attached to the outer ends of the wood cranks support the piston rods, which pivot on bronze sleeve bearings.

I bolted a five inch pulley onto the shaft next to the flywheel. By attaching simple belts made of string to the pulley, I could experiment with driving a fan and creating drag loads to measure torque. Many interesting experiments can be done by changing the length of the crank arms, which changes the stroke of the pistons. Increasing the power piston stroke increases the compression ratio of the engine. This theoretically can increase power and efficiency. But if you try to do this too much, the engine may run rougher or even not at all.

Increasing the displacer stroke theoretically decreases thermal efficiency, but can make less optimal engines run more smoothly. With the more rough-and-ready Stirling engines, designing the displacer to have 1 1/2 times the power piston stroke seems to provide a good balance of power and smooth operation.

Odds, Ends, & Troubleshooting

A thermometer to monitor the displacer water temperature is nice to have. I used a thermometer made by Taylor, which features a dial attached to a

Photo 6: Crankshaft assembly.

long, thin stainless steel stem. It is inserted into the heated portion of the displacer cylinder through a hole sealed with silicone. These thermometers are usually found in the kitchen goods section of a hardware store.

Drain plugs that allow the water and oil in the cylinders to be filled and drained are also handy. Brass machine screws threaded through holes in the PVC pipe cylinders and sealed with thread sealant work fine for this.

If your engine won't run, make sure that the crank arms are set to the correct phasing. The displacer crank should lead the power piston crank by 90 degrees in the desired direction of rotation. Friction is also a big enemy of low power Stirling engines. Try unplugging a hose to relieve compression. Then give the flywheel a push; the engine should freewheel for a couple of turns.

The other big enemy, and a more insidious one, is air leakage. If there is a lot of leakage, the engine can't build any compression, and it simply won't run, period. With all hoses in place and everything sealed, try uncoupling the power piston rod from the crankshaft and pushing down on it. If the compression is good, the piston should push back strongly for a second or longer. It should feel like there's a spring under the piston. You also may hear air hissing out somewhere, but if the air takes one second or longer to leak out, that's okay.

Power Output

When I got my prototype engine running smoothly, I naturally wanted to know how much power it could put out. After some tinkering, I managed to measure its speed and torque, from which it's possible to calculate horsepower. The result? Well, I computed (brace

Stirling Engine Parts List

#	*Item*	*Cost (US$)*
1	1 1/4" pipe (schedule 40), 10 feet*	5.79
4	1 1/4" 90 degree elbows, solvent weld	4.76
1	1 1/4" diam 6" galv. steel pipe nipple	3.29
2	1 1/4" female threaded-to-solvent adaptors	1.50
1	1 1/4" female threaded cap	1.19
1	1 1/4" male threaded cap	1.19
2	1 1/4" straight connectors, solvent	0.98
1	1 1/4" cap, solvent weld	0.69
	Regenerator & Cooling Assembly	
8	Small pipe clamps for plastic tubing	4.40
4	3/8" brass barbed tubing fittings	3.16
1	1/4" I.D., 3/8" O.D. copper tubing, 2 feet	1.58
1	3/4" pipe, 10 feet*	1.39
1	3/8" I.D. clear vinyl tubing, 2 feet	1.38
1	Aluminum window screen (scrounged)	0.00
	Various metal pieces to attach pistons to 1/4" connecting rods (scrounged)	0.00
	Crankshaft & Pistons	
1	Pulley, 5" diameter	9.29
2	1/2" I.D. ball bearings	5.98
2	3/8" I.D. bronze sleeve bearings	3.58
1	1/2" diameter threaded steel rod, 3 feet	2.79
4	3/4" caps, solvent weld**	1.40
1	1/4" aluminum rod, 2 feet	1.29
6	1/2" nuts	0.90
2	3/8" hex bolts, 3" long	0.52
	Wood pieces for framework (scrounged)	0.00
	Wood pieces in crankshaft (scrounged)	0.00
	Miscellaneous	
1	Propane torch and bottle	12.99
1	Taylor stainless steel stem thermometer	9.99
	Pipe thread sealant	4.49
	Silicone glue and sealant	3.99
	PVC pipe solvent	1.99
	Hot melt glue sticks	1.49
	Nuts, screws, bolts, & washers (scrounged)	0.00
	Total	$91.99

All plumbing parts are PVC unless otherwise noted.
* Pipe sold in 10 foot lengths. Less than 10 feet used.
** 2 caps for pistons, 2 caps for regenerator.

yourself!) 0.0007 horsepower, or about half a watt, on my best run so far. This doesn't sound like much power, but the engine is quite impressive to watch as it cranks away with surprising vigor using only the heat of a small propane flame.

I expect that a larger engine of this type—using higher quality components (pistons, bearings, seals) and using more careful engineering in the airflow paths and heat exchange components—should be able to develop at least 0.001 horsepower (0.74 watts) per cubic inch of piston displacement. A skilled engine designer can do much better than this. Obviously a lot of displacement is needed to create significant power, but those cubic inches will be cheap when the cylinders can be made out of plastic drainpipe.

Stirling engines are simple devices. The wet-cycle type of engine that I have described is easy to build, and can utilize relatively low temperature heat sources to produce mechanical power. Remote home applications are easy to imagine. For example, a Stirling engine driven by heat from a wood stove could drive a generator to provide extra electrical power in winter, when solar energy is scarce. Tinkerers and inventors should not hesitate to dive right in and experiment with Reverend Stirling's century-old but still fascinating technology.

Access

Author: Jay Wilson • whitebark@aol.com

Stirling Engines for Home Power, by Brent Van Arsdell, *HP61,* page 20.

Check out engineering college libraries for technically-oriented books. For example, the book *Liquid Piston Stirling Engines,* by C.D. West, 1983 provided some of the inspiration for my engine design.

Web sites on Stirling engines:

www.stirlingengine.com • small engine kits for sale, info, and links

www.baileycraft.com/stirling.htm • small engine kits for sale

www.bekkoame.ne.jp/~khirata • good general info, simple engines you can build, and links

www.sunpower.com • this company is designing "free piston" Stirling engines that burn biomass to produce power

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Measuring Energy Usage for Inverter & Battery Bank Sizing

Mark Patton

Two common questions that most people ask when trying to design a renewable energy system are "What size inverter do I need?" and "What size battery bank do I need?" The answers: It depends on what you want to run and for how long!

A good way of determining the inverter and battery bank size is to enter all your electrical devices into a load analysis spreadsheet—like the one available for download on the *Home Power* Web site. There is a column in the spreadsheet for starting watts, running watts, and how many hours per day the device runs. Personally, I don't know how long some of my smaller appliances run, but I can make a pretty good guess. Most of us don't have any idea how long some of our larger appliances like the refrigerator, well pump, or furnace run each day.

The other important issue in sizing an RE system is to determine the number of these loads that run at one time. This is the largest factor in determining what size inverter is required for a particular application. Well pumps and other appliances with motors are the largest and most difficult loads that a renewable energy system can start and run.

Accumulating Watt-Hour Meter

One way of determining the energy consumption of devices is to get an accumulating watt-hour meter such as the Brand Digital Power Meter or Watts Up? meter. You simply plug the appliance into it, and collect data over a period of time. While this is accurate, it can be difficult to do with some of the larger electrical loads (like furnaces and well pumps) which are hard-wired into the electrical system.

Estimating Energy Using a Data Logger

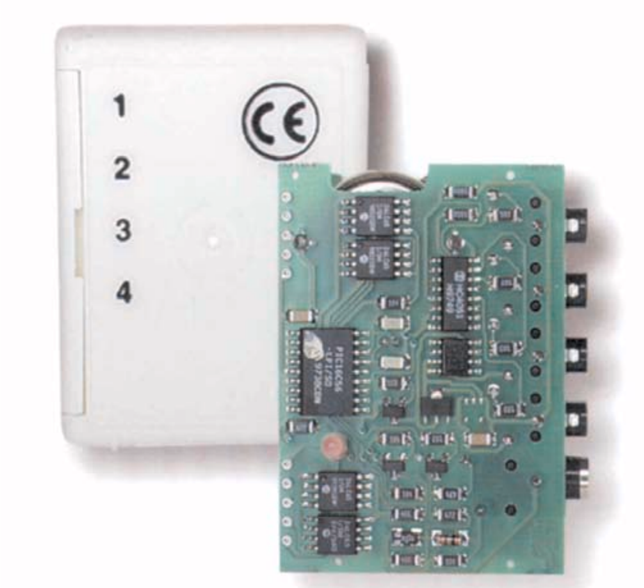
Another way to estimate energy consumption is to measure the current going into the load and multiply it by the voltage across the load. A clamp-on ammeter can effectively measure the current being drawn by the load. But most don't accumulate the current measurements over time so that the energy used can be calculated.

An inexpensive data logging system can be used to store current measurements over time. This may not be as accurate as using a power meter on each device since the data is sampled, and it does not compensate for complex power.

For example: if you use a data logging system to measure current on a refrigerator and set the sample rate to two times per minute, then the measurements will only be accurate to one minute for each time the refrigerator starts or stops. Because the data logger is sampling, the logger will miss the current pulse when the motor starts most of the time. This starting current will still need to be measured using a clamp-on ammeter, or determined using manufacturer's data, or estimated using "rules of thumb."

The advantage of the data logger approach is that the logger can measure a single load or a group of loads

The case and brains of an Onset HOBO four channel external data logger.



together. Using this data, a load profile can easily be determined. This load profile is very useful in determining the maximum power that the loads on a group of circuits is consuming. The load profile can also help track down those dreaded "phantom loads." These are the loads like the little wall cubes that we leave plugged in all the time, which draw a few watts 24 hours a day.

Inexpensive Data Acquisition System

Onset Computer Corp. sells data loggers that work very well for this kind of application. They are very small (about half the size of a pack of cigarettes) battery-powered units called a "HOBO" loggers. There are several models; the one I chose cost US$85 and is a four-channel external logger. "External" means that all four channels are external to the logger itself and are plugged in to the logger via a jack on its side.

Onset also sells split-core AC current sensors that clamp around a single wire. These sensors are available in ranges from 20 to 600 amps AC maximum load. I chose two 20 A sensors (US$84 each) to enable collection of data from both sides of the 240 V line at once. The HOBO external can handle up to four of these sensors (or other sensors).

Using the Current Sensor

The current sensor is "split-core" transformer. It is a donut-shaped device with one removable side that installs around the wire that you want to monitor. The current sensor doesn't make a physical electrical connection with the wire. It measures the induced current generated by the AC current passing through the wire to the load.

This sensor uses the same principle as a clamp-on ammeter. The current sensor is installed by removing the two nylon screws and the removable side, placing the wire in the center of the open donut, and then replacing the removable side and its screws. Installing one sensor takes less than a minute.

To measure the current for a single load, the current transformer must be installed in a single leg (either positive or neutral, *not* ground) of the device being tested. For most appliances where you don't have access to the internal wiring, you will need to split out one of the power leads to hook the current sensor around.

There are two easy ways to do this. One way is to purchase a line separator designed specifically for this purpose. It is a plastic device that plugs in between the appliance and the outlet and splits out all three legs in the circuit. The second way is to build a short extension cord and separate either the hot lead (black) or neutral lead (white) out in a section so that the current sensor can be installed around it.

The split-core transformer current sensor.

Do not remove, cut, or nick the insulation from any of the wires! it is not necessary and is very dangerous. You could cause a fire or be killed!

Sub-Circuits and Panel

To measure the current consumption for a sub-circuit, you will need to install the current sensor around the line feeding the sub-circuit. First, if you are planning to measure the current for a circuit that draws a *lot* of current—such as a whole house—you will need to make sure that the current sensor that you plan to use is sized correctly. Don't use a current sensor that is smaller than the maximum load on the circuit. If the circuit is rated at 100 amps, use a sensor rated at 100 amps or more.

One place to gain access to the lines feeding the house or sub-circuit is in the main electrical panel that contains the circuit breakers for the house. *Please note that working in the electrical panel can be extremely dangerous. You could start a fire, or be injured or killed if you don't know exactly what you are doing. Make sure that the power is turned off to the panel, and verify with a voltmeter before proceeding. If you are not qualified to do any of this work, call a licensed electrician!*

For a 120 V sub-circuit, the current sensor can be installed around the wire coming out of the circuit breaker that feeds the sub-circuit. If the sub-circuit is 240 V, you may need to use one current sensor on each of the two "hot" wires that lead out of the two circuit breakers.

Two sensors are only required if the sub-circuit may draw more current on one 120 V leg than the other. This could be the case with an appliance like an electric clothes dryer in which the heater is 240 V but the motor is 120 V. If the device is strictly a 240 V device, like a well pump or an electric water heater, only one current sensor is necessary because the current is the same between the two legs.

If the circuit is dedicated to one load, it may be easier to access the feed wires where they enter the load. In the case of the furnace, I simply turned the power off at the furnace, removed the front cover, found the black power wire that feeds the furnace, placed the current sensor around it, and turned the furnace power back on. This was much easier and safer than gaining access in the main electrical panel.

To measure the current for a group of circuits, you will need one current sensor for each circuit. The HOBO data logger can handle up to four sensors at once. I measured the current on one circuit at a time for about about one week each. When the week was up, I downloaded the data to my computer for analysis, and then moved the current sensor to another circuit.

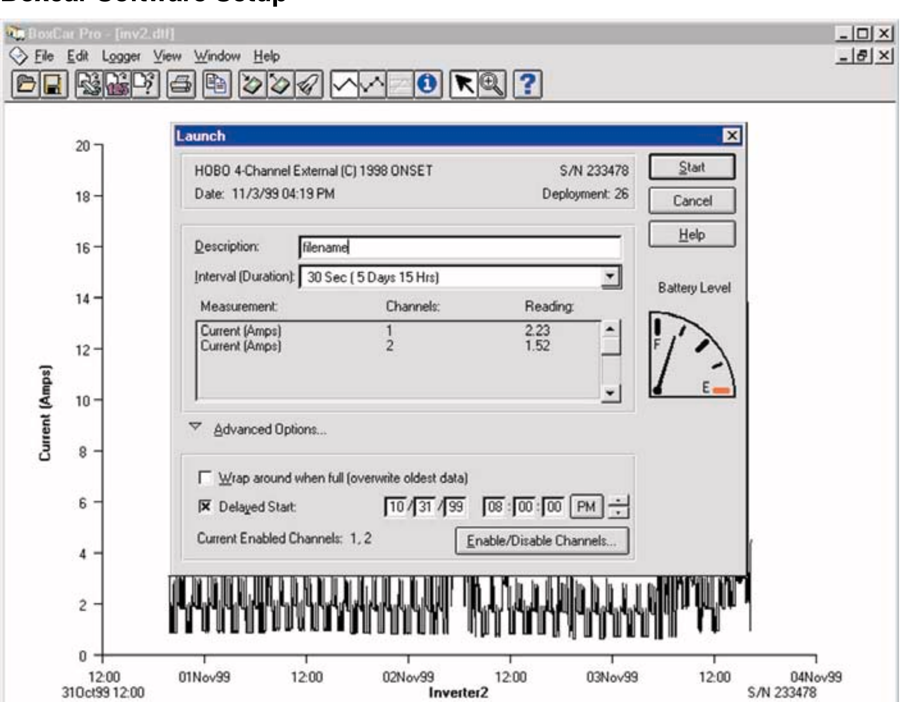
Configuring the Logger
Configuring the HOBO logger is very easy. You simply plug it in to the serial port on the computer using the cable provided by Onset, start the Boxcar software, tell the software which serial port to use, and launch the logger to start gathering data. When the data logging session is complete, you simply plug the logger back into the computer, launch the Boxcar application, and download the data for viewing/exporting.

The data sampling rate can be set as short as once every half a second, or as long as once every nine hours. For this application, thirty second sample intervals were selected. If a single channel is used, the logger has enough internal memory to gather over eleven days of data at this sample rate. You could select a faster sample rate, but if data is collected over a period of time, the amount of data can be overwhelming. At a thirty second sample rate, the logger will collect 2,880 data points per day per channel.

For my measurements, I let the logger capture data for five to seven days. That's well over 14,000 data points per channel to deal with! The logger can be set up to start logging at some future time. This is useful if you want to set up the logger and then need to relocate it to start gathering data, or if you want to collect data starting at a particular time. Once the logger is configured and "launched," it is disconnected from the host computer and quietly collects data at a programmed interval. A small LED blinks approximately once per second to confirm that it is alive.

Downloading the Data
Once the data is collected, it is downloaded to your computer via the serial port and by using the Onset Boxcar software and cable. The data can be graphed using the Boxcar software, or it can be exported to an Excel (or other) spreadsheet for further analysis and graphing. I found that exporting the data to Excel was the easiest way to analyze the data and calculate energy consumption. Or you can download my sample spreadsheet from the *Home Power* Web site, and paste the Boxcar data directly into the sample sheet.

Boxcar Software Setup



Analyzing the Data in Excel
The Boxcar software exports data to a text file that is delimited with a tab character. It is easy to read the data when you open the text file in Excel and answer a couple of questions.

The current sensors have a small DC offset. This means that when there is no current flowing, they read slightly off of zero. In the case of the 20 A sensors, that zero offset is 0.04 A. I used a formula in Excel to make any reading of 0.04 amps read zero. The formula is:

=IF((B5=0.04),0,B5)

This means if cell B5 is 0.04, put a zero in the current column; otherwise use the value in cell B5. Figure 1, Spreadsheet Data, shows the data imported into Excel. The "Date & Time" and "Current" columns are the data imported

Figure 1: Imported Boxcar Data

Date & Time	*Current*	*Normalized Current*
11/7/99 18:21	0.04	0.00
11/7/99 18:21	0.04	0.00
11/7/99 18:22	0.04	0.00
11/7/99 18:22	0.04	0.00
11/7/99 18:23	0.04	0.00
11/7/99 18:23	2.38	2.38
11/7/99 18:24	2.30	2.30

directly from the logger. The "Normalized Current" column is the result of using the formula above.

Figure 2 shows the load profile for a typical automatic-defrost refrigerator. Notice the motor start pulses. The data logger was taking samples at thirty second intervals and just happened to catch some of the motor starting current surges. These surges occur each time the refrigerator compressor motor starts.

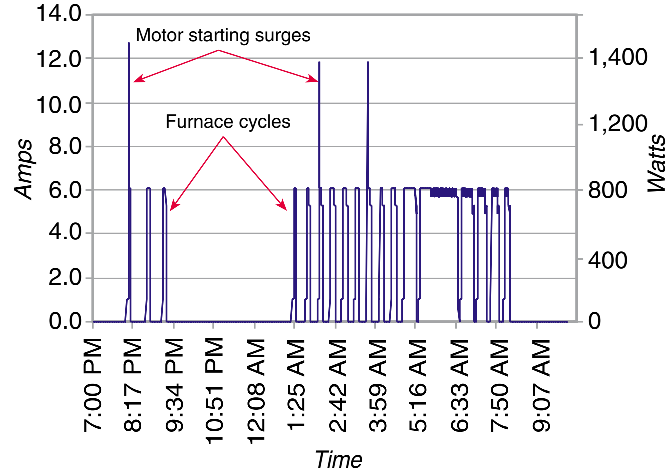
The spreadsheet calculated the energy consumption, and shows that this ten year old refrigerator consumes 3.13 KWH per day. An accumulating watt-hour meter shows that the refrigerator actually consumed 2.99 KWH during the same period. Even though the logger was sampling every thirty seconds, these results were fairly close!

Figure 3 shows the load profile for a forced-air gas furnace. The amount of time that the furnace runs is highly dependent on the weather. The furnace runs much more on cloudy winter days, which is bad news when trying to run it from a PV system.

Measuring Multiple Loads

While measuring the profile of one load is interesting, it gets really interesting when you use the logger to measure the load profile of a group of circuits or a subpanel. Using two channels of the logger and two current sensors (one for each side of the 240 V line) the load profile of a 240 V backup system subpanel can be measured. The HOBO logger has enough internal memory to gather five days, fifteen hours of data using two channels, at a once every 30 seconds sample rate.

Figure 3: Furnace Cycles



Total energy consumption of the subpanel can be calculated by loading the two data channels into a spreadsheet side-by-side and adding them together. Figure 4 shows the results of measurements taken on a backup system subpanel.

This load and profile information can be used to help size RE systems. In this example, the peak load was approaching 4 KW when the well pump was on. This does not account for the peak current when the motor starts. Based on information supplied by the pump manufacturer, the maximum motor starting current is 51 A at 240 V. This requires a surge capacity from the inverters and battery bank of 12.2 KW. Add to this the possibility that other loads are running at the same time and the surge capacity needed rises to almost 14 KW!

Figure 2: Refrigerator Power Consumption

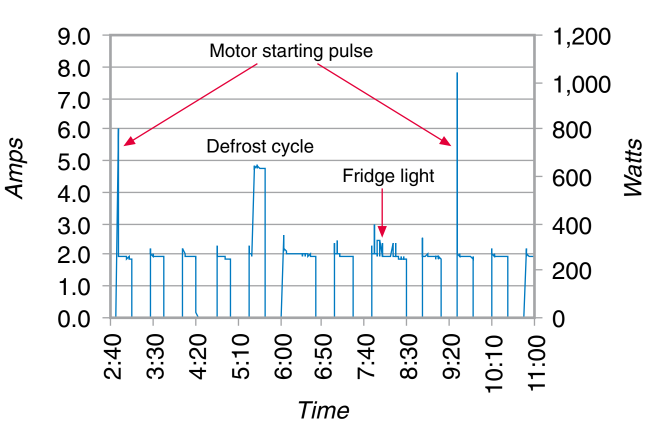


Figure 4: Critical Loads

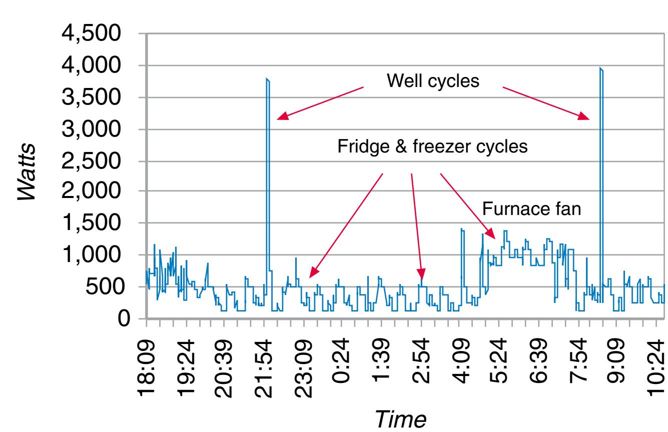
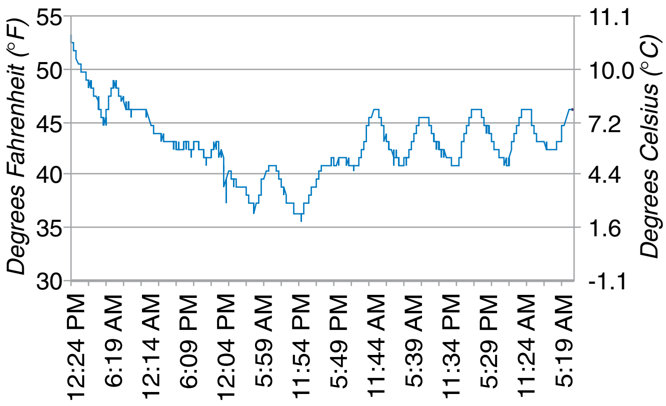


Figure 5: Root Cellar Air Temperature



Based on the information gathered from the backup system subpanel running these loads, this system would need to be sized for 12.9 KWH daily energy use.

Using the Results

Once the data has been collected on a single load or a group of loads, you can input this data into the load analysis spreadsheet along with the other loads to finish the analysis on how to size the system. Using actual data—particularly for the larger loads—will greatly increase the accuracy of the analysis.

Load Profiles & Surveillance

Looking at the load profiles, it is interesting to look at the activity on various loads. For instance, if you look carefully at the load profile for the refrigerator, you can tell when someone opened the refrigerator door and the interior light went on (so much for those midnight raids on the refrigerator!).

The older automatic defrost refrigerators have a timer that turns on a heater to defrost the coils every 24 hours. The load profile will quickly show you when this occurs. If a PV system has excess energy late in the day, this may be a perfect time for the refrigerator to defrost itself. Once the defrost time is determined, the timer can be turned ahead to have it defrost when the excess energy is available. Newer computer-controlled refrigerators may not have a simple defrost timer like this.

Data Logging Costs

Qty.	*Item*	*Cost (US$)*
2	20 A split-core AC current sensors (CT-A)	168
1	HOBO four-channel external logger	85
1	Boxcar 3.6 software & serial cable	14
	Total	$267

Other Fun Applications

We used the HOBO logger with a temperature sensor to measure the air temperature in a root cellar. We needed to make sure that the root cellar didn't get too warm during the daytime, and that it didn't freeze at night. For this application, the sample rate was set to once every five minutes—the temperature inside the root cellar doesn't change very fast! For RE applications, the temperature sensor could be used to log the temperature of a battery bank, inverter, or whatever!

Caution: Please be extremely careful when working around electrical devices or load panels. You can be seriously hurt or killed. Turn all power off before installing any current sensors. If you don't know exactly what you are doing—don't do it!

Access

Author: Mark Patton, 18250 E. Davies Ave., Foxfield, CO 80016 • 303-693-3381
mepatton@mindspring.com

Onset Computer Corporation, PO Box 3450, Pocasset, MA 02559-3450 • 800-LOGGERS or 508-759-9500
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Fuel Cell Cars

Shari Prange

The shape of things to come is very much on everyone's mind these days, as we look forward into a new century and a new millennium. We are impatient to be rid of the inefficient and dirty technology of yesterday, and move on to the "something" better that has always been promised to us for the future. After all, the future is here. So people are not only looking beyond internal combustion vehicles to electric cars, but also beyond batteries to fuel cells.

What's The Difference?

What exactly is a fuel cell, and how is it different from a battery? They have a lot in common. Both of them are containers in which a chemical reaction takes place, creating electricity. Like a battery, a fuel cell has a negative electrode (anode) and a positive electrode (cathode), with an electrolyte between them. The main difference is in how you "refill" each of them when they are "empty."

A battery is recharged by putting electrical energy directly into it. This reverses the chemical reaction inside, and prepares the battery to start over again, releasing electrical energy. You don't add or remove any chemicals. (You may need to add water periodically, but this is a maintenance procedure, not an integral part of recharging.) A fuel cell, on the other hand, uses up its chemicals. To "refill" it, fresh chemicals are added.

Here's another way to think of it. A battery is an energy *storage* device. You put electrical energy into it, and it stores it chemically for later release. A fuel cell, on the other hand, is an energy *conversion* device. You supply it with chemical fuel, and the fuel cell converts the fuel to electrical energy. It does not store energy. The energy is stored in the fuel tank, and the fuel cell merely releases it.

Like batteries, fuel cells are designed for many different purposes, including powering satellites, vehicles, and industrial generating stations, to name a few. Also like batteries, fuel cells that are designed for one application are not likely to work well in a different situation. Our discussion here will focus on fuel cells for vehicles, primarily private passenger cars and other light duty vehicles.

(You may also hear the term "fuel cell" used in reference to conventional race cars, which can be confusing. In that case, it has an entirely different meaning. It is not a fuel cell that produces electricity. Rather, it is a special type of liquid fuel *tank* for a combustion engine, designed to survive crashes without exploding or spewing its contents on the racetrack.)

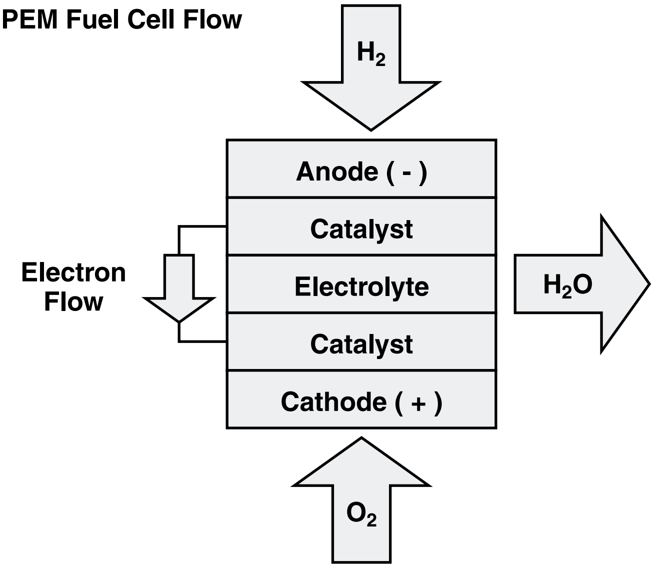
Which Is Better?

There are are pros and cons to both batteries and fuel cells. The most obvious advantage to fuel cells is quick refueling. Some fuel cell systems can be refuelled just as quickly and easily as filling a gas tank. In fact, some of them *are* refuelled by filling a gas tank.

Battery vehicles typically take about six hours to recharge on 220 volt power, and twice that on 110 volts. Of course, this is usually done at home. If you charge at a charging station with access to 440 volt three-phase power, some battery systems can recover most of their charge in fifteen minutes. This pretty closely approximates the fuel cell refill time.

This leads us to the second recharging issue—convenience. Home-built electric conversions usually charge from normal 110 volt household outlets, so they can charge at home, at work, at friend's houses—anywhere they can plug in. Factory EVs generally use specialized charging interfaces. They can charge at home, or at any public charging facility with the right connections, but not at Aunt Minnie's house.

PEM Fuel Cell Flow



Most fuel cell vehicles are not suitable for home fueling. They would have to go to a fueling station, just like a gas car has to go to a gas station. The type of fueling station depends on the type of fuel the cell uses. Some of the fuels require specialized equipment. These might be suitable for fleet vehicles, but maybe not for the general public.

For that reason, auto manufacturers are putting their efforts behind developing fuel cells that can be refilled at existing fuel pumps with methanol or better yet (to their minds, at least) the same "good" old gasoline we're used to using. This is less convenient for the driver than home charging, but no less convenient than gas refueling, which is already accepted. It also means that the fueling station doesn't have to invest in any special equipment, which would be necessary for some other fuels, and for quick battery charging.

How Does it Work?

Just like batteries, fuel cells can be built with many different chemistries. At this time, however, the automotive industry is overwhelmingly pursuing *hydrogen* fuel cells. In particular, the focus is on the proton exchange membrane (PEM) type of hydrogen fuel cell.

The way it works is pretty simple. Hydrogen goes into the fuel cell. The electrodes are coated with a catalyst, which cause the hydrogen molecule to split into two atoms and form electrons and protons at the anode. The flow of the electrons out of the cell provides us with electricity.

Meanwhile, back at the ranch, the protons pass through the PEM to the cathode. There, they meet up and recombine with the electrons, and with oxygen, to produce water and heat.

Hydrogen in; electricity, heat, and water out. Very neat and clean. However, to get the complete picture, you need to take one step further back and ask, "Where does the hydrogen come from?"

Going to the Source

One source is water. You can use electricity to split water molecules into hydrogen and oxygen. But wait a minute! Doesn't the fuel cell release water as waste? That's right. In theory, you could use some of the electricity from the fuel cell to power the car, and some of it to electrolyze waste water into hydrogen and oxygen. Then feed the hydrogen to the fuel cell, where it makes electricity, and recombines it with the oxygen, producing water. A closed circle—perpetual motion, right?

Not quite. First, any process has some losses through inefficiencies. The fuel cell will always put out less water than it uses. Second, the cell requires some energy for its support equipment: compressors, pumps, fans, etc. The hydrogen has to be fed into the cell, operating temperature and humidity carefully controlled, compressed air fed in at the end of the cycle to provide the oxygen for recombination, etc. All of this requires equipment, which needs to be powered.

Finally, you would need a really big fuel cell to provide enough energy to power the vehicle and electrolyze the water at the same time—too big to be practical in an ordinary car.

Okay, so what about solar or wind power for the electrolysis? That's free energy. Well, yes, in the sense that Mother Nature does not send us a bill for using solar or wind energy. There is, however, the significant cost of the solar or wind equipment, as well as the electrolysis equipment. It is also too massive to be installed on the vehicle.

Other sources for hydrogen include a variety of hydrocarbon fuels: methanol, ethanol, compressed natural gas (CNG), and plain old gasoline and diesel fuel. Just as water requires an electrolyzer to release its hydrogen, these other fuels require a piece of equipment called a reformer to strip the hydrogen out of them.

Reformers

Actually, the reformer's job is a little more involved than that. For one thing, it needs to do something with the "leftover" parts of the fuel after it removes the desired hydrogen.

For the most part, the leftovers are carbon and oxygen. Ideally, these are released as carbon dioxide (CO_2). CO_2 is relatively harmless to the environment, and it doesn't hurt the fuel cell if some of it gets mixed in with the hydrogen. It will reduce the efficiency, though, since it takes up precious space better occupied by hydrogen. There are also some trace contaminants in the fuels, such as sulphur, which must be removed. The fuel cell is fairly fussy about its diet. It needs its hydrogen to be as pure as possible.

At this time, there are different types of reformers for different types of fuels. There are people working on the concept of a "universal" reformer, which could handle any of the fuels mentioned. However, even if this becomes possible, each unit will probably need to be "tuned" to work with a specific fuel. In other words, the factory can manufacture the same reformer for many different vehicles, but each vehicle would then be dedicated to a particular fuel type by certain adjustments to the reformer. You won't be able to randomly choose diesel today and methanol tomorrow.

The issue may be somewhat moot, however, in the opinion of Marshall Miller of the Institute of Transportation Studies at the University of California at Davis. He feels that, in the near future at least, methanol is the only fuel well-suited for onboard reforming in light duty vehicles. Other fuels would be reformed at stationary facilities, and the vehicle would carry hydrogen tanks onboard.

Hydrogen Onboard

This, of course, has its own set of issues. Gaseous hydrogen would be carried in a pressurized tank, similar to CNG. The problem is that a gas, by definition, is not very dense. This translates to a short range between fill-ups. This would not seem to be a major issue if filling up is a quick process. In fact, however, much of the buying public has some resistance to needing frequent fill-ups. In their minds, this means inconvenience and limitations.

Liquid hydrogen is more dense, which means it contains more energy in the same amount of space. However, it needs to be stored in a cryogenic (low temperature) tank to keep it liquid. This requires energy to keep it cold. In theory, liquid hydrogen should provide much more range than gaseous hydrogen. In reality, this advantage is reduced by the physical constraints of the vehicle. It is easier to design and fit the gas pressure tanks into the chassis than the cryogenic tanks, so you can get more volume of gaseous hydrogen onboard than liquid. The liquid hydrogen car would still have a somewhat better range, but not enough to compensate for the extra complexity of the cryogenic system in a light duty vehicle.

Fuel Cells & Batteries Together

Fuel cell cars may well turn out to be hybrids that use batteries as well. There are a couple of reasons for this. The first is acceleration. If the vehicle reforms its fuel onboard, the fuel cell is limited by the speed of the reforming process. The fuel cell can provide instant energy, but the reformer can't provide hydrogen to the fuel cell as quickly.

One solution would be a buffer tank of hydrogen, but this is not popular due to the space required. The other option is having a small bank of batteries that can supply extra power for acceleration. This, too, has some drawbacks, of course. The batteries take up space, and the system requires a sophisticated control computer to regulate the power draw from the fuel cells versus from the batteries.

However, batteries have another advantage to offer, which brings us to the second reason for a hybrid system. As we said at the beginning, fuel cells are not energy storage devices. In a pure fuel cell car, you cannot use regenerative braking because there is no place to put the energy. A fuel cell/battery hybrid allows you to take advantage of regeneration for some of your energy needs, making the overall vehicle more efficient.

Which Fuel?

So this is what a fuel cell car might be like in the near future. But which type of fuel is best? What are the relative pros and cons: costs, pollution, energy efficiency, maintenance, and so forth? We'll dig into those issues next time.

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Author: Shari Prange, Electro Automotive, PO Box 1113-HP, Felton, CA 95018-1113 • 831-429-1989
Fax: 831-429-1907 • shari.prange@homepower.com
www.electroauto.com

UC Davis Institute of Transportation Studies, University of California at Davis, Davis, CA 95616
530-752-6548 • Fax: 530-752-6572
its@engr.ucdavis.edu • www.engr.ucdavis.edu/~its

Fuel Cells 2000 Online Fuel Cells Information Center
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112 feet off the ground

It's probably not the best place to check their mailing label, but Ian and Johnny have their safety harnesses on.

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Mike Brown

I'm converting a gas car to electric power. One part of the process I'm confused about is interfacing the car's existing 12 volt electrical system with the high voltage system used to drive the car. How do I do this safely and efficiently, and what do I need for parts?

There are four places (two essential, two optional) where the car's original 12 volt wiring interfaces with the new electric drive system:

- The keyed ignition switch to turn it on (essential)
- The input to the auxiliary battery (essential)
- A motor overheat warning light (optional)
- A "key on" warning light (optional)

The parts you will need are:

- Two single-pole, single-throw relays
- A DC/DC converter
- An automotive style fuse block and fuses
- Wires and connectors

For clarity, keep in mind that "traction batteries" refers to the main battery pack that powers the car's motor. The "auxiliary" or "accessory" battery is a separate 12 volt battery to power the low voltage system in the car.

What To Leave Alone & What To Use

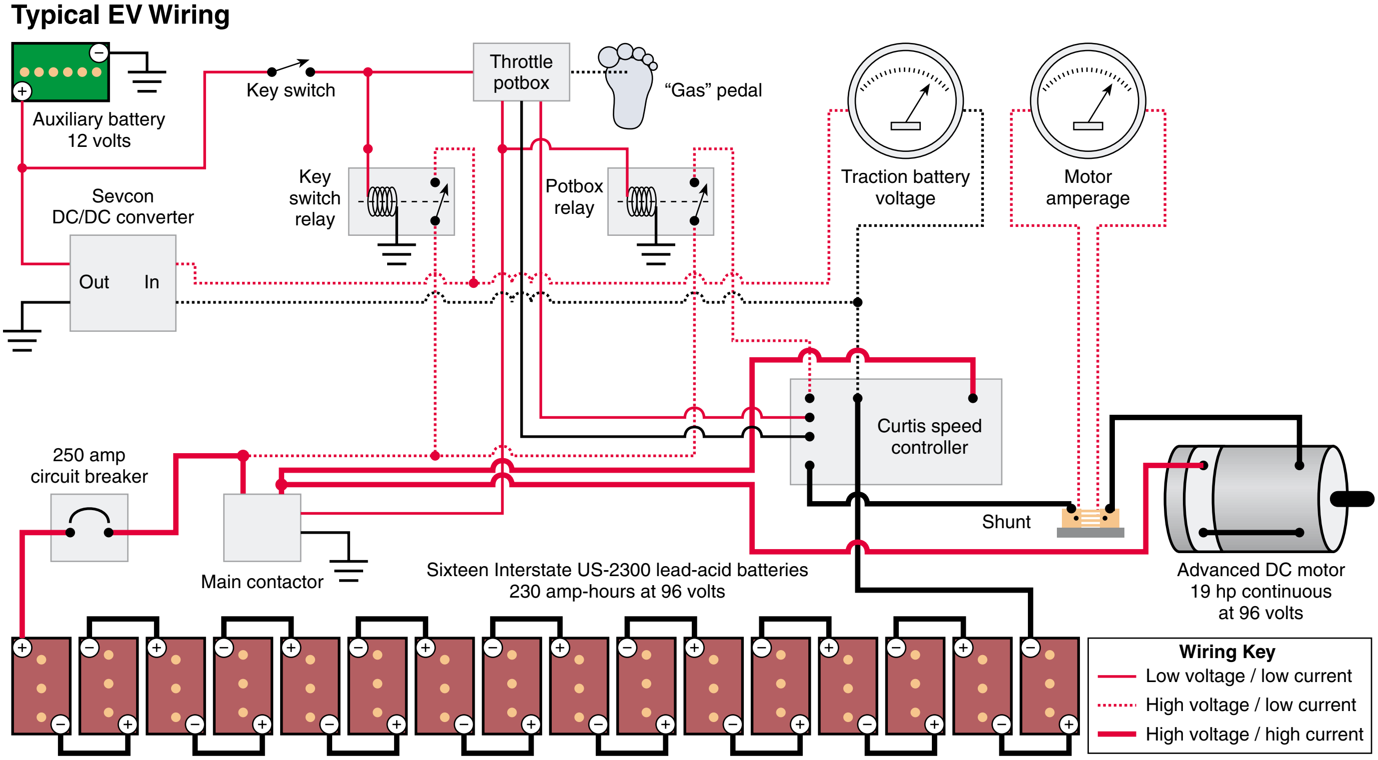
Making this interface is not as hard as it might seem. Most of the car's 12 volt electrical system is left in place. The headlights, running lights, stop lights, turn signals, horn, and windshield wipers—as well as the switches and wiring supporting them—are not altered. The same is true for accessories like the radio/tape player/CD player, heater blower fan, and even power windows.

The parts of the car's electrical system that are the most affected by the conversion process—the wires and components that operate the engine—are also the parts that are used in making the interface between the two systems.

One of the first steps in a conversion is the removal of the internal combustion engine, and its cooling, exhaust, and fuel systems. All the wires connected to any of the components that are being removed should be labeled with masking or duct tape. Write a word or two on the tape with a permanent felt marking pen to note what the wire was attached to.

The original battery/ignition switch/coil wires and the alternator and oil pressure warning light wires are the only ones I use in my conversions. There are other

Typical EV Wiring



systems and wires attached to the engine. But the amount of additional work and parts involved to turn them into something usable in an EV does not seem to be worth it. Some people have made electronic circuits to turn the fuel gauge into a voltmeter so it acts as an electric fuel gauge, but it's a lot of work, and isn't as accurate as a purpose-built EV voltmeter.

Warning Lights
Let's start with the two simplest interfaces. The wire from the oil pressure switch to the oil warning light in the dashboard can be used in the conversion as a motor overheat warning light. This is only true if the car has a plain oil pressure warning light. If so, the light is activated by a simple pressure switch which closes a circuit to ground if the oil pressure falls below a preset number.

If the car has a gauge with a needle instead of a warning light, its switch is a sensor that gives a scaled signal which moves the needle on the gauge. This setup would not be usable for our purposes.

On my conversions, I wire the oil pressure warning light to a normally open temperature-sensitive switch that closes at 120°C (248°F) and then goes to chassis ground. The switch comes factory-installed on the commonly used Advanced D.C. EV motors. If the motor gets too hot, the switch closes and you get a warning light telling you to reduce your amp draw before you damage your motor.

The car's original alternator warning light is wired to a terminal in the alternator that provides a ground only as long as the engine isn't running. When the engine starts, the alternator begins producing electricity, and the terminal's polarity changes from negative to positive, turning off the light.

On my conversions, I use this as a "key on" indicator, since an EV makes no sound sitting still. I wire the alternator warning light wire directly to a convenient chassis ground. When the ignition switch is turned on with the key, the alternator light comes on and stays on, indicating that there is 12 volt power to the control system.

Making It Go
The original ignition wires from the 12 volt battery to the ignition switch, and from there to the ignition coil, serve a similar function on an EV. They supply power to turn on the controller through the main contactor. However, there are a couple of additional skips and jumps along the way, which involve adding two small relays to the system.

Note: the following paragraphs describe the wiring circuits and parts used to install a Curtis/PMC controller in an EV. Other manufacturers' controllers may require different methods and parts. Contact the manufacturer or the supplier of your controller for the installation instructions for their product.

The most important thing to keep in mind when making the connections between the car's existing 12 volt electrical system and the high voltage traction system is isolation. This means keeping the two systems from coming in direct contact with each other. Isolation is necessary for the operation of the controller and traction battery charger, and is a critical safety factor in eliminating shock hazards and short circuits which could cause dangerous electrical fires.

Since all the components of the 12 volt electrical system rely on the metal chassis of the car for their ground path, no connection should be made between the traction battery pack and the chassis, either on purpose or by accident. (This is one reason you can't tap two of the 6 V batteries in your traction pack to supply power to the accessories.) Proper system design, careful routing of wires and cables, and selection of properly rated components will make contact between the two systems unlikely.

All of the components in the ignition system have one thing in common: they use two sources of electricity. "Control voltage" (usually but not always low voltage) causes the component to turn on, or close its contacts. This allows the component to do its job of channeling electricity from the second source—the actual "traction voltage" that moves the car. In effect, control voltage controls a gate through which the traction voltage flows.

The ignition system starts at the keyed ignition switch. The original wire from there to the ignition coil now goes to the potbox microswitch. From there, one branch controls the main contactor. A second branch controls the potbox relay, which controls the logic board of the controller. A third portion of the system goes from the keyed ignition switch to the key switch relay, which funnels high voltage from the main contactor to the voltmeter and DC/DC converter. We'll look at each portion of this in detail.

Keyed Ignition to Contactor
The potbox microswitch is, as the name indicates, a microswitch that is mounted on the potbox. The microswitch is open as long as the potbox arm is in the "off" position. When the car's accelerator pedal is depressed, the linkage or cable attached to both the pedal and the potbox arm pulls the arm off the microswitch contact. The microswitch closes, completing the circuit to the main contactor.

The main contactor is a large electromagnetic switch that closes when 12 volts positive control voltage from the microswitch is applied to its positive pull-down coil terminal. When the heavy duty contacts close, high voltage traction electricity flows from the battery pack to the controller.

The opening and closing of the main contactor each time the accelerator pedal is released or depressed acts as "deadman" switch. In the event of a problem with the controller or the motor, releasing the accelerator pedal shuts off the high current traction electricity to the controller.

Potbox Microswitch to Controller
However, the controller is not fully turned on until its logic board receives positive control voltage from the battery pack (not the auxiliary battery). This is applied to the top-most of three small terminals at one side of the end of the controller. This is the key switch input terminal, and its only function is to turn on the logic board.

The logic board, in turn, tells the controller how much traction voltage and amperage to give the motor. This depends on the control signal the controller receives from the potbox via wires to the two remaining small terminals on the controller.

In order for the key switch input circuit to act as another "deadman" switch in case the main contactor fails in a closed position, it must be switched on and off independently of the main contactor. This is done by using a potbox relay.

This relay gets its positive 12 volt control voltage to its pull-down coil from the same potbox microswitch terminal that controls the main contactor. So it closes and opens at the same time as main contactor. The relay gets its high voltage positive electricity from the "positive" (battery pack input) terminal of the main contactor. When the relay closes, this high voltage electricity goes to the key switch input terminal of the controller and turns on the logic board. This is the only example of a high voltage control input.

The high-voltage contacts of both the main contactor and the potbox relay are isolated from their low-voltage pull-down coils, which are grounded to the chassis. A 12 volt control connection from the potbox microswitch closes the potbox relay whenever the main contactor closes. This allows high voltage to flow, on an isolated path, from the main contactor, through the potbox relay, to the key switch input terminal on the controller, thus turning on the "brain" of the controller.

Main Contactor to High Voltage Accessories
Letting the accelerator pedal control the closing and opening of the main contactor and potbox relay is desirable as a safety feature. But there are some parts of the EV's system where this intermittent off-and-on could be irritating or harmful to components. These components need to stay on continuously while the car is on, and be turned off when the EV is not in use.

A state-of-charge meter or a voltmeter used to measure battery pack voltage should go on or off with the ignition key. The problem of using a grounded 12 volt system to control an isolated high voltage path is solved with the same type of relay used for the potbox relay.

This relay, called the key switch relay, gets its high voltage positive electricity from the "positive" side of the main contactor, just like the potbox relay. The 12 volt positive electricity goes directly from the ignition switch to the pull-down coil of the relay. The pull-down coil is grounded to the chassis.

When the relay's isolated contacts close, the battery pack voltage from the contactor goes to the voltmeter or state-of-charge gauge, and any other high voltage systems it is controlling, such as the DC/DC converter, which we'll talk about in a minute. One relay can control a number of systems as long as the total amperage draw of all the systems doesn't exceed the amperage rating of the relay.

Fuses Are Your Friends; Have Lots of Friends
As an additional safety precaution, I install another fuse block to protect the car's existing electrical system from shorts that might occur in the EV components added to the car. This fuse block gets its electricity from the ignition switch and puts a fuse between the ignition switch and the potbox relay, key switch relay, and any other 12 volt components that might be added during the conversion. Any high voltage accessories such as volt meters and DC/DC converters should have fuses of the proper rating between them and the battery pack.

Possible Complications & Other 12 Volt Sources
Throughout this article I have been referring to the wire from the ignition switch as the source of 12 volt positive electricity. Some car manufacturers put a resistor or a wire with a built-in resistance between the ignition switch and the ignition coil. Remove the resistor from the car if it is a separate part. If your car's shop manual shows a resistor wire, remove it from the circuit or wire around it.

If it's a diesel car you are converting, your source of key-switched 12 volt positive electricity is probably going to be an electric fuel cut-off valve on the injector pump. Again, refer to your car's shop manual to be sure.

Where Is This 12 V From, & How Does It Get There?
In a gas or diesel car, the 12 volt electricity comes from its battery. In these cars, it is called the SLI (starter,

lights, and ignition) battery. If one of these cars is converted to electric power, the SLI battery becomes the auxiliary, or accessory, battery.

Depending on the space available in the car being converted, the SLI battery may stay in place, and only its name is changed. However since space is at a premium in most conversions, the auxiliary battery chosen is usually smaller than the original SLI battery. An EV can get away with a smaller battery because the biggest draw on it—starting the engine—has been eliminated.

The biggest factor in deciding what size to make the auxiliary battery is how it is going to be charged. In the old days, the auxiliary battery was charged with a separate charger at the same time as the traction battery pack, and then discharged as the EV was driven. This is called a total loss system, and it worked (sort of) because the inefficiencies of the motors and control systems drained the traction battery pack before the auxiliary battery was fully discharged, most of the time. One disadvantage of this system was the large, heavy, deep discharge marine battery that was required to do this job.

DC to DC Converter

In the modern conversion world, we have a device called the DC/DC converter to keep the auxiliary battery charged. This is an electronic device that takes the traction battery pack high voltage and converts it to about 14.5 volts at 25 amps. The DC/DC converter carries the car's average 12 volt load and keeps the auxiliary battery charged at the same time.

In times of heavy load, such as driving with the lights and wipers on, both the DC/DC converter and the auxiliary battery carry the load. The fact that there are times when the auxiliary battery has to carry a substantial part of the 12 volt load limits how small you can make the auxiliary battery. This also cancels out any idea of eliminating the auxiliary battery altogether and relying solely on the DC/DC converter.

The circuitry of the DC/DC converter isolates the high voltage battery pack from the 12 volt auxiliary battery. The output side of the converter is fused for protection. The DC/DC converter is one of the high-voltage accessories that is turned on by the key switch relay.

There are four connections to the DC/DC converter. The high voltage (from the battery pack) comes in via the key switch relay to the high voltage positive input terminal. The high voltage negative output terminal connects to the negative side of the battery pack circuit at some point. I pick this up at the battery pack negative terminal of the controller. The low voltage positive output goes to the positive terminal of the auxiliary battery. The low voltage negative connects to chassis ground.

This is an overview of how the high voltage traction system is interfaced with the car's existing 12 volt system. If you have any questions, comments, or disagreements, feel free to contact me. Thank you for your time and interest.

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Mike Brown, Electro Automotive, PO Box 1113-HP, Felton, CA 95018-1113 • 831-429-1989
Fax: 831-429-1907 • mike.brown@homepower.com
www.electroauto.com

Wŏrd Pow´ ẽr

Renewable Energy Terms

P-N Junction—Boundary area in a semiconductor

Ian Woofenden

Derivation: "P" and "N" stand for "positive" and "negative"; "junction" (from Latin iungere, *to join) describes the interface between two different layers in a semiconductor device.*

Photovoltaic (PV) cells convert sunlight into electricity. It seems like magic when you put a cell, panel, or array into the sunshine and watch the meter showing voltage and amperage, or watch a motor or light swing into action. But this magic is not hard for physicists to explain and describe. Making it understandable to mere mortals (that includes me) is another thing, but I'll give it a try....

The heart of a PV panel is what's called the P-N junction. The name sounds mysterious, but it just stands for "positive-negative junction." The cell has two layers of silicon. Each layer is prepared differently, with impurities, or "dopants" added to give it specific characteristics.

The "P" or positive layer has tiny (and very exact) amounts of boron, indium, gallium, or other substances added to the silicon. These substances give the layer a positive charge. Physicists would say that the layer is short on electrons. The bonds between the silicon and the dopant material would be strongest if there were one more electron in the outer shell of the dopant.

The "N" or negative layer has tiny (and very exact) amounts of phosphorus, arsenic, or other materials added. This gives the layer a negative charge—the layer is long on electrons. The bonds between the silicon and the dopant here have an extra electron each. So there are free electrons roaming around this layer.

These two layers are actually built into the same piece of silicon in a PV cell. The two oppositely charged layers instantly try to balance out their charges. The result is that a permanent electrical field is set up across the junction (the area where the two layers meet). This field encourages electrons to move across the junction, but discourages them from crossing back. In electronics, this is called a diode, and when it conducts electricity if illuminated by light, it's called a photodiode.

Why don't all the (negative) electrons and (positive) holes, or lack of electrons, in the two layers balance each other out? Only a certain number of electrons make it across. Eventually they're stopped by the electric field that the exodus of other electrons has created.

When light particles (photons) hit the cell, they bump electrons loose from their bonds. Some of these "slide down" the P-N junction, which is often described as a "slope" or "gradient." In a PV cell, wires are attached to a grid on the surface of the cell (the "N" side) and to the back of the cell (the "P" side). These form a circuit that takes advantage of the junction's tendency to shunt electrons one way and not the other.

The light does all the work by jostling electrons out of their bonds so they're free to roam around. The P-N junction in the solar cell simply "herds" the electrons in the right direction so they can do useful work.

Still confused? Well, join the club. Check out Chris Greacen's more detailed explanation in *HP23,* or go to www.nrel.gov/research/pv/docs/pvpaper.html for an even more lengthy explanation. Or just continue to believe in the magic...

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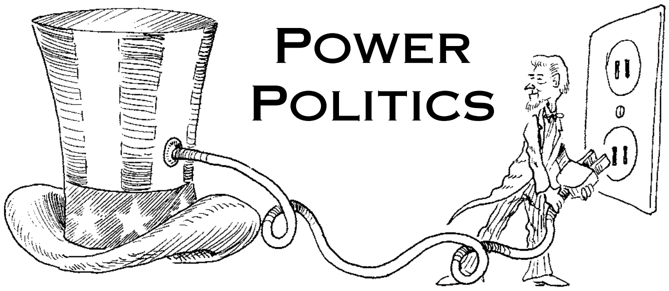
Author: Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • Fax: 360-293-7034
ian.woofenden@homepower.com



Million Solar Roofs

Michael Welch

It's been two and a half years since President Clinton announced his incentive program to install a million solar energy systems on U.S. roofs by 2010. Many wonder what has happened to this program which was announced with such fanfare.

I reported on the Million Solar Roofs initiative (MSR) back in December 1997, in *HP62.* I pointed out that the program itself did not really add any funding to solarizing the nation. It was intended as an "enabler," designed to use available resources to maximize impact on communities. At a speaking engagement two years ago, Richard Perez said that MSR was "actually a wind program, because all we've seen from it is hot air." That got some great laughs from the hands-on and grassroots folks in attendance, but boy were the government types surprised and miffed.

However, I am pleasantly surprised to find that Million Solar Roofs is making some progress. You won't hear me calling it "Million Solar Goofs" again. In a nutshell, the program is doing the best it can, considering the political climate it operates in. Its original expectations are likely to be exceeded.

More RE
The bottom line is that we want more RE out there. I think the Clinton administration's intentions have been honest in supporting that goal. Face it, in the comparatively right wing legislature we've had for the last few years, it would be hard to just go in swinging with an increased budget for renewable energy. Ever since his failed health reform efforts, Clinton's modus operandi has been to not rock the boat too much, but to chip away at the walls between himself and his goals. Eventually he sees light through the cracks, and attains part of his goals.

The MSR program offered a new tool to wield in Congress to get more funds freed up for solar. Similarly, the "Kyoto Protocol to the United Nations' Framework Convention on Climate Change" (there's a mouthful) is a tool to be used to promote renewables and more carbon-based emissions regulation.

Before MSR, much of the nation's energy budget was focused on efficiency and conservation. The funds that were out there for PV and solar heating technologies were mostly concentrated on utility-scale projects. One of the goals of MSR played right into the hands of the small-scale RE industry—trying to refocus some of the existing funds and programs into rooftop PV and domestic hot water (DHW) systems.

Solarizing Government Buildings
The power of presidential decree is great among bureaucrats, and the biggest effect of the initiative has been on government-owned facilities. In June of 1999, Clinton released an executive order designed to urge federal agencies to decrease greenhouse gas emissions and support renewables. Section 204 titled "Renewable Energy" says, "In support of the Million Solar Roofs initiative, the federal government shall strive to install 2,000 solar energy systems at federal facilities by the end of the year 2000, and 20,000 solar energy systems at federal facilities by 2010."

I regularly hear about PV systems being slated for government facilities, and I think the Clinton executive order was just what was needed to get building managers going. With the impetus of a presidential executive order behind them, more and more facility managers will work PV and DHW systems into their budgets. Last fall's quarterly MSR report from the DOE indicates that we are well on the way to achieving the goals for federal facilities. It stated that MSR has resulted in over 1,400 such systems, including 58 PV and 1,348 DHW.

State & Community Partnerships
A key component of MSR is the establishment of partnerships throughout the nation. Partners act as the conduit through which MSR can send information, support, and DOE funding to local projects. Partners can include builders, energy service providers, utilities, non-governmental organizations, and local and state governments.

At the time of the fall quarter 1999 MSR report, there were 41 partnerships established. Mostly they are state and municipal governments, with a handful of utility and business groups involved. These 41 partnerships have made preliminary pledges to install 900,000 of the million solar roofs promised. More active partners are needed to reach the goal, but the program seems to be on good footing.

In fiscal year 1999, $1 million of the US$1.5 million made available to MSR went to the partners and support for them. Another $350,000 is to be awarded for national barrier-removal activities related to solar energy use. These include financing, interconnection, codes and covenants, and consumer awareness. NREL and Sandia were awarded the other $150,000 for technical support for the program and partnerships.

Become an MSR Partner & Get $$$

The DOE is expected to regularly make money available to MSR partners and to organizations that support the partnerships. For example, the most recent grant period closed February 1, and US$500,000 was given to 10–25 recipients at $10,000 to $50,000 each.

A good example of an MSR partnership is the Renewable Energy Development Institute (REDI). This organization is the offshoot of the Solar Energy Expo & Rally (SEER) fairs. These fairs were once the best of the renewable energy fairs that got started as a result of *Home Power's* 1989 call for people's energy fairs.

The SEER organizers were pretty much burned out by putting on these excellent fairs, and were looking for another way to promote RE. After foundering for several years, REDI saw an opportunity to help MSR by developing materials and workshops centered on the financing of RE systems. Keith Rutledge, one of REDI's principals, has been interested in RE financing for a long time. Keith is a loan officer at a bank in Willits, California, and has worked on many loans for RE homes.

REDI is contracted to produce a finance handbook that will include materials on existing programs; case studies of various financing approaches for consumers, the financial community, builders and developers, government officials, and technical specialists; and a "how-to-finance" booklet specifically for residential consumers. REDI will also develop workshops and materials tailored to specific regional needs, to help MSR partners reproduce workshops in their own areas.

Politicians Make Promises, Right?

In January of 1998, at the opening of the BP Solar production facility in Fairfield, California, Vice President Al Gore proposed a US$2,000 solar tax credit to help American homeowners and businesses adopt clean energy technologies. The vice president proposed a tax credit equal to 15 percent of the cost of a rooftop solar system—up to $1,000 for water heating systems, and up to $2,000 for photovoltaic panels.

So far, nothing has happened with it. But according to Scott Sklar, Executive Director of the Solar Energy Industries Association, there is hope. "To Gore's credit, he overruled the Treasury Department's objections, and got part of the administration's tax package included in the proposed budget. But the Congressional Republicans only dealt with expiring tax credits last session, leaving new credits for the next session. Senator Wayne Allard (R-Colorado) and Representative Matt Salmon (R-Arizona) introduced the residential solar tax credit bills which are still alive. So this session is our play—and we could win it."

Mixed Bag

But in spite of some partnership contracts and Gore's tax break efforts, Sklar's assessment of MSR is that it's a "mixed bag." White House and DOE interest seem to have decreased significantly from the active early days. According to Sklar, "In January 2000, the White House announced a new International Energy Initiative that cut the PV budget request from last year by $10 million (15 percent), and the budget for solar buildings by $1 million (or 20 percent). The White House and the Secretary of Energy no longer even talk about MSR."

Scott's "mixed bag" opinion is one that I respect, but I guess the optimist in me likes to look for at least *some* recent progress. I feel that the MSR initiative has definitely helped the home-scale RE movement, and at a very reasonable price tag. The initiative was mostly supportive, but I would still like to see a larger amount of funding to go along with it.

Energy Email List

I have started an email list focusing mostly on energy-related environmental issues. The mailings to the list will be closely screened (no spam), and they will be occasional so as to not deluge subscribers. For more info, contact me. Or to subscribe, just send a blank email message to Get-Active-subscribe@topica.com.

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Author: Michael Welch, c/o Redwood Alliance,
PO Box 293, Arcata, CA 95518 • 707-822-7884
michael.welch@homepower.com
www.igc.org/redwood

Million Solar Roofs, Peter Dreyfuss, Deputy Chief of Staff, Office of Energy Efficiency & Renewable Energy Network, DOE • 202-586-9220
www.eren.doe.gov/millionroofs

Renewable Energy Development Institute, Keith Rutledge, 383 S Main St., #234, Willits, CA 95490
707-459-1256 • Fax: 707-459-0366 • redi@saber.net
www.redinet.org

Solar Energy Industries Association, Scott Sklar, Executive Director, 1616 H St. NW, 8th floor, Washington, DC 20006 • 202-628-7979
Fax: 202-628-7779 • solarsklar@aol.com
www.seia.org

Don Loweburg

Distributed Generation— A Work in Progress

Distributed Generation (DG) continues to be a topic in *Home Power* because DG provides the context for the future wide-scale implementation of PV and other renewables.

The generally accepted definition of DG is "energy sources located at or near the point of load." Because this definition is somewhat vague, it allows considerable innovation. In *IPP 65 (Beyond Net Metering),* I described one model with numerous grid-connected rooftop PV systems. These could be aggregated by a third party, who could sell peak-time PV power at a premium. Such a system would use the Internet and software to manage the transactions, thereby minimizing transaction costs. Synergy between DG and other technologies (such as the Internet) will be the key to realizing the maximum value of DG.

NREL Funds DG Research

The National Renewable Energy Laboratory (NREL) recently solicited research projects regarding a wide range of DG subjects. The solicitation (now expired) reveals NREL's wide scope and vision of what DG could be. In many ways, the language of the proposal is very exciting, because it extends the limits of what DG might be. NREL is clearly looking beyond the status quo of today's energy scene. I would like to share some excerpts from the *Background and Scope* section of NREL's solicitation.

Titled *NREL/DOE Distributed Power Program—Distributed Power System Integration Research and Development,* the solicitation begins: "Interest in the use of distributed generation and storage has increased substantially over the past five years because of the potential to provide increased reliability and lower cost of power delivery to the customer, particularly with customer-sited generation. The advent of competition in the electric power industry and customer choice have, in part, been the stimulus for this increased interest."

"Also contributing to this trend has been the development of small, modular generation technologies, such as photovoltaics, micro-turbines, and fuel cells. Industry estimates that distributed resources will account for up to 30 percent of new generation by 2010. The environmental benefits of distributed power exploiting, for example, renewable resources, combined heat and power, and hybrid systems are substantial."

Foundation of Competition

"The DOE Office of Power Technologies' goal and vision for the 21st century is full-value distributed power captured in an electricity market in which customers can sell power, employ load management, and provide operations support services (ancillary services) as easily as the utility, in an automated and adaptive electric power system. As the cornerstone of competition in electric power markets, distributed power will also serve as a key ingredient in the reliability, power quality, security, and environmental friendliness of the electric power system. In supporting customer choice, distributed power may be the long-term foundation of competition in the electric power industry."

Regulated Monopoly Can Be a Barrier

"Electricity regulation, zoning and permitting processes, and business practices developed under the framework of an industry based on central station generation and ownership of generation facilities by a regulated monopoly can be barriers to orderly development of market opportunities for distributed power in a restructured electric power industry. These barriers need to be identified through active and mutual participation of all parties (industry, government, etc.) in developing solutions and providing leadership and educational approaches to reducing these infrastructural barriers to full deployment of distributed power resources."

Full Value Markets for Local (DG) Benefits
"From an overall market perspective, the most promising vision of a distributed power future is one that allows the full economic value of grid-connected distributed power by stimulating full value markets through local benefits like lower electric cost, enhanced reliability and power quality, facility demand side management, and/or combined heat and power."

Fuel-Electric Hybrids
"The interaction of the gas and electric delivery systems from the perspective of each as component of an integrated energy system are sought. Other topics are to examine the use of gas-fired, customer-sited generation as an integrated electric/natural gas distribution system to determine what synergies can be exploited to decrease emissions and operation costs, as well as avoid adverse operational effects."

DG Revolution
These remarks from the NREL solicitation echo points made here over the last four years. In summary, the DG revolution is driven by deregulation and customer choice, technological innovation (fuel cells and PV for example), and a growing environmental imperative to reduce carbon dioxide emissions. If monopoly power and market abuses are limited, DG can provide a foundation for long term, real competition in electric power generation. The key here is that the customer must be able to capture the *full value* of DG. Institutional and market barriers must be addressed before real competition can occur.

If institutional barriers are not eliminated, we get nothing more than the sham competition that exists in California and other "restructured" states. I say sham, because so far the competition mandated under state restructuring in California has resulted in only 65,000 customers switching during the last three years. This amounts to less than 1 percent of California's utility customers. This does not look like competition to me.

DG Can Be Offgrid
In addition to the solicitation, NREL sent a list of questions and answers that were intended to elaborate on the scope of NREL's vision. The drift of the questions was to refine and clarify NREL's definition of DG. The questions and responses clearly indicate that DG need not be grid connected. Some scenarios presented by the questioner included "distributed fuel" (LP or natural gas).

Question: "Does [the solicitation] include strategic rethinking of the goal and vision of what's referred to as a distributed power or distributed generation, to include distributed energy/fuel? Does this extend to proposals that would eliminate the need for interfacing to the grid by providing stand-alone generation fed by distributed energy networks (for example natural gas lines)?" *Answer:* "Yes."

Question "Is it easier to design a local ultra-reliable freestanding power plant using fuel cell technology (either alone or in conjunction with renewable technologies) than it is to control the myriad of random interactions that would be set in motion by distributing generation on an electric utility's distribution system?" *Answer:* "No." NREL clearly regards DG in the broadest terms, extending DG to offgrid sites.

Ongrid-Offgrid?
Some time ago I referred to offgrid PV applications as simply high value DG. At that time, I was mulling the ongrid–offgrid distinction. I noted then, as I do now, that some people in and out of the PV industry think that ongrid vs offgrid is an important, meaningful distinction.

Some folks think of the offgrid market as a limited niche market and that the "real" market for PV is the grid-tied market. I don't think that this is true. This error has resulted in significant misdirection, especially in the marketing efforts of PV module manufacturers. Marketing efforts based on the presumption that the utility-grid market would be the principle driver for PV sales may be missing the point.

What if the market for PV (and other renewables) is understood to be distributed generation? If DG were to provide the framework of a PV marketing model, then it would seem logical that the highest value DG applications would be the first to be adopted. Since offgrid applications represent extremely high value DG, it is logical that offgrid applications would be served first. This is in fact exactly what happens in the real world.

It is the value of DG that determines where it is installed, not whether it is offgrid or ongrid. Value delivered to the customer is the most important thing. Here lies the challenge for marketing DG. The benefits of DG must go to the customer. If utilities are allowed to capture (or interfere with) the value of DG, the rate of growth of DG and renewables will be retarded.

Good News
In the last two articles *(IPP74 & 75),* I described how Jack, a potential net-metering customer of PG&E in California, had been caught in a standoff between his utility and Trace Engineering. Though it took over six months, I'm pleased to report that Jack now has a net metering contract with his utility. Several things made this happen.

First and foremost, PG&E lifted their ban on Trace interconnections for a period of two months. In the interim, they are accepting the Trace “Certificate of Compliance” that has shipped with Trace inverters for the last three years. The two month window also allows Trace to retool their software so it complies with IEEE 929 (a national interconnection standard for small inverters), and to correct an internal voltage calibration problem.

In addition, the IEEE 929 working group was able to “fine tune” the standard, extending the upper voltage limit to 132 VAC so that connected inverters could avoid nuisance trips caused by utility transients and high line voltage.

Thanks to the people who worked hard to make these changes: John Stevens (Chair IEEE 929 group) and all members of the IEEE 929 working group, Bill Brooks (Endecon), Vince Schwent (California Energy Commission), and Les Nelson and Kathyrn Lynch (Cal SEIA). (Read the comments from IEEE 929 Chairperson John Stevens in the *Letters* section of this issue.)

Just In

On January 30, 2000, IEEE 929 was adopted by the IEEE. The final approval notification arrived just before this article went to the publisher. IEEE 929-2000 (as it’s officially designated) establishes interconnection practices for small inverter systems under 10,000 watts. The intention was to create a national consensus based on the needs of utilities for safety, and the needs of consumers and installers to have a simplified and consistent utility interconnection process.

Spreading the Word

Thanks to an anonymous donor, ten *Home Power* subscriptions have been sent to libraries in central California in the name of IPP. This significant gift supports *Home Power,* and more significantly, supports untold numbers of readers who now can read the magazine at their local libraries. Again, thanks.

Access

Author: Don Loweburg, IPP, PO Box 231, North Fork, CA 93643 • 559-877-7080 • Fax: 559-877-2980
don.loweburg@homepower.com
www.homepower.com/ipp

National Renewable Energy Laboratory, Dick DeBlasio, Distributed Power Program Manager, 617 Cole Blvd., Golden, CO 80401-3393 • 303-384-6452
Fax: 303-384-6490 • deblasid@tcplink.nrel.gov
www.nrel.gov

Institute of Electrical and Electronics Engineers (IEEE), PO Box 1331, Piscataway, NJ 08855-1331
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AWG, RHW, CNN, USE-2, THHN, THW, XLPE, #@%*&!

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

Don't understand the designations, types, and sizes of conductors used in PV systems? Read on. In the next several issues of *Code Corner,* we will deal with the wires, cables, and conductors used in a PV system. Wind power installers should also take note: the conductor requirements for wind systems are very much like those for PV systems and any other electrical systems.

Conductors, Wires, Cables—What's the Difference?
Many people use the terms "conductor," "wire," and "cable" interchangeably. I do too. The *NEC* uses the terms in specific ways, but it also uses the terms interchangeably. Here are some definitions found in Article 100 of the *National Electrical Code® (NEC®).*

Conductor

Bare A conductor having no covering or electrical insulation whatsoever.

Covered A conductor encased within material of composition and thickness that is not recognized by this Code as electrical insulation.

Insulated A conductor encased within material of composition and thickness that is recognized by this Code as electrical insulation.

Premises Wiring (System) That interior and exterior wiring including power, lighting, control, and signal circuit wiring together with all of their associated hardware, fittings, and other devices, both permanently and temporarily installed, that extends from the service point of utility conductors or source of power such as a battery, a solar photovoltaic system, or a generator, transformer, or converter windings to outlet(s). Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

Service Conductors The conductors from the service point to the service disconnecting means.

Service Cable Service conductors made up in the form of a cable.

Section 800-2 (Communications Circuits) has the following definition:

Cable A factory assembly of two or more conductors having an overall covering.

Other sections of the Code mention single conductor cables—the Code does not always define a cable as two or more conductors grouped together. Multiple-conductor cables may or may not have an outer jacket depending on their use and the applicable code requirements. For example, the power cable on an electric drill may have three conductors and be required to have an outer jacket, such as conductor type SOW. On the other hand, a type USE underground service entrance cable may also have three conductors; two are insulated, one is bare, and there may not be a requirement for an outer jacket in some installations.

Section 300-3(a) of the *NEC* says that single conductors specified in this code must be installed as part of a code-recognized wiring system. The process of obtaining listing by Underwriters Laboratories or other testing laboratories poses similar constraints on the use of these cables.

Conductor Properties
The *Properties of Common Conductors* table lists some commonly used conductors and a few of their characteristics. These have been extracted from *NEC* Table 310-13.

The first column (Type) shows the conductor type designation. The second column (Temp. °C/°F) shows temperature rating of the insulation in degrees Celsius/degrees Fahrenheit. The third column (Moist.) shows the highest moisture condition allowed at this temperature. The fourth column (Conduit) indicates whether or not the conductor must be installed in some sort of conduit or raceway. The last column (Sunlight Res.) shows whether the conductor is inherently sunlight resistant (with no marking) or not, or whether it must be marked sunlight resistant if applicable. In some

Properties of Common Conductors

Type	*Temp. °C/°F*	*Moist.*	*Conduit Req.*	*Sunlight Res.*
THHN	90/194	Damp	Yes	No
THWN	75/167	Wet	Yes	No
THWN	90/194	Dry	Yes	No
THWN-2	90/194	Wet	Yes	No
THW	75/167	Wet	Yes	No
THW-2	90/194	Wet	Yes	No
RHW	75/167	Wet	Yes	No
RHW-2	90/194	Wet	Yes	No
RHH	90/194	Damp	Yes	No
USE	75/167	Wet	No	Yes
USE-2	90/194	Wet	No	Yes
UF	60/140	Wet	No	Marked
SE	75/167	Wet	No	Yes

cases, the conductor has insulation rated at more than one temperature. A second entry for the same cable type shows the secondary temperature/moisture data (see THWN).

By this time, your eyes are crossed, you have a headache, and I'll bet at least some of you are wondering about the alphabet soup. The *Wire & Cable Types* table has the insider's info on what all those letters stand for in the *Properties of Common Conductors* "Type" column.

Many conductors will be marked as two or more types, indicating that they meet the listing requirements for each type. An example is a conductor marked "THHN or THWN-2". This dual or triple marking indicates that the conductor has the properties of both types and can be used in the worst-case environment specified for either (for example, 90°C (194°F) and wet). Another example is a conductor marked "USE-2 or RHW-2". Because they have no flame retardant, conductor types marked with just "USE-2" cannot be used in conduit inside buildings. However, conductor type RHW-2 does have the flame retardant, so the dual-marked cable can be used outside in sunlight, underground, and in conduit inside buildings.

Section 690-31 of the *NEC* allows single conductors in types UF, USE, USE-2 (will be in the 2002 *NEC),* and SE to be used for connecting PV modules where the conductors are exposed in free air and subject to those outdoor sunlit and wet conditions. PV module junction boxes may operate as hot as 75°C (167°F). From the above chart, types SE, USE, and UF should be ruled out for most installations, and only used in very cold climates. A dual-marked conductor such as "USE-2 or RHW-2" is one of the best conductors to use for connecting PV modules since it can also be run through conduit to interior locations.

Multiconductor Cables

There are several multiconductor, sheathed cables that do not have to be installed in conduit for protection if they are afforded physical protection by the location of the installation. The first cable is the very common nonmetallic sheathed cable, type NM, commonly sold as standard Romex®. It has two or three insulated conductors and a bare equipment-grounding conductor enclosed in an outer jacket or sheath. This cable is approved for use in residential, dry locations (as in the walls of a house), and has a final temperature rating of 60°C (140°F). It is not sunlight resistant and cannot be used in damp or wet locations.

A second multiconductor sheathed cable is type UF that also must be installed with physical protection in mind. It is frequently marked "sunlight resistant" and usually has a temperature rating of 60°C (140°F). This cable can be installed outdoors as long as it is out of the sunlight and solar heating areas. It might be used for wiring from a PV combiner box mounted in the shade on the roof to a PV power center located in the house.

Summary

So, where do we use which? Conductors in conduits or raceways can be used for nearly any wiring in a PV system. Local codes may require that conduit be used in commercial installations. As mentioned above, modules may be connected to each other and to nearby combiner boxes by using certain types of exposed single-conductors (USE-2). Wiring inside buildings may be made with the sheathed cables (NM and UF).

Battery and inverter conductors tend to be rather large in size and relatively stiff. Conductor types RHW and THW are available in fine-stranded varieties that are considerably more flexible than the normal conductors available at the local building or electrical supply store. Dealers and distributors in the PV industry stock or can get these flexible conductors.

Wire & Cable Types

Type	*Description*
T	Thermoplastic insulation
H	75°C (Note: lack of "H" indicates 60°C)
HH	90°C
N	Nylon jacket
W	Moisture resistant
R	Rubber insulation
U	Underground use
USE	Underground Service Entrance *
UF	Underground Feeder *
SE	Service Entrance *
-2	90°C and wet

** May be either single conductor or multiple conductor cable*

In the next *Code Corner,* I will address the ampacity and sizing of the conductors used in renewable energy systems.

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems following the requirements of the *NEC,* feel free to call, fax, email, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV Industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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Author: John C. Wiles, Southwest Technology Development Institute, New Mexico State University, Box 30,001/ MSC 3 SOLAR, Las Cruces, NM 88003
505-646-6105 • Fax: 505-646-3841 • jwiles@nmsu.edu
www.nmsu.edu/~tdi

Sponsor: Sandia National Laboratories, Ward Bower, Department 6218, PO Box 5800 MS 0753, Albuquerque, NM 87185-0753 • 505-844-5206
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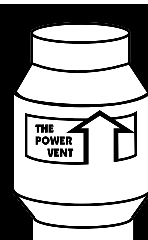

Home & Heart

Kathleen Jarschke-Schultze

I grew up in a Mediterranean climate in the Napa Valley north of San Francisco. We only had two seasons—spring and fall. When I moved north to be with Bob-O, I came to know the other two seasons. The upside of winter is watching snow fall. The downside of winter is the cold.

'Bergs

Unless the weather is hot, I am cold. Our friend, Clive Wilkinson, from the Falkland Islands says I'm a hothouse flower. I do not like to have to bundle up in my own house just to stay warm. I think I should be able to wear short sleeves inside in all seasons. This hasn't always been possible at our house.

For some unknown reason, the people who built our house did not think that the extra expense of insulation was a good investment. We've insulated the attic quite well using the pink rolls of insulation. We have changed out the windows from single pane to double pane. We've crawled under the house, where possible, and stapled and chicken-wired insulation between the floor joists. The winter still brings some pretty severe cold spells.

On cold nights, Bob-O says I am "all over him like a cheap suit." When I put my cold feet on him, just to warm them a bit, he says, "Get those 'bergs off me!" He is the warm one in our partnership. I have asked couples we know, and 90 percent of the time, the male is the warm one. I don't know what I'd do without those wintertime BTUs (Bob-O Thermal Units).

Wood Heat

Our house is heated by a woodstove that extends from a fireplace. Bill Battagin, our friend from Taylorsville, installed a safe stainless steel chimney liner for us that lines the chimney and reaches above it on the roof. When he did the job he told us, "If I do this, you will never be able to use this fireplace as a fireplace again." "No problem," we said, "Do it." We have never regretted that decision.

We usually burn a mix of Madrone, Fir, and Oak. These last two winters we have also had well-seasoned barn wood (see *H&H* in *HP64).* Our winter wood consumption is about three to four cords a year. Since I am the one who gets cold, I am stove monitor. One wheelbarrow of assorted split wood will last me two days if it's not too cold.

Ecofan

A couple of months ago, Bob Maynard of Energy Outfitters sent Bob-O a new product to test—the Ecofan. This small stove fan only weighs 20.2 ounces. At eight and one half inches tall and approximately the same width, it doesn't take up much space. It utilizes a thermoelectric module to power the two-bladed fan. We have the Model 800.

The Ecofan is made in Canada by Caframo. It has a one year warranty, and it's very easy to use. Just take it out of the box and set it on the woodstove. The manufacturer recommends that the Ecofan be placed at the back of the stovetop to be better able to draw cooler air. It is important that cooler air be drawn over the cooling fins. Improper placement will reduce the fan's effectiveness and could damage the thermoelectric module. This would also void the warranty.

The Ecofan on top of the woodstove.

Ecofan Temperature Data

	Time	Inside Temp. (°F)	Outside Temp. (°F)	Difference (°F)
No fan	1 PM	66.9	50.7	16.2
No fan	8 AM	60.8	39.6	21.2
No fan	8 AM	58.6	35.6	23.0
No fan	12 PM	62.6	40.6	22.0
Ecofan	8 AM	61.7	29.7	32.0
Ecofan	8 AM	56.8	22.6	34.2
Ecofan	7 PM	67.6	43.7	23.9
Ecofan	8 AM	55.4	26.4	29.0

It is designed for use on woodstoves with normal surface temperatures of 400 to 700°F (200–370°C). Temperatures above 700°F (370°C) will damage the Ecofan. You can buy a stove thermometer to monitor this. The fan blades, which have been designed to deliver a broad cross section of air movement, start turning when the stove surface reaches 135°F (57°C). I used a candy thermometer to determine that.

Since it runs using only the stove's heat, there is no power consumption. The hotter the stove is, the faster the blades turn. The fan is made primarily of anodized extruded aluminum, which doesn't rust or corrode. It is totally quiet.

There is a bi-metal strip in the base of the fan that arches as the stove gets hotter to lift the base off the stove to protect it from overheating. A small gap (the distance between the fan base and the stove) of about 2 mm is good. A gap of over 5 mm means your stove is too hot; you should remove the Ecofan if that happens. A small recessed wire bail pulls out of the top so you can move the Ecofan without getting burned. The fan's design and appearance is compact and efficient.

Does It Work?

I liked it from the beginning. A couple of days after we placed it on our stove, Bob-O asked me if I thought it worked. I replied, "Did you notice that I am in short sleeves and have no shoes or socks on?" I knew the house was warmer with the Ecofan because I was more comfortable. Every night I stoke the stove and shut the damper. In the morning, the fan is still turning. It turns slowly, but the house starts out warmer because of it.

I told Bob-O I was going to write about the Ecofan in my next *Home & Heart.* He said I should take it off the stove and do temperature measurements so I could have a comparison. I was reluctant to do this. I didn't want to be cold and use more wood. But before my column was due, I did remove the Ecofan and recorded some inside and outside temperatures.

Testing

I am not convinced that these temperature readings are going to give you a complete picture. There are too many variables. Is the wind blowing? What kind of wood is in the stove? When did I last stoke the fire? How many times has Bob-O left the front door open while he stands there and calls the dog? I found that with the Ecofan, there was a 23.9 to 34.2°F (13–19°C) difference between the inside and outside temperatures. Without the fan, there was only a 16 to 23°F (9–13°C) difference.

My test—and the only one I need—is the fact that I feel warmer when we use the Ecofan. I am more comfortable and do not wear overclothes in the house. Other people in the house told me they felt colder when I removed the fan for the temperature measurement. My conclusion is that now that I have one, I will never be without one. The cost is US$95 each—an investment in comfort.

Access

Kathleen Jarschke-Schultze is trying her hand at soapmaking at her home in Northernmost California, c/o *Home Power,* PO Box 520, Ashland, OR 97520
kathleen.jarschke-schultze@homepower.com

Clive and Rosemary Wilkinson, Dunnose Head Farm, Falkland Islands • powersense@horizon.co.fk
www.falklandwool.com

Ecofan: Caframo Ltd., R.R.2, Wiarton, ON, N0H 2T0 Canada • 800-567-3556 or 519-534-1080
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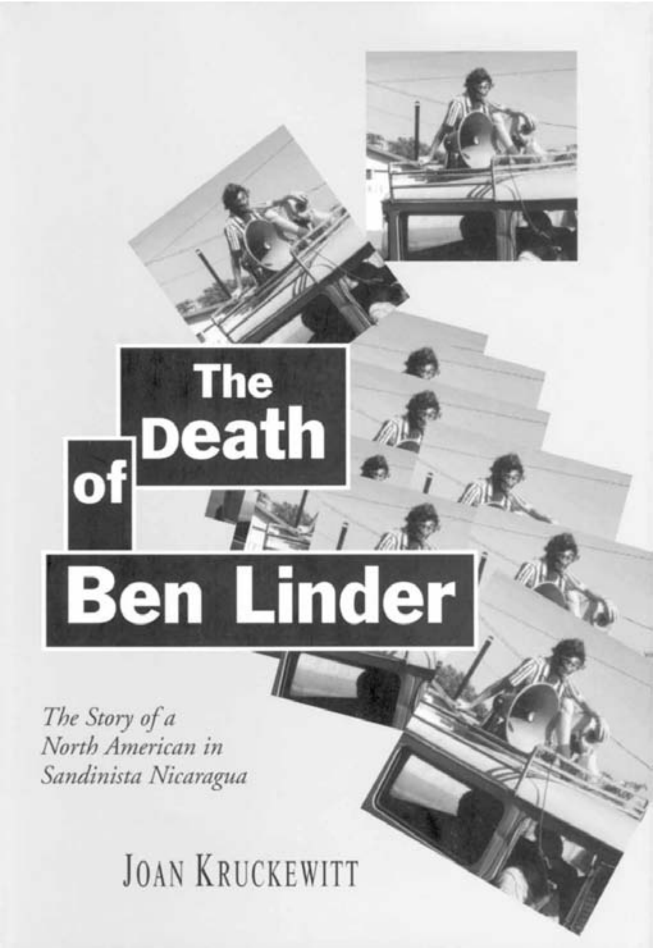

Reviewed by Chris Greacen and Arne Jacobson

Ben Linder was a young renewable energy engineer, a unicyclist, and a political activist working in rural Nicaragua to build microhydroelectric plants for the small villages of El Cuá and San José de Bocay. He was among those killed on April 28, 1987 when a crew making stream flow measurements for a planned microhydroelectric plant near San José de Bocay was ambushed by Contras, Ronald Reagan's "Freedom Fighters."

In *The Death of Ben Linder: The Story of a North American in Sandinista Nicaragua,* Joan Kruckewitt carefully pieces together the story of Ben's life during the nearly four years he lived and worked in Nicaragua. Joan's sources are interviews with friends and colleagues, as well as journals, letters, and CIA documents.

The book is first and foremost about Ben—a committed idealist who believed in justice, peace, and the potential for rural renewable energy projects to bring improved life to the rural poor. The book is also a powerful portrait of the suffering that U.S. policy wrought on the people of Nicaragua.

Home Power readers who have worked (or dreamed of working) on renewable projects in developing countries will also find in *The Death of Ben Linder* a fascinating account of several years working on a 100 KW village microhydropower project in the town of El Cuá. As the story unfolds, we learn what it took to get the project off the ground, to commission the plant in a war zone, to train local people to operate and maintain the plant, to electrify the surrounding communities, and ultimately what electricity meant to people in El Cuá.

Access

The Death of Ben Linder: The Story of a North American in Sandinista Nicaragua, ISBN: 1-888363-96-7, 320 pages, 16 pages of photos. US$24.95 (20% discount for Web site purchases) from Seven Stories Press, 140 Watts St., New York, NY 10013
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Reviewers: Chris Greacen and Arne Jacobson, 310 Barrows Hall ERG, UC Berkeley, CA 94720-3050
cgreacen@socrates.berkeley.edu
arne@socrates.berkeley.edu

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American Hydrogen Association nat'l headquarters: 1739 W. 7th Ave., Mesa, AZ 85202-1906 • 480-827-7915 Fax: 480-967-6601 • aha@getnet.com www.clean-air.org

American Wind Energy Association. Info about U.S. wind energy industry, membership, small turbine use, & more: www.awea.org

State financial & regulatory incentives for RE (reports). North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695 919-515-3480 • Fax: 919-515-5778 www.ncsc.ncsu.edu/dsire.htm

Energy Efficiency & Renewable Energy Clearinghouse (EREC): Insulation Basics (FS142), New Earth-Sheltered Houses (FS120), PV: Basic Design Principles & Components (FS231), Cooling Your Home Naturally (FS186), Automatic & Programmable Thermostats (FS215), & Small Wind Energy Systems for the Homeowner (FS135). EREC, PO Box 3048, Merrifield, VA 22116 • 800-363-3732 TTY: 800-273-2957 • energyinfo@delphi.com www.eren.doe.gov

Energy Efficiency & Renewable Energy Network (EREN), links to gov't & private internet sites & offers "Ask an Energy Expert" online questions to specialists: www.eren.doe.gov • 800-363-3732

Green Power Web site: includes deregulation, "green" electricity choices, technology, marketing, standards, environmental claims, and national & state policies. Global Environmental Options (GEO), & CREST: www.green-power.com

National Wind Technology Center, Golden, CO. Assisting wind turbine designers & manufacturers with development & fine tuning: 303-384-6900 • Fax: 303-384-6901

Tesla Engine Builders Assoc.: info & networking. Send SASE to TEBA, 5464 N Port Washington Rd. #293, Milwaukee, WI 53217 • teba@execpc.com www.execpc.com/~teba

Sandia's Web site, "Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices," "Working Safely with PV," & balance-of-system technical briefs, info on battery & inverter testing: www.sandia.gov/pv

Solar Energy & Systems, Internet college course. Fundamentals of small RE. Weekly assignments reviewing texts, videos, WWW pages, & email Q&A. Mojave Community College. 800-678-3992 lizcaw@et.mohave.cc.az.us http://solarnmc.mohave.cc.az.us

Federal Trade Commission free pamphlets: Buying An Energy-Smart Appliance, EnergyGuide to Major Home Appliances, & EnergyGuide to Home Heating & Cooling. EnergyGuide, FTC, Rm 130, 6th St & Pennsylvania Ave NW, Washington, DC 20580 • 202-326-2222 TTY: 202-9326-2502 • www.ftc.gov

Solar curriculum for upper elementary & intermediate grades—Free! Six week science curriculum or individual sessions. Over 30 classroom presentations & demos using free or low cost materials. Florida Solar Energy Center, Susan Schleith • 321-638-1017 www.fsec.ucf.edu

May 5–6, 2000: Dankoff Solar Products Annual Dealer Training Seminar, Santa Fe, NM. Solar Water Pumping, Power Centers, Maximizing Battery Life, Psychology of Selling Solar, Plus: Industry Reps. Register by April 28 at 505-473-3800, or info@dankoffsolar.com

ALABAMA
The Self-Reliance Institute of NE Alabama seeks others interested in RE, earth-sheltered construction, & other self-reliant topics. SINA, 6585 Co Rd 22, Centre, AL 35960 • cevans9@tds.com

ARIZONA
April 18–20, '00: Hands-on Installations Seminar. Participants will spend three days outdoors, installing a solar array, tower, wind turbine, & water pumping system. May 16–18, '00: Basic Solar Seminar. Training includes overview on solar modules, controllers, batteries, inverters, & system sizing. Contact Kyocera Solar, Inc. Training Dept, 800-544-6466 ext. 7148
Fax: 480-443-4562
seminars@kyocerasolar.com
www.kyocerasolar.com

Tax credits for solar in AZ. A technician certified by the AZ Department of Commerce must be on the job site. ARI SEIA, 602-258-3422

CALIFORNIA
Campus Center for Appropriate Technology, Humboldt State University, Arcata. Ongoing workshops & presentations on alternative, renewable, & sustainable living. CCAT, HSU, Arcata, CA 95521 • 707-826-3551
ccat@axe.humboldt.edu
www.humboldt.edu/~ccat

Energy Efficiency Building Standards for CA. Download or hard copy. CA Energy Commission, 800-772-3300
www.energy.ca.gov/title24

COLORADO
Solar Energy International, hands-on workshops. 1 & 2 week sessions: PV Design & Installation, Advanced PV, Wind Power, Microhydro, Solar Cooking, Environmental Building Technologies, Solar Home Design, & Straw Bale Construction. Experienced instructors & industry reps. For owner-builders, industry technicians, business owners, career seekers, & international development workers. $500/week. SEI, PO Box 715, Carbondale, CO 81623
970-963-8855 • Fax: 970-963-8866
sei@solarenergy.org • www.solarenergy.org

FLORIDA
Apr 28–29 & July 14–15, 2000. Solar Electric Home for the South. Learn to design, size, & install a solar electric system. Learn what makes a home comfortable in hot, humid climates. $125 for 2 days. Energy Conservation Services, 6120 SW 13 St., Gainesville, Fl 32608 • 352-377-8866
Fax: 352-338-0056 • tom@ecs-solar.com

IOWA
Iowa Renewable Energy Association (IREA) meets 2nd Sat every month at 9 AM, Prariewoods, Cedar Rapids. All welcome. Call for schedule changes. I-Renew, PO Box 466, North Liberty, Iowa 52317
319-875-8772 • irenew@irenew.org
www.irenew.org

KENTUCKY
Appalachia-Science in the Public Interest. Projects & demos in gardening, solar, sustainable forestry, & more. ASPI, 50 Lair St., Mt Vernon, KY 40456 • 606-256-0077
aspi@kih.net • www.kih.net/aspi

MASSACHUSETTS
Greenfield Energy Park needs help preserving Greenfield's historic past, using today's energy & ideas, creating a sustainable future. Greenfield Energy Park, NESEA, 50 Miles St, Greenfield, MA 01301
413-774-6051 • Fax: 413-774-6053

MICHIGAN
Tillers International, classes in draft animal power, small farming, blacksmithing, & woodworking. Tillers Int'l, 5239 S 24th St., Kalamazoo, MI 49002 • 616-344-3233
Fax: 616-344-3238 • TillersOx@aol.com
www.wmich.edu/tillers

MONTANA
Sage Mountain Center; seminars & workshops, one day, inexpensive sustainable home building, straw bale const., log furniture, cordwood const., solar electricity, more. SMC, 79 Sage Mountain Trail, Whitehall, MT • Phone/Fax: 406-494 9875

July 23–28, '00, GlobeEx 2000, Riviera Hotel Conference Center in Las Vegas. Includes the Intersociety Energy Conversion Engineering Conference and the NAPM/NPI Purchasing Green Energy Workshop for State & Local Government. Info: GlobeEx 2000, 2330 Paseo Del Prado #C101, Las Vegas, NV 89102 • 702-317-0777
Fax 702-257-7999 • sulrich@ntsdev.com

NEW MEXICO
Profit From The Sun workshops, Moriarty, NM. RE, energy conservation, sustainable living, & energy independence. PFS, 505-281-1300 days • 505-832-1575 eves & weekends • proffit@flash.net
www.proffitfromthesun.com

NEW YORK
Apr 24–29, '00: PV Design & Installation Workshop, Woodstock. Basics of electricity, PV components, solar site analysis, system sizing, & a field installation. SEI, PO Box 715, Carbondale, CO 81623 • 970-963-8855
Fax: 970-963-8866 • sei@solarenergy.org
www.solarenergy.org

Oct 15–19, '00. Bioenergy 2000: Moving Technology into the Marketplace, the 9th biennial Bioenergy Conference: NRBF
202-624-8464 • nrbp@sso.org

May 11–12, '00, Heavy-Duty Hybrid-EV Conference, LaGuardia Crowne Plaza, NY City. NESEA, 50 Miles St., Greenfield, MA 01301 • 724-772-7148 • Fax: 413-774-6053

NORTH CAROLINA
How To Get Your Solar-Powered Home: Seminars 1st Sat. each month starting in March. Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 • 336-376-9530
Fax: 336-376-1809 • solarvil@netpath.net

April 11–May 16, 2000. The N.C. Solar Center is presenting a series of six evening workshops on a variety of RE topics. Apr. 11: Passive Solar Design for New Construction. Apr. 18: Health, Safety, & Energy Efficiency in Homes. Apr. 25: Passive Solar Design for Existing Homes. May 2: Active Solar Water & Space Heating. May 9: Photovoltaics. May 16: Green Building Products. $99 for all six, or $25 per session. Contact: N.C. Solar Center, Campus Box 7401, NC State University, Raleigh, NC 27695
919–515–3480 • www.ncsc.ncsu.edu.

OHIO
RE classes, 2nd Sat. each month, 10 AM to 2 PM. Tech info, system design, NEC compliance, efficient appliances. In advance: $70, $90 w/spouse. Also hands-on straw bale post & beam building. Solar Creations, 2189 SR 511 S., Perrysville, OH 44864
419-368-4252 • www.bright.net/~solarcre

OREGON
Aprovecho Research Center, non-profit edu. org., 3 ten week internships. Spring, Summer, Fall. Appropriate tech, sustainable forestry & organic gardening. Aprovecho Research Center, 80574 Hazelton Rd., Cottage Grove, OR 97424 • 541-942-8198
apro@efn.org • www.efn.org/~apro

SolWest Workshops: Annual Tour of Homes, hosted by EORenew, May 27, '00. Grid Intertie System Installation, a pre-SolWest fair workshop, by Richard Perez and Joe Schwartz, July 25–28, '00. Classroom sessions and a hands-on system installation on the fairgrounds. Tuition $275. John Day, OR. EORenew, PO Box 485, Canyon City, OR 97820 • 541-575-3633
solwest@eoni.com • www.eoni.com/~solwest

PENNSYLVANIA
Aug 21–23, '00. Energy 2000 Energy Efficiency Workshop and Exposition: Pittsburgh, PA. Energy mangers conference. By the DOE's FEMA Program, Dept. of Defense, and the General Services Admin. Contact: Florida Solar Energy Center, 1679 Clearlake Rd., Cocoa, FL 32922
800-395-8574 • joann@fsec.ucf.edu

TENNESSEE
Apr 10–15 '00: PV Design & Installation Workshop at The Farm, Summertown. Basics of electricity, PV components, solar site analysis, system sizing, and a field installation. SEI, PO Box 715, Carbondale, CO 81623 • 970-963-8855

Fax: 970-963-8866 • sei@solarenergy.org www.solarenergy.org

Kids To The Country; a nature study program for at-risk urban Tennessee children. Sponsorships & volunteers welcome. Contact: 51 The Farm, Summertown, TN 38483 • 931-964-4391 • Fax: 931-964-4394 ktcfarm@usit.net

TEXAS

Sep 29–Oct 1, '00: Renewable Energy Roundup, Fredericksburg. RE exhibits, demonstrations, workshops, tours. TX RE Industries Assoc. & Texas Solar Energy Society, 512-345-5446 • R1346@aol.com www.renewableenergyroundup.com

The El Paso Solar Energy Association bilingual Web page. Info in Spanish on energy & energy saving. www.epsea.org

WASHINGTON STATE

San Juan Islands workshops, October, 2000: Microhydro Power, Oct. 13-15 ($250); Photovoltaic Design & Installation, Oct. 16-21 ($500); Wind Power with Mick Sagrillo, Oct. 23-28 ($500); Renewable Energy for the Northwest, Oct 29 ($75). Contact: SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org Local contact: ian.woofenden@homepower.com

WISCONSIN

Midwest Renewable Energy Association (MREA) Workshops. See ad. Call for cost, locations, instructors, & further workshop descriptions. MREA Membership & participation: all welcome. Significant others half price. MREA, PO Box 249, Amherst, WI 54406 715-824-5166 • Fax: 715-824-5399 mreainfo@wi-net.com

June 16–21, '00: ASES, Solar2000-Solar Powers Life, Share the Energy conference. June 16–18, '00: Midwest Renewable Energy Fair. Both events together in Madison, WI. See MREF/ASES ad.

June 12–16, '00, Women's PV Design, $450. Contact: SEI, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

the Wizard speaks...

Fuel Cells

Fuel cells are now being developed which could have an important place in energy production. These devices produce electricity from hydrogen and oxygen. The only byproduct is water.

Fuel cells can contribute greatly to the future mix of power sources. However, there is a problem with the current outlook. A major portion of the hydrogen will be produced from fossil fuels. This will still result in the release of carbon dioxide, although at a reduced level. Fuel cells will have their best effect when using hydrogen produced by renewable sources, such as solar and wind power.

Using renewably-produced hydrogen, fuel cells will be able to power almost all of the vehicles now burning fossil fuels. This will drastically cut carbon dioxide emissions. Using stored hydrogen, these same fuel cells could also be used for the backup power necessary in solar and wind installations. The heat created by fuel cells can also be effectively used, thus increasing their efficiency.

The transition to non-hydrocarbon fuels will have to occur sometime. The longer we wait, the greater the environmental damages. The first step is the installation of massive amounts of solar and wind power. If we start now, we may be finished in time to negate the more serious environmental consequences.

Writing for Home Power Magazine

Home Power is a user's technical journal. We specialize in hands-on, practical information about small-scale renewable energy systems. We try to present technical material in an easy to understand and easy to use format. Here are some guidelines for getting your RE experiences printed in Home Power.

Informational Content
Please include all the details! Be specific! We are more interested in specific information than in general information. Write from your direct experience—*Home Power* is hands-on! Articles must be detailed enough so that our readers can actually use the information.

Article Style and Length
Home Power articles can be between 350 and 5,000 words. Length depends on what you have to say. Say it in as few words as possible. We prefer simple declarative sentences which are short (less than fifteen words) and to the point. We like the generous use of subheadings to organize the information. We highly recommend writing from within an outline. Check out articles printed in *Home Power.* After you've studied a few, you will get the feeling of our style. System articles must contain a schematic drawing showing all wiring, a load table, and a cost table. Please send a double spaced, typewritten, or printed copy if possible. If not, please print.

Written Release
If you are writing about someone else's system or project, we require a written release from the owner or other principal before we can consider printing the article. This will help us respect the privacy rights of individuals.

Editing
We reserve the right to edit all articles for accuracy, length, content, and basic English. We will try to do the minimum editing possible. You can help by keeping your sentences short and simple. We get over three times more articles submitted than we can print. The most useful, specific, and organized get published first.

Photographs
We can work from any photographic print, slide, or negative. We prefer 4 by 6 inch color prints with no fingerprints or scratches. Do not write on the back of your photographs. Please provide a caption and photo credit for each photo.

Line Art
We can work from your camera-ready art, scan your art into our computers, or redraw your art in our computer. We often redraw art from the author's rough sketches. If you wish to submit a computer file of a schematic or other line art, please call or email us first.

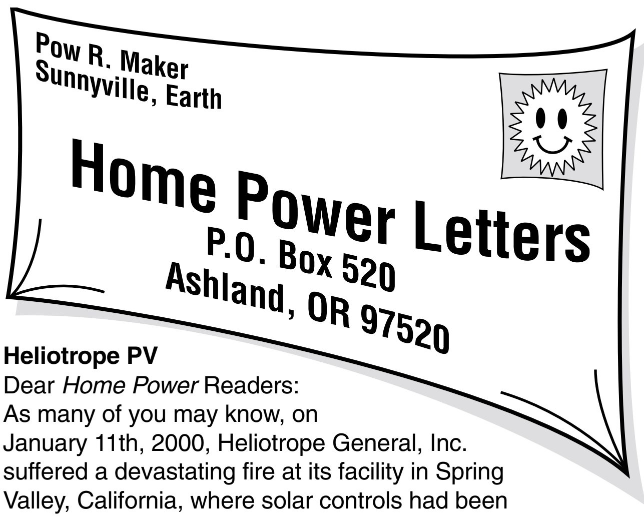
Got a Computer?
Send us the text for your article on 3.5 inch computer floppy diskette, either Mac or IBM format. We can also read ZIP disks (either Mac or IBM), Magneto-Optical disks (128 MB, 230 MB, 1.2 GB, and 1.3 GB, all Mac only), and CD-ROMs. This saves time and reduces typos. Please also send a hard copy printout of your article. Save all word processor files in "TEXT" or "ASCII TEXT" format. This means removing all word processor formatting and graphics. Use your "Save As Text" option from within your word processor. Please don't just rename the file as "text" because it will still include unreadable (at least to us) word processor formatting.

You can send your article via Internet to richard.perez@homepower.com as an attached ASCII TEXT file. If you are sending graphics, or articles with embedded graphics, then use this email address: ben.root@homepower.com

It is wise to telephone or email ahead of electronic file submission. This is particularly true concerning graphics files. There are many, many, many ducks and they all need to be in a row....

Got any questions? Give us a call Monday through Friday from 9–5 Pacific Time and ask. This saves everyone's time.

Access
Richard Perez, Home Power magazine, PO Box 520, Ashland, OR 97520 USA • 530-475-3179
Fax: 530-475-0836 (24 hours a day)
richard.perez@homepower.com
www.homepower.com



Heliotrope PV

Dear *Home Power* Readers:
As many of you may know, on January 11th, 2000, Heliotrope General, Inc. suffered a devastating fire at its facility in Spring Valley, California, where solar controls had been manufactured for 25 years. Damage was extensive, and as a result, Sam Dawson, president and founder of Heliotrope General, Inc., has decided to retire from the solar industry and concentrate his efforts on growing grapes at his vineyard near San Diego.

The Hi-Eta photovoltaic product line of Pulse Width Modulated (PWM) charge controllers and DC power fuse centers has been acquired by Greg and Deborah Holder of Alternate Means. Greg was a very dedicated customer of Heliotrope General, Inc., and was instrumental in the development of the RV-30S and RV-30D charge controllers. Greg has tremendous vision for a more dynamic and technologically advanced Heliotrope PV product line. As the former general manager of Heliotrope General, Inc., I am joining Greg and Deborah as their new director of marketing. Sam Dawson remains available to us as a consultant.

The newly formed company is called Heliotrope PV, and manufacturing has been relocated to Eugene, Oregon. The RV-30S and RV-30D charge controllers will be available in March, 2000 at the same prices offered by Heliotrope General, Inc. Heliotrope PV will begin to cover the warranty on the RV-30S and RV-30D at that time. Other Hi-Eta products, such as the CC-60/120E charge controllers and the Solpan 30B/110 power centers will become available as determined by market research and a survey of Heliotrope General, Inc.'s PV customers. We also anticipate several new and re-engineered products to be added to the Heliotrope PV product line in the coming months.

Heliotrope PV's new address is PO Box 1053, Fall Creek, OR 97438. For sales and customer service, contact me at 541-686-6104. Purchase orders can be emailed to heliotropepv@continet.com, or faxed to 541-683-1759. For accounting, please contact Deborah Holder at 541-937-9812 or fax 541-937-9813. For technical assistance or warranty information, please contact Greg Holder at rvsolar@continet.com or 541-937-9812. Our business hours are 9 AM to 5 PM, Monday through Friday. Please feel free to contact me with any questions, comments or product advice. Very truly yours, Jim Kron, Director of Marketing, Heliotrope PV

On the Brink

Dear *Home Power,* I was most impressed with your WWW site. It offers a significant amount of information, and I appreciate your time and effort. If your magazine continues the same pattern of informative, well written articles, I will be a reader for life.

Why am I interested in home power generation? Damage to the environment, OPEC finally getting their act together, brownouts during the summer months, power loss during the winter, not to mention that deregulation has almost doubled my electric bill.

As I am sure you know, much of our modern society lives on the brink of complete chaos, as we surround ourselves with more and more things we depend on that are totally out of our control. I intend to take some of the control back. Keep up the great work! Dan Schilz • deschilz@gsinet.net

Bugs in IPP?

Dear *Home Power,* As the chairman of the working group that wrote IEEE P929, I was very interested to see what one of our working group members, Don Loweburg, had to say about the proposed standard in his *IPP* column *(Things that Used to Work—Bugs in IEEE 929, HP74,* page 122). I was a little taken aback by what I read. Don seemed to be trying to make folks out to be bad guys who are in reality good guys. The people on the working group who wrote IEEE P929 set about the process with one goal in mind—to standardize utility interconnection of PV systems thereby making the interconnection process predictable, understandable and straightforward. I believe every one of them worked at the process with an open mind and the intention of producing a good, workable standard.

I was particularly disappointed since I had made Don a member of the working group so that he could share his viewpoint with all of us who were writing the PV interconnection standard. Of course Don has every right to write a derogatory column about the process—as long as his writing reflects the whole story. However, Don left out a critical detail that makes his point totally invalid. I'm not going to discuss this detail, as more harm than good would be served by bringing it up at this time. Suffice it to say Don knew about this detail and chose to ignore it. It appears that he was more interested in sensationalism than in presenting a complete picture. I guess that may be because there is no story if the complete picture is presented.

The irresponsibility of presenting this article is highlighted by the fact that the only issue Don had with the standard was the upper voltage limit. The upper voltage limit had been changed to the value that Don espoused before the column was published. Note that Don only has one issue, although the column is titled in part "Bugs in IEEE 929." In the column he also states, "IEEE 929 (as proposed in the current draft) has created barriers." In both cases the use of the plural implies multiple problems.

It seems Don took the opportunity to criticize people and processes for something that he knew was being changed. By so doing, I believe Don has contributed to the despicable "us versus them" culture that seems to pervade the renewable energy industry at the grassroots level.

Standardizing PV interconnection requirements is for the good of the PV industry. It eases the burden for everyone by assuring that a manufacturer of PV inverters can use the same inverter in California, New York, or New Mexico, rather than having a different product for each utility. It also means the system designer/installer knows exactly how to design and install the system (as regards interconnection requirements) in any utility service area in which he may be working.

I should note that the person who probably spent more time on this than any other was Bill Brooks of Endecon Engineering—he deserves a lot of credit for his work. Bill and several others, including a couple of the utility engineers on the working group, discussed an approach for presenting this proposal that would be palatable for all involved. This approach was sound logically and technically, so the entire working group accepted it, and the upper voltage limit was changed to 110 percent, a limit that exists nowhere else as a standard. Sincerely, John W. Stevens, Senior Member of the Technical Staff, PO Box 5800, Albuquerque, NM 87185-0753 505-844-7717 • Fax: 505-844-6541 • jwsteve@sandia.gov

John, I accept that you are disappointed in the article, and in me. However, from my perspective, the article fleshed out and explored a number of problems. A big motivator driving my involvement in this affair was that my customers who wanted to net-meter could not. Due to a standoff between PG&E and Trace, that utility had discontinued all new net metering connections of Trace SW inverters in its service area. This occurred several months before the article was published. Neither Trace nor PG&E were providing my customer any support on this.

You mention that the standard was changed before the article was published. That is true. However, there is a two month lag between the writing and publication of articles in Home Power. *The article was written before the standard had been changed. Because we* (HP *editor Ian Woofenden and I) knew your group was working on a change to the standard, you were sent a proof of the article for comment before publication. Your comments were attached and published at the end of the article.*

You refer to the absence of a "critical detail that makes [my] point totally invalid." I think the detail you are referring to is the poor calibration of the internal voltmeter function of the Trace SW inverters. You are correct in that I did not mention Trace by name at that time. However, I did mention voltmeter accuracy as an issue—affecting nuisance tripping. My point in broad terms was this: A combination of high utility voltage, poor inverter voltage calibration, installation issues, and a pending IEEE 929 standard with a too-narrow voltage window was responsible for inverters disconnecting unnecessarily from the grid. The inverter voltage calibration issue is one of several mentioned. The omission (if that were the case) of a single contributor to the problem still would not make my point totally invalid.

Was the article irresponsible? I don't think so. IPP *works with issues relating to end-users and installers. In this regard we have been responsible to our constituency. You mention the "despicable us versus them culture that seems to pervade the renewable energy industry at the grassroots level." To a certain degree, polarization is a given—a state of Nature. Whether that polarization is "despicable" depends on the perceivers and their point of view. Your view of the dichotomy is somewhat skewed in that you attribute it solely to the "grassroots" of the renewable energy industry. I think there is enough "us versus them" to go around. Regards, Don Loweburg, IPP, PO Box 231, North Fork, CA 93643 559-877-7080 • Fax: 559-877-2980 don.loweburg@homepower.com • www.homepower.com/ipp*

Hands-On Renewable Energy Lab

Over the years, it has become increasingly complex and difficult to install renewable energy systems, often due to institutional barriers. There are many materials and methods that work safely that are not permitted. Additionally, many basic items could be developed that would greatly reduce the cost and difficulty of installations. Certain items currently on the market could benefit from modification.

Renewable energy needs an advocate. The current "advocacy" that solar and RE receives seems to get the map confused with the territory. As many of us have experienced, regulations often reflect existing codes and theoretical ideas as to what is needed. Hands-on workers are seldom consulted. The result is that instead of being able to do things in the most direct, safe, and reliable way, the electrician is forced to "slog through every bog and scale every cliff" to follow the map he is given. Although there are easy trails to good systems, we are forbidden to use them.

Battery Cables: Welding cable is an example that many are familiar with. It was used for years to make battery connections. It has proven safe and effective, but it is not "listed." The cables that are permitted are often very difficult to get, and are also more expensive. The fact that a new dwelling may be denied a certificate of occupancy until the permitted cable can be located and shipped is an additional barrier.

If a funded laboratory were capable of testing welding cable to demonstrate its effectiveness, and then take it through the listing process, it could facilitate the installation of new systems. Other types of readily available cable could be tested for suitability as well.

Inverter Disconnects: Another issue concerns the DC disconnects which are required between batteries and inverters. Currently available units have shortcomings. Trace Engineering supplies disconnects in undersized boxes. At the other extreme, there are elaborate and expensive power centers.

I have found the small Trace boxes tedious to wire. What should take less than an hour to accomplish often takes a large portion of a day. Additionally, the installer can receive cuts while putting large wires into small containments, with sharp objects to work around. To put together a listed DC-rated breaker in a reasonably-sized cabinet at a reasonable price could take a fair chunk off the price of an installed system.

With the well-established requirement for DC disconnects for inverters, it is often forgotten that systems went in for a long time before these were required, with no ill effects that I've ever heard of. With or without the disconnect, there is no way around working with hot terminals when connecting battery banks. The switch seems to serve little purpose.

Additionally, with the disconnect switch and overcurrent protection remote from the battery bank, the battery positive wire enters the disconnect enclosure completely unfused. If this wire were to short against the enclosure, a great deal of damage and/or personal injury could occur. The battery bank could potentially discharge its tremendous store of power in a devastating arc. The systems that are currently required seem to be neither the safest nor the most cost-effective means of connecting batteries to inverters.

DC Circuits: Often customers want DC circuits. Electricians are hampered by a shortage of listed DC lamps and receptacles. Often what is available and legal in lighting is deemed unsatisfactory by customers. Low voltage DC lamp holders require a 660 watt rating, which is available on very few fixtures. For receptacles, 240 volt models are commonly used, but it is often tenuous as to whether or not an inspector will accept them.

48 Volt Issues: 48 volt (nominal) systems often make the most sense technically and economically due to efficient transmission of power and smaller conductor size. Yet the rules are hazy. Battery terminals in domestic installations must be shielded, yet there appears to be no approved shielding available. Many installations are going in at 48 volts without shielding. This appears to be a code violation. This issue needs clarification, since the expense of a rejected system could put a small contractor out of business.

Heat Circulation Loads: A standard forced-air furnace blower will quickly deplete nearly any battery bank. When installing PV on an existing dwelling, the heating system is usually the load that renders the photovoltaic array nearly useless. There supposedly are some high-efficiency motors that could drastically improve the situation, but the prospect of retrofitting a system is intimidating, since methods do not seem to be well established, and the listing on the furnace could be voided.

The problem of high power consumption for heat circulation can be avoided by installing DC-powered hot water pumps with boiler heating systems. These systems appear viable, yet still seem to have some issues.

Code Requirements: Power vents for battery boxes are not approved. Their design could stand improvement. Many other items that are useful in RE installations do not have the proper listings. Tilt-up wind towers may require engineering stamps in order to pass code requirements. This list could go on indefinitely.

Testing & Development Lab: My suggestion is that an independent laboratory be established to assess various products and get appropriate ones listed. Needed items could be developed and manufacturers could be found to produce them. Engineers could be contracted to evaluate items developed by people who have hands-on experience installing and maintaining renewable energy electrical systems. Electrical code writing committees could be attended by paid representatives, and propose rule changes where needed.

This could be done in conjunction with the RE Wrench network. Much time could be saved by studying the results from thousands of installed systems. Wrenches could be contacted to represent the hands-on point of view when relevant seminars occur in their area. They could attend with pay, in order to avoid the financial burden of lost work.

PV and wind energy systems are slowly increasing in popularity. There are some relatively simple and inexpensive things that could be done to allow for immediate quantum leaps. I am looking for interested individuals and a source of funding to set up a lab that will smooth the way for alternative electrical systems. Your input is greatly appreciated.
Sincerely, Drake Chamberlin, Electrical Energy
solar@eagle-access.net

Small is Sustainable
Dear *Home Power,* I just received your latest issue and loved it! I am so glad to see that your magazine is thriving. Now that *CREN (Canadian Renewable Energy News)* is no longer being published, your magazine is the only one of its type, and desperately needed by our society. But…

I am increasingly bothered by the size of solar arrays in your magazine. A 3 KW array is huge! What is worse is that these monsters only provide a fraction of people's electricity. Our offgrid home in Ontario had an array of less than 350 watts. We had a backup generator that used less than $20 of gasoline (that's Canadian dollars and Canadian gas prices!) each year. We had no propane and no wind, and this system satisfied the needs of a family of four in a large house in one of Ontario's snow belts. We also had to deal with haze off nearby Georgian Bay which reduced the amount of bright sunshine in November and December.

The point is that obviously we did not consume as much electricity as most people. In fact, we were downright frugal! We were not offgrid for economic reasons (the hydro lines ran within 50 feet of our house), but for environmental and ethical reasons—primarily our aversion to the nuclear power plant at the nearby BNPD. Our new house, which we will begin to build next spring will have a (large by our standards) 580 watt array to accommodate our growing children and our desire to get on the internet and have a freezer. We will do this without a backup generator by putting much thought into the design of the house and how we use the electricity we have (we won't be putting the freezer in our heated home!).

It is now common knowledge that it is impossible for everyone in the world to consume at the level of North Americans. I hope that your readers will turn their energies to using the electricity they produce as efficiently as possible. Panels and windmills cost a lot of money; conservation is free! Reducing electrical bills by switching to propane or natural gas is just substituting one non-renewable source for another. They are all going to run out eventually. I guess this is why I have always admired those developing-world systems that you occasionally show—a couple of panels, a couple of batteries—that's my size of system!

Another bee in my bonnet is the idea that it is cheaper and more convenient to run everything through an inverter and run the house using 120 VAC. We use 12 volts DC because we think that it's easier and cheaper. Our electronic equipment uses 50–55 percent of the energy using 12 volts DC than it would if it were using 120 volts AC. Also, though we have never had problems finding 12 volt DC stuff, we are glad we can't run every little gadget out there. It makes us think twice about using electricity. Do we really need that appliance? Do we really want it? Usually, the answer is "No!" to both.

The overall point of these ramblings is that you can't be independent when you're a slave to consumerism. If people lived simply, they could reduce the size of their solar arrays substantially. Think of the money they could save! This may offend some of your advertisers. But it is in the interest of the makers of solar equipment to sell large systems and lots of extras, like the large inverters, because they make money! Yes, they make good stuff, and I'm sure they are nice people, but they are not in the business of teaching you to conserve electricity. They are in the business of selling solar equipment, and the more they sell, the more money they make. We all—ongrid and off—need to realize that we use a terrible amount of energy. It would be nice to see more in your wonderful magazine to address this problem. Yours sincerely, Catherine Stanley, Wolfville, Nova Scotia, Canada

Hi Catherine. Thanks for your very important letter. We encourage you and other owners of appropriately-sized systems to write articles for us. Home Power's *articles come largely from our readers. When dealers and consultants write up a system, it does tend to be their largest one—they are proud of them. It's good to show that larger systems are possible, but your points are well taken. We should be even more proud of small, efficient systems that do more with less. I would rather see compact fluorescents on the ceiling than PVs on the roof. Efficiency and conservation should be the first steps. Then your generating sources can be much smaller.*

My heart is with you on the subject of DC systems. My family's system is still primarily DC, and you are right that it's cheaper if you can use only *DC. But the reality of our society is that people are used to having 120 VAC power handy. Most systems installed these days do have an inverter, and dual wiring and appliances take away most of the savings of using DC. It would be great if everyone were as thrifty with energy as your family is, but I'm afraid going back to the days of only DC systems would mean much less RE out there. Still, for many people, your model is perfect (see the article by John Surber and Roberta Corrigan in* HP75).

Your letter is full of spot-on points, capped by the final one. We simply want too much stuff. Many of us left the cities and suburbs to find "the simple life," only to find that we are still running hard to acquire all kinds of tools and toys. My city friends may think that I'm less materialistic, but in fact I just like different material. Your letter is good encouragement to simplify and make do with less. Thanks! Ian Woofenden

Innovative Instrumentation
Dear Richard and everyone, Thank you once again for printing my article. I am starting to get responses and good suggestions from some of your readers about solving some of Melanie's issues with her system *(If I Can Do It, You Can Too, HP75,* page 26). Here is one reader's response, not only for Melanie's situation, but for anyone who may benefit from these innovative solutions. James Thompson websales@bizns.com

Dear Mr. Thompson: That was a great article of yours in *Home Power.* You certainly found an interesting subject to write about. Here are a couple of ideas for you to pass along to Melanie Chacon. To determine if the 403 or panels are charging, simply put a small 12 volt car instrument panel light in series before the diode at the battery. Then by feeling if the bulb is warm, Ms. Chacon will know if the system is charging.

For a voltage indicator, I would use some zener diodes and regular diodes hooked to maybe three or four switches and to a buzzer. By depressing all the switches, one would have a rough idea of what the voltage is.

If you do speak to Ms. Chacon, tell her I wish her the best of luck at being able to stay independent. Steve Hicks, PO Box 394, White Sulphur Springs, Montana 59645 steveahicks@yahoo.com

20 KW Grid-Intertie?
Hello *HP,* I just read the McCorkendale article *(Electric Bills are…Gone With The Wind, HP75)* and it looks like a great project with conscientious owners. It is a very good example of the effort required by the owners to get a system like this installed, not just the equipment installation but the bureaucracy that must be dealt with. Their dedication should be commended. The floor heating system is great for this size of turbine, although usually impractical for smaller systems.

There were a couple of points that may be misleading to readers. The first and most important is the reference to a 20 KW wind turbine on the front cover and table of contents. If the owners put the 23 foot rotors on this turbine, it would have a rating and maximum output of 10 to 12.5 KW. Keeping in mind that the rotor swept area is where the power is coming from, it's not practical to get more than this from 23 foot diameter rotors.

The output from this machine would be determined by the adjustment of the governor that controls the blade feathering and maximum rotor rpm. For 10 KW output, the rotor speed would be set to 195 rpm. For 12.5 KW output, it would be 205 rpm, and the control boards would need to be calibrated accordingly. From the description in the article, this turbine is capable of 17.5 KW if equipped with 26 foot rotors and set for 195 rpm. Running the rotor faster for more output would be stretching the mechanical limits of the turbine and would be an expensive disaster waiting to happen.

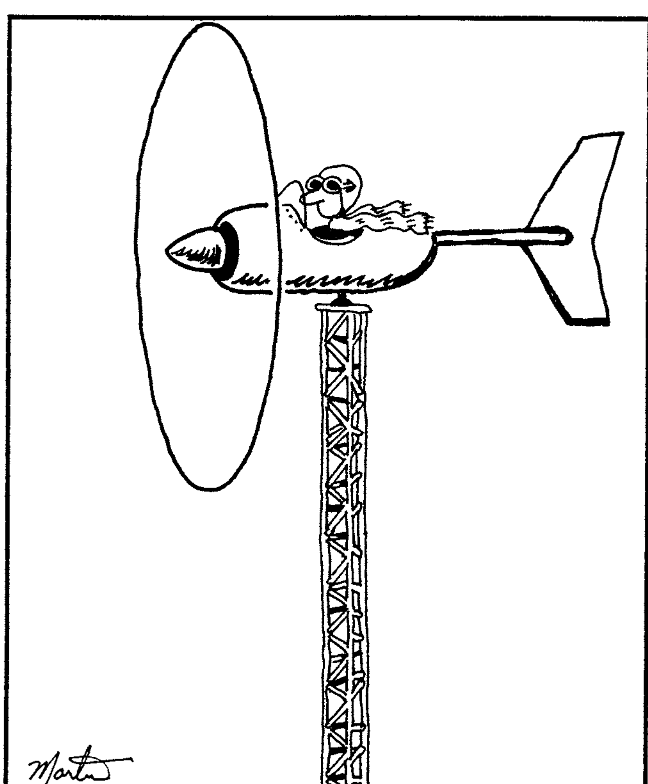
We have encountered several disappointed customers who have bought turbines that were oversold; it is important to know what you are buying. There is one wind company that oversells their equipment and this article may provide them fuel, at least on the surface. Example: in one situation, they told the customer it was a 60 KW turbine, and told the power company it was 20 KW to obtain net billing. It was actually a 40 KW turbine. This same company has sold many 17.5 KW turbines as 20 KW, and has taken these machines far past the mechanical limits they were designed for. I don't think I need to mention what happened next.

There is reference to the 25 KVA alternator being oversized for long life, and there is no doubt that the alternators used in the Jacobs wind turbines have long lives. However, this turbine typically uses 20 KVA alternators, which give you about 17.5 KW max when you take the typical 90 percent power factor into consideration. The Jacobs 20 KW wind turbine, model 29-20, has a few "major" design changes to the one shown here and actually weighs 2,500 pounds (1,134 kg), several hundred pounds more than the one in the article.

The McCorkendales' April output indicates an average wind speed of about 14 mph, which is very good. It would have been nice to have more than one month's data.

The tower foundation is quite interesting although not at all typical. It makes good simple use of a backhoe. It did use over twice the amount of concrete of a typical foundation. Foundations are very dependent on the type of soil. Sometimes concrete can be relatively inexpensive, especially compared to labor and other equipment used in the foundation work, or towers pulling out of the ground. In any case it is better to be safe than sorry. Best wishes, John Hippensteel, Lake Michigan Wind & Sun, Ltd. lmwands@itol.com

Hello HP *crew and John, I thought our article in* HP75 *was really sharp—thanks for the good work you all did. Corinne used to be a journalist and was also very impressed with the thoroughness of your editing process. I am sorry that the editing error was allowed to remain, largely due to my vacation in January.*



harry@vcnet.com

The confusion started with the fact that our 10 KW Jacobs system does indeed operate a 20 KVA alternator, the same alternator used for larger Jacobs machines. The only editing mistake in the entire article was this 10 KW instead of 20 KW. I would like to add that at no time has anyone I have dealt with, while purchasing and erecting our system, ever tried to say our system was anything but a 10 KW system. Clearly the Jacobs system we have is built very robust, making it a very reliable 10 KW system. Tim McCorkendale

Efficiency Update

Dear *Home Power,* Here's a bit of an addendum to my article in *HP71* (page 84) on cutting your utility bills. The article was largely about loads, which lest we forget, drive the design of most renewable energy systems. Back then I was able to reduce my consumption (alas, on the grid) to just about 100 to 130 KWH per month. I also suspected that my old 1950s vintage US$30 refrigerator with its huge mechanical latch was taking up the majority of my 130 KWH per month. I would like to admit here, publicly, that I was quite wrong.

I called my local utility's meter shop and asked about where I might find an old 120 VAC KWH meter—which, by the way, are very rare things among utilities these days. One of the workmen said that they actually tossed certain types of old 120 VAC meters in the garbage. I managed to talk him into saving one for me. When I showed up at the meter shop, he was kind enough to calibrate it within about 1 percent of actual energy consumption.

Next, I made a KWH-metered extension cord and used it on my old refrigerator. With six weeks of data to report on, my poor old, cheap, manual defrost refrigerator uses a mere 1 KWH per day. OK, some of you in Europe must be gasping. But for the rest of you in the U.S. where new refrigerators start at about 550 KWH per year and go up near 700 KWH per year for the bigger models, a measly 365 KWH per year is downright efficient.

The upshot of all this is that my old beat-up and much maligned refrigerator is actually quite a bit easier on energy than any model I could go to town and buy for US$600 new. According to the data I have on efficient Sun Frost refrigerators, a comparable 12 cubic foot refrigerator uses just 0.35 KWH per day—about a third of what my old dog uses. Yet, with the Sun Frost costing about US$2,500, it would have to save me $2,470 in electrical bills within its lifetime just to break even. At just 6.5 cents per KWH for grid electricity here, I don't think the Sun Frost would last long enough to pay for itself.

So, I'll just continue using my battered old fridge until it gives up the ghost. Of course, with a toddler in the house, I'll have to find some way to remove the mechanical latch and put on a magnetic one for his safety…. Regards, Eric Eggleston, Route 2, Box 271, Canyon, TX 79015 • 806-488-2537 wattsworth@juno.com

Hello Eric, I suspect that the low energy consumption is due to the manual defrost, as you mentioned in your article. Automatic electric defrosting adds about 40 percent to a refrigerator's energy consumption. Richard Perez

Eric, in the '50s, many of the refrigerators had fairly low energy use because the walls of the refrigerators were relatively thick, the refrigerator was fairly small, and the units were manually defrosted. In addition, many of the compressor motors turned half as fast as current models, which made the cooling process more efficient.

You have a great deal on grid power at 6.5¢/KWH; the national average is closer to 10¢/KWH. In Northern California, we pay about 12¢/KWH. Of course, with utility power, you do not pay all the hidden environmental, health, and military costs.

We recently did an analysis of the cost of solar energy for Northern California. Lets say you had a stand-alone system with an inverter, batteries, and PV and wanted to produce an additional 1 KWH per day. If the inverter and charge controller were large enough to handle the larger array, you would only have to purchase PV panels and mounts, and expand your battery bank an appropriate amount. If you size the solar-electric system so it would supply 1 KWH per day throughout most of the winter, this system would be sized so that it provides 1 KWH per day with three sunlight hours. Or you could downsize your system so that it would provide 1 KWH per day at the average annual insolation level of four sunlight hours. In this case, you would have to produce about 50 KWH per year with a generator. If the system has a sixteen year system life, you will probably have to supply two sets of batteries (assuming L-16s).

The cost of a power system, two sets of batteries, and US$600 for installation would be US$5,776 for the system with the larger array, and US$5,270 for the system with the smaller array (this includes the cost of backup generator power). If the money for the system with the larger array was borrowed at 7 percent and the loan was paid back in sixteen years, the electricity would cost $1.66 per KWH. If the cost of the charge controller and power center were included, the cost of solar stand-alone AC power would be over $2 per KWH. Saving energy is particularly valuable with a solar system because of these high-energy costs.

Also, the cost of an RF-12 is $1,899 not $2,500. The payback time will be fairly long if you are only paying 6.5¢ per KWH. However, if you had a stand-alone power system, the payback time would be at least 25 times shorter, since the electricity is at least 25 times more expensive. If you did have a stand-alone power system, we recommend using a DC refrigerator if possible, which saves about 10 percent on inverter losses.

An advantage of our RF-12 over your current refrigerator is that it frosts up more slowly, is easier to defrost, and therefore much easier to clean, and has better storage conditions for vegetables. In addition, if you have air conditioning, the waste heat from the refrigerator will have to be pumped out during the summer, increasing energy use by about 50 percent during these hotter months. We will be introducing new Sun Frost DC models this spring, which will be 10 to 15 percent more efficient than our present DC models. Larry Schlussler, PhD, Owner, Sun Frost

Inverter Homebrew

Hi Richard, I read with great interest the letter from Kenny Runner of Galloway, West Virginia in *HP75* about homebrew sine wave inverters. I also tried to weasel some schematics or something out of the Trace people, but they kept their secrets locked down tight. I can understand that, because a lot of work goes into these designs.

Surely there is some sine wave guru out there who will share the secrets with us. I would even enjoy reading about the generic approach. I know that the switching transistors must either be fully on or fully off to be efficient. The things could not possibly run as big amplifiers running after a small sine wave input signal. They would be too inefficient.

As you see, I am confused about how this is done too. Please be on the lookout for someone who will let us in on the general approach taken by the big manufacturers. Thanks, Gerald Wright, Bothell, WA • sciolist@seanet.com

Wanted: Battery Homebrew

Dear *Home Power,* I would like to investigate building my own 12 volt lead-acid battery cells. I would like to see an article on practical homemade battery construction, perhaps using recycled materials and or readily available materials such as sections of larger diameter PVC pipe and fittings for cases. No doubt some of your readers have manufacturing experience and could submit articles with workable prototype designs to spur interest in this aspect of home power. Perhaps a contest with suitable prizes would produce a flurry of interest and a crop of homebrew battery builders. There's much to be learned on this subject. Thank you, Kerry Slattery, 21752 34th Pl. W, Brier, WA 98036 • kslatte@msn.com

Practicality

Hi there, I subscribe to *Home Power*—first year—and have really enjoyed each issue. However, I don't think I have seen any articles aimed at determining the practicality of PVs, wind, etc. in any specific region of the country (world). It seems obvious that PVs would be particularly well-suited to the desert regions. However, although we do not have long sunny summers, we also have reduced power needs for heating or air conditioning (no need for air conditioning). There was one article on fuel cell technology, but I think it suggested the technology may not be available at a reasonable cost yet.

In any case, we are planning to build a small home and a large barn on 3.5 acres on Fox Island (one of the smaller islands in southern Puget Sound in the Seattle/Tacoma region). We have only modest winds, no rivers or streams, and no waterfront. We do have a nice cabin, and our own well and septic system. We also have commercial electric power available.

However, for environmental reasons and to reduce expenses when we retire to the property, I would be most interested in what present day technology offers to eliminate or at least reduce power costs. So, I guess it would be really helpful to read something on evaluating different areas for alternative power generation of various types. Thanks, Larry Carlson tadalex@nwrain.com

Hello Larry, We have 215 Home Power *subscribers who are living on PV and/or wind systems in your area. PV does work in your neighborhood, but it requires more modules to do the job over, say, living in Scottsdale, Arizona. We also show wind systems in your neighborhood, but Puget Sound is full of* *microclimates. Who knows what potential you have until you put up either a recording anemometer or a small wind genny (like the AIR 403). There may be more wind at 60 or 100 feet than you realize.*

If I were in your shoes, I'd invest first in making that home on Fox Island as energy efficient as possible. Check out both the electrical and thermal systems. You want the most efficient appliances you can buy. This will save you money immediately on your utility bill. Make that home well insulated and tight. The first and most cost-effective step in any RE system is load analysis and load reduction. Our rule of thumb is that a buck spent on energy efficiency will save three bucks on system equipment.

Since you are grid-connected, consider a utility-intertied system. Washington is a net metering state. Build your PV system slowly and add modules as you can afford them. Wind power can also be intertied with your PVs.

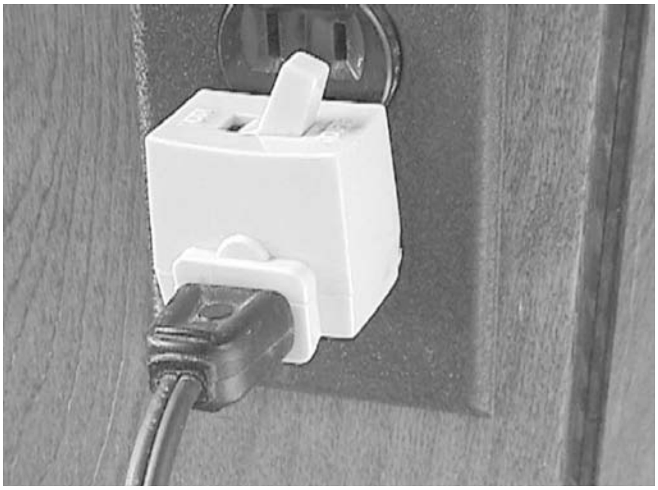
Visit the Home Power *Web site (www.homepower.com) and follow the links to NREL's databases on solar insolation and wind power potential. They are searchable by specific location. I'll bet you will find more sun and wind than you thought. Richard Perez*

Guerrilla Solar 0008

I am pleased to see that some people are taking matters into their own hands when it comes to providing green electricity. Each kilowatt-hour of electricity provided by a renewable source directly saves 0.75 to 1.4 pounds of coal, plus the energy to mine and transport it.

As everyone knows, conserving electricity also saves on non-renewable resources. Too few people realize how easy it is to save 500 watt-hours every day by eliminating phantom loads. VCRs, TVs, boomboxes, and microwave ovens all draw significant power when in the so-called "off" position. I found 19 watts of phantom loads in my one bedroom apartment. I used GE outlet switches like those shown here (US$3–4 each) to cut my electric use by 450 watt-hours a day.

As much as guerrilla solar does make sense, an even greater reduction in the use of energy can be had by switching to a truly high-efficiency refrigerator such as a Sun Frost. After that is in place, I too will be doing some guerrilla solar. PG in NJ



Thermoelectric Power Generation

Richard, You have an absolutely excellent magazine. Your articles and stories have easily saved me thousands in up front costs, and I'm sure thousands more in keeping me from making horrible mistakes that I would have to shell out even more to fix.

I would like to hear thoughts from you and my fellow readers on a power generation system I'm in the process of building. I'm in the middle construction stages of an offgrid remote A-frame home in Alaska, two hours away from Anchorage, for when I retire from the Air Force. I need a way of generating power during the winter when solar panels produce little or no power.

While doing research on power generation I stumbled on thermoelectric power generation, which is basically taking a Peltier cooling module and running it in reverse (the Seebeck effect—a temperature differential across it generates power). A single module is 1 1/2 inches square and 1/4 inch thick. One side is attached to something hot and the other has a heat sink on it. It produces about 6 watts per module. If I run 3 of them in series, I get 15 volts at 1.2 amps, for a total of 18 watts. All you need is a minimum 70°C temperature differential. A high-temperature module costs around $15, and its maximum operating temperature is 200°C. I'm actually planning to put four modules in a series group to generate 20 volts at optimum temperature differentials, but will probably see about 14 to 18 volts average when generating, due to less than optimum temperature differentials.

According to all the research and price quotes I've gotten, I think I can produce power for $3.10 a watt (including all the associated hardware and tank), which is a lot better than all of the photovoltaics I've found so far. I'm planning to use 120 of these modules by attaching them to a pressurized 7 foot high hexagonal insulated tank outside that's fed near-boiling fluid by superinsulated steel pipes that connects to a serpentine pipe grid along the back and top of the inside of my woodstove. I couldn't attach them to the flue directly because flue temps often get above the maximum the modules can take. Besides, the heat storage allows me to generate power longer and more evenly.

The operating fluid is a 60/40 mix of automotive antifreeze and water. Half of the inside volume of the tank is taken up with sealed copper pipes containing a very high melting point (microcrystalline) wax that acts as a good phase-change heat storage medium so I can generate power for a long while after the stove goes out.

It has puzzled me greatly that I haven't found many commercial products using thermoelectric modules. I'm a pretty decent welder and a good all-around handyman, so I can build all of this myself and save a bit of money. None of this is difficult, just very time consuming. A commercial outfit could produce this for about the same or better dollar to watt ratio. I haven't found anybody at all to do this, except a company called Hi-Z (www.hi-z.com). And their thermoelectric application is only for large diesel trucks.

It seems to me that power generation from a woodstove during winter (when it is running almost all of the time anyway) would be an ideal solution, and yet I haven't found a hint of it. The power available from solar heating also seems very obvious. Am I missing something? Or is there another way of generating power that is simpler or costs less? If anybody has a better idea, I would really like to hear it. Thanks, David Harrison, PSC 1013 Box 167, APO AE 09725 davidh@mwr.is

Hello David, Thermoelectric generators (TEGs) are delicate. They can be easily damaged by overtemperature, and require a substantial temperature differential to operate properly. I've heard of problems with low output over time. See Steve Willey's article, The need for Winter Energy Supplement, HP36, *page 47. I know that several of our readers are tinkering with what you suggest, so perhaps they will respond to you directly. Richard Perez*

Adopt a Library!

When Karen and I were living with kerosene lamps, we went to our local public library to find out if there was a better way to light up our nights. We found nothing about small scale renewable energy.

One of the first things we did when we started publishing this magazine twelve years ago was to give a subscription to our local public library.

You may want to do the same for your local public library. We'll split the cost (50/50) of the sub with you if you do. You pay $11.25 and Home Power will pay the rest. If your public library is outside of the USA, then we'll split the sub to your location so call for rates.

Please check with your public library before sending them a sub. Some rural libraries may not have space, so check with your librarian before adopting your local public library. Sorry, but libraries which restrict access are not eligible for this Adopt a Library deal—the library must give free public access. — Richard Perez

To Adopt a Library write or call

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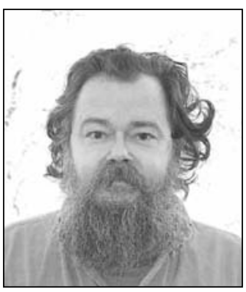
Ozonal Notes

Who Does What at *Home Power?*

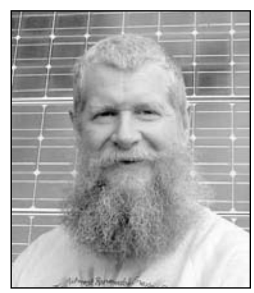
In last issue's *Ozonal Notes* column, I related a short history of *Home Power* magazine. For this issue, I thought you might enjoy meeting the folks who work at *Home Power*— they make this magazine happen.



Richard Perez
Publisher & Editor in Chief
I manage *Home Power's* editorial, art, advertising, production, sales, Web, and CD-ROM crews. I also write articles, editorials, and this column. One of the greatest joys of my job is communicating with our readers by email. I've been living and working offgrid since 1970 with a PV/wind RE system. When I'm not working, I like tinkering with Macintosh computers, amateur radio (N7BCR), and electronics, and watching movies with my sweetheart, Karen. My goal is to change the way we make electric power. Small-scale renewable energy can solve many of our environmental and human problems.

Karen Perez
Publisher & Business Manager
My duties at *Home Power* include managing the money, paying the bills, keeping business ducks in their proper rows, selling advertising, being a database grunt, doing weird business research (paper, trademarks, UPCs, distributors, etc), cooking for the crew, and acting as mediator and den mother. My love and joys are critters (currently two dogs, eight cats, and a very, very old mule), gardening, playing with string (knitting, needlepoint, etc.) while listening to audio books or watching movies, loving my bear, and reading.

Ben Root
Art Director
My degree in graphic design prepared me for the workplace, but not for the shock of our ethicless economy. I often found myself designing pieces to promote the very aspects of society that I think are its largest problems. Graphic design is about communication, and I didn't believe in what I was being paid to communicate. After selling everything but the VW van, and spending a magical summer in Colorado studying at Solar Energy International, I had a mission. By doing the majority of design, layout, and illustration at *HP,* I now have something of value to communicate—information that interests me, and benefits humanity and the planet.



Michael Welch
Associate Editor
& *Power Politics* Columnist
My jobs at *Home Power* include political commentator, Web designer, telecommunications greaser, recycler, and grunt. In 1999, I celebrated my tenth year of involvement with *Home Power.* My other job is a volunteer position with Redwood Alliance, a non-profit that works strictly on energy issues. I do most of my work from Arcata, California, but spend a week each month at the *HP* editorial offices on Agate Flat, Oregon. The rest of my life is wonderfully filled by my partners, Kelly and Emilly Larson. The grown-up one, Kelly, is into RE and biodiesel, and Emilly is into riding her bike.

Joe Schwartz
Chief Wrench
In addition to the university arena, my background is in the construction trades. I'm responsible for keeping *Home Power* electrically and structurally up and running. I install RE hardware, and assist Richard in *Things that Work!* product testing. I also work in the field with Bob-O Schultze of Electron Connection, installing local PV, wind, and hydro-electric systems. I live on a small farm outside of Medford, Oregon where we raise all manner of critters—horses, llamas, sheep, and chickens. On the farm, we're working our way skyward with a tower for a Jacobs short case wind genny that will be intertied with the local utility.

Joy Anderson
Associate Editor

My two careers may sound very different, but they both involve making information accessible to folks. I edit all *HP* articles while on the road with a laptop, modem, and cell phone, and travel to Funky Mountain Institute for proofing during magazine deadline. I'm also a certified freelance Sign Language Interpreter. I have a B.A. in biology, and am fluent in Spanish. I explore the West Coast with my cat and co-pilot, McBean, in our 18 foot motorhome, with my recently installed solar-electric system (yay!). I dream of gardening, beekeeping, and setting up a wind generator and glass studio.

Ian Woofenden
Associate Editor
& *Word Power* Columnist

My primary job with *Home Power* is to copyedit the articles and columns. I take the rough text and try to make it clear and readable for you. I really enjoy working with the authors. Later I proofread the articles, columns, and other text to find the bugs we missed in edit. I write *Word Power,* do an occasional interview, answer reader inquiries, and evaluate articles. And I try (in vain) to keep up with the rest of my over-full life, which includes trimming trees, putting up wind generators, coordinating SEI workshops, singing, and trying to keep my large family busy, fed, and laughing.

Kathleen Jarschke-Schultze
***Home & Heart* Columnist**

I had a great childhood in a large family in the Napa Valley of California. Checkered past: Psychiatric Technician, EMT, Owner/Rider of a BMW R90/6, Restauranteur, and On-Grid Consumer. Now: Mail-order Bride, Homesteader, Bee Wrangler, Organic Gardener, Vermi-Composter, Rose Rustler, Garlic Grower, Haus Frau, Cookbook Collector, Solar Cook, Basket Weaver, Self-Proclaimed Vidiot, Raconteur, Avid Reader, International Author, Workshop Presenter, RE Appliance Queen, Tai Chi Student, Trekker, Devoted Dog Mom, Tarot Reader, Fairy Sister—Energy Park Electric Co. at OCF, Ham—KB6MPI, Sainted Wife of Bob-O, *Home Power's* First Hired & Retired, Renaissance Woman, Optimist, Survivor.

John Wiles
***Code Corner* Columnist**

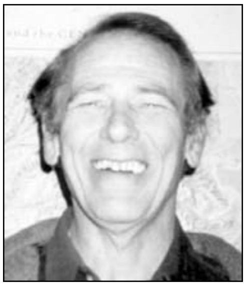
I am a Program Manager at the Southwest Technology Development Institute at New Mexico State University. I assist the PV industry, electrical contractors, and electrical inspectors in understanding the PV requirements of the *National Electrical Code (NEC).* I drafted the text for Article 690 in the 1999 *NEC Handbook,* and serve as secretary for an NFPA-appointed task group involved with Article 690. I installed my first PV system in 1984, and live in an offgrid, PV/wind-powered home (permitted and inspected, of course) with my wife Patti, two dogs, and two cats.

Shari Prange
***GoPower* Columnist**

I grew up in Illinois, and moved to the San Francisco Bay area in 1978. In 1982, my VW was towed into Brown's Auto Service, home of Electro Automotive. By 1983, Mike Brown and I had joined both our personal and business lives. My auto education was on-the-job. In 1988, I put my background as a writer to use as Mike and I co-authored *Convert It.* My niche is taking technical information and turning it into simple language that a non-technical person can understand. We live and work in the Santa Cruz mountains, with our two cats and a boa constrictor.

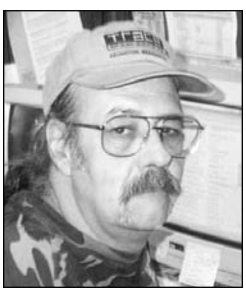
Mike Brown
***EV Tech Talk* Columnist**

I'm a Nebraska native, and I studied engineering briefly at the University of Wyoming before settling in the San Francisco Bay area in 1965. I worked as a mechanic at various auto dealerships, but my specialty was Volkswagens. In 1975, I opened my own auto repair shop and gas station. During the gas crisis of 1979, a customer asked me to build an electric car. I discovered a dearth of conversion parts suppliers. So I founded Electro Automotive, and eventually closed my gas car repair business to work full time on electric cars. I now live in the Santa Cruz, California area, and run Electro Automotive with my wife, Shari Prange.



Don Loweburg
Independent Power Providers
Columnist

I was born in 1943 in Los Angeles, California. After being in the Army, I completed an MS (Physics) on the GI bill. My wife, Cynthia, and I own and operate Offline Independent Energy Systems, and have been in business since 1983. The company is a licensed California contractor specializing in the sale, design, installation, and service of RE systems. We have lived offgrid for 22 years with a solar and microhydro system. I research and write the *Independent Power Providers* column in *HP.* I also teach algebra part-time at a local junior college, and sit on the boards of IPP and CalSeia.



Don Kulha
CD-ROM Producer

I've done a lot of stuff on the way here... I've been a journeyman mechanic, CAD designer, auto racer and builder, aerospace worker, BBS operator, disaster services worker, and ham radio operator. I've worked on the Chandra space telescope, built and operated an engine rebuilding plant, and, most important, been a dad to my son Alex. I produce *Home Power's Solar* CD-ROMs, write a little, and help work the energy fairs. My goal is to help educate and encourage kids and adults to embrace and apply solar energy so we can have a sustainable and fruitful future (and have as much fun as possible while doing it).

Myna Wilson
Office Manager

Kathleen asked me if I wanted to work for *Home Power* almost six years ago. We shared the office duties for several years while having the privilege of working out of our homes. I now manage the office crew and the warehouse at our new business office in Phoenix, Oregon. The bucks stop here first. I oversee the receipt of incoming funds and orders, and then ship out the merchandise. I share a home on a small piece of land on the Klamath River with my husband, Dave, and our dog Mack. I keep my spare time filled with gardening, cooking, music, woodworking, crochet projects, and grandchildren.

Anita Jarmann
Customer Service

I'd read *Home Power* for ten years, and was thrilled when I was hired to help with the order department. *HP* gave me the knowledge necessary to set up my own solar-electric system. I wisely chose to have a professional install it, but I knew what I wanted, and why. I currently live on 40 acres of remote, forested land, 3 1/2 miles from "services," adjacent to a National Forest. I share space with assorted critters—nine cats, one dog, one horse, and four chickens. My ongoing project is finishing my self-built house—doors and flooring would be nice!

Connie Said
Advertising & Circulation

I joined the *HP* staff in 1999. I am thrilled to be working for a company that is a big part of the planetary solution for sustainable living. I work in the business office with Myna and Anita, taking customer orders via phone, Web, and mail. We process the orders and get them out to you ASAP. My work also includes soliciting new advertising customers, and helping Karen with other advertising business. In my spare time, I enjoy life with my two wonderful children. I also work part-time doing anthropological research.

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You can reach any of the *Home Power* people via email. Just use their first and last name in this format: firstname.lastname@homepower.com

Q&A

Irresistible Biodiesel

Joshua and Kaia Tickell's article *Fuel for the New Millennium, One Low-Tech Solution to a High-Tech Problem (HP72,* page 84) was very interesting. I could not resist trying it out, as my country, Malaysia, produces lots of palm oil. Before proceeding, I consulted a chemist friend who told me that potassium hydroxide can be used as an alternative to sodium hydroxide (lye). Potassium hydroxide produces a softer soap!

The fuel turned out as described in the article after calibrating the containers for mixing the raw materials and carrying out a batch to test efficacy of the methoxide. Altogether I made approximately 12 litres of the biodiesel. My contractor was a bit skeptical about the biodiesel, but I managed to collar a couple of victims to try it out. The response was encouraging. They could feel their engines running more quietly and with less vibration because the biodiesel provides better lubrication than mineral diesel.

I did a further experiment. I doped gasoline with approximately 2 ml of biodiesel per litre of gasoline for use in a carbureted engine (1.5 ml per litre for fuel injection engines). The engine in the passenger car I am using did not suffer disastrous consequences. It performed beyond my expectations. The biodiesel is being used like a two-stroke lubricant for upper cylinder lubrication, and also as a fuel. The engine runs quieter and with less friction (all subjective).

When I manufactured the biodiesel, I controlled the pH (acidity) of the biodiesel to approximately pH 12 as my chemist friend suggested, with the help of pH strips. After discussions with him, I realised that the biodiesel is a really good fuel because the internal combustion engines we are using spew out tonnes of acid (sulphuric). This can be neutralised by biodiesel which has been set at the correct alkalinity. Any ideas on how much this pH should be and the dosage for gasoline and diesel fuel to neutralise the acid? Thanks to your good work, and I'm looking forward to many more articles. YC Lim • limyenchung@yahoo.com

Mr. Lim, It's great to hear about your success with making biodiesel in Malaysia. I'm glad you pointed out that potassium hydroxide (KOH) can be used instead of sodium hydroxide (NaOH). As I mention in From the Fryer to the Fuel Tank, *KOH is more readily available in some parts of the world, and you're right, it does produce a milder soap. In fact, if you need to add potassium to your soil (this is the purpose of many fertilizers), the leftover glycerin soap from a KOH biodiesel reaction is a perfect fertilizer.*

While I haven't done any serious experiments to this end, I have read a few recent papers on the use of biodiesel as a gasoline fuel additive. Although a gasoline engine will not run on biodiesel, very small amounts of biodiesel can apparently be added to gasoline to increase its lubricating and cleaning properties. I'd love to hear from more folks who have tried this.

I don't know all of the ins and outs of emissions chemistry, but I must mention here that biodiesel contains no sulfur and therefore emits no sulfur dioxide (SO_2). Fuels that do contain sulfur, like gasoline and diesel fuel, emit SO_2 as a result of the sulfur in the fuel attaching to the oxygen in our atmosphere. The only way to effectively neutralize sulfur dioxide emissions is to remove the sulfur from petroleum fuel or use a fuel which contains no sulfur, like biodiesel. Again, good work, and I look forward to hearing more about your biodiesel program as it develops. Joshua Tickell biofuel@best.com

DIY Wind

Home Power, I would like to know how to rewind an ordinary 3-phase motor into a permanent magnet, direct drive, slow-speed alternator for wind applications. I would also like to know how to rewind automotive alternators for direct drive, slow-speed wind applications in such a way as to eliminate the need for gear up and the field terminal.

What is the best aircraft alternator to use for wind applications? Do they need to be rewound for this also? If so, how do I make a direct drive, slow-speed unit to eliminate the need for gearing up and the field terminal? I will be anxiously awaiting your reply. Sincerely, David Hodgson

David, people have been awarded master's degrees for answering the questions you've asked. While I can't answer your question with an exact number of turns in a given coil of wire, I can send you in some good directions.

Way back in HP17, *I did an article titled* So You Want to Build a Wind Generator? *That article reviewed a number of plans, articles, and books about designing your own alternator or generator, or rewinding an existing one for different voltage, current, and rpm specifications. Many of the sources cited will take a bit of serious research to unearth, but they're still out there. Print copies of* HP17 *are still available from* Home Power, *and the issue is also on the* Solar2 *CD-ROM. Contact* HP *about availability and prices.*

Hugh Piggott of Scoraig, Scotland, released a book last year titled Windpower Workshop *(see the review in* HP65, *page 92). While not a cookbook recipe for winding your own, Hugh's book is another good reference for do-it-yourselfers.*

Another excellent reference is a book titled The Homebuilt Dynamo *by Alfred T. Forbes of New Zealand. This book was advertised in* Home Power *a few years back. This detailed book does lay out a recipe for building a permanent magnet alternator, from scratch. The* LeJay Manual *is great for rewinding DC automotive generators for wind generator applications, but not automotive alternators. It's available from small book publisher and reprinter Lindsay Publications, PO Box 538, Bradley, IL 60915 • 815-935-5353.*

Finally, if you are interested in rewinding automotive alternators or generators for low rpm, as for a wind generator, the old standby is a small book titled Autopower, *originally published in 1935. It's out of print, but you might be able to find it at your local library or through an out-of-print book-finding service such as Amazon.com.*

By the way, building your own alternator is not a project for the weekend handyperson. You will need full-blown skills in machining and welding, with side experience in mechanical engineering. Don't forget your solar calculator! Good luck with your project. Please keep us posted on your progress. Mick Sagrillo msagrillo@itol.com

Ceiling Fan to Wind Genny

Hello Richard, I was talking to you the other day about my rather unusual attempt to convince an old ceiling fan to produce power when taken down from the ceiling and stuck on the high end of a pole to have the extended blades turned by the wind. I know the unit won't be weatherproof, but I'd still like to know if any of your readers have tried a similar project, and if they were able to get some power out of that "decorative windmill."

So far, I have not been able to measure any electricity being produced by the fan motor even in a stiff breeze (shortly before the extended blades broke off and took flight into outer space…). I have used a standard ceiling fan with no light fixture, and I've bypassed all the switches to get a good connection to the windings of the motor—but still no sign of electricity. Since my electrical knowledge is limited, I wonder if one of your professional people or "advanced tinkerers" could give me a hint of what else I could do to get this to work.

I've heard that it's possible to use any AC or DC motor as an alternator producing at least unregulated voltage. Doesn't this apply to ceiling fan motors? Any comments, ideas or reports, or Web site links of similar projects are thankfully welcomed. Kind regards, Art boats@artcanoes.com

Hi Art, I have never tried this but it should work in theory. As you discovered, ceiling fan blades are not very robust, so I am not sure that the idea is a winner. It is true that any motor can be used as a generator. I suspect your fan motor is an induction motor. In that case, you will need to connect capacitors to the motor. The correct size of capacitor will depend on the speed of the machine, but there are wind turbines that work on this principle.

Making it work can be ticklish business. You will also need some magnetism in the machine to start the process off. You will need to connect a battery across the windings to magnetise the core before it will be able to excite itself as a generator. A brief spark will do the trick. Another solution would be to fit magnets to the rotor of the motor, in which case the capacitors would not be needed. The spacing between magnet centres should be about the same as the space between one side of a coil and the other. Keep on experimenting! But be careful—when it works it may give you more voltage than you bargained for. Hugh Piggott hugh.piggott@enterprise.net

Very Small Computer UPS

Hi there, I was wondering if you could help me find a UPS system that would accept quasi-sine wave input. I do a lot of switching around on my system, and I would like to have a steady supply of power. The load would be about 300 watts or so, so the printers could get shut off and not get crazy. My battery voltage is nominal 144 VDC, and the other systems I work on vary from 12 to 60 volts nominal. It's hard to find a very small efficient 144 volt inverter to just keep hooked up to my computer.

If you know of one that would work, I would like to buy it from whoever you would suggest and then probably buy a few more for some people that I know that have the same problem. We have tried about three standard ones—and even one that you could adjust the voltage down 12 volts from 120—but they would not recognize the inverter input. Thanks for your help. I figure that you guys will know if anyone will. Jerry Lilyerd lilyerd@ncis.com

Hello Jerry, I'm not surprised that you've had problems getting a UPS to accept power from a modified sine wave inverter. How 'bout it readers—is anyone out there running a commercially made UPS from a mod-sine inverter? Richard Perez

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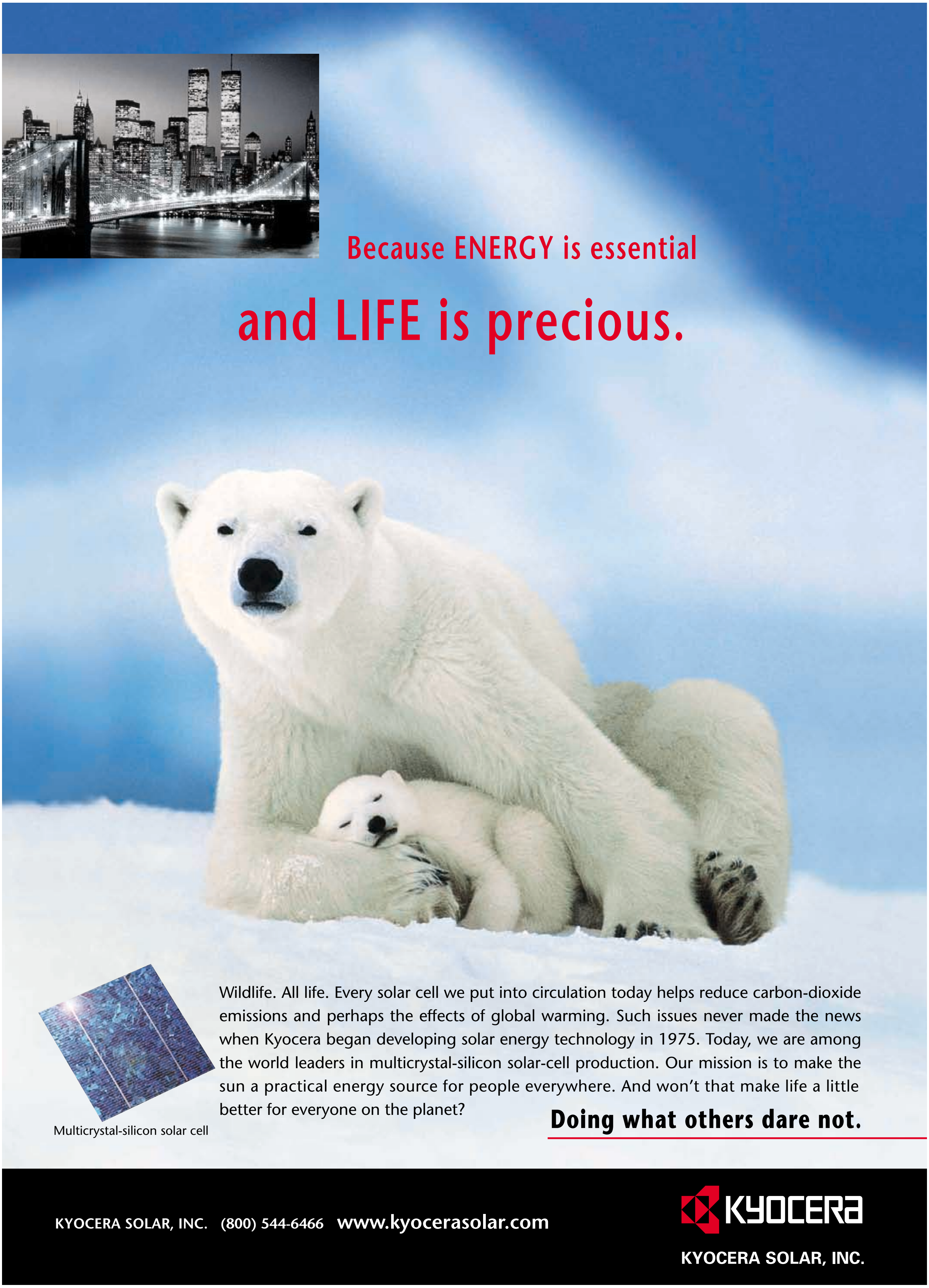
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- ❑ Transportation power (electric vehicles)
- ❑ Water heating
- ❑ Space heating
- ❑ Business electricity

RESOURCES: My site(s) have the following renewable energy resources (check all that apply)

- ❑ Solar power
- ❑ Wind power
- ❑ Hydro power
- ❑ Biomass
- ❑ Geothermal power
- ❑ Tidal power
- ❑ Other renewable energy resource (explain)

The GRID: (check all that apply)

❑ I have the utility grid at my location.

I pay ______¢ for grid electricity (cents per kilowatt-hour).

____% of my total electricity is purchased from the grid.

❑ I sell my excess electricity to the grid.

The grid pays me _____¢ for electricity (cents per kilowatt-hour).

(continued on reverse)

I now use, or plan to use in the future, the following renewable energy equipment (check all that apply):

NOW	FUTURE		NOW	FUTURE	
❑	❑	Photovoltaic modules	❑	❑	Methane digester
❑	❑	Wind generator	❑	❑	Thermoelectric generator
❑	❑	Hydroelectric generator	❑	❑	Solar oven or cooker
❑	❑	Battery charger	❑	❑	Solar water heater
❑	❑	Instrumentation	❑	❑	Wood-fired water heater
❑	❑	Batteries	❑	❑	Solar space heating system
❑	❑	Inverter	❑	❑	Hydrogen cells (electrolyzers)
❑	❑	Controls	❑	❑	Fuel cells
❑	❑	PV tracker	❑	❑	RE-powered water pump
❑	❑	Engine/generator	❑	❑	Electric vehicle

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