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HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

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THE HANDS-ON JOURNAL OF HOME-MADE POWER

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Access

Home Power Magazine
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Think About It

"When you come to the fork in the road, take it!"
Yogi Berra

Cover

Solar energy was a step-by-step process for Rick and Pat Walker. Story on page six.

Photo by Therese Peffer.

Puzzles

Karen Perez

Well folks, here we go again. Home Power is again at a crossroad. The time has come for a major change in the appearance of Home Power. We know the first reaction of many will be, “Oh no, they’ve sold out and gone glossy.” This decision was not made lightly. It took several weeks of round ‘n round within our own crew to reach this decision. We’re not moving to offices in New York. We’ve not sold out to a big publishing house. The content and subscription price WILL remain the same. We’re still in our techno-primitive household here on Agate Flat. We’re the same demented crew.

Why Change?

The reasons are many and complicated. Getting the info out to more folks, newsstand sales, advertisers, and environmental impact are the biggies.

Why worry about getting out on newsstands? Many of you would not be reading this if it weren’t for our being on newsstands. Many of you might not have picked up Home Power without the color cover. Many people tell us how hard the information found in Home Power is to find. Many newsstand buyers won’t give us a chance without the “look”. Our newsstand sales have grown 175% in the last year. This could easily triple or quadruple, with the right appearance.

Why worry about advertisers? They help pay the bills and give us all a much broader selection of products and services to choose from! Many of our advertisers have complained about their logos filling in and muddy looking photos. Some of these advertisers won’t advertise again until this problem goes away (i.e. print quality improves), some potential advertisers won’t even give us a try. Advertisers also want to reach as many potential customers as possible. So we are again back to newsstands and appearance.

This brings us around to environmental impact. I have spent many hours on the phone talking to environmentally conscience magazines, paper mills, ink manufacturers, and environmental organizations about this issue. Many more hours have been spent digesting literature from all of the above. This move will reduce the environmental impact. This is complicated so read on!

A very short printer primer

Currently the insides of Home Power are printed on an open web press. This type of press does not have a heater to help dry the ink as the newly printed paper comes out of the press. The amount of ink that soaks into the paper is hard to control. Newspapers use open web presses. This type of press uses giant 5000 pound rolls of paper. It currently takes two plus of these giant rolls for our 15,000 press run. The type of paper that open webs can run are limited.

The covers are printed on a sheet fed press. This type of press does have driers and produces a much finer looking print job. The limit here is the type of paper used. Uncoated recycled papers soak up a lot more ink and the colors look darker.

People

David Booth
Barry Brown
Joel Chinkes
Sam Coleman
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Bob-O Schultze
Tom Stockebrand
Pat Walker
Rick Walker
Michael Welch
John Wiles
Robert Wills

Printing

Southwest Offset, Gardena, CA

Cover 50% recycled (40% pre-consumer, 10% post-consumer), low chlorine paper. Interior is 50% recycled paper. Soybean inks used throughout.

Legal

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The move we want to make is to a heat set, computer controlled web press. This type of press does have heaters and much more control of the amount of ink that is laid down on the paper. It allows a much wider choice of paper. It also means much finer halftones (photographs) and much cleaner type. Most magazines use heat set web presses.

We are also planning to move to a different type of binding. We are at the ragged edge of the saddle stitch (stapled) binding technology we have been using. The machinery cannot gracefully handle 116 pages. The image on the page appears crooked and sometimes because of this "slipping" we have come very close to losing parts of pages. The binding we are moving to is called perfect bound. This binding has a spine. The machines that do this type of binding can easily handle our page count and gives us room to grow.

The paper puzzle

We have made no firm decision on just what paper we will be moving to. We are still gathering information. We have learned a lot though.

The main problem with "glossy" clay coated paper is public perception. Clay coated paper is between 28–40% coating by weight, that means less wood fiber is used. The coating is made from calcium carbonate, starch and clay. Coated stock can have a much higher postconsumer paper content and still be strong enough to be run through the high speed rollers of the web presses without tearing. The clay coating helps strengthen the paper. Coated paper does not soak up as much ink. For the cover, we are currently looking into a 70 pound coated paper that contains 75% postconsumer fiber made by a non-chlorine mill. The bleaching of the fibers is accomplished with oxygen instead of chlorine. Chlorine bleaching forms dioxins, a nasty toxic waste This coated paper is 60% wood fiber and 40% coating. We are also researching a 50% recycled (between 15–20% postconsumer paper) super calendered paper for the interior. This paper has less of a coating and is not as shiny. This paper is 72% wood fiber and 28% coating.

Clay coated paper can be recycled, but it's not accepted everywhere—yet. This is slowly changing as more people demand recycled paper and as more recycled mills are built. The demand for the so called mixed paper (magazines, the dreaded junk mail etc.) is expected to quadruple within the next year. The reason that the demand is expected to increase so radically is because of the increasing number of recycled paper mills. If we all continue to do our bit and demand recycled paper more and more recycled paper mills will be built.

Inks

We have used only vegetable oil inks for the last couple of years. We will continue to use low volatile organic compound (LVOC) inks. Even though vegetable inks are more environmentally safe than "dead dinosaur" types of ink they still contain between 6-10% nasty stuff in the form of heavy metals. So the less ink used, the better and we're back around to coated paper which absorbs less ink.

Putting the puzzle together

It's a pretty complicated puzzle. We want to keep everyone happy. We want to be environmentally conscientious. We want renewable energy to spread. It's a real juggling act. Is this selling out? We don't think so and hope you won't either.

I'd be happy to discuss this in more detail. Just give me a call at 916-475-3179, but be prepared, printing & paper is my version of "nerd".

Karen

Solar As You Go

Therese Peffer & Amanda Potter

Pat and Rick Walker live in a beautiful remote area of northern California with their cockatiels, Sassy and Junior, two cats, and two horses. They didn't leave amenities behind when they left town — electricity and hot water are provided by the sun. They communicate with friends and family and run a solar business with their radiotelephone and CB radio. "We're the learn-as-you-go people," Pat says. "We'd never built a house, we'd never done plumbing, we'd never done electrical wiring." "We'd never drilled a well," Rick added. They are still learning as they go, with no end in sight.

Sunny Beginnings

In 1987, the Walkers bought 40 acres of beautiful tree-covered property four miles outside the small town of Big Bend, California. For the first three years, they set their 23 foot trailer among the pines and oaks. Pat had started reading books and catalogs on solar years before. Three years ago they equipped the trailer with photovoltaic panels and third-hand golf cart lead acid batteries. "All the neighbors went together and bought panels so we could get a good price — everybody got two," Pat said.

When they started building a log home two years ago, they transferred their solar electric system from the trailer to their new home. The utility lines run about a mile away from their home, but for the Walkers, it wasn't even a consideration. "I like doing solar." Pat says. Rick followed, "It was economical for us to use solar....We like it more than paying a bill. Boy, that gets old!"

Solar Business

For the Walkers, starting their solar business, Lotsa Watts Solar, was a natural step. "I bought solar equipment for a couple of years for everybody around here," Pat said. "I knew everybody." Pat was used to spending time on the phone getting deals for herself and her neighbors. Working on the phone from her home works well for her. The Walkers didn't want to drive an hour and a half into Redding, the nearest city, to work. They wanted to work where they live.

Power System

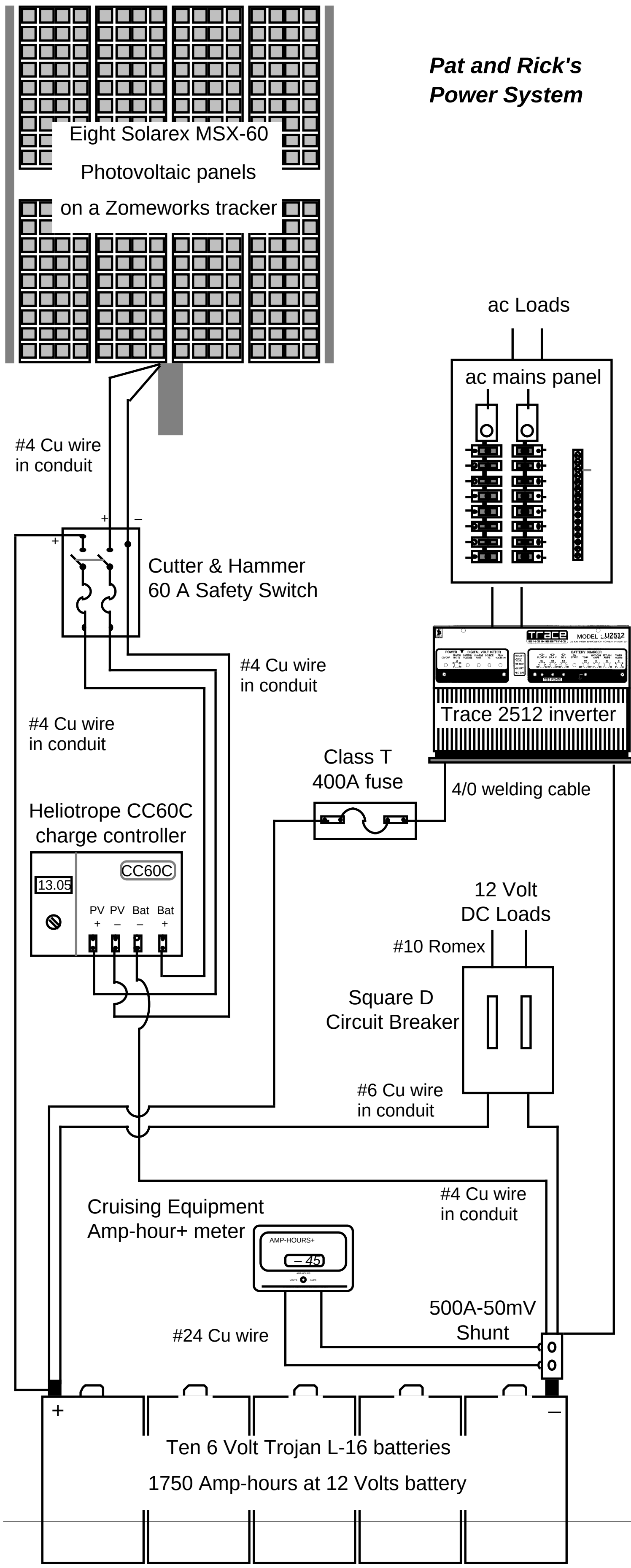
Rick and Pat had done the wiring on their trailer and the solar water pump with the help of a neighbor. They wanted the electrical system for the house "done right" so they called Bob-O Schultze of Electron Connection. Their eight Solarex MSX-60 PV panels sit on a Zomeworks tracker. The Walkers like the simplicity of the Zomeworks, although they have to "wake it up" in the morning (turn it towards the sun). The panels charge the 12 Volt battery at 32 Amperes on a cold sunny day. The tracker increases the panel's power output on a yearly average by twenty-five percent. The tracker's pole is connected to a ground rod to protect against the build up of static electricity which can attract lightning.

Ten 6 Volt, 350 Amp-hour Trojan L-16 deep cycle lead-acid batteries store the sun's energy — a total of 1750 Amp-hours of storage. A Heliotrope CC 60C charge controller prevents overcharging when the battery voltage rises too high. The CC 60C also contains a 60 Ampere Schottky diode to prevent current from flowing back from the batteries to the panels at night and being dissipated as heat. In keeping with the National Electric Code, Bob-O installed a Cutler & Hammer 60 Amp double pole fused safety switch. The switch disconnects the charge controller from the solar array and battery.

The system sits in the middle of the house. A central location is good for keeping tabs on energy usage and in case they need to turn the power off in a hurry. After reading about Home Power's experience with a battery exploding in the living space (HP#27), they decided they will build an enclosure for the battery. Hydrocaps replace the standard battery caps. These special caps allow the recombination of hydrogen and oxygen which are normally vented by the battery at the end of its charging cycle. This lessens the potentially combustible mixture of hydrogen and oxygen and minimizes water lost from the electrolyte.

A Trace U2512 inverter converts the DC electricity from the battery to ac electricity for the loads. The 2500 watt inverter is protected by a Class T 400 Ampere DC-rated fuse. The continuous output current rating of the inverter is 20 amperes at 120 volts rms. Its output is connected directly to an ac circuit breaker box. The Walkers did their own ac wiring following the book, *Wiring Simplified*.

The DC loads are protected by a DC rated Square D circuit breaker. A Cruising Equipment Amp-hour+ meter uses a



500 A, 50 mV shunt to keep track of current flowing in and out of the battery.

Energy Usage

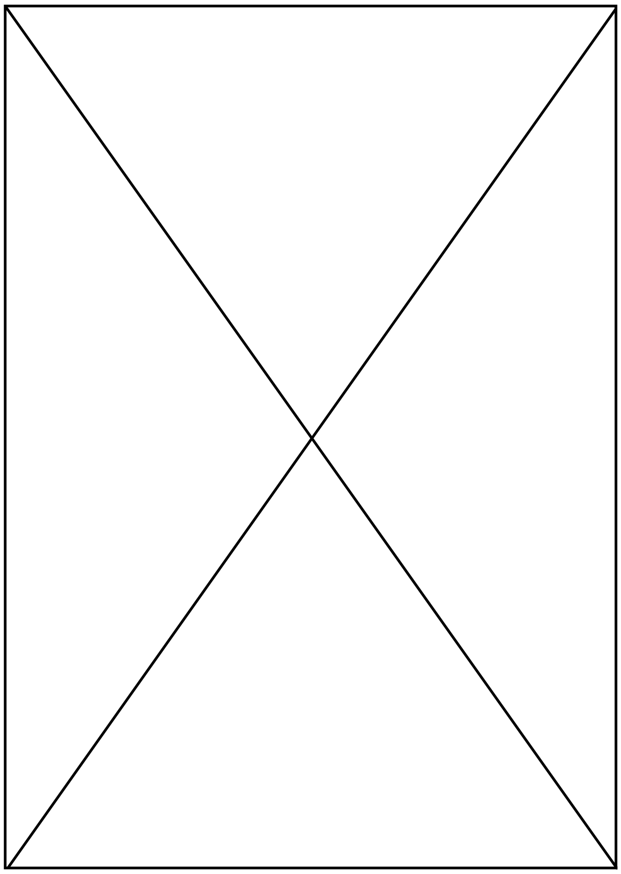
The Walkers don't have a generator. Pat was adamant about not using a gas generator for a backup on the days the sun doesn't shine. They sized their system accordingly and watch their usage when the battery starts to get low. Pat says she doesn't like to use more than 50% of the battery capacity.

The primary consumer of power year round is the Sun Frost RF-12 refrigerator/freezer. This last winter when the batteries started getting low — about 500 Amp-hours down — the Walkers turned off the Sun Frost. "We had all these storms. It started looking pretty bad, but we probably could have kept going," Pat said. Rick carved an "ice box" outside in a snow bank, framed it with 2 x 4s, and fashioned a door of plywood. It worked great for three weeks — then the sun came out again. The only problem with the outdoor cooler was when foxes got in and stole 6 pounds of butter! To reduce Sun Frost use the rest of the year, they have a small "cellar." A trapdoor in the floor opens up to reveal beer, potatoes, garlic, and other foods kept cool most of the year.

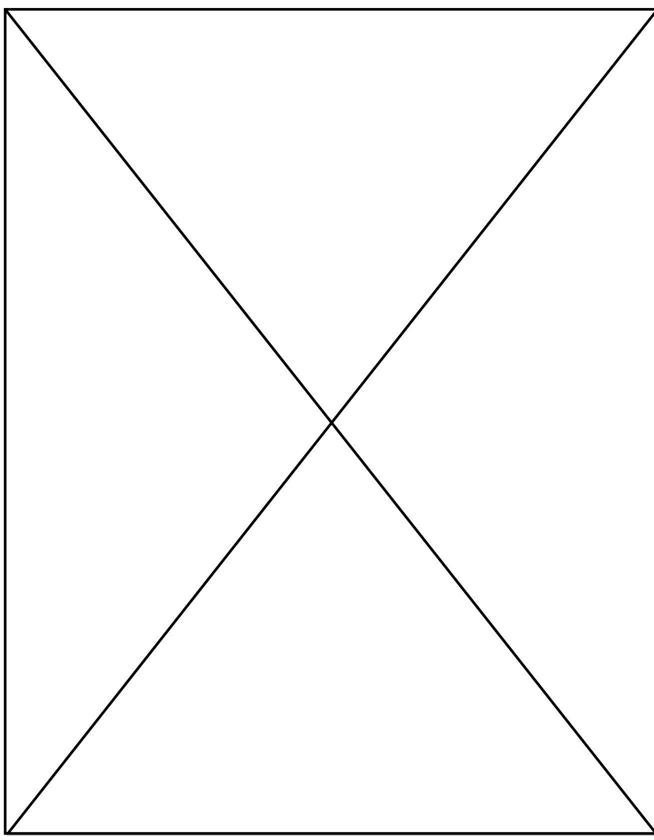
Another big consumer of electricity is lighting. Pat likes to read at night, so for efficient lighting, they use compact fluorescent lights. All of their lighting is ac lighting. Ten lights are 7, 11, and 15 watt Osram compact fluorescent lights; three are Lights of America 32 and 22 watt compact fluorescent lights. The 15 watt lights are just right for night reading!

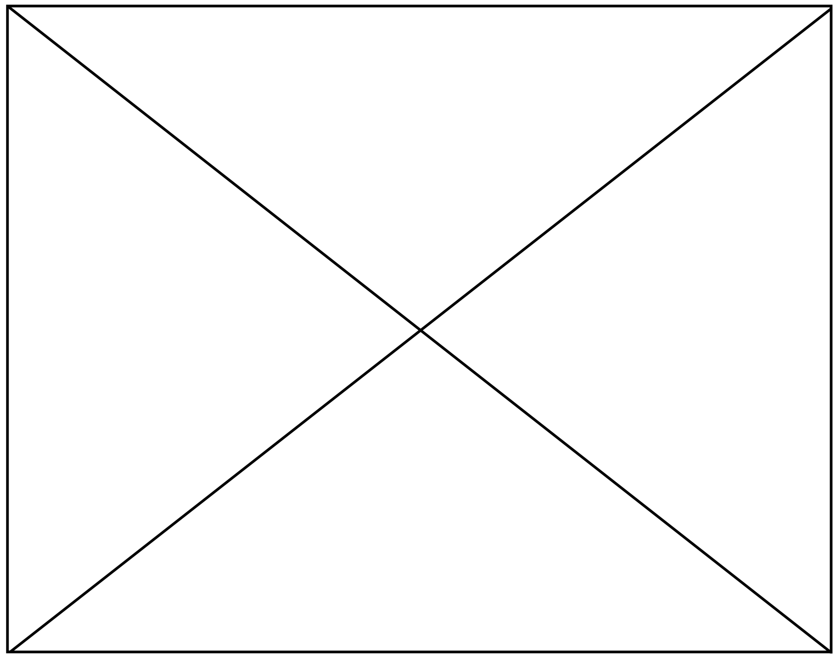
In the summer, they have excess electricity — a great time to make bread! Pat now has an electric bread machine — the kind that you throw all the ingredients in, wait four hours, and then eat. Pat says that the bread machine draws about 2 Amps at 12 Volts for much of the mixing and kneading cycle, and then draws 60 Amps at 12 Volts during the baking cycle (about 50 minutes). Another summertime appliance is the 500 watt microwave oven.

Pat really enjoys her Amp-hour meter. When she is curious how much an appliance draws, she can run over to the meter, flip a switch and watch the numbers change. Now she can see first hand whether appliances meet their specified power requirements. One of the reasons she hangs on to

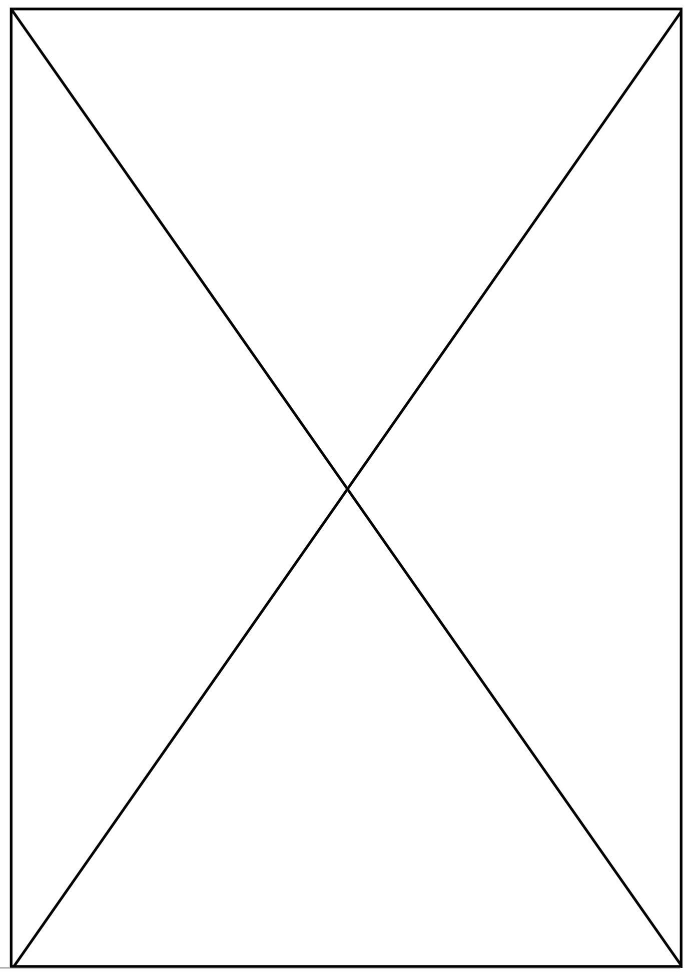


Above: Rick Walker and his cockatiels, Sassy and Junior.
Below: Rick and Pat Walker smile for the camera.





Above: Pat Walker, staying warm inside on a snowy day, doesn't mind explaining their solar system.
Below: How much is that vacuum drawing? Pat checks out the Amp-meter.
Photos by Therese Peffer



Where the Energy Goes...

12 Volt DC Loads	*DC Amps*	*Hrs/ Day*	*A-hrs/ day*	*Days/ Week*	*W-hrs/ week*	*W-hrs/ day*
Sun Frost RF-12 refrig/freezer	3.5	8.00	28.0	7	2470	353
Pumps for water heater	0.5	7.00	3.5	7	309	44
Ceiling fan	0.3	12.00	3.6	7	318	45
Nicad battery charger	0.3	24.00	7.2	2	181	26
					Subtotal	468
ac Loads						
Compact fluorescent lights	3.0	6.00	18.0	7	1588	227
1965 Kenmore washing machine	10–45	0.45	25.0	5	1575	225
500 watt microwave oven	50.0	0.25	12.5	7	1103	158
Hitachi Automatic Home Bakery	2–60	4.00	68.0	1	857	122
Coffee maker	50.0	0.07	3.5	7	309	44
Toaster	100.0	0.03	3.0	7	265	38
Kirby vacuum cleaner	40.0	0.50	20.0	1	252	36
					Subtotal	850
					Total Watt-hours per day	1318

her 1965 Sears washing machine is that it draws less power than newer models.

Hitting Water

Digging a well was one of the first things the Walkers did when they moved to their property. They borrowed a DeepRock Hydra-Drill to drill their well. The Hydra-Drill's two-stroke engine runs the bit at the end of the pipe; water is used to flush out the tailings. With the help of some friends, they drilled a 90 foot deep well, using five foot sections of galvanized pipe. “You just keep putting pieces on and go deeper and deeper!” Pat said. The Hydra-Drill is not a heavy duty machine — at 73 feet, they hit rock. Fortunately, there was only 4–5 inches of rock, but it took hours to get through those few inches! They cased the well down to about 65 feet. “We got water for that one year,” Rick says, “but then things kind of dried up.” “We had a lot of water — it's probably overflowing now,” Pat added, “but the drought happened and we got less and less, and pretty soon we were pumping mud and thought we better quit.”

Luckily there was a spring about 15 feet from their property. Pat and Rick promptly bought the small piece the spring was on and redeveloped the spring. “We started pumping out of the spring.” Rick said. “About 60 years ago somebody framed it in with cedar....we pumped it all out, and dug it out.” Now they have a steady supply of cool water for themselves, their garden, and their horses.

Solar Water

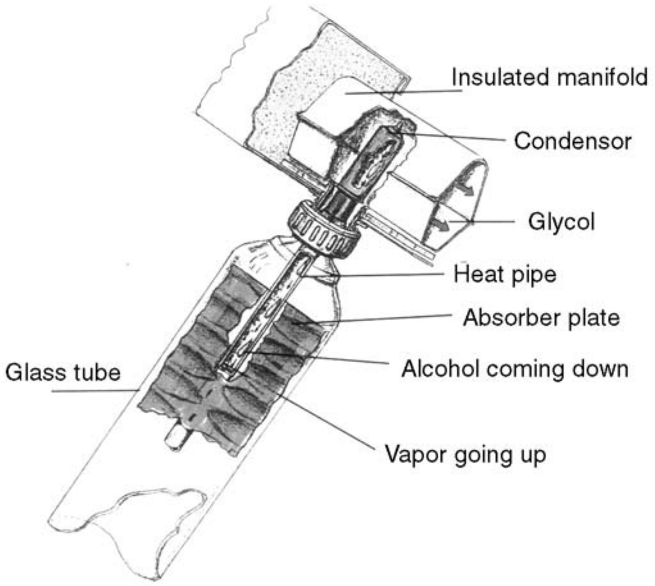
They use a solar-powered Flowlight Slowpump to get water from the spring. Two Solarex MSX-60 PV panels power the rotary pump; the panels are mounted on an old angle-iron bed frame on a pole near the spring. The water from the spring has a fair amount of sediment, which the Flowlight pump doesn't like. Currently the water is filtered, but the Walkers plan to build a holding tank down below the spring this summer. The pump moves the cold water up 70 feet elevation to a 1550 gallon storage tank that is about 1000 feet away. Water reaches the house by gravity flow — the tank sits about 50 feet above the house. A run-dry switch shuts off the pump when the water gets too low.

Pat and Rick have two different pump heads for the Flowlight pump. The smaller pump head pumps about 40 gallons per hour, and only needs one panel to power it. The big pump requires the output of both 60 Watt photovoltaic panels and pumps about 180 gallons per hour.

A seven Amp SunSelector Linear Current Booster (LCB) made by Bobier is used to run the higher output pump head. The two 60 Watt Solarex panels, wired in parallel, put out 17 Volts and seven Amperes on a cold, sunny day. On cloudy days, the current out of the two PVs will decrease quite a bit. The bigger pump head requires seven Amperes of current to run. The LCB converts the power (Volts times Amperes) from the PVs to a lower voltage and higher current for the pump. There is no loss in power (except through the small inefficiency of the LCB) — the pump just sees more current but less voltage than what the panel is producing.

Hot Water

The Walkers heat enough water for all the showers, baths, and dishwashing they need. They use cold water for washing clothes. Water is heated by both their wood stove and a Thermomax solar collector. The hot water is stored in a 120 gallon tank they bought second hand. Bob-O helped them put up their Thermomax system just before last summer. “We'd been getting hot water from the wood stove and of course I don't want to run that in the summer! The woodstove is great for winter though, we get all the hot water we need,” Pat said.



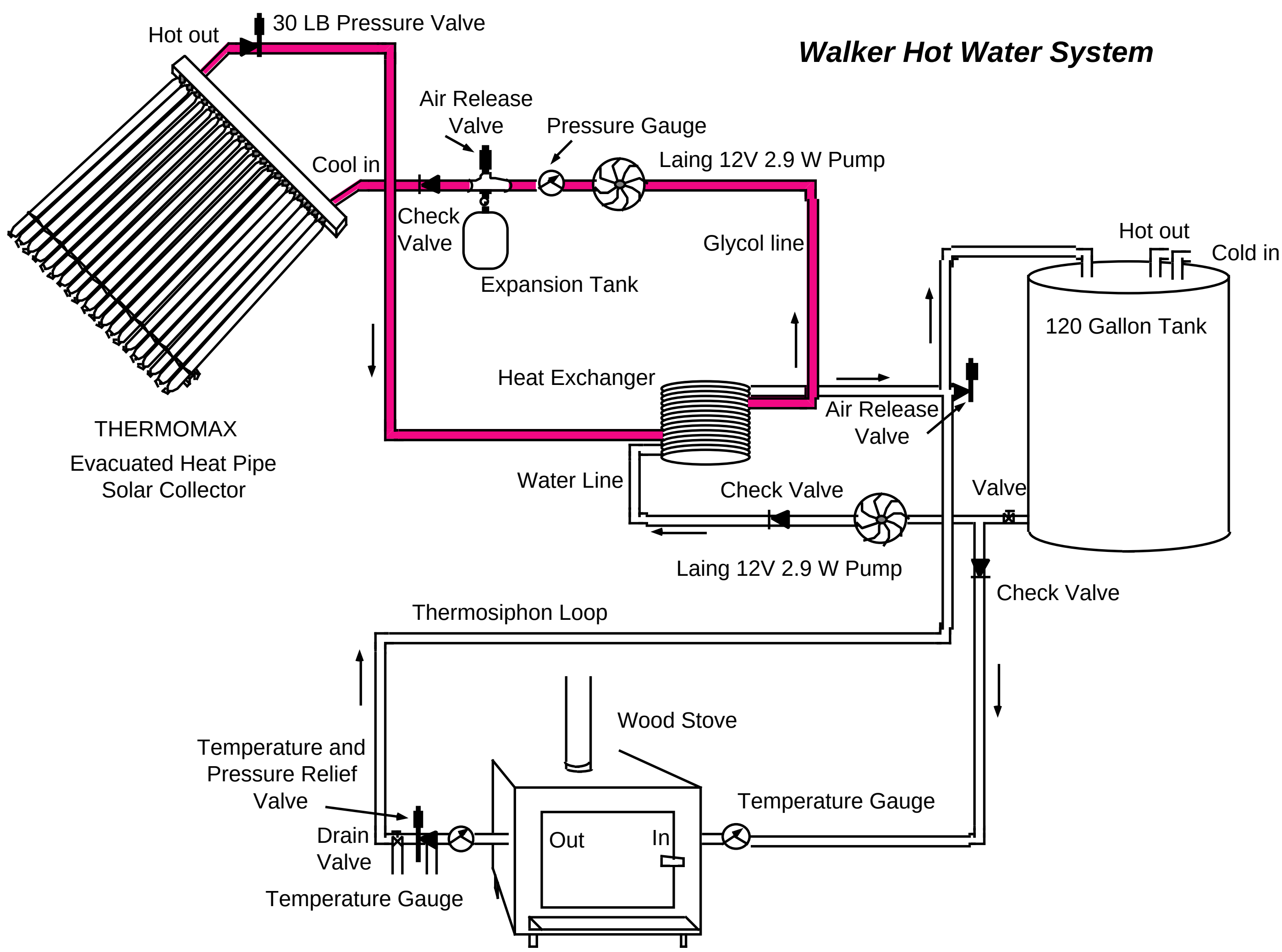
Above: Detail on one of the Thermomax evacuated tube collectors, which uses solar to heat water even on cold sunny days and partially cloudy days.

The Walkers are very happy with their Thermomax solar water heater. They've found that the evacuated tube collectors heat water very well even on cold, cloudy and windy days. They like the fact that they don't need to worry about a lot of weight on their roof or about freezing pipes. Their system is made up of a manifold and 20 solar collector tubes and only weighs 100 pounds (45 kg). Initially the Walkers had problems with their Thermomax system. They got a good deal on a water storage tank and didn't realize that there was sediment at the bottom of it. The sediment was circulating in the water lines and eventually clogged the heat exchanger. Fortunately, once the dirt was flushed out, the problem was solved.

How the Thermomax Works

The Thermomax works like a one-way themal valve. Heat from sunlight can only pass one way — in. Sunlight passes into an evacuated glass tube and is absorbed by the black

Below: The Walkers' woodstove and solar hot water system. Diagram by Amanda Potter



absorber plate. The absorber plate has a wavelength selective semiconductor coating which enables high energy absorption and low heat radiation losses. Even infrared rays on cloudy days are absorbed and changed into heat. A heat pipe welded to the absorber plate transfers this heat to alcohol. The absorber and heat pipe are enclosed in a glass tube. The air is evacuated to prevent heat loss by convection and conduction. The vacuum also protects the absorber plate, selective coating and heat pipe from rain, moisture, air and pollution.

The heat pipe contains a liquid (alcohol) which undergoes an evaporating-condensing cycle. Heat from the sun evaporates the liquid. The vapor rises up the heat pipe and condenses in the manifold transferring its heat to the glycol. The condensed alcohol flows down the heat pipe to the evaporation zone completing the cycle. Heat is transferred quickly and in only one direction allowing sustained high temperatures in the collector. The glycol is circulated from the manifold of the Thermomax into the house where it transfers the heat to the water via another heat exchanger.

Hybrid Hot Water System

If wood is burning in the wood stove, water circulating in the stove heats up and expands. This causes the water to rise up to the water tank — the Walkers put their 120 gallon water tank upstairs on the second floor. A thermosiphon is thus created from the bottom of the tank, through the wood stove, to the top of the tank. See diagram on the bottom of the previous page. If the glycol at the Thermomax is nine degrees warmer than the water in the bottom of the tank, then temperature sensors cause two 12 Volt DC, 2.9 Watt Laing pumps to turn on. One circulates glycol out of the Thermomax through a heat exchanger and back again. The other circulates water from the bottom of the storage tank through the heat exchanger to the top of the tank. Heat from the glycol is transferred to the water at the heat exchanger.

Heat

The Walker's home is heated with wood heat, an extra large Consolidated Dutch West wood stove that sits in the center of the house. Rick gathers black oak and other wood from around their area — they use about three cords of wood per year. At 2600 foot elevation, they see about 6–8 feet of snow every winter. They make good use of their cross-country skis to feed the horses and get around! Pat and Rick like to stay warm — the ceiling is insulated to R-30 and the floor is insulated to R-19. Large windows on the south side of the house let in the sun's light and heat. They installed a 12 Volt fan in the high ceiling to circulate heat in the winter (and helps cool things down in the summer.)

Pat and Rick Walker's System Cost

Solar Electric Equipment	*cost*	*%*
Eight Solarex MSX-60 PV panels	$2,700	23.8%
Ten 6V Trojan L-16 lead-acid batteries	$1,500	13.2%
Trace 2512 inverter	$1,275	11.2%
Eight-panel Zomeworks tracker	$800	7.0%
Miscellaneous cables, wires, etc.	$250	2.2%
Cruising Equipment Amp-hour+ meter	$295	2.6%
Heliotrope CC-60C charge controller	$285	2.5%
Cutler&Hammer 60 Amp safety switch	$115	1.0%
Twenty Hydrocaps for L-16 batteries	$130	1.1%
400 Amp fuse	$69	0.6%
Inverter cables	$75	0.7%
Subtotal	$7,494	

Solar Water Equipment	*cost*	*%*
Thermomax solar water heater system	$2,500	22.0%
120 gallon hot water tank (used)	$200	1.8%
Two Solarex MSX-60 panels for pump	$675	5.9%
Flowlight 1305 pump	$375	3.3%
SunSelector LCB-7MT	$90	0.8%
Run-dry switch for pump	$30	0.3%
Subtotal	$3,870	
Total	$11,364	

Still Going...

Solar energy is a way of life in the Walker's neighborhood. Although the utility lines keep getting closer, there are plenty of folks nearby using solar power. Last summer a forest fire raged over the area, burning a home they had owned in Round Mountain. Part of the solution for homeless fire refugees was solar. Altogether, 330 homes were lost. The Walkers are doing their part to help (see story on page 37). "We're trying to help people down there buy stuff. We're selling it to them at cost," Rick said.

Pat and Rick are still finishing their house and system. As with any new home, they can always find new projects! And as solar equipment dealers, the Walkers keep their eyes on new things to add to their system. They like to get others interested in solar — Pat says there is always someone in line to buy her used equipment!

The system continues to grow, just as it has from the beginning, a little at a time. "We've scrimped and saved, we've done without much for a long time, we do it pretty easy," Rick says. "I never thought I'd be this fortunate to live up here." And with solar — electricity, water, and business — they can.

Access

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Authors: Therese Peffer & Amanda Potter, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Ελεχτρον Χοννεχτιον
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Solar Pioneers in Central America

John H. Rogers

In La Aradita, a small village off a dusty road in Honduras' western state of Santa Barbara, atop an adobe house with a red clay tile roof stands a harbinger of things to come, an answer to the darkness in the rural areas....a solar panel. Luis Alonzo, who raises cattle and coffee in the La Aradita area, is the proud owner of a 48 Watt solar module. The photovoltaic module has been faithfully providing energy for lighting, radio, and television since installation in December 1991.

Alonzo is a solar pioneer, among the first to take advantage of a new program in Honduras led by the U.S. Peace Corps and Enersol Associates of Somerville, Massachusetts. This program aims to bring light to the country's rural population in an economical, environmentally-friendly way.

Energy in Honduras

A third of Honduras' five million people are served by the national power company. The electricity comes from one large dam and several smaller ones, plus a few grid-tied thermal diesel plants and smaller municipal systems. The total installed capacity is some 400 megawatts. The rest of the population relies on traditional off-the-grid solutions such as small generators, kerosene-fueled Coleman lanterns, hurricane lanterns, candles, and sticks of ocote, a bright-burning type of pine.

Honduras' experience with solar before the Peace Corps/Enersol push was almost entirely limited to a few bigger or community-wide systems for pumping or clinical refrigeration. These efforts generally suffered from lack of local know-how, proper technical support, and a sense of personal ownership on the part of the beneficiaries.

The first step towards development of a sustainable program in solar-based electrification came in 1989, when Enersol Associates appeared on the scene. Enersol is a non-profit organization dedicated to spreading the solar gospel. It was founded in the mid-1980s to promote solar-based rural electrification in the Dominican Republic through training and small business development.

With support from Sandia National Laboratories (SNL) and others, Enersol began to explore the possibilities of expanding its highly successful Dominican program into Central America. Over the next couple of years, Enersol provided some training and small demo systems.

The solar effort kicked into gear in late 1991, with a couple of five-day Enersol workshops. The workshops aimed at sparking interest within local non-government organizations (NGOs) and installing various demo systems in western Honduras. One other veteran Peace Corps volunteer and I began to focus almost exclusively on getting things moving in the solar field.

A year later, solar businesses were up and running in a few areas of the country. Fifty-some systems were installed in houses, small stores, churches, and health centers. Financing funds, albeit small ones, were available — a small beginning, but a beginning nonetheless.

Meeting the Needs

The systems we're promoting here are far smaller than those usually portrayed in Home Power, but so is the current household demand in rural areas. The majority of the systems to date have included a 40 to 50 Watt panel, a 12 Volt battery, a locally-manufactured control box, and four to six 15 Watt fluorescent and incandescent lights. Plus there are hookups to black-and-white televisions, tape players, radios, blenders, and anything else we can find (including, to date, a Casio keyboard and a concrete vibrating machine for roof tile manufacture).

For photovoltaic panels, we use what's available. So far we have tried 40 Watt Siemens panels, 48 Watt and 20 Watt Hoxan panels, and 51 Watt Kyocera panels. Siemens was the only company with representation in the country, but it wasn't doing much with solar in Honduras when we began.

Storage

For storage, we started with Honduran lead acid car batteries, choosing 75 to 105 Amp-hour batteries for 40 to 50 Watt systems. I was pushing for the larger capacity batteries, figuring that the owners would use a smaller percentage of the total capacity and therefore would benefit from longer battery life. In reality, some of the larger batteries seemed to get the owners used to deficit spending, using a little more each day than the panel generated. By the time the control box marked low voltage, they were days from a full charge. Those with smaller batteries seemed more attuned to the panel and battery (and weather) relationship and the limits of their systems. These folks were happier in the long run.

Recently we tried NAPA car batteries, figuring that imported batteries would offer better service without too much increase in price. It's too early to know the results.

My partner on one of Honduras' Bay Islands had other prospects. Located off the north coast of the mainland, the Islands have good contact with the U.S. because of direct shipping and a large English-speaking population. The project started there with imported marine batteries and now uses true deep-cycle Trojan batteries.

As soon as someone can come up with a good way to get those on the mainland, that'll probably be the way to go, even given the 40–50% import duties on batteries. In the long run, as they say here, the cheap option is expensive, the expensive option is cheap.

Another distant possibility is local manufacture of more appropriate batteries. For both economy and sustainability, the greater the local component, the better, especially as currency devaluation is a continual concern. But manufacture of deeper-cycle batteries will require high quality materials and lots of supervision, not to mention capital — all a bit beyond our present capacity.

Control box

The manual control boxes manufactured in Santa Barbara are very basic. The design — the same used in the Dominican Republic — consists of a disconnect switch, diode, fuseholder, and battery voltage indicator lights (the insides of a Radio Shack #22-1635). Also there are connections to the panel, battery, and lights, plus a voltage reducer for 6 or 8 Volts (using the ECG 962/964 as suggested in HP #30).

Lighting

The small fluorescent lights are assembled by the same small company in Santa Barbara, comprised of my electrician landlord and his brother. They special-order the metal boxes from a national fluorescent fixture maker, and add an imported ballast. The fluorescent tubes, 14 Watt (F14T8) or 15 Watt (F15T8), are available locally, but sporadically, so the lamp assemblers have to be versatile. We've also used the 8 and 15 Watt Thinlite fluorescent lights — so far, so good.

Low-wattage 12 Volt incandescent lights are still very hard to find on the mainland. We had to bring them in from the Bay Islands or hand carry them back from the U.S.

Of the accessories, the most in demand are television sets — for news, soap operas, and sports — and radio/tape players. The day we went back to Alonzo's house to hook up the TV, the battery got a good workout because of an all-important futbol game which attracted a crowd of neighbors. Blenders, too, are popular, given the heat here and the abundance of tropical fruits. The *licuados* — blended fruit drinks — are magnificent.

Economics and Energy Budgets

A 50 Watt system, installed and guaranteed, is selling for about $700 U.S.: panel: $370; control box: $30–35; battery: $70; and lights (fluorescent): $30–35 each. What kind of bang do customers get for their buck? From a 50 Watt panel, we generally plan on having about 200 Watt-hours of energy available daily. We take into account insolation data on the one hand and losses (panel efficiency, battery auto-discharge, etc.) on the other. A small rural store, for example, might budget that energy in the following way:

Energy Usage for a Honduran store/home

Location	*12 Volt Appliances*	*Rated Watts*	*Hours/ day*	*Watt-hrs/ day*
Store	fluorescent light	15	3.0	45
Store	black & white TV	15	2.0	30
Kitchen	fluorescent light	15	2.0	30
Living room	incandescent light	15	2.0	30
Living room	tape player	8	5.0	40
Bedroom	incandescent light	15	0.5	8
Bathroom	incandescent light	15	0.5	8
			Total Watt-hours per day	190

The impact of these systems is immediate. In Alonzo's house, lighting was probably previously provided by candle and hurricane lamp. No TV provided contact with the world. Even 15 Watt incandescent lights are a vast improvement over candles, and more convenient. The TV and radios hooked up, however, are definitely the most important items in that family's energy budget.

A store and home in high altitude coffee country is now powered by solar. The pre-solar energy needs were met by a Coleman lantern for light and dry cells for the tape player. A car battery that powered the TV was taken periodically to the nearest town for recharging.

One fish restaurant on Honduras' Lake Yojoa already had electric light, at least a couple of bulbs for the patrons, and some television for the family. Both lighting and television were powered by the battery from the family pickup. But the drain meant that the truck had to be used daily to recharge. The solar panel offers hassle-free power, plus the option of a few more lights.

Above: Luis Alonzo's home has PVs installed on its tile roof.

Far Left: Would-be solar technicians during the August 1992 PV Training Workshops.

Left: PVs light small stores and homes.

Cooking is done with wood; refrigeration, where present, is kerosene-fueled. But solar is a convenient, economical solution to many of the traditional energy needs.

The Market

The initial customers were mostly what I'd call middle class. In Santa Barbara, these would be owners of medium-sized coffee plantations or herds of cattle, or proprietors of small stores or others businesses. With businesses, solar lighting — plus TV, music, and *licuados* — offers an attraction and acts as a lure, at least in the initial stages of a community's exposure to the technology.

Teovaldo, the owner of the fish restaurant, pushed hard to get his system installed before big holidays last April. As in other Latin American countries, Holy Week is an all-important vacation time, and fish is high on the list for Holy Week eating. Doubtless the presence of light, with the strategic positioning of one fluorescent lamp by the entrance, helped to draw the nighttime crowds. That week, business was booming.

Many of these solar customers are able to pay for the systems outright or over a short period of time. The vast majority of the country's rural population, however, obviously doesn't have that kind of cash lying around. Finding reasonably-priced financing is still an obstacle that needs to be overcome if we are to reach beyond the rural middle class, as Peace Corps, Enersol, and many poorer Hondurans would like. Most Hondurans have little access to credit for such systems. But they could be reached through longer-term financing which would bring the payments down to the range of their current monthly energy expenditures for candles and dry cells.

Where there are existing home-improvement loan programs, it's easier to tap in and take advantage of the in-place administrative procedures for loan disbursement and collection. Around Santa Barbara, however, those who received the first (Enersol-donated) systems made down payments of 15 to 70 percent. The loan was repaid over 24 months or less into a local account set up for solar loans. The interest they pay is comparable to the market rates.

In some areas, money is a very seasonal commodity, with "peaks" during coffee harvests and bleaker months following. This affects not only the coffee pickers, but all the local businesses as well. If payment schemes can be geared to reflect these annual fluctuations, with higher payments during one season and lower ones in the next, a greater portion of the rural population in these areas will be able to take advantage of the solar option.

Technology Transfer

Education and well-developed technical support are key for these systems to last and for the solar program to be sustainable. After an installation, a technician teaches the new owners about battery safety and basic maintenance. The technician also helps them design an energy budget matching intended consumption to panel production and battery storage capacity. System abuse by the owners will shorten the batteries' already grim lifelines and make for unhappy customers.

Training of the technicians themselves, and of NGO representatives, is done by Enersol in conjunction with Peace Corps. Enersol has an array of workshops for different audiences.

The technician workshops are five-day affairs, imparting knowledge of basic electricity, PV technology, system design, and small solar business start-up. They also include two day-long installations to show the participants how to put it all into practice.

The would-be technicians who attend generally have practical experience with electricity and construction. The one with whom I worked most closely, for example, was an electrician with the national power company and got into solar after hours and on weekends. Another was an entrepreneurial type who had her own 20 Watt system and saw a lot of interest in her area.

With the workshops and a bit of follow-up from Enersol or Peace Corps, the technicians are ready to fly. Because the panel, at least, can be obtained on short-term credit, a few tools and a bit of working capital are enough for a trained technician to get into the business. Enersol has also made small business loans available to new graduates.

Subtracting the balance of system, transportation, and labor leaves about $100 for profit and the guarantee. This is an attractive sum for a semi-skilled technician in the rural areas. As the network of technicians and suppliers grows, prices may fall.

At every stage in the program's development, letting the costs dictate the price seems to be the proper thing to do. Subsidized sales in the early days of the project could have given the market unrealistic expectations about the cost of solar energy and retarded future sales.

One of the strongest points in favor of the Honduran solar program is that for the most part the systems are installed as the result of business dealings. The systems are purchased, not given away or subsidized. Shelling out the bucks for one of these systems generally prompts the owner to take good care of it, to maintain it well, and to experience that ol' sense of personal ownership which the community-wide projects lack.

And word gets around. Satisfied customers like Alonzo and Teovaldo are the best PR for this project, which is why we tried to start with a focused program and move slowly. Well-placed demo systems, promotional pamphlets, and press coverage — national newspapers, local TV and radio — also help to spread the word.

Problems

Customer satisfaction depends heavily on product reliability and after-sales support. Along with education and orientation, the technicians give complete system warranties of 3 to 12 months. The panels come with the factory warranty, 10 to 12 years, redeemable through the technician or the importer. The batteries come with 12 to 15 month partial guarantees. Beyond the warranties, it's up to the owners to pay a technician to set problems right.

But under warranty or no, problems do arise. Aside from minor hardware difficulties (and lengthy rain spells), the main problems have been with the Honduran batteries and some of the lighting.

The batteries are, predictably, the systems' weakest point. The Honduran lead-acid batteries are unlikely to perform beyond their meager warranty periods. Even during that time, the sellers probably will declare the warranty void if they know the batteries haven't been used in a car.

The couple of battery failures that I have seen in the Honduran lead-acids resulted from one dead cell in each. I don't know enough about battery construction to know why that happened, but in at least one of the cases, the humidity seemed to have been a contributing factor.

Some of the fluorescent bulbs begin to blacken on the ends after a short time. I don't know whether to blame the tubes themselves, the ballasts, or the weather. Experiments with some auto lights also proved unfruitful.

Vandalism, fortunately, has yet to be a problem. Theft of panels is unlikely, as they are well bolted to the roofs and the house are all lived in full time (and it's impossible to sneak around unobtrusively on a corrugated tin roof.)

The Future

Individual solar home lighting systems are only one aspect of the program. Solar offers a viable alternative, here as in other countries, for water pumping, refrigeration, and telecommunications, once the supply chain and technical support are fully in place.

In late 1992, SNL and VITA (Volunteers In Technical Assistance) collaborated on fixing several solar-powered community water pumping systems on the Bay Islands. The presence now of trained solar technicians and supply channels as a result of the Peace Corps/Enersol work will help ensure the durability of those efforts.

The future lies in expanding the network of solar technicians and suppliers, increasing the scope of the program to other parts of Honduras and ensuring competition. Peace Corps/Honduras has assigned a few enthusiastic volunteers from the small business development sector to work on the business aspects. Enersol's regional staff person has been providing training and administrative guidance to Peace Corps and to interested NGOs and government organizations at the national and local levels.

There's no question about the viability of these systems in areas served by the grid. Here, as elsewhere, solar is not ready to take on the centralized power, not until the powers that be level the playing field by taking into account environmental impacts. (And not until quite a bit more ground work is done to set up the channels for products and financing.)

But in the more rural areas, the new solar program is offering light and sound to the first generation of solar pioneers in an economically and environmentally sound way. And *licuados magnÍficos*. Cheers!

Access

Having done all he could in Honduras, John Rogers is heading for Southern Africa to try his luck there. He can be reached c/o Julie Rogers, 10944 San Pablo Avenue, #224, El Cerrito, CA 94530 • 510-215-5840

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ALTERNATIVE ENERGY ENGINEERING
full page
camera ready (probably needs slight reduction)

Above: Jerry Fetterman, his son, and the family dog prepare to go for an electric buggy ride.

Solar Powered Wheels

Jerry Fetterman

In the early ‘80s, I first got the fever — electric car fever. We were paying a visit to Windy Dankoff in New Mexico and got to see his electric-powered Corvair. What a great way to dump the surplus power from a photovoltaic (PV) powered home and cut down on the use of gasoline! Not only would an electric car be a wonderful place to dump my surplus power, I thought the car would be a good way of advertising our solar business, Yellow Jacket Solar. For the next several years, I dreamed of buying a surplus generator and a junker car (this part really worried my wife), and putting together my electric vehicle. However, I am not (or ever will be) as handy a tinkerer as Windy is, and realizing my limitations, never did accumulate the necessary parts.

.The First Car

In 1986, the battery distributor I had been dealing with turned me on to Jet Manufacturing Corporation, a manufacturer of electric cars. Although I learned Jet was no longer in business, I was able to locate and buy a used Jet Escort hatchback. The Jet Escort hatchback was a Ford Escort hatchback that was converted to run on electric power. The literature available on the Jet Escort indicated that it had a range of 60 miles and a top speed of 70 mph. It ran on 96 Volts (16 golf cart batteries) and had a 12 Volt marine battery to run the electronics and lights. The battery power was delivered via an SCR controller to a 20 hp G.E. DC motor which connected directly to a stock clutch and transaxle.

The first problem I ran into was how to charge the car. While it had a 220 Volt built-in charger, the only way I could charge it was through my #$&@ gas generator — hardly the idea I had in mind when I bought the car. I eventually rigged up a variable transformer with a full wave bridge rectifier to charge the batteries from my Heart Interface inverter, but this system was only partially successful.

Since the car was supposed to show the ability of solar power at the trade shows we went to, I decided to put some solar panels on it. With 96 Volt nominal battery pack and 12 Volt nominal panels I needed 8 panels to charge it: no small financial undertaking or small array to fit on a Ford Escort. We ended up settling for eight 16 Watt panels and mounted them on a roof rack.

The next problem we had with this vehicle was its limited range. While it was reported to be able to travel 60 miles on a charge, this figure must have been obtained on a downhill slope with a tail wind. Given our hilly terrain and the added friction of gravel roads, we could only get about 25 miles on a charge before the batteries were empty.

Which leads to the next related problem: the voracious appetite the car had for electric power. While it didn't bother me to see 24 Volts / 60 Amps running into my inverter to power my washing machine, it really bothered me to see 96 Volts / 100–200 Amps going into the motor of the Jet Escort.

With that kind of load, it took a long time for the car to charge between drives. Thus we drove the car less and less and after a year or so of owning the car, I realized that if I didn't sell it, the car would slowly deteriorate into the ground. While my electric car fever wasn't broken, the Jet Escort surely reduced it.

Contemplation

After selling the Escort, I got to thinking. Maybe trying to run conventional cars on electricity is like running conventional houses on solar power. It can be done but it takes lots of power and batteries. Perhaps if I applied the energy-efficient techniques used in solar home construction to my solar car's construction, I could design a vehicle that would meet my needs yet not consume excessive amounts of power. One element of the Escort, the weight, just kept coming back to me. Jet Manufacturing started with a standard, heavy American-made vehicle (albeit one of the lightest ones available). They therefore had to put in a heavy, powerful motor to propel the car, and this in turn had required numerous heavy batteries.

When I figured it out, I knew I wanted to build a light electric vehicle. At the same time, I knew that building an ultralight vehicle from scratch was beyond my technical abilities. So I decided to build an electric car from a stripped-down converted donor vehicle.

Since my only period of surplus power is during the summer, I decided to build a strictly summer-use car. This meant that I could forego the need for doors, roof, etc. and thus save weight. The design started to take the form of a modern horseless carriage — an electric buckboard. Within a short time I had decided to use a VW bug as the donor vehicle and a sand rail frame as means of lightening the framework of the bug.

The sand rail frame was a good idea, but I could see that it would need some customizing. First, I didn't want a race car, where you sat on the floor of the vehicle, but rather more of a buckboard — a sort of Jeep with a bench seat and a pickup bed. Second, I needed room for stowing the batteries.

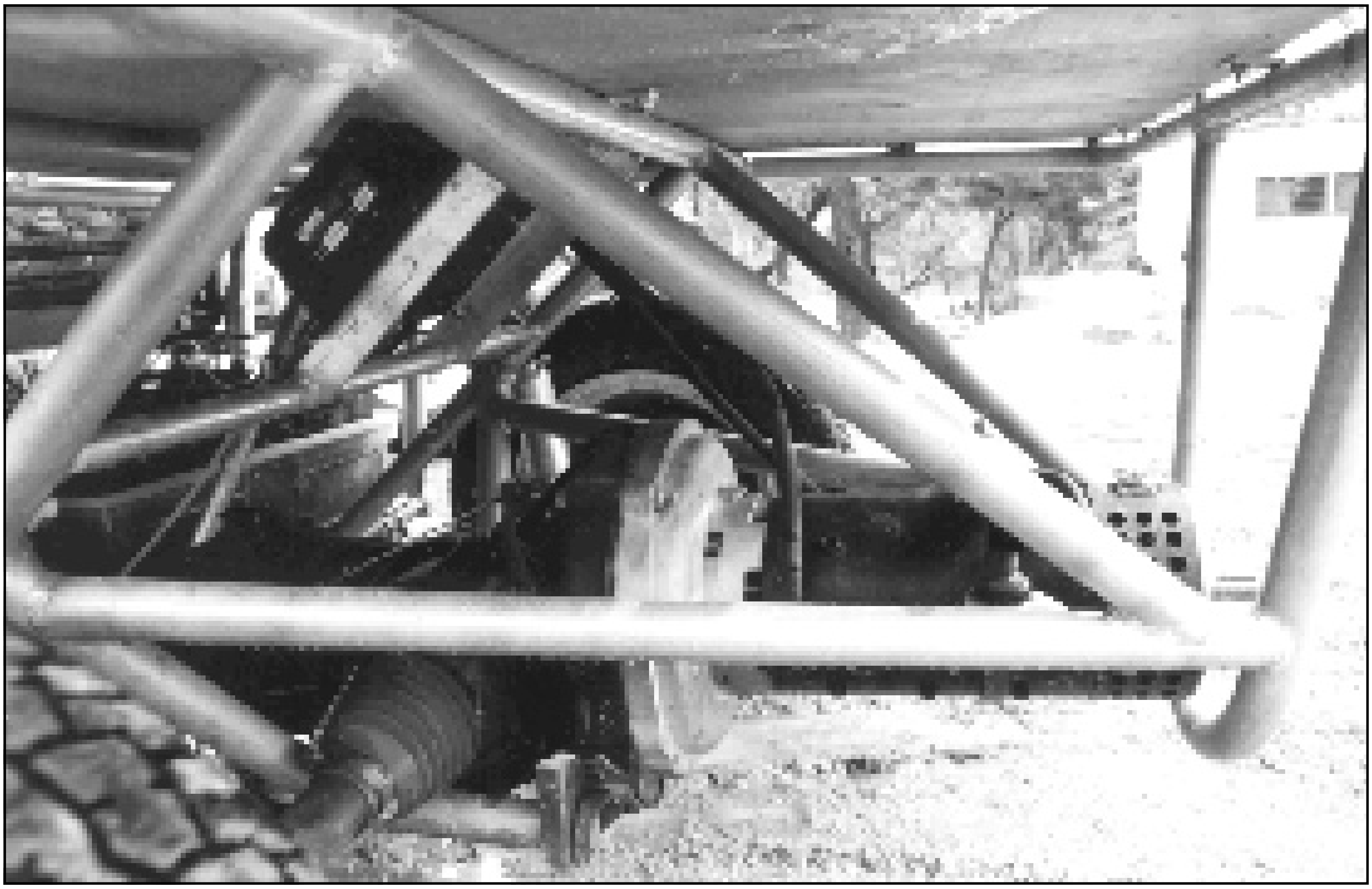
Originally, I had really wanted a 24 Volt system running the car, since at that voltage, I could easily dump surplus power from my house. However, several electric car enthusiasts convinced me that I would be very disappointed in 24 Volt DC motor performance. I therefore decided use a 72 Volt 10 hp system. To minimize weight in the car, I decided to go with six 12 Volt RV marine batteries, instead of twelve 6 Volt golf cart batteries. This would save over 350 pounds in the car but would also leave me with vastly inferior batteries. In anticipation of charging the batteries, I hooked up my solar panels through a series of relays triggered by voltage sensing switches. When my house voltage got low, the panels were configured at 24 Volt nominal to charge my house batteries. When they reached 28 Volts, the panels would switch to 72 nominal and charge the car batteries to 90 Volts. At this point the panels would switch back to 24 Volts nominal to float my house batteries.

While I was developing the initial design of the car, I was very lucky to meet John Davis, master mechanic and welder, and a Bug aficionado. I did the rough sketches and John did the final design work, welding, and fabrication. The end result of the vehicle is as much a result of my ideas as John's pragmatic and technological abilities.

The New Car

In designing and building the new solar car, we kept in mind four goals: the car should be light in weight, tough enough to handle rough roads, safe, and capable of being licensed as street legal.

In order to lighten the car, we used aluminum for the fabrication of the frame and the front end beam. We replaced the stock rear torsion suspension with a



Above: A solar powered electric motor replaces the old dead dinosaur burner.

coil-over-shock suspension system. It became real obvious in short order that how light the car would get would be directly proportional to how much money I wanted to put in it. The after-market products available for dune buggies and sand rails are numerous and often expensive. After indulging with some things (gas shocks that weigh only 5 pounds each) and stopping at others (disc brakes), we ended up with a relatively light vehicle that could be further lightened as funds became available.

Specifications

The vehicle weighs 900 pounds, of which 325 pounds are the batteries, 100 pounds are the motor, 150 pounds are the frame, and the remaining 325 pounds are the transaxle, clutch, wheels, tires, seat, etc.

The power components were purchased new from Steve Van Ronk of Global Light and Power. They consist of a 10 hp (72–120 Volt DC) motor, a pulse width power controller (to vary the speed of the motor), and adapter plate to mount to the VW transaxle, a lightened flywheel, meters, and various relays and power disconnects. The power is run from six 105 Amp-hour RV/Marine batteries in series.

Acceleration is quick and power is amazing. The car climbs any hill without the slightest hesitation and is wonderful on back-country 4-wheel-drive roads. Top speed on a flat surface in fourth gear is 50 mph. Faster speeds could be obtained by increasing the voltage (adding more batteries in series).

Power consumption is approximately 200–300 Watt-hours per mile (0.2–0.3 kiloWatt-hours per mile, or 3–4 Amp-hours at 72 Volts DC per mile) in hilly country on gravel roads. This is two to three times better than the 750–800 Watt-hours per mile I got with the Jet Escort.

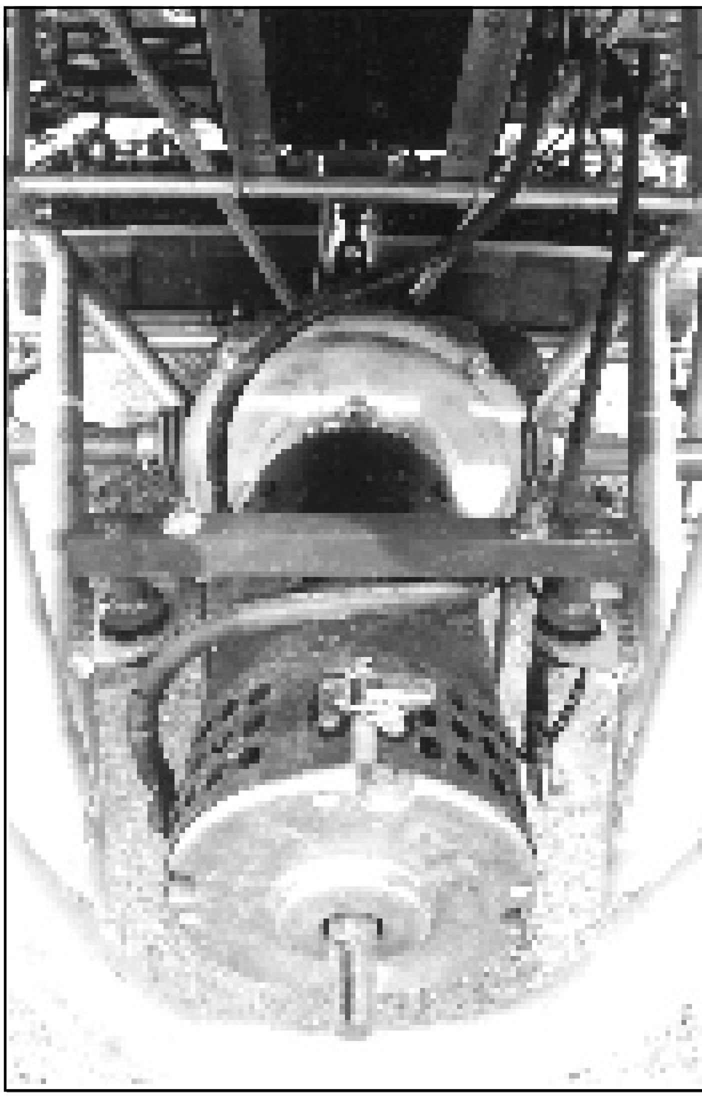
With the RV/Marine batteries my range is approximately 30 miles — not much better than the Escort. However, a longer range could be achieved with (you guessed it) a larger battery bank.

Conclusion

The vehicle I have built fits my needs wonderfully. I use it to go to our garden (3.5 miles from our house), to get the mail (7.5 miles), to visit friends, to explore back country roads, and to go to the local convenience store. It is a great

Above: The electric buggy's battery.

Below: A view, from the rear of the vehicle facing forward, of the electric motor installed into the VW transaxle.



Above: The front end and suspension of the electric buggy.

Below: A view of the rear suspension of the electric buggy.

Jerry Fetterman's Electric Buggy Cost

Item	*Cost*	*%*
Motor, Controller, Disconnects, and Meters	$1,720	34%
Aluminum and Steel Metal	$900	18%
Motor Adaptor Plate	$660	13%
Front Wheels, Front Bar, and Shocks	$640	13%
Tires, new components, and used seats	$500	10%
Batteries, Cables, and Connectors	$400	8%
Original Donor Car	$200	4%
Total	$5,020	

vehicle for taking short trips on remote roads. The open air approach allows driver and passengers the wonderful experience of enjoying their surroundings while being whisked silently along. Doubling the satisfaction is the knowledge that the power used to propel the car is surplus power generated by solar electricity. One friend stated that driving in the car was like sailing on a boat. This car, however, is hardly the electric vehicle for everyone. Its open-air approach makes it basically useless in inclement weather, and it is of questionable safety in commuter traffic.

Based on the work we have done on the car, I believe that a practical, efficient electric commuting car can be made. Such a vehicle must be light enough to cut the consumption of power. If we continue our current trend of making heavy cars and charging them on utility power, all we will have done is to substitute decentralized power production and consumption (many motors burning fossil fuels) with centralized power production and decentralized consumption (large fossil fuel burning power plants generating electricity to be used later in vehicles). We need to rethink the automobile, not just remodel it.

Access

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Heatin' with Hydrogen

Walt Pyle, Jim Healy, Reynaldo Cortez, & David Booth

We want to share our experiments running a catalytic space-heater on hydrogen fuel. Three space-heaters are now installed in various rooms of one of the author's Richmond, California home. They are currently fueled with natural gas. These heaters present an almost ideal opportunity for conversion to hydrogen combustion. We plan to operate these space heaters routinely in the near future on hydrogen produced at home.

Gas Appliance Conversion

In the last issue of Home Power (#33), we examined an approach for modifying conventional kitchen stove burners (intended for natural gas or propane use) to allow cooking on hydrogen fuel. This method involved using stainless steel wool as a catalyst, and delivering hydrogen to the burner head without pre-mixing the fuel with air. The originators of this technique refer to this approach as "flame assisted catalytic combustion of hydrogen."

In this article we'd like to focus on pure catalytic combustion of hydrogen and air. Catalytic combustion of hydrogen and air can occur in the presence of certain noble metal catalysts (such as platinum or palladium), without any flame whatsoever. Water vapor and heat are byproducts of the reaction.

The Platinum CAT™

Catalytic space-heaters are available as mass-produced, low-cost consumer appliances. Some are intended for propane and some are for natural gas fuel. We chose to work with a Platinum CAT™ catalytic space-heater since it was the only model with forced external venting and an American Gas Association approval. Our intended application was for a home, not a recreational vehicle.

The manufacturer of the Platinum CAT™ flameless, catalytic, radiant space-heater is Thermal Systems, Inc. of Tumwater, Washington. The propane versions were conceived with the recreational vehicle market in mind, so they rely on 12 VDC power. The natural gas models are very similar in overall design, but they require 120 vac for operation of the solenoid gas valve and blower fan. Both types require a vent to the outdoors for the exhaust gases.

Our Platinum CAT™ was a Model 1500 120 vac 60 Hz version with a gas orifice sized for pipeline natural gas. (Model 1500 can also run on propane with the correct orifice installed.) The first CAT was installed in the living room during 1991 and operated for one year on natural gas to gain service experience. We were so pleased with its performance that we ordered and installed two more CATs during 1992.

Multiple Benefits

The radiant heat available from the Platinum CAT™ is long wavelength infra-red radiation similar to the sun's own rays. Radiant heat, unlike convection or conduction heat, is transmitted through space, and only releases its energy when the rays strike objects and/or people. Warmth from this space-heater is felt immediately, unlike forced air convection systems which first must heat the surrounding air.

The efficiency of catalytic hydrogen-air combustion with platinum catalysis is extremely high. The range of efficiencies commonly reported in technical literature is 85–100%. Efficiency is high because the combustion takes place at a substantially lower temperature than under ordinary conditions. This means in the presence of the platinum catalyst, no pilot light, spark, or glow plug is needed to initiate flameless combustion. This important safety feature helps prevent the accidental buildup of unburned gas and air mixtures. Also, catalytic combustion occurs far below the threshold temperature at which oxygen and nitrogen can react to form polluting nitrogen oxides (NOx). As a result, these emissions are 0.1 parts per million (ppm) or less compared to conventional burners at 200 to 300 ppm.

In the future, we will take full advantage of the higher heating value of hydrogen. This can be accomplished if the byproduct — water in the vapor state — changes back to a liquid and gives up its heat before it leaves the heated space. This is called the latent heat of condensation.

Conversion of The Platinum CAT™ to Hydrogen

These space heaters can be modified for the direct use of pure hydrogen by controlling the feed flow rate of hydrogen gas (and thus the heat release rate). The hydrogen flow rate to the Platinum CAT™ can be adjusted by raising or lowering the delivery pressure, or by resizing the gas inlet orifice. It may not be necessary to adjust anything if you are content with less output from the space heater.

Piping and Wiring the CAT

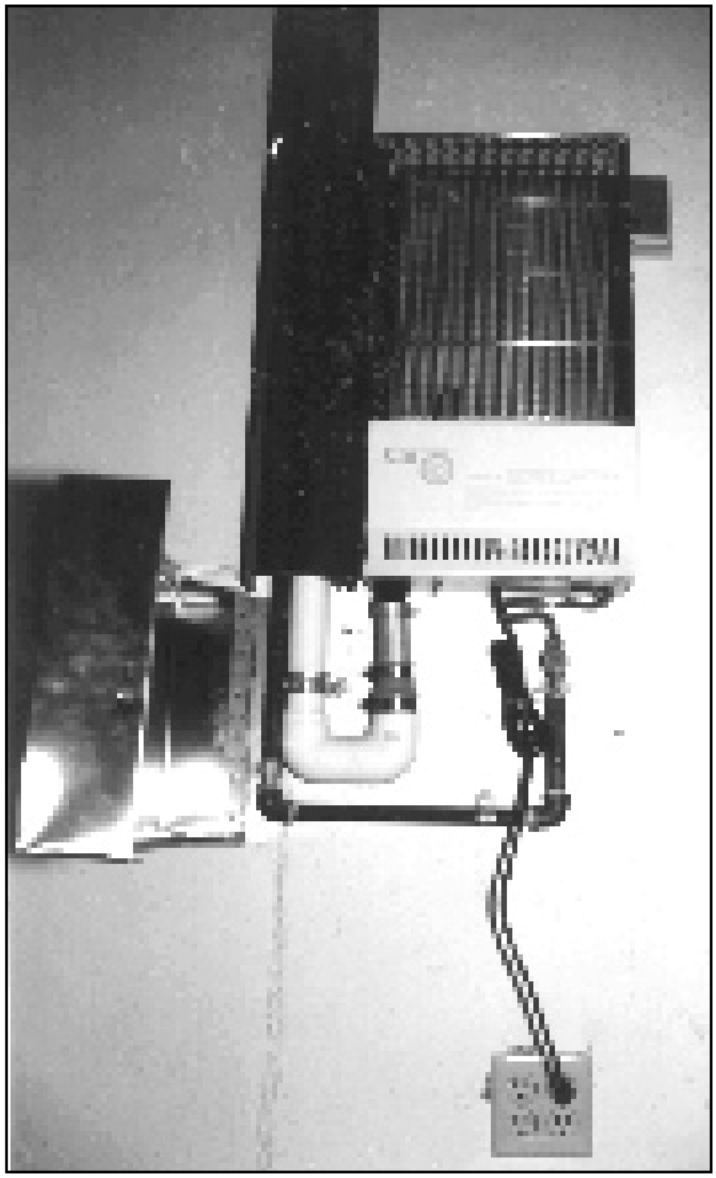
An excellent instruction and installation manual comes with the Platinum CAT™. The installation must conform to local codes. In the absence of local codes, the installation must conform with American National Standard (National Fuel Gas Code) known as NFPA 54 and ANSI Z223.1 1984.

We used threaded 3/4 inch black iron pipe for the fuel delivery line with a high quality thread sealer (Permatex Industrial Hydraulic Sealer). A fuel gas shut-off valve was installed at the appliance entrance flex hose.

A 2 inch plastic flue pipe was used since the flue gases are low temperature with the fan running. The heater will not open the fuel gas solenoid valve unless the fan is running. No provision was made for condensed water removal, since we are operating the unit in a mild climate where this is not a problem.

A soap solution was used for leak testing the piping after installation. A product useful for this purpose is called Rectorseek Leak Detector (Rectorseal Corporation).

A thermostat is supplied with the unit to control the temperature in the room. It works by turning the space heater "on" or "off" as required. We mounted our thermostat at the upper right of each unit so the wires could be hidden behind the heater frame. With this configuration we found that one must set the thermostat to a higher temperature than that desired for the room. The thermostat is heated by local conduction somewhat and tends to shut off prematurely. Placing the thermostat further away from the space-heater would benefit some installations.



Above: Platinum CAT™Space Heater in Basement bedroom showing vent piping and fuel supply line.
Photo by Reynaldo Cortez

The control unit for our natural gas approved Platinum CAT™ had a 120 vac power card, so we just plugged it in and we were "on the air"!

Is Venting Needed?

Platinum CAT™ heaters produce radiant heat as the result of flameless catalytic combustion, whether or not hydrogen gas is the fuel of choice. With propane and natural gas, the space-heater exhaust gases will contain water vapor, carbon dioxide, and minimal quantities of carbon monoxide, NOx, and hydrocarbon pollutants. Common sense, AGA safe practices, and local building code regulations require that space-heater exhaust gases be vented away from the living space.

Only with hydrogen fuel is water vapor the primary combustion end product. So, why must the space-heater on hydrogen be vented? Well, you might argue, homes heated in the winter are in need of further humidification to raise the “comfort factor”, and much valuable heat is lost (your energy dollars) up those exhaust flues. It is tempting then, to think about venting the space-heater into the room. We advise against this practice.

Dangerous and harmful situations could arise if a space-heater on hydrogen (or conventional fuels) is not vented to the outdoors:

- Excessive moisture could condense in the home causing damage to building materials and the growth of unwanted bioorganisms.
- Loss of oxygen in the breathing atmosphere of a tightly sealed or “superinsulated” home could lead to asphyxiation or loss of consciousness for occupants.
- Confinement of a potentially explosive mixture of hydrogen and air is possible.

A simple well designed vent can prevent these problems from occurring with any hydrogen appliance. The vent system (shown in photo on page 27) was made for our second Platinum CAT™ space-heater, which we installed in 1992 in a basement bedroom.

Our Experience to Date

During the summer of 1991 we made the first test of the Platinum CAT™ using hydrogen fuel. The hydrogen came from a high pressure compressed gas cylinder followed by a two stage pressure regulator. This allowed us to drop the pressure from as high as 2300 psig (pounds per square inch gauge) down to a pressure of about 4 inches of water column (w.c.), suitable for a gas appliance. We found that the hot wire starter for natural gas operation was unnecessary for initiation of hydrogen-air catalytic combustion. The hydrogen gas reacted with air on contact with the platinum coated silica quatz pad, giving off about as much heat as when running on natural gas.

A few weeks later, we contacted Thermal Systems, the manufacturer of the Platinum CAT™, and discussed operation on hydrogen with Arnie Lind, their resident R&D Lab Engineer. Arnie was interested in our approach. A few weeks later when we talked again, Arnie told us about some experiments he had run in the lab using hydrogen in a Platinum CAT™. Arnie became even more interested in the hydrogen fuel space heater after talking to Sandy Stuart from Electrolyser Corporation in Canada (to whom we had provided a copy of the Platinum CAT™ literature). Arnie confirmed that he had reliably obtained catalytic combustion of hydrogen and air without the ignitor, within 45 seconds or less after he turned the Platinum CAT™ on.

Using a 5 inch w.c. hydrogen supply pressure to the Platinum CAT™, Arnie measured fuel consumption of about 16 cubic feet per hour. On natural gas the fuel consumption was about 5 cubic feet per hour using 4 inches w.c. pressure at rated output of 5200 BTU/hour. An even combustion pattern was seen on the silica quartz pad face, glowing a dull orange when viewed in a dark room. Arnie found that he could get the same heat release as natural gas if he enlarged the natural gas orifice (normally 0.043 inches) to 0.052 inches (drill size #55).

One of Arnie Lind’s primary concerns was in testing to assure that the surface of the catalyst silica quartz pad was not damaged by overheating (temperatures greater than 1100°F were known to cause problems). By using a non-contact infrared thermometer he found that the surface temperature of the rock wool was only 600° to 800°F when operating on hydrogen at the rated heat input, and not a problem. Another of Arnie’s concerns was about the flue gas composition. He planned to obtain samples of the gas for analysis. Maybe there will be an AGA approved hydrogen Platinum CAT™ in our future! We hope so.

Demonstrating Flameless Combustion

We shared the news of this novel appliance with David Katz of Alternative Energy Engineering. He proceeded to order one for his home, but initially it became our handy demonstrator unit for a recent alternative energy fair and a one day hydrogen workshop. Even without plumbing or wiring this device, we amazed more than a few curious souls and skeptics with a simple demonstration of flameless combustion. After removing the protective grill on the heater, a silica quartz pad with minute amounts of platinum is left exposed. All that was needed to instantaneously produce heat and a reddish-orange glow was the direction of a slow, steady stream of hydrogen from our compressed gas cylinder across the surface of this material. Of course, this was only done to visually confirm the novel quality of flameless combustion. We don’t suggest that this approach is in any way a substitute for a properly piped and wired installation. In one of our demonstrations, the hot silica quartz pad surface started a flame in the stream of hydrogen, which jumped out to the end of our delivery line! The catalytic combustion temperature was above the ignition temperature, and a hydrogen flame was kindled.

Flameless combustion or oxidation is really not that unique a phenomenon. The body’s oxidation of carbohydrates, the yellowing of newspapers, and the rusting of iron are well known examples.

Safety Warning

Please be forewarned that although our experience may indicate that such a conversion is relatively simple, the use of this appliance with hydrogen fuel is not yet approved by the manufacturer. Approval from the American Gas Association must be obtained before the Platinum CAT™ on hydrogen will be ready for commerce. The use of any gaseous fuel in a space heater, other than the one recommended specifically by the manufacturer will void the warranty, and may not comply with American Gas Association (AGA) safe practices.

If you want to try any hydrogen space-heater experiments on your own, be aware:

- Installation should only be done by a qualified service person.
- Any changes to the heater or its controls, or attempts to clean the catalytic pad can result in damage, defective operation, and may be dangerous.
- Any experiments with hydrogen fuel should be done outside.
- Hydrogen gas is odorless; you cannot smell a leak.
- Remember that hydrogen gas and air mixtures are potentially combustible and explosive over wide mixture ratios (4 to 75% hydrogen in air). Only pure gases should be stored, never mixtures of hydrogen and air.

Access

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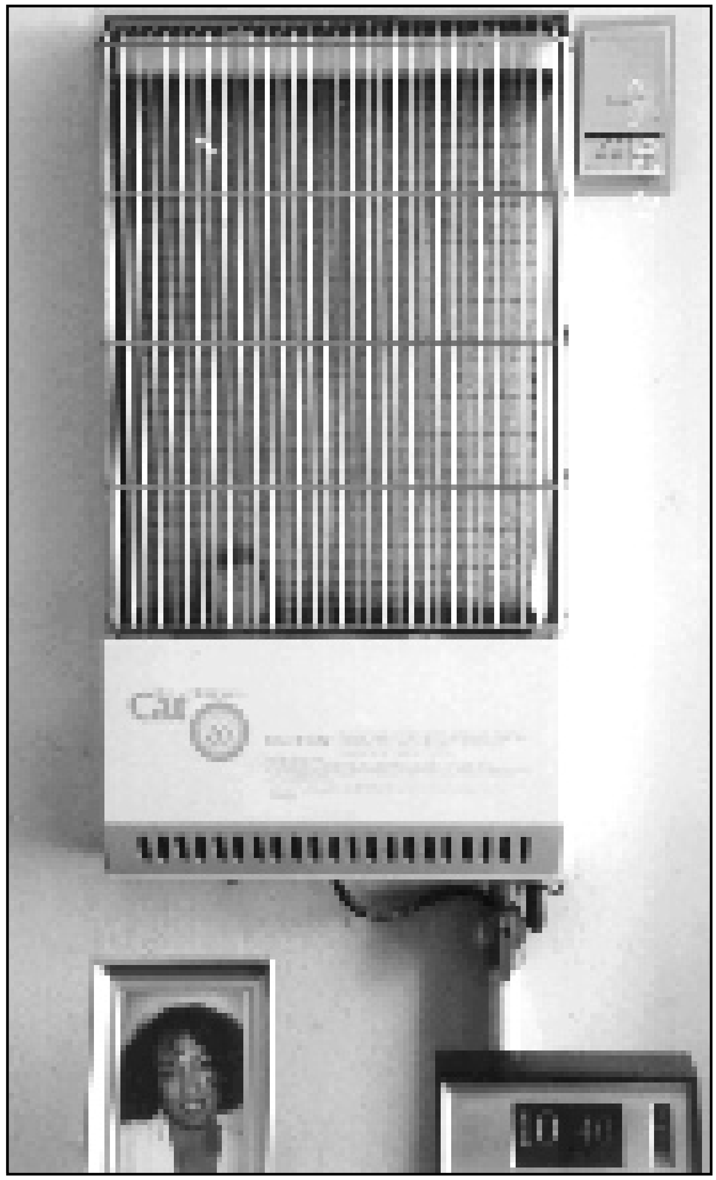
Safety Regulations: NFPA 54 and ANSI Z223.1 1984 from: American National Standards Institute Inc., 1430 Broadway, New York, NY 10018 or National Fire Protection Assoc., Batterymarch Park, Quincy, MA 02269



Above: Multi fuel space heater at work warming the living room. The heater normally runs on natural gas, but runs equally well using hydrogen.
Photo by Reynaldo Cortez

Tech Notes

Using your Electric Meter as a Watt Meter

Tom Stockebrand

Sometimes you would like to know the wattage of a load on your grid-connected system. You can do it by timing the rotation of the disc on your watt meter. If you can determine the on-time of the load each day you can figure out the energy use of that load in watt-hours per day.

Like me, you probably do not own a watt meter and are not about to buy one since they are expensive. You can determine what you need to know by applying the:

Meter Person's Equation

$$\text{Watts} = \frac{\text{Kh} \times 3600 \times \text{Rev}}{\text{Sec}}$$

where Kh, which is the watt-hours per revolution of the disc, is a number printed on the meter. My meter has a Kh of 7.2 watt-hours per revolution. Thus if the disc spins once per second it will go 3600 revolutions in an hour yielding 3600 x 7.2 or 25,920 W-h per hour. That's a load of 25.92 kW.

Power

To find the power being used, measure how long it takes the wheel to make some convenient number of revolutions and plug it into the equation. If for example your meter had a Kh of 7.2 like mine and it took 35.4 seconds to make 1 revolution then the power consumption is 3600 x 7.2 x 1 / 35.4 = 732 watts. If 5 revolutions took 54.8 seconds then you'd be consuming energy at a rate of 3600 x 7.2 x 5 / 54.8 = 2.39 kilowatts.

Meters come in various sizes. I have one whose Kh is 1.8 and another which says Kh = 2/3. This last one is a smallish meter: 2400 watts makes the disc spin once per second.

In order to measure a particular load while others are on you need to measure the wattage consumption first with the load "off" and then with the load "on" and determine the difference, which is therefore due to the load that you added. You should make the measurements several times to be sure that the background load has not changed in the meantime.

Energy

Once you know the wattage drawn by a load, then to determine the watt-hours used each day by that load you need only to measure how long it is on during the day. One way to do this is to find an old electric clock and splice it into the load. Set the clock to read 12:00 at a particular starting time, wait one day more or less, depending on the accuracy you want, then determine the hours the appliance runs each day by reading the time on the clock! If you read it about the same time each day for awhile and record the readings you will get a very good feel for the hours it runs per day. Multiplying this by the wattage measured above will give you the watt-hours used per day.

One difficulty with this method of determining energy use is that it's sometimes hard to find a place to wire in the clock since it has to be *after* the switch on the appliance. Estimates of the on-time may suffice, however. Those of you with electronic backgrounds can rig an op-amp across a sense resistor and put it in series with the load externally and then use its output to run an hour meter. This scheme will not work for measuring variable loads, such as electric ranges. If you really want to know about one of them, you can buy a used meter for $15–20 from a place like C&H Sales in Pasadena and wire it into the range. This idea only works with 220 volt appliances, however. 110 volt electric meters are hard to come by. What's needed is a Watt/kWh/Time meter that you can just plug in the line between your appliance and the wall. One fancy device was described in *Home Power* a few months ago but this one could be of limited function and could trade accuracy for cost. Stay tuned.

Access

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Why Wind???

Mick Sagrillo

Wind power has taken a lot of bashing in recent years, for a variety of reasons. Some of the criticism has been justified, but most of it is completely unfounded. A fresh look at wind power and its place in a renewable energy (RE) system is in order.

Dispelling Myths

Let's take the most frequently used excuses for not considering wind power in an RE system and analyze the whys and why nots. By the time we're finished, you will have clearer understanding of wind's place in the whole RE picture.

"Wind doesn't work"

One reason given for not wanting to use wind power is that the equipment apparently doesn't work. "I drove past this wind generator and the blades weren't spinning." Well, maybe the wind wasn't blowing, or maybe it was blowing too hard. Maybe the wind system was shut down for routine maintenance. Maybe the owners' batteries were charged up and the power was not needed. Maybe...I could go on and on, but I'm sure that you get the picture. We humans are very visual yet blind creatures in that first impressions are often the most lasting impressions. When one glances quickly at a PV array, a solar hot water heater, or even a hydro plant, you have no idea if it's operating or not. You can't see what's going on inside. But it is always obvious when a wind generator is or is not operating.

This isn't to say that wind generators always work. In the late '70s and early '80s, there were scores of companies who set up shop building wind generators. In many cases, their motivation was greed. They were attempting to cash in on the 40% federal tax credit that was granted to buyers of RE equipment. Most states also offered tax incentives for RE purchases. Homeowners could get up to 70% of a $10,000 investment back from the government.

The problem was that there were no standards for most of the RE equipment that folks bought. Consumers were in the mood to spend lots of cash, and manufacturers were all too willing to take their money. No standards, lots of money, and the tax credits all combined for what would ultimately be a major setback for renewables. There is no question that a lot of junk was being sold. Many of these travesties still hang from their towers as a dismal reminder that their owners had been had. Not only wind power, but all forms of renewables got a black eye that is now just healing. Unfortunately, many people developed a sour taste for RE. Ronald Reagan even got a laugh at one of his State of the Union speeches by poking fun at wind farms and Jimmy Carter's solar water heaters.

Six years after the sunset of the tax credits, virtually all of the 80 or so wind generator companies doing business in the U.S. are gone. Only a handful of manufacturers have survived the shake-down. And these survivors are still cranking out the same reliable equipment that the fly-by-nighters tried to emulate a decade ago. There is no question that the equipment available today is reliable, and their manufacturers stand behind their designs. These people know that a wind generator manufacturer is in the business to help generate renewable electricity, not just build and sell RE equipment. Today's wind generators work!

"No Power!"

Many folks have the misconception that there is no real power available in the wind. Therefore, why bother with a wind generator. Let's look at this more closely.

The equation for determining the power available to a wind generator is as follows:

$$P = \frac{1}{2} d AV^3$$

where P is the power in the wind, d is the density of the air, A is the swept area of the rotor, and V is the wind speed or velocity.

What we are interested in here is V^3 or V x V x V. When we double the wind speed for a given location, say from 5 to 10 mph, we increase the value of V^3 by a factor of eight! Multiply 5 x 5 x 5 and you get 125. Double it to 10. Multiply 10 x 10 x 10 and the result is 1000, an 800% increase.

There are two lessons here. The first is that even small gains in wind speed can result in enormous increases in the power in the wind. As the wind steadily increases, the power in the wind increases exponentially.

The second lesson is that, because the power gets so large so fast, it must be awfully difficult to build a wind system that will survive high winds. Any do-it-yourselfer who has tried to design a wind generator has learned this lesson, probably the hard way. So have all those bankrupt manufacturers that were mentioned earlier. But today's wind generators know how to behave without self-destructing in high winds.

"No Wind?"

A lot of people have the idea that wind power is so site specific that they probably have little or no wind at their site. Richard and Karen Perez even fell into this category, until a manufacturer gave them a wind generator to test at their home. Lo and behold, they now have more power than they oftentimes know what to do with!

The chief culprit here is that wind power has been saddled with a very poor yardstick: average wind speed. Dealers will ask a prospective buyer what their average wind is. If it's down around eight or nine miles per hour, the dealer will usually disregard the wind system in favor of photovoltaics (PVs). But average wind speed is the wrong question to ask. An example is in order.

Let's assume two locations, each with an average wind speed of 10 mph. We are only interested in the average for one month, and we are going to take readings on a weekly basis. The wind speeds for our two imaginary sites are as follows:

Wind Speed for two Sites

	Site 1	*Site 2*
Week 1	10 mph	0 mph
Week 2	10 mph	0 mph
Week 3	10 mph	40 mph
Week 4	10 mph	0 mph
Monthly Average	10 mph	10 mph

While both sites have the same average, they have not been created equal! Let's develop the example a little further. Remember the power equation, $P = 1/2dAV^3$? Let's plug in the weekly values for wind speed from sites one and two, and then add them up to determine the monthly value for V^3. Note that the units for the numbers don't matter here. What we are interested in is the numbers themselves.

Obviously, when we plug the value of V^3 into the power equation, 64,000 times something is going to be a lot more than just 4,000 times that same thing. While both sites look the same with regard to their average wind speeds, one site has a lot more fuel than the other!

Wind Speed cubed for two Sites

	Site 1	*Site 2*
Week 1	10 x 10 x 10 = 1000	0 x 0 x 0 = 0
Week 2	10 x 10 x 10 = 1000	0 x 0 x 0 = 0
Week 3	10 x 10 x 10 = 1000	40 x 40 x 40 = 64,000
Week 4	10 x 10 x 10 = 1000	0 x 0 x 0 = 0
Monthly Total	4000	64000

Even though your site may appear to be poor for a wind system based on the average wind speed, a low average wind speed is not enough in and of itself to disregard a wind installation.

Another major problem with the average wind speed readings that we have for the vast majority of the U.S. is that these averages are not representative of our wind resources. Wind speed data is usually collected by people like the National Weather Bureau or a local airport. The trouble lies in the location and height of the recording equipment. Weather bureaus are interested in wind speeds at street level, where the people are. But wind generators live 80 or so feet up in the air, far above ground level obstacles and turbulence. A similar situation exists with airports. Traditionally, airports were located in sheltered areas, because, traditionally, airplanes had trouble coping with cross winds when landing. While modern jets and planes have much less trouble with the wind, we're still stuck with wind speed readings from traditional airport locations. Airports don't spring up like strip malls.

The bottom line: average wind speeds at hub height, the height where the wind generator will be installed, are always substantially higher than those recorded by weather bureaus and airports.

"For how long?"

We have been told that to get a reasonable idea of the wind resource for a given location, the site must be monitored for at least a year. Longer if possible. But why bother, you say. After all, if you have to wait a year to see if you even have any wind, why not just install PVs? This seems reasonable. All you need to do is look in a book to find what the weather bureau tells you is your solar resource.

This is nonsense! All this kind of talk does is dissuade one from even considering a wind system. There is a way to make weather bureau and airport data useful. Let's say you were to install a recording anemometer at your site and take daily readings for a month. During that month, you also called the weather bureau or airport for their readings once or twice a day. At the end of the month, you would see a relationship between your data and their data. As a matter of fact, you could extrapolate your data as far back as you wanted to, using the relationship between the two sets of data. You now have an excellent set of numbers describing your site's wind resource.

In order to make these numbers useful, the readings that you take at your site must be at hub height. This may entail getting up 60, 80, or 100 feet. Remember, wind generators spend their lives up above the trees and buildings, out of the turbulence. Taking the data at roof top level is about as useful as relying on weather bureau readings.

"Not Reliable"

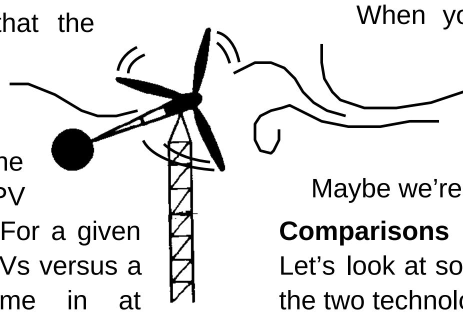
Photovoltaic converts often point to the arrays and ask how a wind system can possibly compare to photovoltaics for reliability. After all, PVs have no moving parts. There are wind systems out there that are just as reliable as PVs. Let's look at a few examples.

I recently took down a Jacobs wind generator that had been in service for nearly 60 years. At one point it had been moved from one farm to another. At that time the bearings were replaced. One blade was replaced after being hit by lightning. And periodically, the brushes were replaced. Sixty years of service is why the old Jakes have earned the reputation as being the "cadillac" of wind generators.

Today's technology has comparable machines. Bergey wind generators are known to operate year after year with little or no attention. This is why Bergey is a frequent choice of power supplies at remote telecommunications and coast guard sites.

"Expensive"

Another criticism leveled at wind is that the systems must be expensive because a generator has to be installed on a tower. The tower is certainly an added cost. However, when one compares the costs of a wind generator tower with a PV array tracker, an interesting fact arises. For a given generating capacity, say 3 kiloWatts of PVs versus a 3 kW wind generator, towers come in at approximately the same cost as trackers.



All of the other system components used — the batteries, the wire runs, the inverter, the switches, fuses, and disconnects — will be identical in cost no matter what electron generator is employed.

The real cost advantage is with the wind generator itself. Wind generators are 20–40% of the cost of PVs, watt for watt, depending on the economy of scale — the size system you buy. The exception is very small "micro" wind generators.

"Too Erratic"

Wind has often been criticized as being too erratic and inconsistent. No argument on this one. Well, maybe a little bit of a disagreement. The sun is pretty predictable. It comes up every morning, and goes down every night. You can bank on that one. The wind comes and goes. You never know when it might blow. But the wind is more predictable than you might realize at first. After all, the wind is a form of solar energy.

"Capacity factor" is a term used by electric utilities for comparing different generating technologies. The term refers to the amount of time that a given generator type is producing its kilowatts compared to the total time available for production. For example, let's say you live in an area with an average of 4 peak hours of sunlight for PV production. Since there are 24 possible hours of production available in a given day, your PVs would have a capacity factor of 4 divided by 24, or a 16% capacity factor.

Annual average capacity factors for fixed PVs in the lower 48 run from about 8% to about 25%. That number can increase for the northern tier of states by about half with the addition of a tracker. In comparison, annual average capacity factors for wind generators range from 10% to about 28%. Taller towers can do for wind what trackers do for PVs.

While the weather bureau does a poor job with average wind speeds, daily and seasonal wind patterns are very well documented. For about 90% of the U.S., the wind is quite noticeable during the fall, winter, and spring. During the summer, the wind ceases to exist in many places. When you think about it, the wind usually blows when the sun doesn't shine. And the sun is usually really bright when the wind isn't blowing. These daily and seasonal patterns exist for the bulk of the U.S. Maybe we're onto something here!

Comparisons

Let's look at some of the advantages and disadvantages of the two technologies:

PVs advantages include:

- No moving parts. This is PVs trump card, by far.
- They are on the ground. No dangling from 80 feet in the air when it's time to remove dirt or bird droppings.
- They're modular. If you don't have enough capacity, just add a few more panels. You can't do anything like this with a wind system. If you need more wind capacity, you get a bigger wind generator, or install a second unit.

PVs only disadvantage:

- Cost! PVs are, by far, the most expensive of the renewable energy technologies.

Wind power's advantages include:

- Cost. It is one of the more cost-effective renewable energies, coming in behind only solar hot water heating and some hydro electric generators.
- More power in the resource. Because of the cube law, $P = 1/2\ dAV^3$, wind generators can deliver awesome amounts of electricity in a brief period of time. For the folks with batteries, that means it's equalize time.

Wind power's disadvantages are:

- Heights! Wind generators live on top of towers, making service and maintenance more difficult. Tilt-up towers make this disadvantage a moot point, because the generator tilts down to ground level.
- They have moving parts. Any device with moving parts will eventually need maintenance. By the way, don't let anyone tell you that their wind generator needs no maintenance. Any mechanical system with moving parts will need some attention eventually. However, recent improvements in materials science have eliminated many of the problem components in older machines.

A Marriage

The point of this exercise was to dispel misconceptions about wind power that exists in the PV community. But more than that, it was to get you to think about the possibilities that exist with a wind/PV hybrid system.

Let's compare advantages and disadvantages of wind/PV hybrids.

Advantages:

- The resources are quite complementary. Long sunny days and periods of good winds rarely overlap.
- Because the resources complement each other, their peak operating times occur at different times of the day and year. This means that the capacity factors are somewhat additive. A PV system with a 15% capacity factor and a wind generator with a 20% capacity factor may combine for a total system capacity factor of 30%.
- Higher capacity factors for the generating devices means less storage is needed with the batteries. This often results in a downsizing of the balance of the system's components.

Higher capacity factor means that you can retire your stand-by gas generator, like the crew at Home Power did. *[We did give away the old generator, but sometimes poor weather forces us to run the 12 Volt Honda/alternator — about 12 hours for this issue. – TP]* Less fossil fuel means that our atmosphere as well as the rest of us can all breathe a little easier!

Disadvantages: None!

Access

Mick Sagrillo enjoys his wind generators at Lake Michigan Wind & Sun, E3971 Bluebird Rd., Forestville, WI 54213 • 414-837-2267

Out of the Fire and into the Sun

Pat Walker

It was a hot time in the small towns of Round Mountain and Montgomery Creek in northern California. Starting on August 20, 1992 and continuing for many days, a giant, out-of-control fire burned through both towns and the surrounding 60,000 acres of timberland.

After a house we owned in town burned to the ground in minutes, I watched as the fire swept wildly after people fleeing with whatever they had been able to grab quickly. A horse tied to a truck trotted up Highway 299 followed by an odd assortment of vehicles, people, and animals looking for a safe place to stop.

Countless pets, farm and wild animals were killed. Miraculously, no people perished although there are many harrowing tales of daring escapes and feats of bravery. Many people lost their homes — 330 houses were destroyed in the fire.

Enter FEMA

With wet weather on the way, a much overworked government organization, the Federal Emergency Management Agency (FEMA) arrived to help.

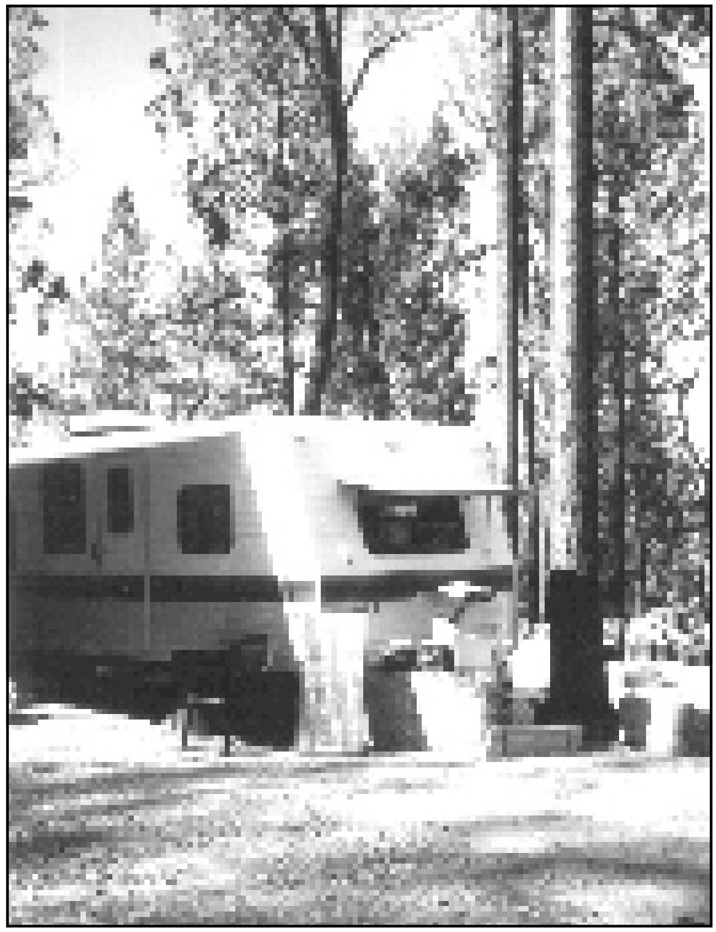
In early October I received a phone call from Jeff Jurew of FEMA. Would I meet with them and discuss the possibilities of designing some small solar systems for people living beyond the power lines?

I liked Jeff immediately. He is a very caring and diplomatic man, just the type of person needed to deal with all the displaced and frightened people. He was hundreds of miles from home and worked for weeks without a day off. He listened to people and got the job done.

The problem was that the trailers that were brought in to house people required electricity to run lights and the 12 Volt blowers on the heaters. Plus an ac water purification pump was to be installed.

Suggesting Solar

FEMA was considering providing gasoline generators to these people. As many of the folks had used solar power before the fire, they suggested solar to Jeff. It was a nice surprise for them that Jeff and FEMA were willing to consider it. Generators were all the FEMA people knew about. They had never considered solar power in past disasters.



Above: The Feds see the light! FEMA provides solar power for folks displaced by a forest fire.
Photo by Pat and Rick Walker

So I met with the G-men. I learned the requirements to run the trailers. I gave them as low an estimate as I could. Fearing I might frighten them away from all this new “solar thinking” I tried to keep things at a bare minimum.

They agreed to the solar. The only catch was they wanted it immediately. With the help of Bob-O Schultze of Electron Connection, we got everything together in two days.

Each system mainly consisted of one Solarex MSX-60 Watt panel, two Trojan 220 Amp-hour T-105 batteries, a small SunAmp controller and a PowerStar 200 watt inverter. We also created a small water pumping system made up of a 12 Volt pump and one 60 Watt Solarex panel. The big gasoline water pump that was being considered for this tiny trickle of water was just plain crazy. And solar power was less expensive.

Above: Mark Harzarian, one of the fire victims, and Jeff Jurew of FEMA celebrate the first completed solar system.
Photo by Pat and Rick Walker

The electrical contractor already doing work for FEMA did the installations. He had never been involved with solar before, yet the work went fairly smoothly. All the trailers and the water system were running in two more days.

Postscript

We found that most of the people did fine with their solar equipment (it was theirs to keep). Most added on to their systems with new or salvaged stuff from the fire. One person did have a problem keeping his battery full. I think using the lights caused the battery drain. One 3.5 Amp panel just couldn't keep up.

My husband Rick and I are replacing solar systems in this area. The main work will come this spring and summer when most of the houses are to be rebuilt. Lotsa Watts Solar will replace all solar equipment that was burned in the Fountain Fire at cost.

Access

Pat Walker, Lotsa Watts Solar Electric, No. 1 Shotgun Road, POB 167, Big Bend, CA 96011 • 916-337-6687

Electric Car Adaptors

Shari Prange

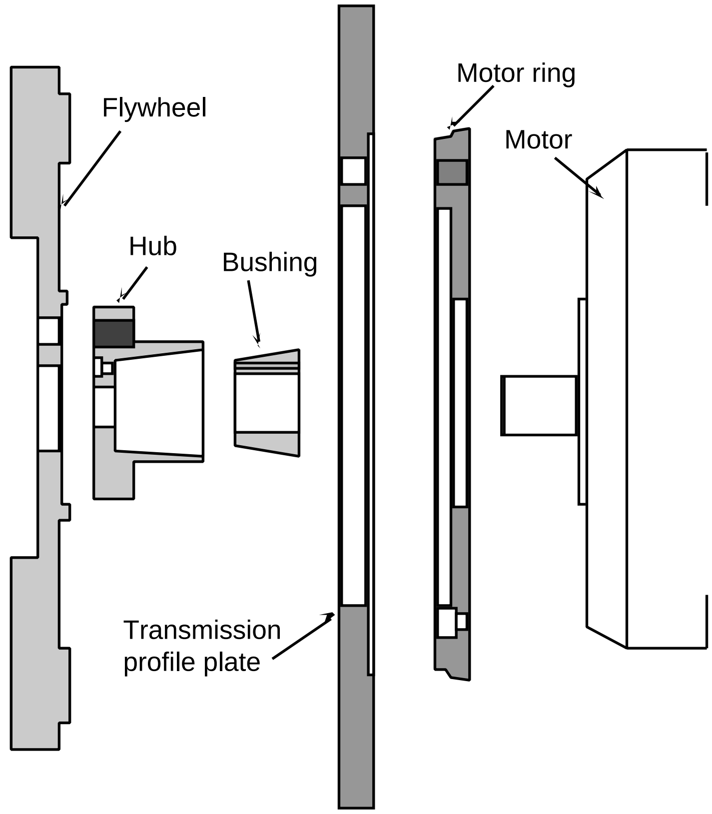
A chain is only as strong as its weakest link, and so it is with an electric car's drivetrain. All of the horsepower and torque needed to move the car down the road must pass through the adaptor on its way to the transmission and wheels. This is no place for half measures.

The adaptor needs to be designed, machined, and installed precisely. This does not mean laying the transmission face down on a piece of cardboard and tracing the outline and holes with a pencil to make a pattern. A professional adaptor manufacturer will measure and machine each bolt or dowel hole, as well as the thickness of the plate itself, to within a few thousands of an inch tolerance. This kind of accuracy assures a secure fit between motor, adaptor, and transmission. Any sloppiness in fit will eventually cause poor performance and could damage the motor or transmission.

What is an Adaptor?

Okay, let's look at what an adaptor is. Pay attention, there'll be a quiz later. There are two sections to an adaptor: the plate that mounts the motor to the periphery of the transmission, and the hub that connects the motor shaft to the flywheel and physically transmits the power. The plate can be made of aluminum in order to save weight. It should be no less than $^5/_8$ inch thick for adequate rigidity. The plate may actually come in two parts, as long as they are precision machined to fit together. At Electro Automotive, we use a $^5/_8$ inch thick transmission profile plate and a motor ring that varies from $^5/_8$ to 2 $^3/_4$ inches in thickness.

There are two reasons for this design. The first is weight and economy. There is a minimum thickness needed, which is determined by the space needed for the hub. If the profile plate were this thick, it would be very heavy and expensive. The ring, which is the diameter of the motor rather than of the transmission, is much more affordable and light.



Above: An exploded side view of an electric motor to transmission adaptor.

The second reason is that it allows the car to be upgraded to a newer or larger motor by simply changing the ring, instead of the entire adaptor.

Adaptor Hubs in the Naked City

The other section of the adaptor is the hub. This connects the motor shaft to the flywheel. This must be made of steel, not aluminum. The motor shaft has a square steel key in it that fits into a slot in the hub. If the hub is soft aluminum, that steel key will eventually egg out the slot and start cutting into the hub like a machine tool bit. This is not a pretty sight, especially at 50 mph.

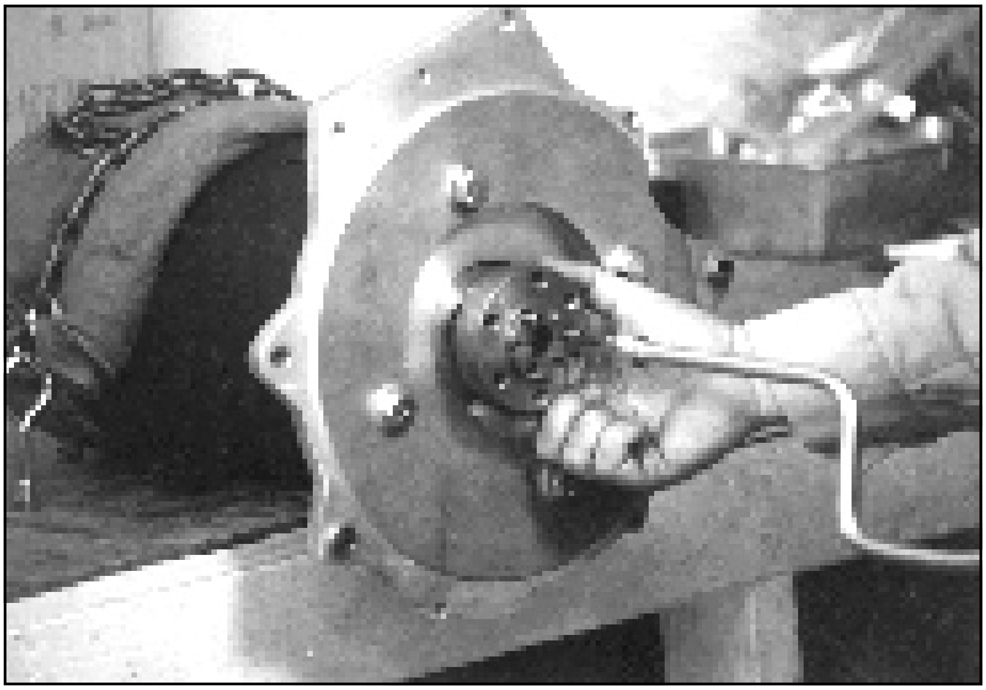
There are a million styles of adaptor hubs in the naked city, (twenty points if you can identify that TV show reference) and most of them are wrong. All the power of that motor passes through a little hub the size of a hockey puck. This is not the place to skimp.

One style holds itself in place with a setscrew in the side of the hub. Another uses a flat washer and a bolt in the end of the motor's output shaft. Both have the same problem: threads loosen. It doesn't matter how much Loctite you use, it will eventually work loose, and you'll be a pedestrian.

A third style is the shrink fit. In this type, the hub is heated to very high temperatures, then slipped over the shaft and allowed to cool and shrink into place. This will give a good secure connection. Unfortunately, it's too secure. If you ever need to remove that hub, you've got a problem.

The last style is a taperlock. This, like the plate, comes in two pieces. One is a cone-shaped bushing that slides over the motor shaft. It also slides inside the second piece, a hub that mounts to the original flywheel. The cone has a slit through it, and starts out a little bigger than the hole it fits into, so it won't go in all the way. As screws are tightened to pull it in, it compresses the slit and squeezes the rotor shaft. It's easy to install, but once it's in place, the only way it will come off is with a special pulling tool.

Now, class, who can tell me which style is the right one? The taperlock? Good, fifty points! This type of connection is the standard for industrial power shaft connections.



Above: Securing the taperlock hub on the electric motor shaft.
Photo by Shari Prange

Special Numbers

There are some numbers that need special attention here. The first is what we call the "magic number." On the gas or diesel car, this is the distance between the back of the motor and the farthest flat surface of the flywheel. This distance needs to be duplicated when installing the flywheel on the electric motor.

The second number is a measurement of torque. The hub is attached to the flywheel using the original bolts. These are special hardened bolts. When installing them, "use the Force, Luke." Specifically, use a torque wrench and the torque numbers in the manufacturer's service manual.

In order to get the leverage you will need to tighten these bolts, the electric motor needs to be immobilized. One way to do that is by using one or two very muscular friends. A better way is to strap the motor to the workbench. This can be done by installing sturdy eyebolts in the workbench on either side of the motor. Then pad the top of the motor with shop towels, and run a length of chain between the eyebolts and across the motor. Tighten the chain with a turnbuckle until the motor doesn't move.

Flywheel

Still with me? Okay, let's move on. We discussed earlier why we use a transmission and clutch at all (see "Electric Car Conversion," Home Power #32), and why it needs to be a manual transmission (see "Choosing a Conversion Car," Home Power #31). Now let's talk a little about the flywheel.

The flywheel has a safety function. If you were to over-rev the motor with no load (flooring the throttle with the car out of gear, for example), the motor could "run away" and self-destruct. The flywheel provides just enough load to protect against that.

Some people suggest lightening the flywheel to improve drivetrain efficiency. There is some advantage to this. The most benefit would come from removing the ring gear, which is no longer needed. The spinning flywheel teeth actually create some drag through air turbulence. This modification is not really necessary for the average conversion, though. It's something for electric vehicle hotrodders to play with, since they don't have carburetors anymore.

There are some reasons not to alter the flywheel. Too much lightening will dangerously weaken the flywheel, and efficiency gains are minor. Also, it may be impossible to find a local machine shop capable of doing this specialized work.

The flywheel is part of the clutch assembly. When you are installing the adaptor, this is the time to replace the clutch pressure plate, disc, and release bearing with new parts. If you do it right the first time, you won't have to change the clutch again until you replace the motor brushes at 80,000 miles.

After the Fact

Once you have your motor attached to the transmission with a good quality adaptor, and the entire assembly installed in the car, it's time to take a break, pat yourself on the back, and have a cold drink. You've earned it.

Access

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Alkaline Cell Operating Tips

Richard Perez

Alright, spring is here and part of spring cleaning is getting the battery back into shape after a hard winter's work. This article begins a series on alkaline cell operation and reconditioning.

This is for hands-on alkaline cell users. If the info here reads like Greek, then check out the battery articles in Home Power issues #27, #28, and #29. These articles are a quick course in battery basics.

First Examine Your System

Undercharging is the most common cause of alkaline cell problems. The cells making up a battery are never identical, especially reconditioned cells. After months of partially cycling the battery, some cells become more discharged than others. It only takes one weak cell in a series string to limit the capacity of the entire series string.

Check your voltage regulator or charge controller. If the voltage cutoff or regulation point of the regulator is set too low, then the battery is not being fully recharged. Set the regulator for at least 1.6 VDC for each series-connected cell in an alkaline system. This means 16 VDC for a ten series cell nicad or nickel-iron battery. This information applies to PV, wind, and hydro systems using either series or shunt regulators.

Charge and Discharge Test

Recharge the battery until you are really sure it is totally full and measure how many Ampere-hours you can get out of it. Even if you're sure that you have weak cells, the charge and discharge test is the best prelude to cell reconditioning.

Get to know your cells on an individual basis. Give each cell a name or number. Get a clipboard and record all the measurements. If you have a battery Ampere-hour meter (like the Cruising Equip. models), then you already have an instrument that will be of great aid in diagnosing lost capacity. If not, then you will need an accurate voltmeter.

How do we know when the battery or cell is fully recharged? Just look within the cell. Is it gassing furiously? Is the electrolyte alive with a cloudy mass of bubbles that burst on its surface? Sustained, heavy gassing is a sure sign that the cell is as recharged as possible. Measure the voltage of each cell. Write this data down next to the cell's number on the clipboard. While still undergoing recharging, the voltage difference between the highest and lowest cell should be no more than 0.1 VDC. If continual recharging does not bring the cells within this voltage spread, then these cells have problems and should have further treatment. If you have an Amp-hour meter, then overcharge the battery to between 130% to 160% of its rated capacity. If you are using a voltmeter, then continue recharging for five to seven hours after the cell reaches 1.6 VDC.

Now discharge the battery or cell and measure the number of Ampere-hours that it delivers. This is simple to determine if you have an Ampere-hour meter. Discharge cutoff voltage for an alkaline cell is 1.0 VDC. After discharging, read the number of Ampere-hours removed from the battery on the Ampere-hour meter. If you don't have an Ampere-hour meter, then discharge the battery or cell at a constant rate, measure this discharge rate with an ammeter, and multiply this rate by the number of hours it takes the battery (or cell) to reach the discharge cutoff voltage of 1.0 VDC. This results in the number of Ampere-hours removed from the battery – its capacity.

More complete instructions for this charge / discharge regime are in my battery articles in HP#27 and #28. I am repeating some of this info here because most battery problems are really just chronic undercharging. This method is both tedious and sure.

Finding Weak Cells the Easy Way

While the recharge / discharge routine will find the weak cells, the process is both time and energy intensive. Here is a procedure that does not use the refill/empty routine and requires no record keeping.

Wait until your alkaline battery voltage is low (below 11.5 VDC for ten series connected alkaline cells). Measure the voltage of each cell in the battery. The weak cells will have a low cell voltage at this point (between 0.5 and 0.8 VDC per cell). The good cells will have higher voltages (between 1.1 and 1.2 VDC). The voltage differences between the weak and good cells are very dramatic at this point.

We recently did this to our 150 cell, reconditioned, nicad battery. We are a 12 Volt system. Our battery is configured as fifteen series strings of ten cells. Each ten cell string is wired in parallel with the next ten series string.

Out of the 150 cells we found the ten cells with the lowest voltages. Oddly enough, no two of the ten lowest cells occupied the same series string. This meant that a single cell was limiting the performance of the other nine cells in the string. Our battery had this problem in ten of its series strings. What should have been a 1,500 Ampere-hour battery was behaving like a 700 Ampere-hour battery.

“I had to rearrange their faces and give them all another name…”

We then rearranged our battery so that all of the ten weakest cells were in the same series string. This means that ten weakest cells are not holding back the performance of ninety good cells. The weak cells now have their own series string and limit only the performance of each other.

The performance difference was immediate and well worth the small amount of effort. After the next sunny period the battery recharged and we went into another discharge cycle. This discharge cycle showed the battery behaving like it contained over 1,000 Ampere-hours. Successive cycling has produced even further capacity increases.

If the weak cells are low in capacity because they have not been properly recharged, then this procedure will restore their lost capacity. If the weak cells do indeed have diminished capacity, then at least they are isolated where they have the least effect on the remaining good cells. If the battery’s performance doesn’t increase after this procedure, then something else is wrong with the cells.

The Dance of Carbon Chemistry

The electrolyte used in alkaline cells is a 25% solution of potassium hydroxide (KOH) in water (about a 5N solution for chem techies). Carbon dioxide (CO_2) will enter into chemical change with the KOH and form potassium carbonate (K_2CO_3). High concentrations of carbon compounds in the electrolyte manifests as a loss in electrolyte density (specific gravity) and a loss in the cell’s ability to store electricity (diminished capacity).

If you really want to measure the exact amount of carbonate in the electrolyte, then perform a titration. The process is relatively simple desk top chemistry, but involves some lab equipment and reagents. See the side bar for specific titration instructions.

If you are equipped to do titrations, then by all means do them before reconditioning any cells. If you are not equipped, then either hire the job out, or recondition the cells without titrating their electrolyte. While you may waste your time and resources trying to recondition unfit cells, you will not damage any reusable cells.

Causes of Electrolyte Carbonation

There are several ways to rapidly carbonate an alkaline cell’s electrolyte. The first and most common way is to neglect the mineral oil layer floating on top of the cell’s electrolyte. Pocket plate nicads and nickel-iron cells use a 1/8 inch thick layer of pure mineral oil (Chevron Oil 22) floating on top of the electrolyte. Since this oil is less dense than the electrolyte, the oil floats. This thin oil layer isolates the electrolyte from contact with ambient air (which contains carbon dioxide).

Another cause of carbonation is chronic overcharging. When the cell is gassing heavily, the gas bubbles stir up the oil layer and work air into the electrolyte. Daily sustained gassing of the cell can result in electrolyte carbonation within a few months.

Distilled water, in a sealed but half filled jug, will dissolve carbon dioxide from the air and can transfer this CO_2 to the cell.

Another cause of carbonation is not thoroughly cleaning the cells when they are reconditioned. Reconditioning alkaline

Titration for K_2CO_3 in Alkaline Electrolyte

Materials required

- Hydrochloric Acid, 1 N
- Buret, 25 ml
- Buret stand, white porcelain base
- Pipette, 5 ml
- Phenolphthalein pH indicator, 1%
- Methyl orange, 0.1% (w/v) Aqueous
- Erlenmeyer flask, 250 ml
- Graduated cylinder, 100 ml
- Distilled water

Procedure

1. Using pipette remove 5 ml of electrolyte from the cell and transfer it to the 250 ml Erlenmeyer flask.
2. Add 50 ml distilled water to the Erlenmeyer flask.
3. Add 2 drops phenolphthalein pH indicator to the Erlenmeyer flask. Note the pink color to the liquid.
4. Using the buret, titrate with 1N HCl until clear. Record the number of milliliters 1N HCl to clear as A= ml.
5. Add 4 drops methyl orange to Erlenmeyer flask. Note the yellow-orange color.
6. Continue the titration until the yellow-orange color changes to pink-orange. Record this final value of the titration as B= ml.

(2(B-A)/B) 100 = % K_2CO_3 in the electrolyte

For alkaline cells up to 15% carbonate concentration is considered operable. If the K_2CO_3 exceeds 15%, replace the electrolyte.

cells essentially means cleaning out the cell and replacing its electrolyte. Graphite is used as an electrically conductive packing material in the cell's anodes. Over time (a shorter time if the cell is routinely overcharged) the graphite gradually works itself out of the pocket and into solution with the electrolyte. Graphite is mostly carbon and contributes to electrolyte carbonation —a harbinger of cell failure. If you have ever wondered what that black scum floating on top the electrolyte was, well now you know — it's graphite. The graphite that is not buoyed up by the oil layer sinks and forms a thick black sludge on the bottom of the cell. This sludge must be removed during the reconditioning process or it will rapidly contaminate the replacement electrolyte. If you are buying "reconditioned" cells, reject any that have black sludge!

All carbonation reactions take place faster at higher temperatures (over 120°F or 40°C).

A Question of Carbon

You may ask yourself why does a maker of alkaline cells deliberately add a carbon containing material to a cell that is sensitive to carbon contamination. I know I have. Thomas A. Edison did. Graphite is added as a flexible, low resistance, path binding the powdered nickel oxide. Finely powdered graphite is mixed with nickel oxide to make the cells active anode material. This mixture is compressed into the anode's pockets during folding and pressing the plate. The graphite provides good electrical connection between the active anode material (nickel oxide) and the framework of the plate. The only cells of this type that do not use graphite are the new fiber nickel-cadmium cells made by Hoppecke.

Carbon compounds in the cell's electrolyte eventually attack the cathode's active material — cadmium oxide (CdO). The cadmium forms cadmium carbonate ($CdCO_3$) which is a poor conductor of electricity. Cadmium carbonate coats the negative plate and chokes out the more active cadmium oxide. Changing the cell's electrolyte decomposes the cadmium carbonate and converts the active cathode back into cadmium oxide.

And the dance of carbon still goes deeper. The graphite used in pocket plates is very pure; it contains very few impurities. High on the list of graphite impurities is any iron compound, specifically iron oxide — rust. If a cell is operated with high graphite concentrations in its electrolyte, then eventually the iron impurities (from rust molecules in the graphite) attack the cell's active anode material — nickel oxide. This terminal reaction is known as "iron poisoning of the anode" in classical electrochemical literature. Anodes can also be iron poisoned by adding water with dissolved iron compounds to the cell.

A Word on Alkaline Cell Storage

Alkaline cells are best stored with their electrolyte in place. If you must remove the electrolyte and are not ready to replace it with new electrolyte, then fill the cell with distilled water. Do not store unsealed cells in a dry condition for over 30 days. Atmospheric degradation begins immediately and can ruin a cell within a month.

What Next?

If you've run these tests and examined your cells, then you have a good idea of candidates for reconditioning. Next issue's battery article will have specific details on the reconditioning process, including making your own electrolyte and proper disposal procedures for spent electrolyte. Till then get to know your cells in preparation.

Access

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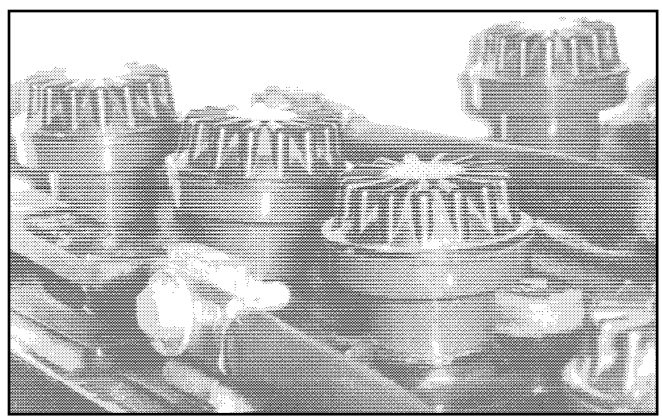


How Electric Motors Work

Amanda Potter

We use electric motors everyday. They are in our refrigerators, washers, stereos, computers, power tools, water pumps and electric cars — to name just a few. Electric motors use the relationship between electricity and magnetism to transform electrical energy into mechanical motion. Understanding how they work helps us determine the best motors for our applications. In renewable energy systems, motors and inverters can be a quarrelsome combination. Knowing how motors work helps you understand the motor's electrical needs.

Magnetic Fields

Magnetic fields exert a force on ferrous metals (like iron) and magnets as well as on electric currents without any physical contact. Lines of force or flux were invented to help us visualize the magnetic field. Stronger magnetic fields are shown with more lines of flux.

Magnetic flux density is proportional to the number of flux lines per unit area. See Figure 1.

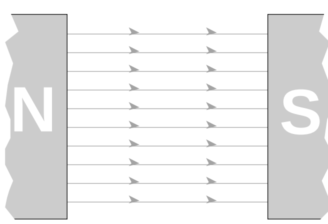


Figure 1

DC Motor Action

An electric current produces a magnetic field. The flux lines of a staight, current carrying conductor are concentric rings around the conductor. See Figure 2. The direction of the magnetic field lines are determined by the direction of the current. Your right hand can be used to show this relationship. Your thumb points in the direction of current and your fingers curl in the direction of magnetic field.

Current flowing through a conductor in a magnetic field exerts a sideways force on the conductor. In Figure 3, the permanent magnetic field and the induced magnetic field oppose each other in the region above the wire, reducing the total flux. Below the wire, the two fields are in the same direction and the total flux is increased. The resulting magnetic force causes the conductor to move upwards into the area of the weaker magnetic field.

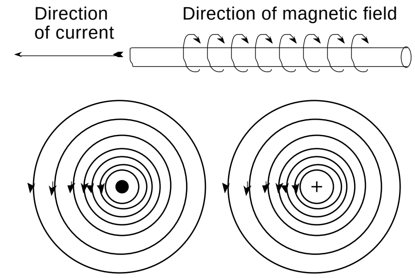


Figure 2 : Flux flow of current flowing a) out of the page b) into the page

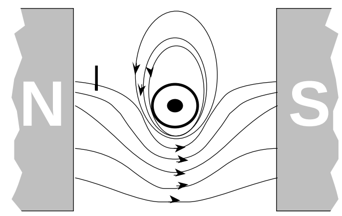


Figure 3

If an armature loop is placed in a magnetic field, the field around each conductor is distorted. See Figure 4. These repulsion forces are proportional to the flux density and the current in the armature loop. The repulsion forces push the armature upwards on the left and downwards on the right. These forces are equal in magnitude and opposite in direction and produce a torque which causes the armature to rotate clock-wise.

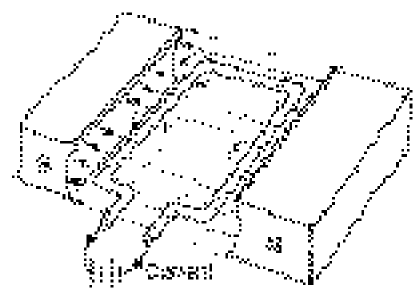


Figure 4

Commutation

The magnitude of this torque is equal to the force multiplied by the perpendicular distance between the two forces. It is maximum when the conductors are moving perpendicular to the magnetic field. When the loop is in any other position, the torque decreases. When the plane of the loop is perpendicular to the magnetic flux (we call this the neutral plane), the torque equals zero. As soon as the armature passes this point, it experiences a force pushing it in the opposite direction and is eventually magnetically held at the neutral position. In order to maintain the motion of the armature, the battery connections to the armature loop must be reversed as the loop rotates past the neutral plane. This is the basic principle behind a DC electric motor. Electrical energy (current) supplied to the armature is transformed into mechanical motion (the loop rotates).

With the type of motor described above, the torque varies from zero to its maximum twice in each revolution. This variation in torque can cause vibration in the motor and the equipment it drives. Also, a motor stopped with the armature in the neutral plane is very difficult to start. Additional armature coils solve both of these problems. Figure 5 shows a motors with one coil, two coils, and 16 coils. The more coils that an armature has (each with two commutator segments), the smoother the torque output. Torque never drops to zero when there are two or more coils.

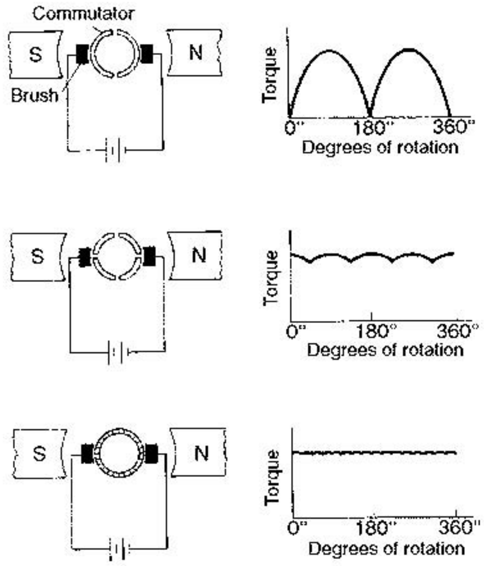


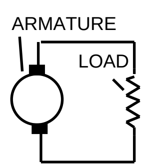
Figure 5

Back EMF

Whenever a conductor moves through magnetic lines of flux, voltage (emf) is induced in the conductor which is opposite to the voltage you applied to the motor to make it spin. The magnitude of this emf depends on the speed of rotation. It is called the back emf or contervoltage. The difference between the applied voltage and the back emf determines the current in the motor circuit. So, the back emf helps to limit the current flowing in the armature.

DC Motor Types — Permanent Magnet Motors

Permanent magnet (PM) motors are comparably small, light, efficient motors. Their high efficiency and small size are due to the use of permanent magnets to produce the magnetic field. They do not have the added bulk and electrical losses of the field windings normally required to produce the magnetic field.



Permanent magnets are produced by ferromagnetic materials that have been magnetized by an external magnetic field. Ferromagnetic materials can produce magnetic fields several times greater than the external field and will remain magnetized even after the applied magnetic field is removed.

Speed Regulation

Speed regulation is easily accomplished in a PM motor because the speed is linearly related to the voltage. The speed can be increased simply by increasing the voltage. The speed is inversely proportional to the torque. This means that the torque increases as the motor slows down for heavy loads. See Figure 6. The torque a motor can apply at start up (starting torque) and the torque which causes the motor to breakdown (breakdown torque) are the same for these motors. PM motors have a high starting torque for starting large loads. This torque results from a high starting current, 10 to 15 times normal running current. PM motors cannot be continuously operated at these currents, though, since overheating can occur. Runaway in a motor occurs when the motor builds up speed under no load until its bearings or brushes are destroyed. Runaway is unlikely in PM motors.

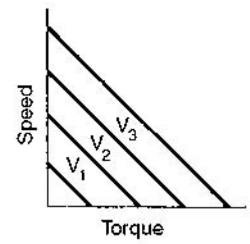


Figure 6

Dynamic Braking

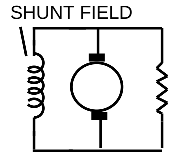
Sometimes it's necessary for a motor to stop rotating quickly after power is disconnected from the motor. This can be achieved by mechanical braking (friction) or electrical braking (dynamic braking). Dynamic breaking is accomplished in a PM motor by shorting the armature connections and converting the motor into a generator. The rotational mechanical energy is converted to electrical energy and then to heat. PM motors can be braked very quickly using this method without the use of brake shoes which wear out. PM motors are also be easily reversible when the motor is running or stopped.

The most serious disadvantage of PM motors is that the PM fields can be demagnetized by the high armature currents that result from stalling or "locked rotor operation." This problem becomes more of a concern at temperatures below 0°C. Also, permanent magnet motors are normally small motors because permanent magnets can't supply enough magnetic field to produce large PM motors.

PM motors can be used for applications requiring small, efficient motors which have high starting torques and low running torques (inertial loads). They are commonly used in well pumps and appliances in RV systems. Jim Forgette of Wattevr Works uses PM motors in his washing machine retrofit kits.

Shunt Motors

In shunt motors, the magnetic field is supplied by an electromagnet which is connected in parallel with the armature loop. The primary advantage of shunt motors is good speed regulation. Variations in torque by the load do not have a big effect on the speed of the motor unless it is overloaded. Shunt motors have lower starting torques and



lower starting currents (three times running currents) than other motors of same horse power. See Figure 7.

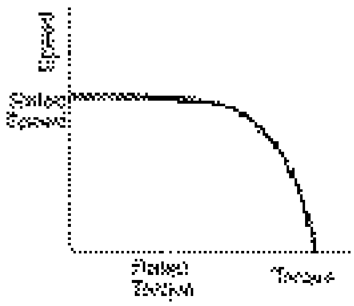
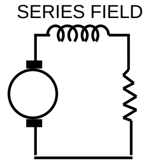


Figure 7

The National Electrical Manufacturer's Assn has agreed on four standard speeds for shunt motors: 1140, 1725, 2500, and 3450 rpm. The speed is normally controlled by varying the armature supply voltage. Speed varies linearly with armature supply voltage and torque is unaffected.

Shunt motors are typically used for loads which require good speed regulation and fair starting torque. If very heavy loads are to be started, a starting circuit may be required. Starting circuits connect progressively smaller resistances in series with the armature. Runaway can occur in shunt motors if the field current is interrupted when the motor is turning but not loaded. Dynamic braking and reversibility are both options with shunt motors.

Series Motors



In series motors, the field coil is connected in series with the armature loop. The field coil has a large current (the full armature current). Heavier copper is used for the field coil but not many turns are needed. Series motors are usually less expensive and smaller in size than other motors of the same horsepower because less copper is used.

Due to the small number of turns and the resulting low inductance, series motors can operate on both ac and DC power. For this reason, series motors are often called universal motors. Power to both the field and armature loops reverses at the same time when operated on ac power and so the resulting magnetic force remains the same. Series motors may perform differently on ac than DC because of the difference in impedance of the windings. One shouldn't assume all series motors are universal. Some may be optimized for a particular power supply and perform poorly or fail prematurely if not operated on the correct supply.

As the motor's speed is decreased by heavy loads, the motor supplies high torque to drive the load. This helps prevent stalling and provides high starting torque. Starting currents are also high but are not usually a problem because series motors are normally small motors. See Figure 8. The speed of series motors can be adjusted by varying the supply voltage with a rheostat, variable transformer or electronic controls. Series motors are not normally used if constant speed over a range of loads is required.

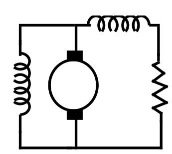
Figure 8

Series motors are very common motors in household appliances and power tools. They are used in blenders, juicers, food processors, and hand power tools such as drills. They are very versatile and have the highest horsepower per pound and per dollar of any motor that operates on standard single phase ac power. They deliver high motor speed, high starting torque and wide speed capability. Series motors are usually operated at speeds over 7000 rpm or more. In routers, small grinders and sanders, speeds of 25,000 rpm are not uncommon. Series motors are often connected to a built-in gear train to reduce shaft speed and/or provide more torque. Gear trains also provide loading which prevents runaway.

Series motors have comparatively high maintenance. Brushes and bearings need to be regularly replaced. They are the only motors that are usually given an intermittent duty rating. Other disadvantages of series motors are that they are not usually designed for dynamic braking and reversibility. They should not be run without a load as runaway can occur.

Series motors have a moderately low power factors — normally between 0.5 and 0.7. Resistors have a power factor of one. The more reactive a component, the lower its power factor. Low power factors can be a problem for modified sine wave inverters. Appliances with low power factors may run three quarter speed. Sine wave inverters do not have trouble with power factors less than one. Series motors are typically small motors and so their high starting currents are not usually a problem for inverters.

Compound Motors



A compound motor provides a mixture of the characteristics of both shunt and series motors. Its field coil is split into a series field which is connected in series with the armature and a shunt field which is connected in parallel with the armature. The magnetic fields can either aid (cumulative compound) or oppose each other (differential compound).

Cumulative and differential compound motors have different speed/torque characteristics. Cumulative compound motors provide more torque than shunt wound motors and better speed regulation than series wound motors. Differential compound motors have almost perfect speed regulation but lower starting torque. See Figure 9.

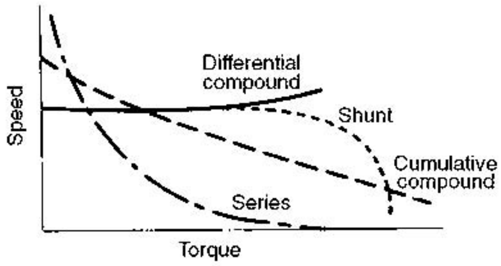
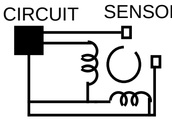


Figure 9

Compound motors were often used in the past. Inexpensive electronic controls has made it possible to replace them in many cases with lower cost series and shunt motors. They are still used sometimes in large DC equipment which require high torque and good speed regulation.

Brushless DC Motors

Brushless DC motors are actually not DC motors at all. They are ac motors with built-in micro inverters to change the DC supplied to the motor into ac to be fed to the field windings. A logic circuit senses the position of the permanent magnet rotor and controls the distribution of current to the field windings. Field windings are energized in sequence to produce a revolving magnetic field.



BRUSHLESS DC MOTOR

The greatest advantage of brushless DC motors is the replacement of carbon graphite brushes and commutators with long life solid state circuitry. They provide low maintenance, low electrical noise motors with good speed control and constant torque. They cannot, however, be easily reversed and are not easily adaptable to dynamic braking. They are also more expensive than conventional DC motors. They are used frequently in audio-visual equipment and “muffin” cooling fans, such as the ones found in inverters, charge controllers, and computer equipment. They are also used in Sun Frost refrigerators.

AC Motors — Induction Motors

The majority of motors in service today are ac motors. Many of these are universal motors. Induction motors, though more expensive, are also very common due to their high reliability. Polyphase induction motors are cheaper, more efficient, more reliable, and have a higher starting torque than single phase induction motors. We are only discussing single phase induction motors here though because only single phase power is available to most homes.

Induction motors use a squirrel cage rotor construction. This means that the rotor is made of thick aluminum or copper that is one turn only and is joined at each end by an aluminum or copper ring. This frame is then filled in with laminated iron to provide a low reluctance magnetic path. The bars of the rotor are angled with respect to the shaft to provide a smoother output torque and more uniform starting performance.

Voltage is induced in the rotor when it is placed in a rotating magnetic field. The induced voltage produces a high current because of the rotor’s very low resistance. This high current flowing in the rotor produces its own magnetic field. The magnetic interaction of the rotor and the rotating stator field exerts a torque on the rotor, making it follow the magnetic field. Thus an induction motor produces a torque on the rotor without any electrical connections to the rotor. This eliminates the use of brushes and bearings and is the reason for the induction motor’s high reliability.

Normally, the rotating magnetic field in induction motors is produced with three-phase power. A magnetic field established with single phase power will pulse with intensity but will not rotate. A squirrel cage rotor placed between the poles of a single phase motor will therefore not rotate either. Once the rotor begins rotating, however, it will continue to rotate. Thus some means must be employed to create a rotating magnetic field to start the rotor moving. This method determines the type of single phase ac induction motor.

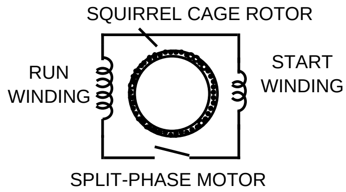
Split-phase Motors

In split-phase motors, a rotating magnetic field is produced with a start winding and a run winding. The start winding is made of smaller gauge wire. The resulting higher

DC Motor Characteristics

Motor Type	*Starting Torque*	*Starting Current*	*Revers-ibility*	*Speed*	*Dynamic Braking*	*Size/Weight*	*Cost*	*Horsepower Range*
PM	high	high	easy	varying	yes	smallest	low	under 1
Shunt	low	low	easy	constant	yes	normal	moderate	any
Series	high	very high	not usually	high & varying	no	small	low	under 2
Compound (Dif)	low	low	easy	very constant	yes	large	high	any
Compound (Cum)	high	high	easy	fairly constant	yes	large	high	any
Brushless	high	high	difficult	constant	no	small	high	low

resistance and lower reactance produces an approximately 60° phase difference between the currents in the two windings. This phase difference produces a rotating magnetic field which causes the rotor to start rotating. See Figure 10 below. The start winding is disconnected from the circuit when the motor reaches 70% of operating speed. The start winding will overheat if it conducts current continuously. Once the rotor begins turning, the distortion of the stator magnetic field by the rotor's magnetic field produces enough magnetic field rotation to keep the rotor turning.



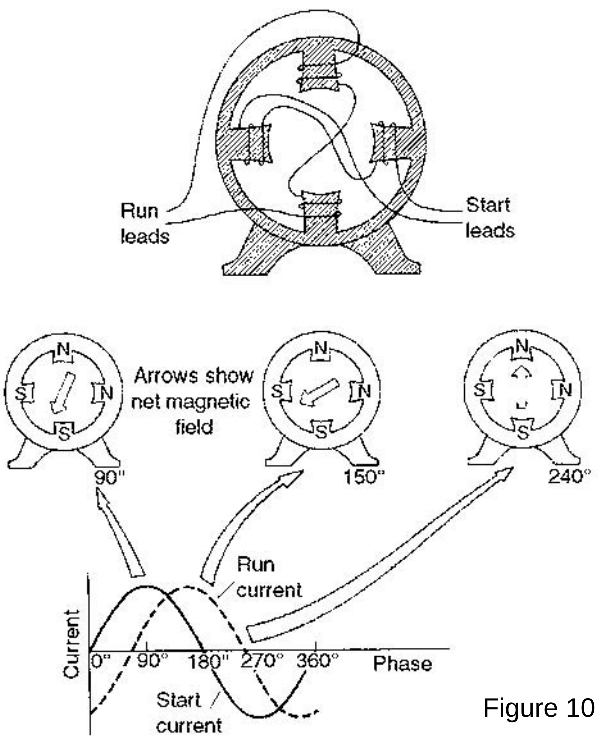


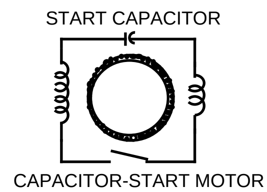
Figure 10

Split-phase motors are very common and not very expensive. Oxidation of centrifugal switches was once the most common type of failure. Solid state devices have improved the motor's reliability. They have a moderate starting torque and a high starting current (8–10 times running current). They are a good choice for easy to start application such as large fans, blowers, washing machines and some power tools, including bench grinders and large table saws. Overheating can occur if the motor is heavily loaded and the speed kept too low for the switch to open. Heat builds up with the high starting current and the high start winding resistance. Overheating can also result from frequent starting and stopping.

Split-phase motors operate at practically constant speed and come up to rated speed very quickly. The motor's speed varies from 1780 rpm at no load to 1725–1700 rpm at full load for a 4 pole 60 Hz motor. Split-phase motors can be reversed while at rest but not during operation. Dynamic braking can be accomplished by supplying DC power to the field coils via either an external DC supply or a rectifier, resistor and charging capacitor.

Split-phase motors can cause problems on inverters because of their very high starting currents. Richard learned a trick after damaging many inverters trying to start his bench grinder. If you start the wheel turning with your finger, you can get the grinder started with a lower current. Be sure to get your finger out of the way before you turn the switch on.

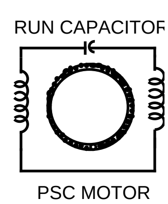
Capacitor-Start Motors



Capacitor-start motors have a higher starting torque and lower starting current than split-phase motors. They do this by connecting a capacitor in series with the start winding which increases the phase difference between the start and run fields. Low cost ac electrolytic capacitors are normally used since they are only used for a few seconds when starting. Capacitor-start motors are used to start very heavy loads such as refrigerators, pumps, washing machines and air compressors. The starting currents can be quite high when the motor is operated with large loads. This much current is hard on centrifugal switch contacts and so many capacitor-start motors use a current or potential relay instead of a centrifugal switch.

Capacitor-start motors often have problems on modified sine wave inverters. The field coils and the capacitor make up a tuned circuit which requires 60 Hz frequency for proper operation. Although modified sine wave inverters have an average 60 Hz frequency, the instantaneous frequency is sometimes much, much higher. Richard's found in his experience that substituting the capacitor for a higher or lower value may solve the problem. It's a matter of testing different values. Sine wave inverters do not have any problems starting capacitor-start motors.

Permanent-Split-Capacitor (PSC) Motors



Centrifugal switches and relays are the most likely part of the capacitor-start motor to fail. They can be removed if slightly larger wire is used for the start windings so that they can be left connected without overheating. A higher capacitor value is required to compensate for the higher

AC Motor Characteristics

Motor Type	*Starting Torque*	*Starting Current*	*Revers-ibility*	*Speed*	*Dynamic Braking*	*Cost*	*Horsepower Range*
Split-phase	moderate	high	easy, at rest	relatively constant	yes	normal	up to 2
Capacitor-start	high	medium	easy, at rest	relatively constant	yes	high-normal	up to 5
PSC	mod. high	med. low	easy	relatively constant	yes	high-normal	up to 5
Two-capacitor	high	medium	easy, at rest	relatively constant	yes	high-normal	up to 5
Shaded-pole	low	low	not reversible	relatively constant	yes	low	up to 1/2

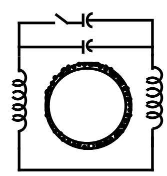
inductance of the larger windings. Oil-bath type capacitors are usually used because the capacitor is now used during start and run operation.

PSC motors operate in much the same way as a two phase ac motor. The capacitor ensures that the capacitor winding is out of phase with the main winding. There is now a rotating magnetic field during start and run operation. This gives the motor greater efficiency and quieter and smoother operation than ac induction motors that only have a rotating magnetic field during start operation. The capacitor value is a compromise between the optimum value for starting and running. This results in a lower starting torque than the capacitor-start motor.

PSC motors are used in applications where frequent starts and stops and quiet smooth operation is required. Examples are instrumentation and low noise equipment fans.

Two-Capacitor Motors

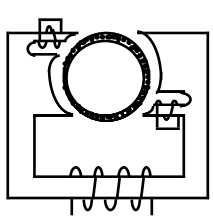
Two capacitor start, one capacitor run motors use an electrolytic capacitor for starting and an oil-type capacitor for starting and running. The two capacitors are connected in parallel. This motor type preserves the efficiency and smooth, quiet operation of PSC motors while running and provides the high starting torque characteristic of the capacitor-start motors. Optimum starting and running characteristics are obtained at the expense of using some sort of switch again.



TWO-CAPACITOR MOTOR

Shaded-Pole Motors

Shaded-pole motors' magnetic fields are made to rotate by the inductive effect of two or more one-turn coils next to the main windings in the stator. The time varying magnetic field set up by the alternating current in the main winding induces current in the shading coils. The induced current in turn establishes a magnetic field in the shading coils which lags behind the main field by about 50°. This sets up a rotating magnetic field in the stator.



SHADED-POLE MOTOR

Shaded-pole motors are simple in design and construction. They have no internal switches, brushes, or special parts. These motors offer substantial cost savings in applications which require constant speed and low power output.

Shaded-pole motors are inefficient, have low starting torque and can have unsmooth running torque. They are nonetheless cheap and reliable and are used in countless consumer applications ranging from inexpensive blowers to room air conditioner fans. Shaded-pole motors run without problems on sine wave inverters but may run slow on modified sine wave inverters.

Speed Control of ac Motors

Speed control of ac series motors can be accomplished by using SCR's and triacs to turn ac power on for only part of each cycle, reducing the average voltage to the motor without dissipating large amounts of power.

Induction motors are usually designed to run at a single speed controlled by the frequency of the ac power supply driving them (which is usually a constant 60 Hz). At a higher cost, they are sometimes specially designed to provide speed variations. This is usually accomplished by changing the number of poles. A motor with two coils per phase will run half as fast as a motor with one coil per phase. Thus a motor can be made with two or three coils per phase and the number of coils can be switch selected.

Energy Efficient Electric Motors

Split-phase, capacitor-start, PSC and two-capacitor motors are all available in energy efficient models. Improvements in efficiency are mainly due to increased conductor and rotor areas, improved grade of steel and improved ventilation. These motors are begining to be found in larger home applliances and may make these appliances an option for RE systems.

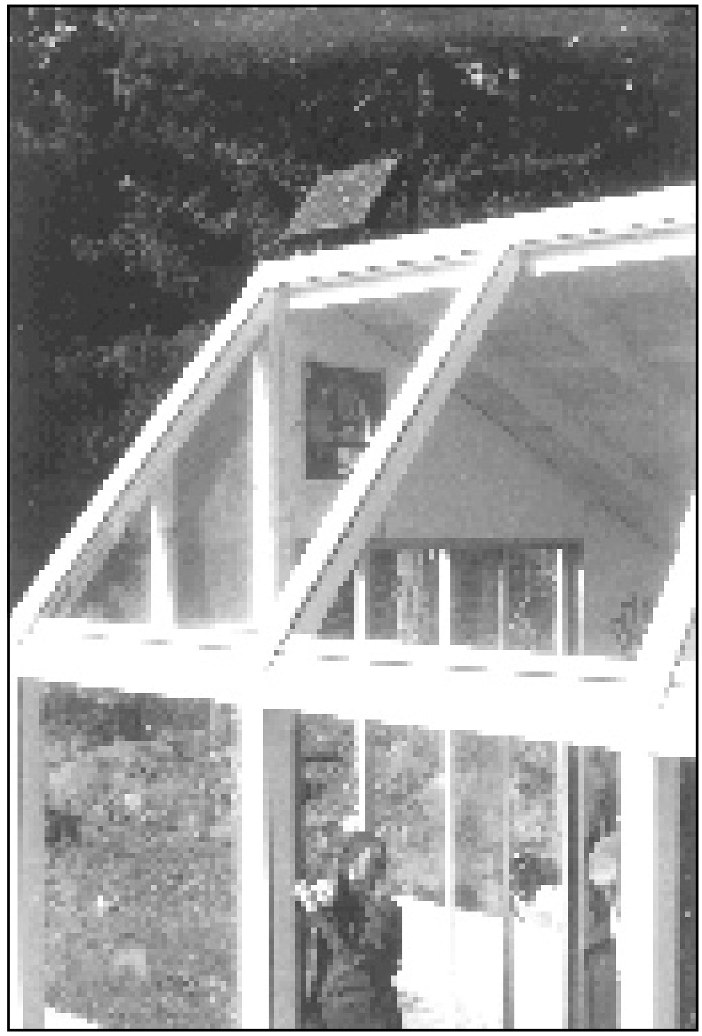
Access

Amanda Potter, c/o Home Power Magazine, POB 520, Ashland, OR 97520 • 916-475-3179

Solar Electric Greenhouse Ventilation

Chris Greacen

Seeds planted in our greenhouse have made the miraculous transformation to small green starts poking optimistically through the potting soil. As these plants grow they will need sun and warmth and water. To grow strong and prevent mold and mildew, plants also need a supply of dry, carbon dioxide rich air from outside. In fact, greenhouse growers recommend 150 air changes a day, with an air change every couple minutes in the hottest time of the day. For our greenhouse, a solar powered fan was the solution to adequate greenhouse ventilation.



Lela, my mother, switches on the fan. The electricity comes from the solar panel on the roof. Photo by Chris Greacen

Solar Breezes

There's something clean and wholesome about sunlight powering the movement of air in a solar greenhouse. Also, since our greenhouse is several hundred feet from utility power, a solar powered fan was the cheapest ventilation available. When it's bright and sunny the fan blows like crazy. At these times the greenhouse needs the most ventilation because of the heat, and because the plants are active making oxygen and evaporating moisture. When light levels are low, the fan barely turns, but this is great too, because the plants' metabolism is down, and the greenhouse needs to preserve heat.

Sizing

An air change every couple of minutes! Seems like an awful lot. To figure out the size fan you need, first find the volume of air in your greenhouse. Ours is about 15 feet by 20 feet, and an average 15 feet tall. Multiply the dimensions together — ours is 4500 cubic feet. For an exchange of air every five minutes, we'd need a fan that blows 900 cfm (cubic feet per minute). We chose a 16 inch fan in a 20 inch housing, driven by an efficient DC permanent magnet motor. Under full sun, powered by an 18 Watt photovoltaic panel, it is rated at 1000 cfm. If this isn't enough, another panel, doubling the voltage, will more than double the cfm.

Installing the Fan

I mounted the fan in a 20 inch by 20 inch 2x4 framed hole above the door on the west wall of the greenhouse. On the east wall at ground level is a vent for incoming air. It's ideal to have a low "intake" and higher exhaust vent to keep air from forming stagnant stratified layers and to take advantage of the draft formed by air heated in the greenhouse. In fact, with no fan at all, vents in this configuration would help create a gentle breeze. Orient the vents to make use of the prevailing wind direction. In our area wind blows most from east to west, therefore we designed the exhaust vent on the west side. To seal off the vents at night to keep in the heat, build a door for the vent, or use a solar vent opener (available from greenhouse suppliers). Put screens over the vents to keep the bugs out.

Look Maw! No batteries!

There's no battery in this system. This is a good thing. Batteries are usually the weak link in renewable energy systems. Anytime you can leave out the battery, your system will be more reliable and longer lived. In this case we're interested in ventilating only when the sun is shining, and blowing more when the sun is brighter, so there's no need for energy storage.

To make the system work well in low light, though, a bit of fancy electronics called a Linear Current Booster (LCB) is needed. In low light, a photovoltaic panel produces power at a voltage/current combination which is poorly matched with the current and voltage the motor needs to begin turning. To get useful power out of the panels in low light, the LCB (model 3T) "trades" the panel's higher voltage for higher current needed to run the motor. It runs slower than in full sun, but without the LCB, it wouldn't run at all. Be sure to mount the LCB so that you can access the small "tuning" potentiometer on the back. You'll need to diddle this knob when you set it up so that the LCB does its job most effectively electrically matching your fan and photovoltaic panel.

Include a switch on the panel's positive output so that you can turn on and off the fan. Figure out how much wire you'll need and consult wire tables (you'll find a set on page 32, Home Power #18) to determine which gauge to use. Solder all connections to prevent corrosion (incidentally, there's also a great article on soldering in HP #18).

Finally, install the photovoltaic panel. I made an adjustable rack out of angle iron. With a drill press I drilled holes which allow the angle of the panel to be adjusted with the changing seasons. Since we live at around 48° latitude, so I made the rack so that it could be set at 48° (spring and fall), 48° – 23° = 25° (summer), and 48° + 23° = 71° (winter). The magic 23° comes from the tilt of the earth's axis.

Cost

You should be able to find 18 Watt Solarex panel for around $235, the fan for $105, and the LCB-3T for $80. For about $10 less you can get a non-tunable LCB-3 which will also work, but won't allow you to add a second series panel.

Access

Author: Chris Greacen, Home Power Magazine, POB 520 Ashland OR 97520 • 916-475-3179

Fans, panels & LCBs: Bob-O Schultze, Electron Connection, POB 203, Hornbrook, CA 96044 • 800-945-7587; Steve & Elizabeth Willey, Backwoods Solar Electric Systems, 8530 Rapid Lightning Creek Rd., Sandpoint, ID 83864 • 208-263-4290; Alternative Energy Engineering, P.O. Box 339, Redway, CA 95560 • 800-777-6609

Doktor Data Explains Sunshine

Dr. Leøj Data

Note: the following research was made possible by a generous grant from the *Home Power Tax-Free Institute for the Study of Sunshine*, whose generosity made the following research possible.

Solar beginners often ask me privately about sunshine. This is understandable, because sunshine is the most complicated part of solar energy. Newcomers to solarism ask, "I think I can perceive sunshine, but how can I really use it?" Students demand, "Dr. Data, if you're so full of knowledge and grant money and experience, why don't you write down what you know for future generations to study and build upon?"

Well, Dear Reader, thanks to a generous grant from the *Home Power Tax-Free Institute for the Study of Sunshine*, the time has come to let you know what you've been missing: the solar energy secrets that were hidden from you; the reason your neighbor's batteries stay charged, while yours just leak nasty chemicals.

The first and biggest problems faced by apprentices is summed up by asking, "Do solar panels work at night?" Unfortunately, years of laboratory research prove that they do not. Solar panels charge your batteries all day, but that's all they're good for. In fact, the main disadvantage of solar panels is that they don't work at night. At night you need to use *Lunar Panels*.

Lunar panels convert moonlight and starlight into usable 12 Volt charging power, enabling you to watch late night movies on your wide screen color T.V. without running down your batteries. State-of-the-art lunar panels are eight feet wide and nineteen feet six inches long, so you can easily fit two of them on the roof of your barn or forty foot RV. Prices have dropped to only $63,500 each, well within the budget of dedicated late night movie fans.

Daylight Savings Time

The second most asked question is, "How do I reset my solar panels for Daylight Savings Time?" This was a real stumper. Even Dr. Data had to ponder this one. "There has to be an easy way," I thought. "It can't be all that complicated!" Months of research followed. Then the answer came to me one day, when I was in line at the bank depositing some generous grant money. Solar panels are easy to reset!

In the fall, simply locate the "plus 12 Volt" wire (usually colored red from your panel to your battery, and cut it. Carefully reconnect the wire one hour later, and you are ready to go. In the spring, when you want to set the panel forward an hour, instead of back, you will have to disconnect and reconnect the "plus 12 Volt" wire twenty-three times, instead of just once. Each time you reconnect the wires, be sure to solder and wrap the joints carefully with red electrician's tape and red heat shrink tubing. Save the black tape for your "minus 12 Volt" wire, which has more electrons.

Look for later articles in this series by Dr. Data. You'll learn how to keep your solar panels from becoming guano depositories by running them in reverse when birds approach. Also, you will find out how to make your own solar panels using toxic chemicals from worn out hearing aid batteries. Do you have any questions for Dr. Data? Send your questions and grant applications to Dr. Data, care of this magazine.

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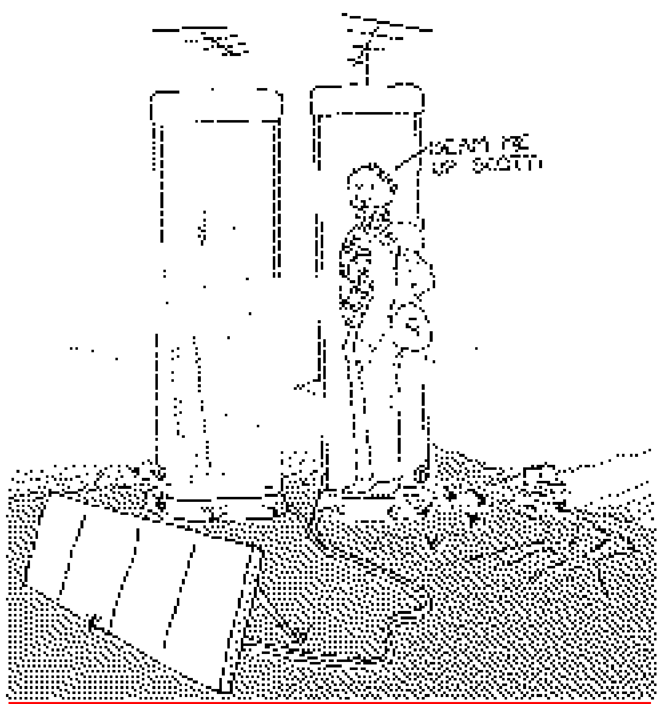

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☐ **As my primary power source**
☐ **As my backup power source**
☐ **As a recreational power source (RVs)**

I want to use alternative energy in the FUTURE (check one that best applies).

☐ **As my only power source**
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My site has the following alternative energy potentials (check all that apply).

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HP#34

I now use OR plan to use the following alternative energy equipment (check all that apply).

NOW	FUTURE		NOW	FUTURE	
☐	☐	**Photovoltaic cells**	☐	☐	**Gas/Diesel generator**
☐	☐	**Wind generator**	☐	☐	**Batteries**
☐	☐	**Water power generator**	☐	☐	**Inverter**
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Performance Testing at the 1992 American Tour de Sol

Dr. Robert Wills, P.E., Co-Director
American Tour de Sol

The second most frequent question asked to an electric vehicle owner is "How far can it go?" Electric vehicle range is determined by two things – the on-board energy storage available in the vehicle batteries, and the amount of energy needed to travel a unit distance (i.e. the energy consumption, or vehicle efficiency, in Watt-hours per mile). One of the major aims of the 1992 American Tour de Sol, at the request of the U.S. Department of Energy, was to measure both vehicle range and efficiency under controlled conditions.

Efficiency Testing

In 1991, we devised a means of measuring electric vehicle (EV) energy consumption that was simple, quick to install, portable, and easily adapted to any vehicle electrical configuration. This involved measuring average battery voltage and average motor current (at the motor controller/battery interface) using Fluke Model 87 Digital Multimeters. These innovative instruments are capable of sampling their input every 100 milliseconds and calculating a true average value for periods of up to 36 hours.

We use two Fluke 87 meters in each test setup. One meter measures average battery voltage directly while the other measures battery current via a 0-1000 Amp clamp-on DC current probe (a Fluke 80i-1010). To facilitate installation, 15 foot extension test leads were made using flexible two-core rubber cable. The voltage leads were terminated in heavy duty, fully insulated alligator clips and fused in-line near the clips to protect against a cable short - for example from being compressed under the vehicle hood. Fluke fully insulated banana plugs were used for safety. The current probe leads were a simple extension adapter for the Fluke 80i-1010 leads.

The power measurement is obtained by multiplying average battery voltage by average battery current. This is an approximation - the true energy consumed would be the average of the instantaneous power (P= V x I) - however as the battery voltage remains relatively constant during the tests, little error is induced. (This may not be the case for a testing cycle that has large amounts of acceleration and regenerative braking). A measure of this error can be obtained from the minimum and maximum data available from the Fluke meter. For example, the Solectria Force GT showed the following data for its 35 MPH laps at the Thompson Speedway:

Force GT	*Voltage*	*Current*
Maximum	80.8	208.8
Minimum	76	2.4
Average	79	65.5

The voltage variation of 6% probably only occurred briefly during the constant speed laps, and so is unlikely to result in more than 3% error. When instrument and timing error is included, it is still likely that overall error is less than 5%. Another possible source of error is that some high frequency current components from the motor controller may not be sensed by the current probe, but again this should be minor.

It is important to clamp the current probe on the battery side of the motor controller, as the actual motor current may be significantly higher than the battery current, especially at low speeds (the motor controller acts like a DC transformer). Similarly, the voltage connection must be made on the battery side of any contactors, otherwise zero, rather than the true battery voltage will be averaged during coasting or braking periods.

The vehicle efficiency is calculated from:

Av. Power (Watts) = Av. Volts x Av. Current (Amps)

Energy Used (Watt-hours) = Av. Power x Time (Hours)

Efficiency (Watt-hours/mile) = Energy Used/distance (miles)

The average power consumption of the vehicle at a certain speed is related to the efficiency by:

Average Power (Watts) = Efficiency (Watt-hours/mile) x Speed(mph)

For example, using the data above for the Force, the average power is 5.175 kW, the Energy used (over 1.70 minutes) is 153.5 Watt-hours, and the efficiency (over the 1.04 mile course) is 141 Watt-hours/mile. Multiplying 141 Wh/mile by the actual speed of 36.7 mph gives the average power, again of 5175 Watts.

The Efficiency Testing Courses

Efficiency tests were performed at the initial scrutineering in Albany prior to the race, at the Thompson Speedway (Thompson, CT) on day 4, and in the Boston city traffic, at the end of the race.

The Albany course was a 3.15 mile loop from the Rockefeller Plaza, across the Hudson River to Rensselaer, and back up to the Plaza. It ran on highway quality roads, had a height change of 160 feet down to 25 feet above sea level, and back again, and had several sharp turns and several possible stops. Entrants were required to travel this course at a minimum speed of 25 mph, with some allowance being made for necessary stops. Due to time constraints, not all cars could be tested on the Albany course.

The Thompson course was the 5/8 mile banked oval track of the Thompson Speedway in Thompson, Connecticut. This track had an acceptable but not excellent road surface, and was surprisingly difficult to drive at speeds above 35 mph - the two end turns are steeply banked and quite tight. The measured distance around the inside of the track was 0.52 miles. Efficiency testing at Thompson was mandatory for all commuter class vehicles, and optional for the other categories.

A second agenda for the Thompson testing day was to give all vehicles the opportunity to demonstrate their full range capability. After a 25 mile run to the speedway, each category was given a two-hour period to run to full range. The minimum allowable lap speed was 35 mph for the commuter categories.

The Boston course was a 2.1 mile loop through Boston City streets to test vehicle performance under actual (worst case) stop-start driving conditions. Testing in Boston was optional for all categories.

Results

The Tour de Sol Commuter category includes practical commuting vehicles with a limit on battery capacity of 7,200 Wh for two-seat , 9,600 Wh for three seat and 12,000 Wh for four seat cars. PV array size (in peak Watts) is limited to 1/10th of the battery capacity.

The results for the Tour de Sol Commuters were much as expected. Most vehicles used between 150 and 250 Wh/mile for speeds ranging from 25 to 45 mph.

An interesting comparison can be made between Solartech II and S-CAR-GO which are similar vehicles with different drive trains. Solartech is a little lighter (2000 lbs vs. 2800) and has a Solectria 16 HP brushless motor, while the S-CAR-GO has a 17 HP Advanced DC series brush motor. They showed similar performance on the Thompson track, but S-CAR-GO's lack of regenerative braking showed up as significantly worse results in the Albany test which included a long decent followed by a climb back to the start.

The concept cars in this category - Solectria's Flash, New Hampshire Technical Institute's Sungo and Unatego high school's Solar Bullet demonstrated what can be done with ground up design. All showed energy consumption of only 50-70 Wh/mile at 25 mph. The Sungo, in particular, speaks to a new, practical class of small commuter vehicle that could well become a commercial product. With its solid aluminum chassis, four-wheel design, and dual 11 HP Solectria brushless motors, (one for each rear wheel), the Sungo could satisfy most people's commuting needs while consuming less than 100 Wh/mile.

Tour de Sol Commuter Results

The American Commuter category is also aimed at practical commuting vehicles, but has no limit on battery capacity, apart from performance tradeoffs and the manufacturer's Gross Vehicle Weight. Vehicles in this category tended to be heavier (2500 to 3500 lbs), being conversions of conventional IC engined vehicles, and had accordingly higher energy consumption results.

Notable cars were the very low energy use shown by the Solectria Force GT, the E96 Saab conversion and the two St. Johnsbury academy cars, the Jewel and the Hilltopper. Solar Car Corporation's Chevrolet S-10 pickup conversion, despite being the heaviest vehicle in the race, showed excellent performance with 177-270 Wh/mile (and a 90 mile range test run). The Sorrel Chevy S-10 conversion was not entered in the race but came for the Thompson display and was tested there. It is a similar vehicle to the Solar Car Corp. conversion, (they in fact used a Solar Car Corp. conversion kit) and the efficiency results showed good agreement between these cars.

An interesting comparison here is between Solectria's Force GT, and the Force (which ran in the TDS Commuter category). The heavier (2350 vs. 2142 lbs) and more powerful (22 vs. 16 HP) Force GT had significantly lower efficiency results than the Force at higher speeds. This may simply be a result of driving style - slowing down for the tight corners of the Thompson Speedway - but may also be an indication of increased frictional losses, for instance from a wheel alignment problem. An interesting point is that these extremely efficient electric vehicles will require

Measured Electric Vehicle Efficiency in Watt-hours per Mile

Car Name	Team	Est. Range miles	Actual Range Day 4 35 mph	Albany W-h/mi.	Albany Av. speed mph	Thompson W-h/mi. 25 mph Nom.	Thompson Av. speed mph	Thompson W-h/mi. 35 mph Nom.	Thompson Av. speed mph	Thompson W-h/mi. 45 mph Nom.	Thompson Av. speed mph
Tour de Sol Commuter Class											
Lectric Lizzie	Champlain College	40	37	208	24	168	21	193	27		
S-Car-Go	Delta College	40	33.2	263	25	161	26	195	35	273	44
Solartech	New England Tech	70	39.6	132	21	102	21	70	21		
Solartech II	New England Tech	100	41.7	185		156	31	246		268	
Sungo	NH Tech. Inst.	68	57.9			71	16	89	30	98	34
The Force	Solectria Corp.	60	73.5	139	24	118	22	175	28	209	39
The Flash	Solectria Corp.	100	84.5	69	24	53	28	73	36	115	39
Solar Bullet	Unatego High	70	49.5			48					
American Commuter Class											
Poetry in Motion	Albert Hutton, III	45	66.8			291	25	249	33	270	42
Force GT	Solectria Corp.	60	100.2			124	25	141	37	188	45
The Jewel	St. Johnsbury	95	77	276		130	26	209	34	278	44
Elec. Hilltopper	St. Johnsbury	125	96	290		161		209		248	
SAAB E96	VT ElectriCar Corp.	60	63.6	236		146		187		201	
Kineticar	Waterbury State	80	87.6	251	24	321	25	401	31	369	38
VW Van Con.	Scott L. Isgar	40	48.5			264	24	331	32	454	42
Electro Chevy	Solar Car Corp.	58	90.8	207	29	177	26	226	32	269	42
S-10 Pickup	Sorrel Chevrolet	85				197	24	218	26	276	31
Open Category Class											
Aztec	MIT	150	80.3			60	36				
Moves with Sun	Laser Sound	40	44.6			37	18				
Sunpacer	Cato-Meridan High	45	66.2								
Envirocycle	CCSU	60	56.3	126	26	102	20	102	31		
Sun Runner	SETS	100	60.5	144	18	58	18				

regular maintenance, such as checking tire pressure and alignment, for their performance to be sustained.

American Commuter Results

The Tour de Sol Racing Category is for solar powered vehicles that are limited to 480 Wp of solar charging and 4800Wh of battery storage. Most vehicles performed in the 50 to 60 WH/mile range, both in the Thompson and the Albany tests. Trenton State's Sunlion had obvious problems in testing at Albany that turned out to be a dragging parking brake. (Again, vehicles that rely on efficient performance for range must be well maintained).

Two exceptional vehicles were the Conval Sol Survivor II and Dartmouth's Sunvox IV. The Sol Survivor II tested at such a low value in Albany that we initially thought it to be instrument error. The Sol Survivor team has spent three years refining their car, and in addition, has carefully measured and modeled vehicle efficiency themselves. This level of knowledge, together with an excellent car, enabled Conval to win the Tour de Sol Racing category, defeating many experienced college level teams. Conval also received the prize for most efficient Racing Category car. The prize was based on data collected in Albany.

Tour de Sol Racing Results

The Cross Continental Category is for solar powered vehicles that conform to the World Solar Challenge (Australia) and GM Sunrayce (USA) rules of unlimited battery capacity and PV array peak power, but a PV maximum area of 2 x 4 meters. Only one measurement of efficiency was made on these cars, as all use Uniq mobility controllers and motors which appear to have extremely high peak battery currents, or emit electromagnetic interference that upsets the operation of the Fluke current probe. For other vehicles, the Fluke 80i-1010 current probe converts measured current to 1 mV per Amp. The Fluke model 87 meter is set to average on its mV scale, with a maximum reading of 999 mV (or 1000 Amps peak). The Uniq Mobility drive systems evidently draw currents in excess of this 1000 Amps as normal operation causes a meter overrange

Measured Electric Vehicle Efficiency in Watt-hours per Mile

Tour de Sol Racing Class

Car Name	Team	Est. Range miles	Total Miles Driven	Albany W-h/mi.	Albany Av. speed mph	Thompson W-h/mi. 25 mph Nom.	Thompson Av. speed mph	Thompson W-h/mi. 35 mph Nom.	Thompson Av. speed mph	Thompson W-h/mi. 45 mph Nom.	Thompson Av. speed mph
Sol Survivor II	Conval High	100	300	37	26	43	23	48	20		
Sunvox I	Dartmouth	125	172	64	25						
Sunvox IV	Dartmouth	200	297			29	27	42	35	56	40
SolDancer	Ethyl Walker High	100	91.9			50	27				
Suntech	NH Tech. Inst.	68	307	61	27						
Husky Solar	Northeastern U	65	122								
SunLion	Trenton State		93	167	24						
SunBlazer	UMass	100	241	70							
Cross Continental Class											
SunQuest	Queen's U		36								
Wild Solarcat II	Villanova U		293	65	25						
Solaray II	Virginia Tech		315								
Sundragon III	Drexel U	125	249								

and average data is lost. Switching the Fluke 87 to the Volt range, rather than the mV range, solved this problem, but this was only discovered at the end of the Albany testing and no Cross-Continental cars opted to be tested at Thompson.

Cross-Continental Category Results

The Open Category is for vehicles that do not meet the requirements of other categories, but that promote the aims of the event. This category contains a wide variety of vehicles, from bicycles, to motor-cycles, to vehicles that for one reason or another decided not to run in a standard category. An example of the latter is the MIT Aztec which had suspension problems and decided to run in Open with only a single occupant, rather than in the Tour de Sol Commuter category with two people aboard. Their testing results show them to be potentially the most efficient of the ground-up commuters (perhaps because of their innovative aerodynamic design and MIT race bred components) using only 60 Wh/mile vs Flash's 72 Wh/mile at 36 mph.

Electric motorcycles are a mode of transportation that have not been paid much attention at this time, but will have to be addressed in a future gasoline-free society. This year, we had two motorcycle entries, the Envirocycle and the EM/120 which was not finished in time to run the race road course, but was tested in Boston. The Envirocycle, a converted Honda, could well be expected to perform a little better than 100 Wh/mile with its advanced DC 4 HP motor and aerodynamic fairing. More attention should perhaps be given to rolling resistance and drive losses. The EM/120 is a very exciting machine, beautifully faired and probably capable of more than 150 miles with its 8100 Wh of batteries.

Boston Testing Results

The final efficiency tests in Boston were performed in stop and go traffic. The tests were totally voluntary, and only a few teams took advantage of them after the five long days on the road. Envirocycle again showed a consistent 100 Wh/mile performance, while Kineticar showed just how much energy can be used in Boston traffic. In this stop and go driving environment, the lack of regenerative braking and the disadvantage of a heavy car (3281 lbs) are very apparent. The Audi conversion was brought for display on the last day of the race by a member of the Electric Auto Association. It used an Advanced DC motor and Curtis controller similar to the Solar Car Corp. cars, and showed very reasonable performance.

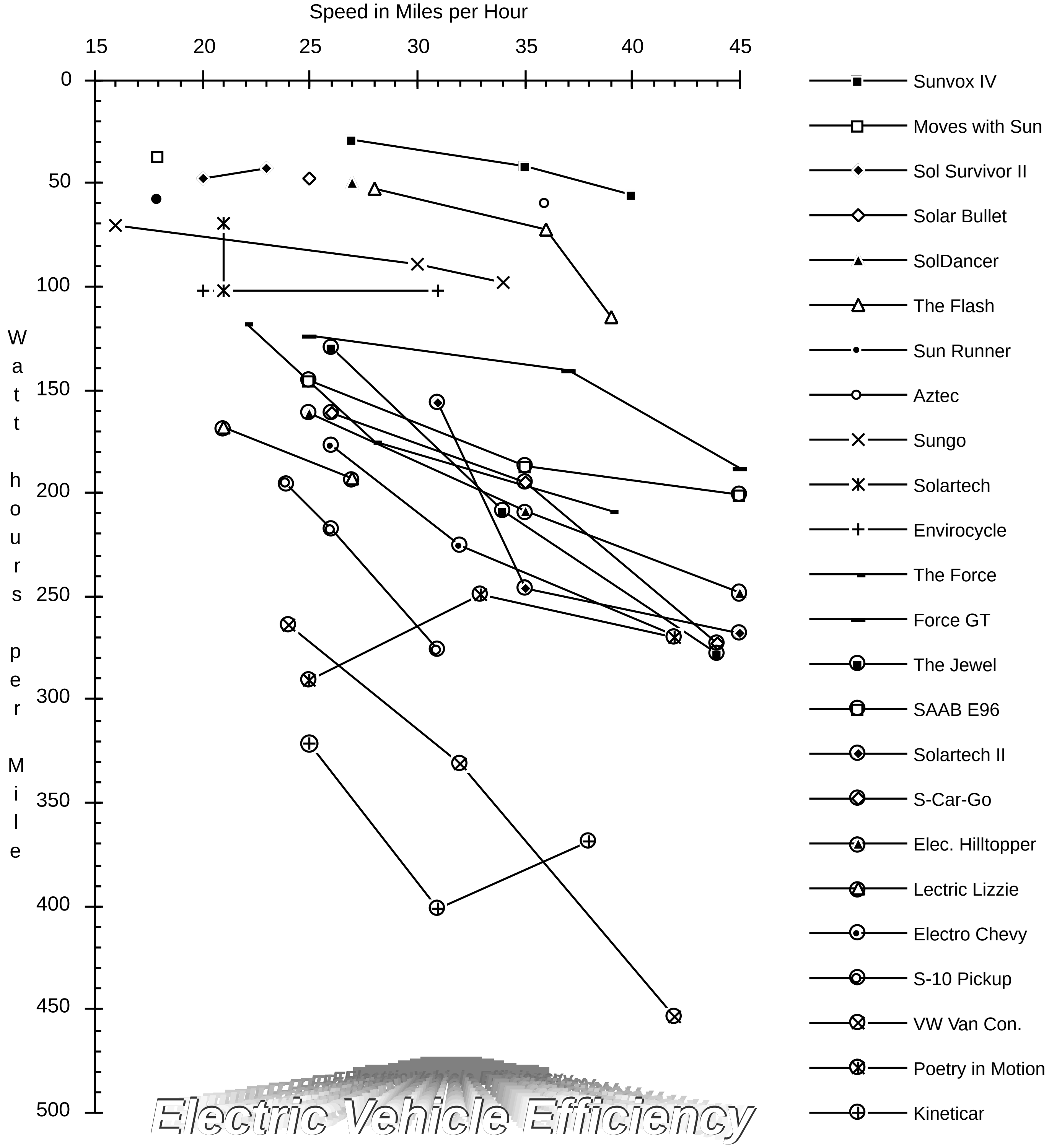
Electric Vehicle Efficiency

The following graph shows the full set of testing results obtained at Thompson. This graphical presentation brings out several interesting points:

Measured Electric Vehicle Efficiency in Watt-hours per Mile

Boston Stop and Go Traffic

Car Name	Team	Boston W-h/mi.	Boston Av. speed mph	Boston W-h/mi.	Boston Av. speed mph
EM-120	Vehicle Design	56	11	51	14
Envirocycle	CCSU	109	16	100	21
Kineticar	Waterbury State	470	14	514	12
Audi Conversion		243	10	315	19



1/ The cars are grouped in three area

- Large vehicles with poor aerodynamics such as the VW Van Conversion, Kineticar and Poetry in Motion
- Medium size conversions such as the Force and Solar Car Corp. cars
- Ground up electric vehicles such as the TDS racers, the Sungo and the Flash.

2/ Aerodynamic drag effects (a Wh/mile increase proportional to velocity squared) are not seen to be significant. This may not be so for the Force GT and the Flash, which are highly optimized vehicles with minimal friction, but for the remainder, performance improvements are more likely from lower rolling resistance and drive train improvements than from better aerodynamics.

3/ The two tests on the Solar Tech car (a small converted BMW Izetta) at roughly the same speed , but with different driving style are interesting. The first test showed 102 Wh/mile while the second, with the speed pedal held at maximum (i.e. constant speed) resulted in only 70 Wh/mile. Driving style can have a large effect on performance.

4/ Similar results are evident for the Solectria Force which showed very low energy consumption at low speeds but jumped up dramatically at higher velocity. This is most likely a result of slowing for, and accelerating out of the corners.

5/ Some cars, notably Poetry in Motion and Kineticar showed lower energy consumption at higher speeds. This is an indication of incorrect gearing, or perhaps again an improved driving style as the driver gets used to the course.

Range Testing

The day four range information is presented in the tables above. Most notable were Solectria's Force GT , which was using nickel cadmium batteries, which drove 100.2 miles to receive the prize for greatest range. Two cars that used lead acid batteries also performed very will. The St. Johnsbury Academy's Electric 'Hilltopper drove 96 miles, and Solar Car Corp's Electro Chevy drove 90 miles on a single battery charge at a minimum speed of 35 mph.

Other Tests

The scrutineering process at the American Tour de Sol includes many other safety related tests including rules compliance, construction and safety, a cone driving test, starting on a incline, acceleration, and a brake test.

The brake test was of interest as most cars end up carrying a rather full load of batteries, though all but one of the entrants managed to meet the race rule requirements. A standard automotive decelerometer was used for the testing. It proved to be an excellent indicator of brake performance.

One interesting point that came out from the design of the Sungo was that dual motor drive systems require careful balancing both for forward acceleration, and especially for regenerative braking. There is a need for the motor controllers to communicate and match the wheel torque under these conditions.

Conclusions

Efficiency testing at the 1992 American Tour de Sol produced consistent and reasonable results that may be used as benchmarks for the design and testing of electric vehicles and EV programs. Because of the limited number of tests and variations in driving style, this data should not be used in deciding whether one car is "better" than another, but can be used as a guide as to what is possible, both today and in the future.

There were two significant changes from the previous year:

- A new class of highly efficient electric commuter vehicles, with performance in the 50 - 100 Wh/mile range is evolving - for example Solectria's Flash and NHTI's Sungo.
- Performance in the racing categories is clearly improving with cars testing in the 28 to 42 Wh/mile range (Dartmouth's Sunvox IV and Conval High School's Sol Survivor II) compared to typical values of 47-60 Wh/mile last year.

During the 1993 American Tour de Sol, we plan to refine our testing procedures further with a full day of testing at a race track, some form of start-stop urban driving cycle, an obstacle course and other tests of practicality and utility, and more refined efficiency measurements including electronics to calculate instantaneous power from our voltage and current probe inputs to increase the measurement accuracy.

Technical Testing was made possible by a grant from the U. S. Department of Energy through the Argonne National Laboratory. Many thanks to U. S. DOE and Argonne National Laboratory staff, American Tour de Sol participants and the many volunteers that assisted NESEA in performing the tests and collecting the data.

Access

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Things that Work!

Things that Work!
tested by Home Power

LED Flashlight Lamps

Tested by Richard Perez, Barry Brown, and Mark Newell

Every time my Mini Mag® AA flashlight puked in the middle of the night, in a snow storm, on a rush trip to the outhouse, I wished for a better way. Well, my Physics fairy godmother (in the form of Delta Lights) came through with a super efficient LED replacement lamps for standard flashlights. The Delta Light LED lamps give our flashlights over 12 times more operating time on the same batteries! And the LED lamp lifetimes are measured in decades instead of hours!

Basic Equipment

We joke around here about recognizing back-woodsies by the gear in their pockets. Country folks always carry a pocket knife (usually a real Swiss army knife) and a flashlight (the Mini Maglite® AA model is a favorite). While both these tools are well-built and last a lifetime, the flashlight has a serious appetite for batteries and bulbs. Using AA nicads in the Mini Maglite® gives about one hour of light with its standard incandescent flashlight bulb. Incandescent bulb life is about 20 hours before replacement with another $2 bulb.

A better way

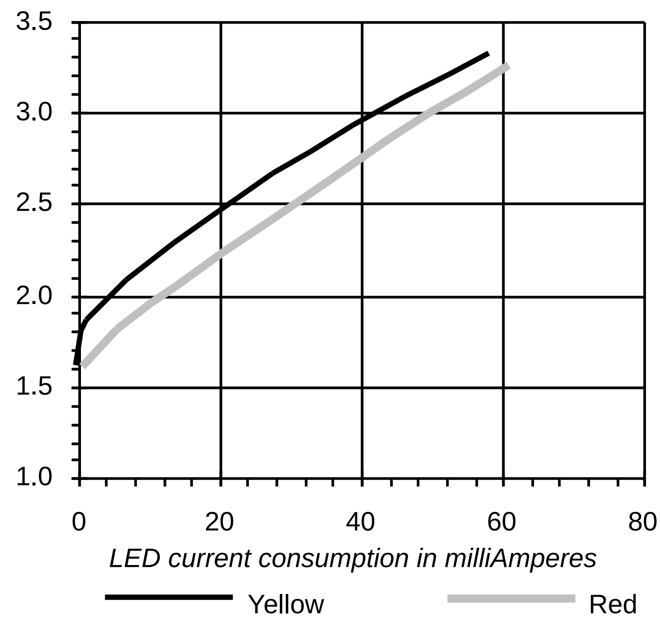
Delta Lights makes LED replacement lamps for flashlights. We tested two types. One replaces the PR2 series flashlight bulbs in virtually any flashlight using two C or D flashlight cells. The other replaces the tiny incandescent lamp used in the Mini Maglite® flashlights.

When it comes to making light from electricity, no device made by man is more efficient than the Light Emitting Diode or LED. The LED is a semiconductor device and does not use the superhot incandescent filament employed in regular flashlight bulbs. While flashlight bulbs have lifetimes in the order of hours, LEDs will burn bright for ten continuous years or more. LEDs make light of a single pure color, in this case either red or yellow.

Delta Light LED Performance

The red Delta Light measured an average power consumption of 97 milliWatts and an average current consumption of 35 milliAmperes during our testing. The yellow Delta Light measured an average power consumption of 74 milliWatts and an average current consumption of 27 milliAmperes during our testing. This data was gathered by operating the lamps over the entire voltage range of the batteries (2 to 3 VDC).

LED Flashlight Lamp Performance



LED power consumption is between 13 and 17 times less than the power consumption of the stock incandescent bulb. This means that the batteries in the flashlight last 13 to 17 times longer before replacement or recharging.

These LED replacements are not nearly as bright as the incandescents which they replace. Please don't put them in your flashlight and expect it to illuminate distant objects. While I can't see objects twenty feet away, I had no trouble with seeing within a six foot radius. The red LED in particular provides enough light to walk around at night. Since the red LED produces very pure red light, it does not spoil our night vision. The red LED is the best flashlight we have ever used inside a vehicle. It brightly illuminates the vehicle's interior without ruining the driver's night vision.

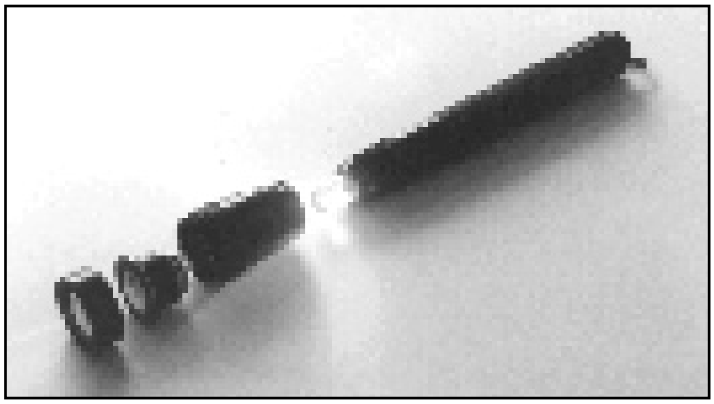
We hoped to have real battery lifetime data for this article. We started testing these LED flashlight bulbs over 3 months ago. Barry Brown put a red LED bulb into a flashlight with two freshly recharged AA nicads (500 mA.-hrs at 1.2 VDC per cell). After 96 days of regular, normal use, the nicads still have better than 60% of their power left. Barry used to go through a pair of AA nicads in about a week. We figure that it now takes him about six months to discharge the same cells.

Cost

These LED lamps from Delta Light are a new product. In fact, Bill Mack of Delta Light is looking for companies and stores to distribute his products. Bill will sell to retail customers in orders of ten LED lamps or more, so coop the flashlight folks in your neighborhood. Cost for the various LED flashlight lamps runs from $8 to $9 each in lots of 10.

The Future

Consider that one of these LED lamp replacements pays for itself in twelve hours of operation (based on battery and bulb life). Consider that you will never have to change the flashlight bulb again (in normal service the LED lamp will live longer than any of us). Consider the billions of disposable batteries that will last about 15 times longer before becoming a waste disposal and environmental problem. Consider not being in the dark, in the snow, on that midnight dash to the outhouse…



Above: a red LED replaces an incandescent lamp in a Mini Maglite® flashlight. The LED consumes about 1/12 the power and lasts for over ten years.

Access

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Switchmode Electronics with Dr. Klüge

Chris Greacen

Let's speak biologist's talk for a moment. In the past decade a new genus of electronics, called *switchmode* circuits, has evolved for home renewable energy systems. Species within this new genus include inverters, charge regulators, and linear current boosters™ (LCBs) which are small, efficient, and reliable. Outside of the renewable energy market, you'll find them in the heart of power supplies for computer equipment, as battery chargers, and as controllers for efficient variable speed motors. Inside their black boxes these switchmode circuits control the electrical current which flows through them by switching that current on and off thousands of times a second. Let's look at why and how.

Why Switchmode?

Transistors are electrically-controlled electricity faucets. They can be turned anywhere from full-on (conducting) to full-off (insulating). Last issue I showed some circuits which use a small amount of electricity to turn a transistor greater or lesser degrees of "on". As we saw last time, these circuits are inefficient at regulating the amount of current that is delivered to a load. To regulate electricity they have to waste some as heat. For example, in the circuit in figure 1, if we want just 0.1 Amperes of current to flow through the 60Ω light, then Ohm's law (V=IR) tells us that the voltage drop across the light is (0.1A)(60Ω) = 6 Volts. This means the remaining 6 Volts must be lost across the transistor. The transistor wastes half of the power the circuit consumes! If you want even less current in the lightbulb, a greater percentage is lost in the transistor.

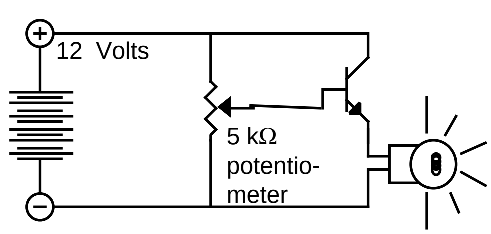


Figure 1

The problem here is that the transistor is turned only part way on. The switchmode solution is to turn it fully off, then fully on, then fully off... many times a second. When the transistor is turned fully on, the voltage drop (V) across it is very small, and therefore the power dissipated (P = IV) is small. On the other hand, if it is turned fully off, the transistor dissipates zero power because no current (I) flows.

The trick is to switch the transistor on and off fast enough so that the load it is driving does not behave strangely. If the load is a lightbulb, then you want to turn it on and off fast enough that your eyes don't notice a flicker. In a movie theater, for example, about 30 frames a second are shown on the screen. Our eyes and brain blur them into a continuously moving scene. To make an electronic dimmer for a 12 Volt light, we might choose to have it turn on and off, say, 100 times a second. If the load is a motor, you want to drive it fast enough that its motion isn't jerky. In many circuits, switching at 100,000 times a second is not uncommon. It turns out that the faster the circuit switches, the smaller (and less expensive) some of the components can get. It is possible to switch too fast, especially for loads with lots of coils of wire in them (like motors). These inductive loads reject high frequency power.

Duty Cycle

Now lets say that the transistor in this light dimmer spent 50% of its time off and 50% of its time on. On average the circuit will draw 50% the current it would if the transistor was on all the time. We say this circuit has a duty cycle of 50%. Likewise, if it spends 75% of its time on, and the remaining 25% off, it will conduct 75% of the full current. It has a 75% duty cycle. In circuits like the Heliotrope CC series charge controllers, electronics vary the duty cycle of current

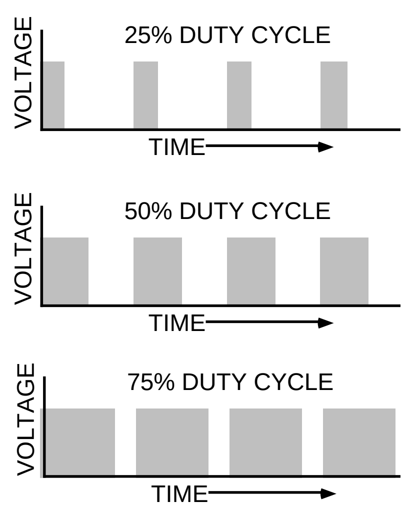


Figure 2

coming from the PV panels. When the battery's voltage is low, duty cycle is 100% so that all current goes to charge the battery. As the battery voltage rises, the duty cycle shrinks, so current from the PV panels is "refused" a larger and larger fraction of the time.

There are two ways to vary a switchmode circuit's duty cycle. Most often, the frequency of the pulses is kept constant, while the pulse duration is changed. This is called "pulse width modulation" (PWM). The other method is to keep the pulse widths the same, but vary the frequency.

How Switchmode Circuits Work

We've looked a bit at why switchmode transistor circuits are common, and what they do. Now lets look at how they do it. The important new element here is it is necessary to measure time. The pulse needs to be on for a controllable amount of time, and then off for a controllable amount of time. In switchmode circuits this is usually done with a relaxation oscillator with timing controlled by a resistor and a capacitor.

What's a capacitor? A capacitor is a lot like a battery, but instead of storing lots of electricity in a chemical reaction, it stores a small amount in a static electric field. In fact, if you've lived in a dry climate, you've felt what it's like to be a capacitor, charging up as you walk across a rug floor, and discharging "ZAP!" if you touch a piece of grounded metal or another person.

In this series of articles, the capacitor is the first electronics component which can be easily used to measure *time*. If it is fed a constant current, its voltage rises constantly over time. The capacitor's voltage is proportional to the charge (Q) it holds: V = Q/C. Charge is current times time. Capacitance (C) is measured in Farads, and indicates how much charge the capacitor will hold at a given voltage.

If a capacitor is charged through a resistor from a set voltage "V_{cc}" (like the a battery voltage) then the voltage across the capacitor doesn't increase steadily. It increases more like a punctured tire deflates: quickly at first, then slower and slower. If you multiply R (resistance) times capacitance (C), the answer is in units of seconds. It takes about 1.1RC seconds for the capacitor to charge from $^1/_3$ V_{cc} to $^2/_3$ V_{cc} (or discharge from $^2/_3$ V_{cc} to $^1/_3$ V_{cc}).

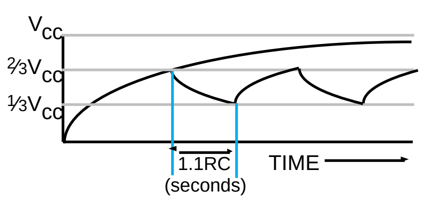


Figure 3: A capacitor charged through a resistor from V_{cc}. The capacitor's voltage rises quickly at first, then slower and slower. Charging or discharging the capacitor between $^1/_3$ V_{cc} and $^2/_3$ V_{cc} takes 1.1RC seconds.

Klüge Plumbing Capacitor

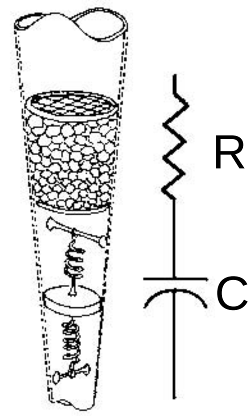


Figure 4

In the interest of clear mental imagery, Dr. Klüge has assembled a plumbing capacitor. It's a piston in a pipe, restrained by a couple of springs. Turn on the water pressure and the cylinder in the capacitor is pushed down by the water pressure. Some of the pressure is lost going through the gravel filled "resistor", limiting the current which displaces the piston. Over time the spring gets tighter and tighter, and less and less water flows in past the resistor. It's fully charged when the spring is so tight that no more water can flow into it. In other words, the pressure on the capacitor is equal to the pressure of the water supply, with no pressure drop across the resistor. The bigger the capacitor or the greater the resistance of the resistor, the longer the capacitor will take to charge up. If the water pressure is turned off and the capacitor is allowed to drain, water gushes up through the resistor — a lot at first, and then less and less as the spring relaxes.

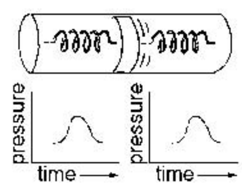


Figure 5

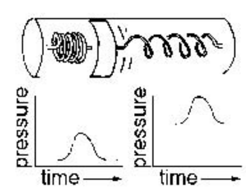
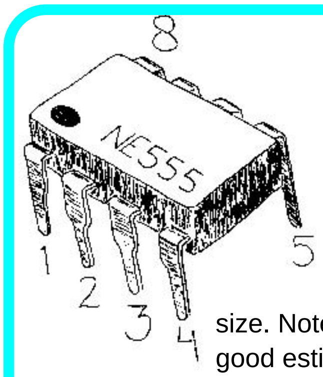


Figure 6

Notice no water flows *though* the capacitor. A capacitor looks like an open circuit to direct current flow. But it can pass "pressure jolts." A pressure pulse on one side of the capacitor jerks the cylinder, passing the jolt to the other side (Figure 5). The pressures on either side of the capacitor need not be equal for this "jolt passing" to work (Figure 6). In this way, real electrical capacitors are often used to pass voltage pulses from one DC voltage to another. In a similar application, a capacitor from + to - in a DC system will let noise pulses pass to ground, effectively drowning them out. A capacitor in this service is called a "filter capacitor".

The 555 Relaxation Oscillator

Now for the oscillator, the part that turns the transistor quickly on and off. Fortunately integrated circuits (ICs) handle a lot of the dirty work for making reliable, accurate oscillators (Figure 8). The favorite around here is the venerable 555 timer chip — you'll find a liberal sprinkling of circuits which use this chip in Home Brews in back issues. The 555 works by watching the voltage on pins 2 and 6. When pin 6 is greater than $^2/_3$ V_{cc} (V_{cc} is the supply voltage), then the output (pin 3) goes low (zero volts). When pin 2 goes below $^1/_3$ V_{cc}, pin 3 goes high (12 Volts).



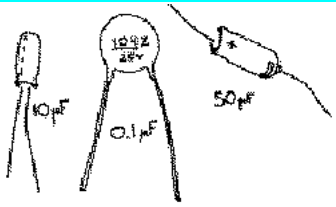
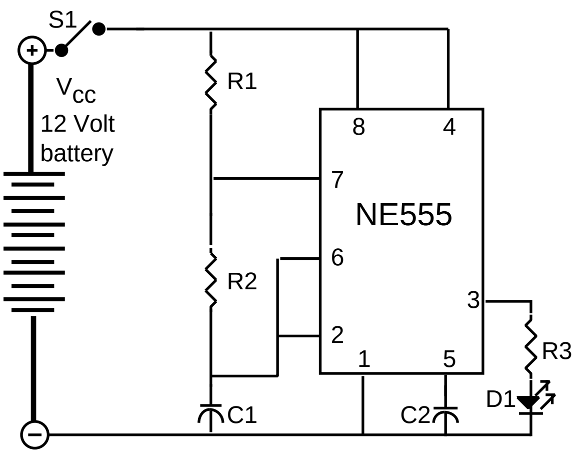


Figure 7 (above right): several capacitors, shown $1/2$ real size. Note thatphysical size is not a good estimation of capacitance. The one in the middle is a ceramic capacitor. The capacitors on the sides are electrolytic. Watch out! Electrolytic capacitors are polarized, and can blow up if plugged in backwards. + or - leads are printed on the capacitor canister. Figure 8 (above left): 555 chip in a Dual Inline Package (DIP). On all DIP chips, pin number 1 is identified with a sunken dot.



Parts Listing

Diodes: D1- LED, your favorite color	Resistors (1/4
Capacitors (25 VDC rated)	R1- 2.2 MΩ
C1 & C2- 0.1 µF	R2- 10 kΩ
Switch S1- SPST use > 2 Amp rating	R3- 1 kΩ

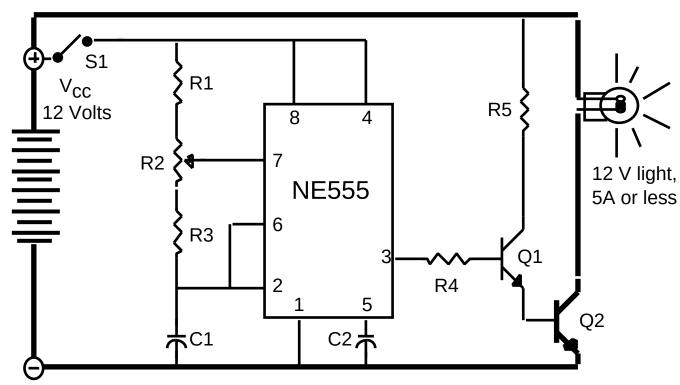
Figure 9: 555 Oscillator driving a LED

Pin 7 is like a drain valve — whenever pin 3 is low, pin 7 opens up a drain to ground. Above is the simplest oscillator you can make with a 555 chip. I chose large resistors so that the oscillator cycles slowly — you can see it pulse on and off. Dr. Klüge has assembled an analogous “plumbing 555 circuit” (Figure 11, facing page) as a pulsing bird bath for his duck friends. The dashed lines encircles everything going on inside the “chip”. In every cycle the capacitor charges up through gravel filled “resistors” R1 and R2. When the pressure level reaches $2/3$ V_{cc}, a switch turns on lights alerting the upper duck to shut off the output (pin 3), and the lower ducks to open the drain to start discharging the transistor. The capacitor then drains through resistor R2. When it drains to $1/3$ V_{cc}, the other set of lights come on, alerting the upper duck to turn on the output, and the lower ducks to shut off the drain that was draining the capacitor.

It seems like a hopelessly complicated way to make something turn on and off, doesn’t it? But we’re in the universe of electronics. Rube Goldbergian solutions are not penalized heavily here. Electrons are flexible travelers. And the advantage is that the oscillator’s frequency and duty cycle are controlled by the choice of external components — in this case two resistors (R1 & R2) and a capacitor (C).

Mildly Techie Stuff: Real Light Dimmers

It’s fun to see the blinky lights, but for a real light dimmer the light needs to blink so fast you can’t see it. Below the circuit is modified to make it 100 times faster, adjustable, and able to drive a big light. Pin 3 drives a small transistor, which, in turn drives a 15 Ampere power transistor. This configuration of transistors is called a Darlington pair, and is a common way of increasing the power of switched signals.



Parts Listing

Capacitors (25 VDC rated)	Resistors (1/4 W)
C1 & C2- 0.1 µF	R1 & R3- 2.2 kΩ
Switch S1- SPST use > 2 Amp rating	R2- 100 kΩ potentiometer
Transistors: Q1- 2N2222A NPN	R4- 240 Ω
Q2- 2N3055 NPN	R5- 40 Ω 10 Watt

Figure 10: Similar, faster circuit, now as a light dimmer.

Improved Duty Cycle Range

The oscillator in Figure 10 isn’t as flexible as you might like. While the oscillator’s frequency can be controlled over a wide range, its duty cycle cannot.

The time the capacitor takes to charge from $1/3$ V_{cc} to $2/3$ V_{cc} is 1.1(R1 + R2)C. The capacitor then discharges to $1/3$ V_{cc} in 1.1(R2)C seconds.

Duty cycle = time on ÷ (time on + time off)

= (R1 + R2)C ÷ [(R1 + R2)C + (R2)C]

= (R1 + R2)C ÷ [(R1 + 2R2)C].

If R1 is large compared with R2, the duty cycle approaches 100%. If R2 is large compared with R1, the duty cycle approaches 50%, but that’s as low as it goes.

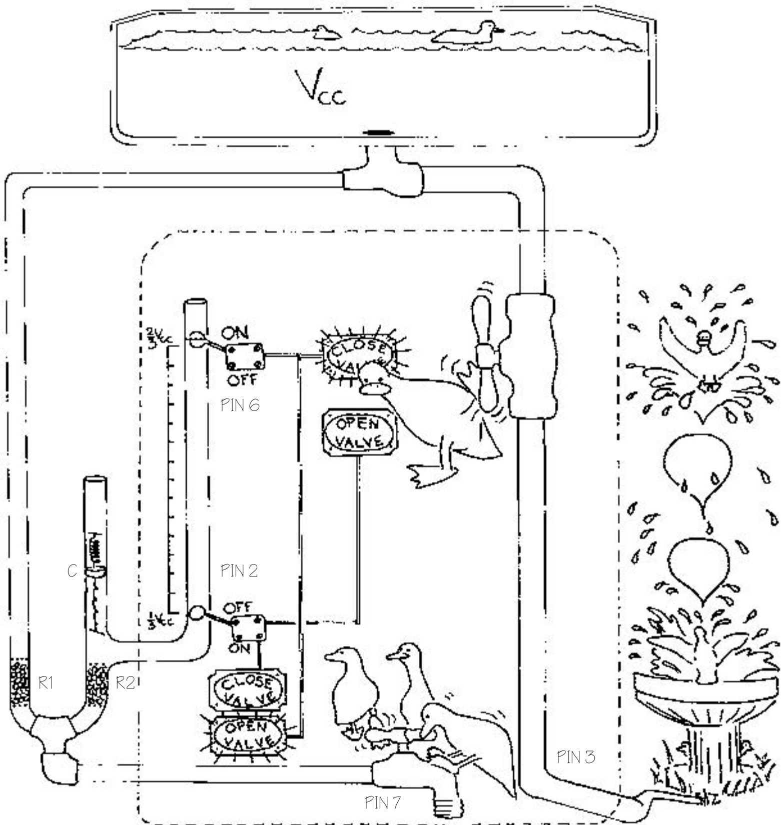
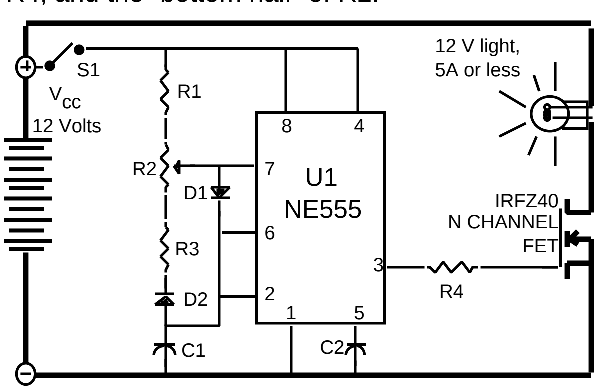


Figure 11: Ducks operate Dr. Klüge's pulsing birdbath "555 chip".

The circuit below has a duty cycle adjustable from 5% to 95%. It's one we use in the "pulsar" battery charger (HP #30 page 54) and the Mark VI alternator field controller (HP#2). The capacitor C charges through resistor R1, the "top half" of R2, and the diode D1. When pin 7 opens up the drain to ground, the capacitor discharges through D2, R4, and the "bottom half" of R2.



Parts Listing

Diodes: D1 & D2- 1N914
Capacitors (25 VDC rated)
C1 & C2- 0.1 µF
Switch S1- SPST use > 2 Amp rating

Resistors (1/4 W)
R1 & R3- 2.2 kΩ
R2- 50 kΩ Potentiometer
R4- 100 Ω

Figure 12: 5% to 95% duty cycle dimmer

Field Effect Transistors

A decade ago, 12 Volt DC to 110 ac inverters were finiky and inefficient, with low surge currents. You could count on them blowing up annually. Today they're standard equipment in renewable energy homes — they're powerful and rock-steady. Power Field Effect Transistors (FETs) are a large part of the reason why. FETs also handle the power in electric vehicle motor controllers, and renewable energy charge controllers. Compared with regular bipolar transistors (the NPN or PNP transistors we covered last issue) they're easy to use, efficient, and extremely powerful. Properly heatsunk, an IRFZ40 FET in a TO-220 case the size of a large raisin can switch 50 Amperes. This is about 10 times what a similarly sized bipolar transistor can switch.

What is a FET? It's a charge controlled transistor. Bipolar transistors (the NPN and PNP transistors we've looked at so far) are current controlled devices. You put a current into the base of a bipolar transistor, and the transistor allows a proportionately larger current to flow through the collector and out the emitter. In a FET, conduction between the drain and source is controlled by an electric field, produced by voltage applied to the gate electrode. This is the main advantage of a FET — the gate draws current only for an instant. The gate is electrically sealed from the rest of the transistor. It charges up like a tiny capacitor. When the gate is charged to about four volts (usually fractions of microsecond), the FET begins conducting. Once it's on, it stays on as long as the voltage continues to be applied to the gate. To turn it off, bleed this charge to ground.

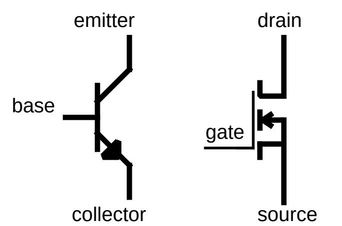


Figure 13: In a FET, the names of the terminals are all changed. The *gate* corresponds to a bipolar's *base*; the *drain* corresponds to the *collector*, and the *source* corresponds to the *emitter*.

As a result, a FET can be controlled by a much weaker signal than an equivalent bipolar transistor. In electronics jargon, we say FETs have a "high input impedance". This can simplify circuit design. As an exercise in FET appreciation, compare the output sections (everything to the right of pin 3) of Figures 10 and 12. In the bipolar version two transistors are needed sinse the output of the 555 isn't strong enough to directly control the transistor that controls the light. Instead, pin 3 drives the base of a 2N2222A transistor through a current limiting resistor. The current limiting resistor keeps the 555 output current to well

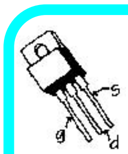


Figure16: TO220 package for IRFZ40 FET. FETs can be destroyed by static electricity, and if humidity is down to 10% to 20% you can build up to 35,000 Volts just walking on a fluffy carpet. When handling them, it's best to ground your wrist with a wire attached to your electrical system's ground.

below its 200 mA maximum. When this transistor is turned "on", it draws current through R5 (12 Volts ÷ 40Ω = 0.3 Amperes). This amplified current in turn supplies the base of power transistor Q2, which, finally, lights the light bulb.

In the FET version, only a 100Ω resistor is required to limit the output current of the 555 as the gate charges. In a fraction of a microsecond the gate is charged, the FET turns on, and the 555's job is over until it's time to turn off. The FET makes life easy for the 555 — and for the circuit designer.

Access:

Author: Chris Greacen, Home Power Magazine, POB 520 Ashland, OR 97520 • 916-475-3179

Parts: Your local electronics store. IRFZ40 FETs (or similar part IRFZ42) are available for around $4 a piece from DigiKey 1-800-DIGIKEY. For currents under 5 Amps, you can use a weaker IRF511, available for about $2 in most electronics stores.

Further reading: *The 555 Timer Applications Sourcebook*, Howard M. Berlin, 1976 Howard W. Sams & Co., Dept. DM, 4300 West 62nd Street, Indianapolis, IN 46268

The Art of Electronics, 2nd Edition, Paul Horowitz and Winfield Hill, 1989 Cambridge University Press. Over 1100 pages of this stuff, in depth, well-written, "hands on info".

OFFLINE
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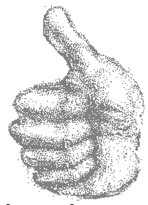
Things that Work!



Remote Measurement Systems ADC-1 Data Acquisition and Control

Tested by Chris Greacen and Richard Perez

What is a battery's voltage profile over a number of charge/ discharge cycles? When it's added up, does most of the wind turbine's output come from constant breezes, or the gusts? How much more energy does a tracked module put out, month by month? How do we use power in the course of the day? Precise answers to these questions require loads of measurements, taken at constant intervals, for long periods of time. You could dedicate your days, and those of a few friends, recording measurements like clockwork, armed with a multimeters, clipboards, and superhuman patience. Indeed, this is the way we've collected data for dozens of tests on inverters, charge controllers, and PV modules in past issues.

Data Logger Lust

This is a job for a machine — a data logger — a sort of a super multimeter which records measurements from different sensors into a computer at constant intervals. Here at Home Power we lusted after a data logger for over a year. We looked at units by big companies like Fluke and Hewlett Packard, but found these machines built with *too many* features (high speed, internal microprocessors and data storage) driving the price up into thousands of dollars. Often the machines were designed for companies like Boeing, who want to take 10,000 measurements a second on jet engines. We don't need that — we need to take measurements once every few minutes, or every few seconds at most. Besides, none of these machines interfaced gracefully with the Macintosh computer.

The Remote Measurement Systems ADC-1

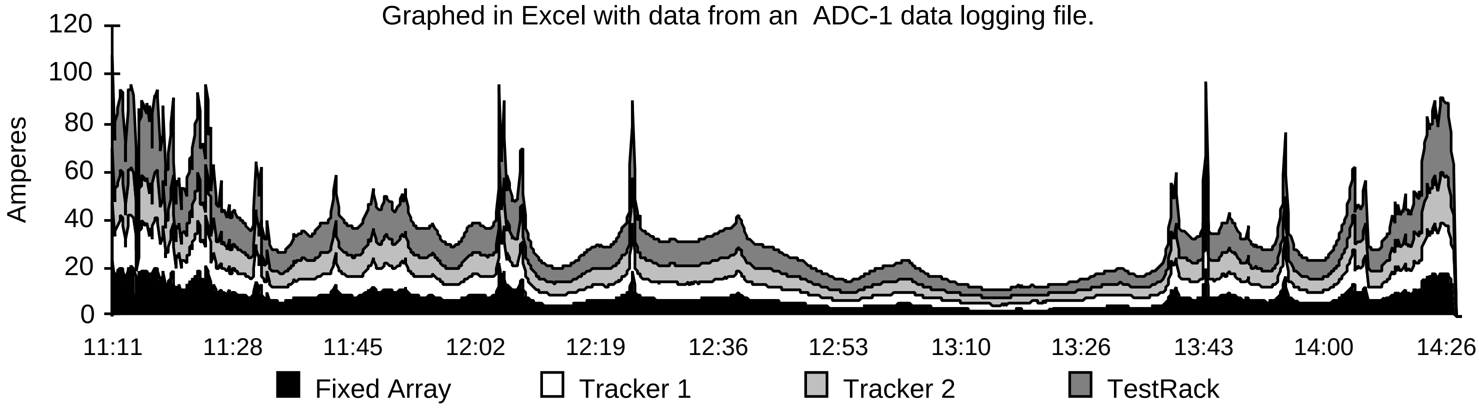
Imagine our delight when we received, to test, the Remote Measurement Systems ADC-1. It's a 12 bit resolution, ±0.1 mV accuracy data logger, and the bare bones units sells for $489. With some added hardware for appliance control, a power supply and serial cable, a temperature and light sensor, and software to run on the Macintosh, it is packaged as the "EnviroMac", and sells for $899. The ADC-1's 8" x 7" x 2" blue aluminum box has four terminal strips on the front for 16 differential analog inputs, 5 digital inputs, and six controlled outputs. Inside the box, analog to digital (A/D) circuits change the voltages you want to measure into a digital signal for the computer. This signal travels through a RS-232 connector into the computer (on the Mac, it plugs into the modem port). The ADC-1 is powered by a 9 Volt, ac adaptor. It takes 20 mA at 5 Volts, and can run on any DC Voltage from 5 to 18 Volts.

A cable from the ADC-1 also runs to a BSR X-10 ac line-carrier remote control system. This plugs into an ac outlet and allows the computer to send signals over your house ac lines to control up to 32 appliances plugged into X-10 modules (you get one module in the EnviroMac package). The ADC-1 also has six controlled 5-Volt TTL outputs. This means it's not just a data-acquisition system — your computer can make decisions based on the data, and turn on and off appliances. For example, you could program your computer to control heating, cooling and airflow in your home, water your garden depending on soil moisture, and work as a security system.

For Macintosh Users

On the second page of the manual it says, "If it takes you longer than 30 minutes [to get the ADC-1 running on your

Below: Current (in Amperes) from each of our four photovoltaic arrays, charted over several hours on 5 February, 1993. Graphed in Excel with data from an ADC-1 data logging file.



Macintosh], then you should call RMS (ask for Keith), and explain what aspects were confusing or time-consuming." Keith is the president of the small Seattle company.

I found I didn't need to call Keith. The Macintosh ADControl program is fairly intuitive and user friendly, with buttons and pull down menus. It will run on any Macintosh with one megabyte of RAM. The program allows you to condition the data as it is being created. For example, a voltage drop across a shunt could be divided by resistance of the shunt to display current. Stock equations handle inputs like wind direction and speed, or temperature from a variety of sensors. You can build your own 8th order polynomial equations if you like. The software allows you to control the outputs with IF... THEN... ELSE... statementsusing menus, dialog boxes, and buttons. For example, I could set it to turn on a fan if the temperature in the living room is greater than in the bedroom, during the hours 10 pm to 9 am.

There's three ways to view the data within ADControl. You can watch all the values of inputs and outputs on a formatted two column list. Or you can watch the numerical values of the inputs and outputs superimposed wherever you want on a PICT graphic (we might paste them on picture diagram of our renewable energy system). The third option is a plot of a running line graph of one input. I enjoyed watching this plot form mountains and valleys while monitoring a photovoltaic array in intermittent sunshine.

Excel Data Files

In the past, after we'd taken lots of measurements, we'd take our clipboards and enter the data into a Microsoft Excel spreadsheet. From here we'd massage the data, finding averages, sums, products, minimums & maximums, and make the charts and graphs you see in Home Power. The ADControl software will write the data it collects to a text file which can be read by any spreadsheet, word processor, or graphing program. It does this in the background, under System 7. This means that while we're taking data, we can use the Macintosh for other things. You can choose which inputs to record, how often to sample data (from hours to once a second or so), and whether to put time/date stamps onto each data point. The program will even start a new file at midnight if you want.

The graph on the left shows how much current each of our PV arrays contributed during four hours on the 5th of February. Data was sampled every 10 seconds. As I waited while our 25 MHz Macintosh choked graphing these thousands of data points, the words, "invitation to excess" rang in my mind. You want fine grained data? Be careful, you'll get what you ask for.

Documentation

The EnviroMac unit arrived with over 400 pages of well-written documentation. The Macintosh ADControl software comes with a 170 page manual, but I've found the software intuitive enough that I rarely need to turn to it. The 250+ page ADC-1 manual covers everything else: computer programming, installing and calibrating sensors, turning on and off wireless ac appliance control modules, trouble shooting, and gory technical details on the chips used and modifications you can make. There's a list of far-out current applications for the ADC-1, like monitoring environmental quality for molting blue crabs, or automating a cosmetics manufacturing line. Keith wrote me that it has also been used via laptop computer to measure windspeed and wind stress on an airborn glider, and for respiration research using parakeets on a treadmill.

For Other Computer Users

If you're an IBM user, you can get the Applications Toolkit for MS-DOS which has demonstrations and example data acquisition programs in BASIC, C, and Pascal. We didn't test it. The 200+ page ADC-1 manual assumes a familiarity with BASIC computer programming, and takes you from the ground floor up in getting an IBM and the ADC-1 to talk to each other. For other older computers, the manual has an appendix of software routines, written in BASIC to read data from the ADC-1. Also included are RS-232 pinouts so you can make your own cables for these computers. The intention is clear: to provide enough info that you can put your dusty old 8-bit computer back to work as a cheap but accurate data logger or controller.

Installation

We wired the ADC-1 to the Ananda Power panel in our battery room. Inside the Ananda are current sensing shunts (PV current for four arrays, total array current, wind turbine current, DC loads, and current out for different inverters), and points for measuring voltage in our system. Bringing this information to the ADC-1 requires wires which are shielded against electromagnetic fields. The job required 40 feet of high quality information cable salvaged from a television transmitting station. This cable contains 14 shielded pairs. Each pair is wrapped in an aluminum sheath with a bare, uninsulated shield wire. We connected all shields to system ground, and to the GND terminal on the ADC-1. The ADC-1 is limited to analog inputs of ±400 mV. To measure system voltage, wind turbine voltage, and PV array voltage, we built voltage dividers each with a precision trimming potentiometer. The rest was easy: plug in the power and plug the ADC-1 into the Mac's Modem port. It now lives on the wall next to our main computer.

Testing

We measured accuracy against a Fluke 87 multimeter on all 16 channels, and the unit was within the 0.1 mV accuracy specified by RMS. The ADControl software works as advertised. We hooked up the X-10 ac appliance module. This unit worked, controlling lights via software, but only when our house was powered by a sine wave inverter. When we ran on a PowerStar modified sine wave inverter, the X-10 failed to respond. We also found the unit did not work with when the appliance was four lengths of extension cord wiring away from the ADC-1 X-10 controller. Neither of these failures are surprising: the X-10 works by putting a small signal on the ac lines when the ac voltage crosses zero. This signal gets drowned out in funky wiring, and by the jolting switching of modified sine wave inverters.

Final Comments

There are sensors available for nearly anything you could think of. The ADC-1 is available in versions with instrumentation amplifiers for measuring very small signals, in a version with 12 controlled outputs instead of 6, and in a version with 32 single ended analog inputs instead of 16 differential inputs.

This is a powerful tool, and is easier to use than we could have hoped. It gives us new fine-grained data on our immediate environment. It gives us the software/hardware link to control systems which live in and shape this environment. It is a way to watch the mosaic of energy flow which is inherent in renewable energy powered homes. You'll be seeing data collected with this instrument in future issues of Home Power. We're impressed. We're going to get two more.

Access:

Remote Measurement Systems, Inc., 2633 Eastlake Ave. E., Suite 200, Seattle, WA 98102 • 206-328-2255 FAX 206-328-1787

Author: Chris Greacen, Home Power Magazine, POB 520, Ashland, OR 97520 • 916-475-3179

Super Simple Magnetic Field Meter

Homebrew

John Mills

New information presented at the 1992 International E.M.F. (Electro Magnetic Field) Research Conference in San Diego has given us some new reasons to be more careful around electricity. This study by Maria Feychting and Anders Ahlbom examined the medical records of about 500,000 people who lived near large power lines. They found that children continuously exposed to levels of ac magnetic fields of 1 milliGauss had twice the risk of developing leukemia compared with children whose exposure was much less. The risk for children exposed to 2 milliGauss was three times higher and those exposed to 3 milliGauss levels was about four times higher than normal.

A milliGauss is a measurement of magnetic field. These magnetic fields are around just about everything electrical that is energized, such as: power lines, house wiring, tools, lights, and appliances. This project is a simple ac Gaussmeter that you can build and use to learn about the magnetic fields in your environment.

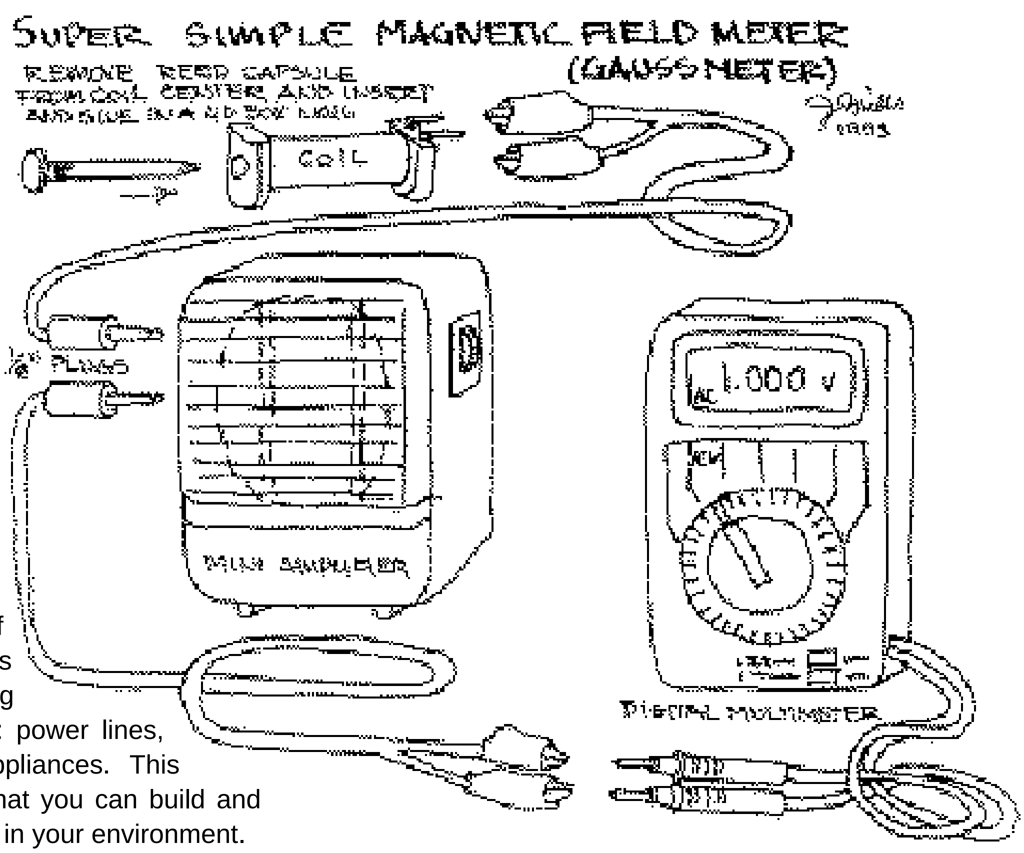
How It Works

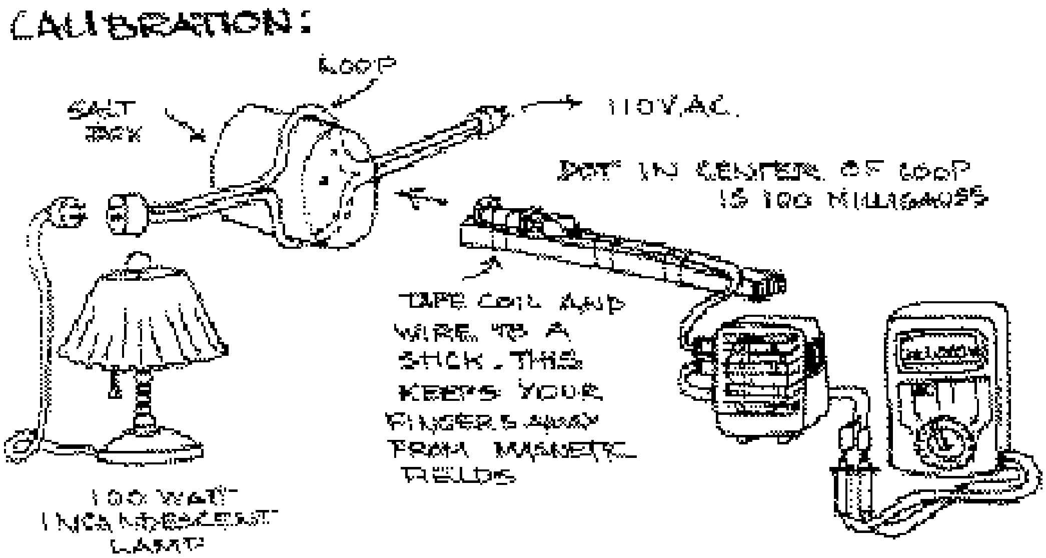
The reed relay coil acts as an antenna. The steel nail inside boosts its sensitivity. When the coil is near an ac magnetic field, it produces a small signal and the mini amplifier is used to make this stronger. The meter tells us exactly how strong the magnetic field is numerically.

Super Simple Magnetic Field Meter Parts List

Parts	*cost*
One 4D box nail (1.5 inches long)	
Reed relay coil, 12 V, 1050 Ω. RS* #275-233	$1.89
Two cables, 1/8" plug to alligator. RS #42-2421	$4.70
One mini amplifier. RS #277-1008	$11.95
One 9 Volt battery	$1.00
One 16 inch long stick	
Digital multimeter. RS #22-171 or similar	$24.99
Empty round cardboard salt container	
Two to three feet of #18 AWG lamp cord	$0.45
One 110 volt plug	$0.90
One 110 volt socket	$1.35
Lamp with a 100 watt incandescent light bulb	
Total	$47.23

*RS = Radio Shack part number





Use it Uncalibrated...

It is not necessary to calibrate your Gaussmeter. You can use it with the volume on the mini amp at maximum. At this setting the magnetic field, in milliGauss, is approximately equal to volts on the meter times 28.6. Table 1 shows how to translate voltage to milliGauss readings if the volume of the amplifier is at maximum.

Volts	MilliGauss
3.500	100
0.350	10
0.035	1
0.003	0.1

Table 1: Conversion table for uncalibrated Gaussmeter.

You can listen in to magnetic fields around you by simply unplugging the meter. Fields from inverters may sound different from those produced by the regular power lines. If you put the coil near speaker wires or headphones, you might be able to hear some unique sounds also.

Calibrating Your Gaussmeter

If you would like to make accurate readings of electrical things around you in milliGauss, you can calibrate your meter. To get a calibrated magnetic field, we need a loop of wire with a controlled current flowing in it. Remove one end of an empty salt container (3.75 inches in diameter). Attach a 110 volt plug and socket to the ends of a 2–3 foot length of #18 lamp cord. Pull the wires apart in the center of the cord for about 5.5 inches. Now slip this over the open end of the salt container. Plug a 100 watt incandescent lamp into the socket and the other end into a 110 volt ac source. The light bulb limits the current to just the right amount so that the center of the coil (at the black dot on the diagram) is about 100 milliGauss. Next, place the Gaussmeter probe coil into the center of the loop and adjust the amplifier volume so that the voltmeter reads: 1.000 volts ac. Your Gaussmeter is now calibrated to this scale: volts on meter times 100 equals magnetic field in milligauss (Table 2).

Volts	MilliGauss
1.000	100
0.100	10
0.010	1
0.001	0.1

Table 2: Conversion table for calibrated Gaussmeter.

Mark this place on the volume control as a reference point. Now you are equipped to measure and listen to magnetic fields. You will discover that the position of the coil is important. When making measurements, always orient the coil for the highest reading on the meter. Because of limitations inherent in the digital multimeter, you will only be able to measure magnetic fields up to about 1000 Hertz. Computers, televisions, and electronically-ballasted fluorescent lamps produce some magnetic fields above 1000 Hz so you may not be able to measure them accurately with this meter. It will work well, however, for power lines, house wiring, and just about everything else. If you wish to measure strong fields above 200 milliGauss, you will need to calibrate at a lower volume to ensure that your meter is not overloaded. If you set the volume so that 100 milligauss is equal to 0.100 volts then: volts times 1000 equals magnetic field in milliGauss (Table 3).

Volts	MilliGauss
3.000	3000
0.300	300
0.030	30

Table 3: Conversion table for strong magnetic fields.

Be sure to remember to turn the mini amplifier off after making measurements to keep the battery fresh. Stay tuned — next issue we will work on a tin can gizmo that will turn your Gaussmeter into a microwave meter for checking microwave oven leakage.

Access

Author: John Mills, 10475 Vineland Rd, Ben Lomond, CA 95005

Well, we can't exactly promise another earthquake on the day of our fair like happened in 1992, but who knows — this is California, after all. Because our fair was solar powered, our event was the only public place in Humboldt County that did not suffer a power outage! This fair takes place in our Redwood Community Park, proclaimed by those in attendance last year as the most beautiful place in the U.S. holding an energy fair. We are proud to continue Arcata's tradition of being in the forefront of providing services like this to the American public.

Since SEER won't be having a public exposition this year, we invite you to attend and even exhibit in our Second Annual Renewable Energy Fair.

For further information or an exhibitor's application write to us at:

R.E.F., PO Box 4179, Arcata, CA 95521 • 707-822-3481

Sponsored by: Campus Center for Appropriate Technology, Citizens for Social Responsibility, Solutions, Home Power Magazine, Power 96 KFMI, Earth Options Institute, Providence Power, and Redwood Alliance.

Let's Put Solar Panels Back On The White House

Michael Welch

In the 1980's, Former President Jimmy Carter installed a solar hot water heating system on the White House. There was an energy crunch underway and his administration thought that it was important to send the public a message that each of us can do something to help our nation's energy problems. It was, and would be again, a more-than-symbolic boost to the renewable energy industry.

When Ronald Reagan took office, one of the first things he did was to have those solar panels removed. His intentions were clear: to send a message to the nuclear, fossil fuel, and utility industries that they would be getting every break possible under his administration, and that the renewable energy industry was to be looked upon with disfavor by our new government. Now we have a new President who, by his own account, wants to improve our nation's energy future. As evidence, I bring you an awesome quote of his. During his February 17, 1993 speech on the economic plan to the Joint Session of Congress, Clinton highlighted his strategy for budget cuts by saying, *"We are eliminating programs that are no longer needed such as nuclear power research and development, ..."*

Applause, dancing in the streets and high-fives for everyone! For 20 years, energy and environmental advocates have been waiting for a President with the guts and the vision to take this position, which not even Carter would take (although he did remove funding for building a proposed breeder reactor). Now that we have him, we need to help get his agenda through Congress. I urge each of you to call your Congressional Representatives to support President Clinton's economic plan.

But, I digress. With the next issue of *Home Power*, we will be starting a drive to obtain thousands of postcards and letters asking for President Clinton to put a solar hot water system back on the White House roof. We would like to see him further the energy/environmental cause by amending the Comprehensive Energy Bill to include an even brighter energy future. The watered down version that President Bush and his nuclear and oil lackeys pushed through Congress last year just isn't good enough.

Home Power Magazine will be contacting America's environmental and energy organizations, including Greenpeace, Solar Lobby, Earth Island Institute, Safe Energy Communications Council, Public Citizen, American Solar Energy Society, Redwood Alliance, Nuclear Information and Referral Service, Union of Concerned Scientists, The Communications Consortium, and the Solar Energy Industry Association, to try to coordinate a nation-wide letter writing drive which will culminate in a much publicized delivery of the cards and letters to the White House this summer. Stay tuned for more information and a page for you to fill out.

Clinton's proposed Energy Tax

Almost all the hubbub in the energy world since the President's Congressional address has surrounded his proposed Energy Tax. The Energy Tax will help raise funds to offset our growing national debt and help fund more renewable energy, efficiency, and conservation programs. Information is still sketchy but some very interesting things have come to light. Thanks to Greenpeace for helping gather this information.

What is the energy tax? According to Reuters News Service, the tax rate would be 25.7 cents per million BTU of coal and natural gas, and 59.9 cents for crude oil. The Department of Energy (DOE) estimates that the new energy tax would add 2.5 cents to each gallon of gasoline, 2.75 cents per gallon of heating oil, 8.75 cents per thousand cubic feet of natural gas, and 75 cents to the average monthly electric bill, all in the first year of the tax's implementation which is scheduled for July 1, 1994. After the three year implementation schedule is complete, these amounts will have tripled.

First, the good news: wind, solar and other renewable sources would not be taxed. This should add some incentive to expand these technologies. Hydroelectric is not included as untaxed with these other renewable resources because, one could assume, the Clinton administration may feel that it is not environmentally appropriate to encourage the building of more massive river damming projects. I fully agree with that consideration. A bright side to this proposed tax is that a lot of the monies raised will go to make our nation's energy future brighter.

According to the *Los Angles Times*, some of the raised funds will go to the DOE and the Environmental Protection Agency to weatherize 62,000 homes, purchase 20,000 alternative fueled vehicles, and initiate ambitious energy conservation plans. Other energy related programs will also benefit, as should the fight against the deficit. Some consider any tax to be bad news, but not me. United States consumers have some of the lowest energy prices in the world. Many energy industry followers believe that our energy prices are held artificially low because fossil fuel and nuclear energy programs are so heavily subsidized by the Federal government and because prices don't adequately reflect the societal and environmental costs of energy production. The new Clinton energy tax plan will go part of the way to correct both of these inadequacies. I will be writing more about the subsidies and the hidden costs of energy in the future.

The bad new is the regressive nature of this type of taxation. Such taxes have a larger effect on people without much income. Wealthy persons can still afford to drive wherever and whenever they want, and can still afford to heat their homes in whatever way they care. Needy persons, especially those on fixed incomes, really feel the impact of these marginal increases a lot more. To offset the regressive nature of this tax, the government could provide an income tax break tied to small income size, local climate, and driving milage. Discounts on energy bills could be offered to low income families. Of course, for those without enough income to file Federal tax returns, the first suggestion does not help a bit. We will have to wait and see how the Clinton administration deals with these inequities.

Energy Bill re-revisited

I have taken some flack for my positions regarding the diluted nature of the Comprehensive Energy Bill which was signed last year. Many have pointed to the gains made in energy efficiency and renewables and the removal of the provision allowing drilling in the Arctic National Wildlife Refuge (ANWR) as steps in the right direction. I say hogwash. These "gains", while good, are minimal, and I believe they were handed to the public to placate them in effort to head off true reforms in national energy policy. The gains were further offset by the gifts the bill handed to the nuclear power industry. Though its removal was something of a victory for the environment, I don't consider the stopping of drilling in ANWR to be a "gain", since it wasn't ever in the cards till the Reagan/Bush administrations introduced it. This introduction was successful since it managed to take environmentalists' attention off other important issues. It ended up serving as a bargaining chip to get mainstream environmental groups off Congress's and the President's backs, and the ploy worked.

We still need a truly comprehensive national energy strategy. Toward this end, I'd like you to know about the "Sustainable Energy Blueprint", presented to the Clinton Administration by a broad array of environmental, industry, sustainable energy, consumer and citizen groups, and coordinated by Ralph Nader's Public Citizen. According to the Executive Summary, the Blueprint echoes the goals outlined by the President in his book, *Putting People First*. Specifically, it is designed to achieve the following:

- Create at least one million new jobs through investments in sustainable energy technologies,
- Reduce overall energy use at least 10% by 2010,
- Reduce U.S. greenhouse gas emissions by 25% from 1990 levels by 2005,
- Triple renewable energy contribution by 2010,
- Reduce the production of radioactive waste.

The Renewable Energy section of the Blueprint asks our government to "ensure that renewable energy technologies (biomass, geothermal, solar, and wind) are responsible for at least 25% of new or replacement electric and thermal capacity, and at least 25% of new or replacement transportation fuel sources, by the year 2005 through a series of initiatives addressing access to capital, regulatory barriers, tax equity, information needs and "externalities" (i.e., indirect costs)".

As a radical environmental and energy activist, even this plan does not go far enough to satisfy me. But, it may well be the best plan out there that is realistically passable in Congress. For this reason, I and the Redwood Alliance and nearly a hundred other organizations support it as the key to a truly comprehensive national energy strategy.

If you'd like a copy of the Sustainable Energy Blueprint and Sustainable Energy Budget, send SASE to me at the Redwood Alliance address listed below. The Blueprint and Budget are also available for downloading from the Home Power Communications System BBS at 707-822-8640.

Access

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Inverter Grounding

John Wiles

Safely grounding inverters poses some unique problems. A photovoltaic (PV) power system with a standby inverter, a backup generator, and an ac load center is a very complex system of neutral conductors and equipment grounds. Similarly, all ac systems using generators or uninterruptible power systems pose similar problems. This article will highlight the problem areas, and will provide answers for some installations.

The Problem

The equipment grounding conductors in a system are normally uninsulated (bare) conductors that are grounded. They are intended to carry currents only during fault conditions and are the last line of defense to protect the user from short circuits in equipment. When these equipment grounding conductors are improperly connected, currents can and do flow in these bare conductors (during non-fault conditions) posing a safety problem. When currents flow in these conductors, shock hazards can exist and equipment damage is possible. At the very least, electronic equipment such as TVs, stereos, computers, radio telephones, and PV instrumentation and control systems may not work properly.

PV systems are easy to connect, but they can also be connected in a manner that allows currents to flow in these equipment grounding conductors. With the presently available equipment, it is sometimes difficult to avoid the currents. The National Electrical Code (NEC) specifically prohibits connections which result in these currents and requires that actions be taken to eliminate them.

The Equipment — Load centers

An uninsulated copper or aluminum bus bar is installed in most standard ac residential load centers (circuit breaker box). This bus bar is fastened (electrically connected) to the load center enclosure. All neutral (white insulation) conductors and all equipment grounding (bare) conductors are connected to the bus bar, and it is connected to the ground rod. This load center internal connection represents one connection between the neutral and equipment grounding (grounding for short) conductors. If this was the only such connection, no problems could exist.

Inverters

The PV inverter with hard-wired and receptacle outlets must have the neutral connected to the grounding conductor to provide safety for plug-in loads. This represents a second connection between the neutral and grounding conductors. If the inverter is connected to the load center described above, there will be two connections between the neutral and the grounding conductors. These two connections place the wires in parallel and allow currents to flow through both, a decidedly unsafe situation.

Some inverters have no receptacle outlets and have a floating neutral which is not connected to the grounding conductor. When connected to the load center, they work properly and no objectionable currents flow in the grounding conductor.

Standby inverters with receptacles should supply the internal connection when operating as the ac source in the inverting mode. When wheeling ac power through the inverter (internal transfer switch) from a backup source (such as the grid or an ac generator) to the load, the connection may pose problems. In either case, the internal connection will create parallel paths if the inverter is connected to the load center with the bus bar.

Still other inverters have an internal relay that opens the connection between the neutral and grounding conductors when an external power source is used for battery charging. This presumes that the external generator or power source has the necessary connection. It also presumes that there is no load center connected which has the internal connection. Underwriters Laboratories allows this relay and may even require it although it may not be the best solution.

Generators

Most standby generators used in PV systems are less than 6 kW and have receptacle outlets and sometimes hard-wired outputs. For safe use of plug-in loads, the neutral and grounding conductors are connected internally. This third connection provides another parallel path when the generator is connected to either the load center or the inverter. Generators with only hard-wired outputs may have an optional connection at the wiring panel. Some generators do not connect the neutral to the grounding conductor, and the neutral floats all of the time.

Solutions — maybe

Because the equipment that is used in PV systems is not standardized and frequently is designed for other purposes (construction generators), it will be difficult to generalize about possible solutions.

If a stand-alone PV system provides ac power to a residence, the most durable hardware will be the ac load center. The load center is most likely to be the piece of equipment that will not break and will always be in the system when generators or inverters are down, disconnected, or otherwise not available to the system.

Because the load center is the most durable unit in the system, it should be the single piece of equipment that contains the single connection between the neutral and equipment grounding conductor. If the connection in the load center is used, there should be no connection in the inverter or in the backup generator. This may require equipment modification of existing inverters and generators.

Precautions

The following modifications should only be attempted by the technically qualified person. These modifications will void any warranties on the modified equipment, and some factories may refuse to service modified equipment. Factory service departments and service manuals should be consulted to determine if proper operation can be obtained after the modifications. The factory may be the best place to have the modification made. In new systems, the equipment may be ordered in the modified form with a standard warranty. In no case should the modified equipment be used when not connected to the PV system and the standard ac load center.

Inverters and Generators

The basic concept is to convert the inverter and generator to hardwire outputs only and to remove any internal connection between the neutral and grounding conductors. These devices become part of a permanent installation and the generator and inverter lose any portable, stand-alone capability they may have had. They should not be used by themselves after the modifications.

Remove the receptacle outlets, if any, and block the remaining access holes with metal cover plates. Some inverter manufacturers have a hard-wire conversion kit available or can make the conversions at the factory. Using flexible conduit, hardwire the inverter or generator ac output to the transfer switch or the load center as appropriate. The flexible conduit can be attached to the metal plate covering the holes where the receptacles were located. Find the connection in the inverter or generator between the neutral and grounding conductors. Break that connection and carefully tape and shrink wrap any cut wires.

Connect the inverter to a load center which has the necessary internal connection. Since the ac branch circuit needs overcurrent protection, this load center may be only a single circuit breaker in small systems. The ac system is also grounded in this load center.

There is now only one connection between the neutral and grounding conductors. That connection is in the load center where it normally resides and where the inspector expects to find it. The inverter and generator are hardwired into the system and can no longer be safely used by themselves. The load center makes the safety connection for the entire system. The ac system grounding conductor for the ground rod goes from the load center bus bar to the ground rod just as it does in a conventional ac-only system. If either the inverter or generator is removed for repairs, the ac system remains safely grounded.

Alternatives

If the choice is made not to modify the inverter or the generator, then the neutral-grounding conductor connection could be severed in the load center. Actually, the neutral conductors should be connected to an insulated terminal strip so they do not contact the bare grounding conductors or the enclosure. The single connection will now have to be made in either the generator or the inverter. Also, the connection between the neutral conductor and the ground rod will now have to be made somewhere other than the load center. At all times, under all operating conditions, there should be one and only one connection between the neutral conductor and the equipment grounding conductor.

For safety, consult the factory before making these modifications and have them made by only a qualified person.

Access

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Home Business Basics

Mark Newell and Richard Perez

A home business is an ideal way of keeping beans on your remote homestead table. However, a home business is more of a lifestyle choice than a meal ticket. It means being able to spend more time in your beautiful home, with your family. It allows you to use less resources and live a lower impact life. A home business eliminates the daily commute. In some some places, such as here at Agate Flat, a commute is not even a consideration. Not only is it long and tedious, but in the winter and spring it is near impossible. Commuting is also a dangerous place for you and your family to spend a lot of time. And who hasn't wanted to be their own boss. A home business will do these things. For those who want a self-sufficient lifestyle, a home business provides a solid economic base.

Pick your product, not any product

We have come up with some suggestions for getting you started. The first place to start is with a product. Pick a product or service that you use. We have all had flashes of inspiration, ideas that we thought would be great. Dig through them and see what has real possibilities. Start with something that you know and find a way to do it better. Your ideal product is something that you believe in and gets you excited! (And keeps you there for more than a few months.) Find that hole that needs filling!

Start with one good, new, reliable product. It can lead to others but get one thing down well. Use your product. If you don't use it how can you convince others to?

In general, you can sell goods or services. For goods you can be an original equipment manufacturer (OEM), a distributor, a dealer or any combination of the above. Why all these distributors and dealers? If you're a lightbulb manufacturer, you probably don't have the time to sell each individual bulb. Instead you offer large quantities of bulbs at a lower cost to distributors who will sell the bulbs in smaller quantities to dealers. Often the dealer and distributor roles are condensed into one. There are lots of opportunities for dealer/distributors — manufacturers need them.

Bill Battagin of Feather River Stove Works (See H.P.#33) chose to make and sell super efficient, catalytic wood stoves. He saw a stove in an old house he was moving into and thought he could do better. Building a better stove was a challange that intrigued him. That's all it took, that and a quality product, and a successful business was born. Though it isn't always easy, he has fun making it grow. He now makes his stoves using solar photovoltaic power. There are no distributors or dealers involved. He likes to sell his own product and is the beginning and the end in the chain to the customer.

Dottie Simmons of Simmons Handcrafts started making soaps because of her skin sensitivities and was unable to find locally a soap that she could use. Other examples of small home business products are refurbished vacuums by Sanderson's Rebuilt Vacuums, fresh oysters from Nahcotta Oyster Farms, hydroelectric generators constructed by Harris Hydroelectric, and a hot photo magazine, *SHOTS*, full of traditional and non-traditional work put together in a tipi. The list goes on and the variety range is endless. The common denominator with these people is that they started out with a single product. It's not easy to classify each of these businesses as OEMs, dealers, distributors or what not. Most of these businesses don't fit into the classical business models either. Actually, most businesses don't, especially in the beginning. The idea that there is only one way to start a business is absurd. They started as an interest, a hobby, a curiosity, and grew from there.

The service industry

You can also sell a service. There is no fine line where goods and services meet but there are two general areas. Often services are sold with goods. An installing dealer of photovoltaic equipment installs as a service to his customers. There are many services that you can provide that don't involve goods. They are products in themselves. Graphic design, market research, accounting, writing and consulting are all types of services that you can provide. Many of these services require another skill to produce a product. For example, a technical writer needs to not only understand her or his subject, but also needs to be able to write. Remember that with any service, you are selling yourself. Quality, professional, on-time service will pay you back over and over. Service is your advantage over larger companies that sell products for less.

The computers potential role in home service business is immense. A computer makes many home business tasks easier. If you are a writer, a consultant, or graphics artist, a computer is almost essential. Accounting and customer databases can be a nightmare without a computer. A high volume sales or a mail order type business is very hard to manage without a computer. A more professional look, the ease of writing letters, and the help in making advertisements are all fringe benefits of having a computer.

With your computer you have access to a network of other computer users. This gives you an even more powerful tool for independence and home business. Using a telephone you telecommute to work by logging on a computer network. The network becomes the office where you pick up mail, contact potential customers or look for needed services. For example if you are a writer or a graphics artist, there are networks where editors can be contacted. Here, you can market yourself, make contracts and leave the finished product.

Be forewarned, however, there is more to a business than a good idea and a product. You will need more to manage your business, especially as it grows. Bob-O and Kathleen of Electron Connection not only design and install the renewable energy systems that they sell but they also do all their accounting, advertising, production of brochures, and answering customer questions. (He maintains his truck to boot.) If you find this daunting, don't despair. These are things that you can learn

Here at Home Power we provide information. To do this we not only have to know our subject, but there are other things that we need to know as well. Without a good understanding of computers, specifically the Macintosh environment, we could not make the magazine that you have in your hands. We also need a basic understanding of publishing, photography, writing, and graphic design. A lot goes into a single issue of *Home Power*.

Serious Questions

Before we go any further, *here are some questions that you need to ask yourself*. Can you afford to or are you willing to put in 80 hour work weeks? Is your husband or wife or significant other supportive or willing to be involved in this project? If not, your relationship is in for some potentially rocky times. Can you afford to lose money for at least the first two years? Are you willing to mix your business with your home life? If your answer to any of these is no, then save yourself some heartache and ulcers. Don't go into this just to make money. There a lot of easier ways to do that, using much less of your time. You will be investing a lot of time, money, and effort into this project, so make sure that it is something you enjoy!

If you have always wanted your own business, then do it in your home. This magazine is an example what can be done at home. There is something very organic about the way work and home life intertwine. We love the way it works for us and want to encourage more home businesses. Next time we'll talk about putting together your business plan. If any of you with a home business have any comments or advice, please write in.

Access

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Information: For more information on telecommuting contact Sequoia Technical Services. They offer free consulting to California residents but will answer your questions if you are out of California. 1-800-366-8370

In H.P. #17 on page 51, is a review of Don Lancaster's excellent book on home business. *The Incredible Secret Money Machine* . *Smalltime Operator* is another great book full of useful information. If you want more information but don't have the time to go to business school or the money to make mistakes then hunt these books down. *The Incredible Secret Money Machine* is available from Synergenics for $18.50 postpaid. Box 809-HP, Thatcher, Arizona 85552. • 602-428-4073. *Smalltime Operator* is $16.95 postpaid from Bell Spring Publishing, POB 640, Laytonville, CA. 95454 • 707-984-6746

Home Businesses: Bob-O Schultze, Electron Connection, 19101 Camp Creek Rd., Hornbrook, CA 96044 • 916-475-3401

Bill Battagin, Feather River Stove Works, 5575 Genesee Rd., Taylorsville, CA 95983 • 916-284-7849

Don Harris, Harris Hydroelectric, 632 Swanton Rd., Davenport, CA 95017 • 408-425-7652

Larry Warnberg, Nahotta Oyster Farms, 270th & Sandridge Rd., On the Old Rail Line, POB 43, Nahcotta, WA 98637 • 206-663-4930. Their oysters are fantastic and they do UPS delivery.

Bill and Katcha Sanderson, Sanderson's Rebuilt Vacuums 20295 Panoche Rd., Paicines, CA 95043 • 408-628-3362

Daniel Price, *SHOTS*, POB 109, Joseph, OR 97846. A one year subscription is $18 or write for more info.

Dennis and Dottie Simmons, Simmons Handcrafts, 42295 Hwy. 36, Bridgeville, CA 95526 • 1-800-428-0412

ADS

Designs on the Sun

Therese Peffer

Sometimes things turn out great without any planning, sometimes they don't. We hadn't seen the sun in several days, but as soon as I made some progress on my system, we had five glorious blue-sky sunny days! My small renewable energy system certainly wouldn't be what it is without any planning. The time spent planning has saved hours of ripping up and starting over.

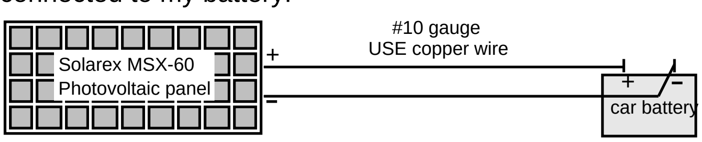
Several months ago, I bought a 60 Watt photovoltaic panel and scrounged a frame for it. I bought 60 feet of #10 wire with USE insulation (this insulation resists degradation by sunlight and can be used outdoors). A friend gave me a car battery from a dead SAAB, so I hooked the two together and charged the battery just for fun.

That's what got me started. It sounds so simple doesn't it? Just "hook the two together." Since then I've spent many hours thinking and rethinking my little system for my trailer. I've looked at other systems in *Home Power* for ideas. I've drawn countless sketches, both electrical schematics and physical diagrams.

One of my "hurdles" was learning how to use a wiring diagram. I had a difficult time translating the electrical lines and squiggly representations to how things were physically connected. I was much more comfortable drawing the system as I saw it, with all the fuses, plugs, wires, and connectors.

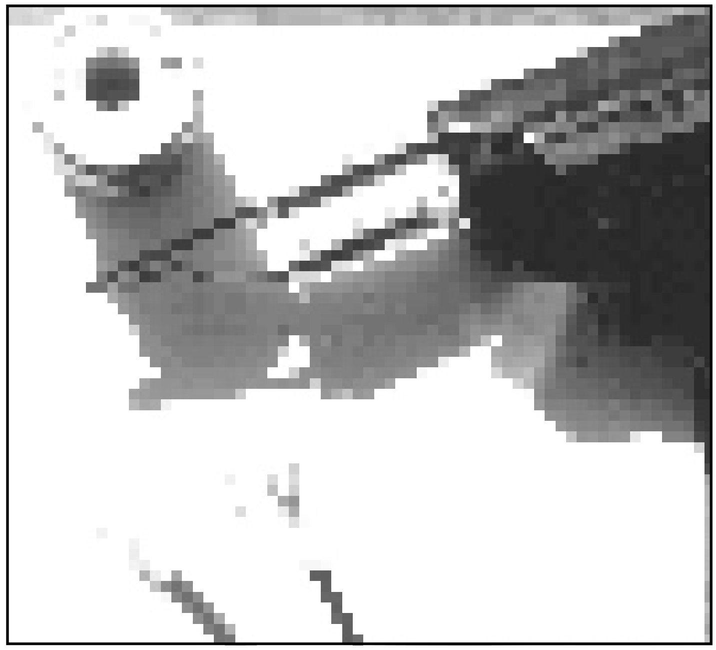
Simple Connections

So I started from a very simple concept: my PV panel connected to my battery:



The panel sits about 20 feet from the trailer, so allowing for slack I cut two 25 foot lengths of the wire. The Solarex panel requires spade connectors (the connectors are shaped like a U or fork), so I added spade connectors to the ends of the wires.

I crimped and soldered all connections. Solder increases the contact of the metal connector to the wire, reduces resistance, and seals the connection from corrosion. There's a lot of connections in my circuit! If there is a poor electrical connection (resistance) at any one of the junctions, this affects the whole circuit. The resistance of the whole circuit will affect how much of the electricity gets to the battery and appliances. First, I stripped the ends of both wires about an inch with a pocketknife — wire strippers are no match for USE insulation! Next I crimped the spade connectors to make a good mechanical connection and soldered the connector to the wire to ensure a good electrical connection (see photo above).



Above: One down and one to go! After stripping wire and crimping the spade connector comes a dab of solder.

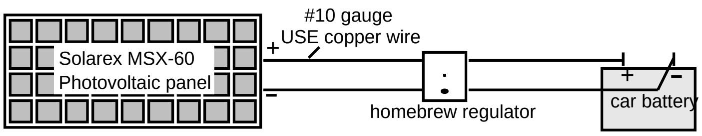
The car battery had round posts — too large to accept ring connectors. I bought wing nut battery terminals at an auto parts store. The terminal fits around the battery post and has a 5/16 inch bolt. I connected the appropriate size ring connectors to the battery ends of the wire, tightened the wing nuts, and charged away!

One immediate problem arose — I couldn't leave the system alone for very long. I was constantly heading down to my simple setup with the voltmeter to check on the battery. I sure didn't want to overcharge the battery!

Controlling the Charge

I took a look at Chris Greacen's portable system (described in HP #28), and borrowed a few ideas. One step was to add a regulator which would prevent the panel from overcharging the battery. (Of course this would free up my time, too!) I liked the idea of having the "brains" — the regulator, meters, outlets, fuses — of the system arranged neatly in a box. I didn't want to cut or drill holes for components in the inside wall of the trailer, so a box seemed to make sense. There's a shelf just above the seat under which the battery lies — just the place for a small (9 inch by 14 inch by 7 inch tall) plywood box.

I "homebrewed" (built) a regulator like Chris' (see HP#28 for details), my first homebrew experience. It's not a neat, pretty regulator — the metal box which holds the perforated board and wires barely closes — but it does work! So now the wiring diagram looks like this:

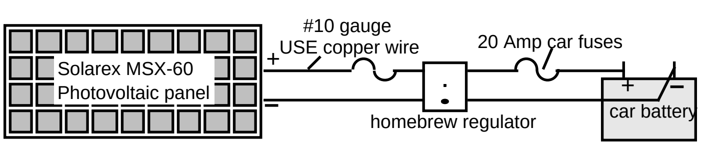


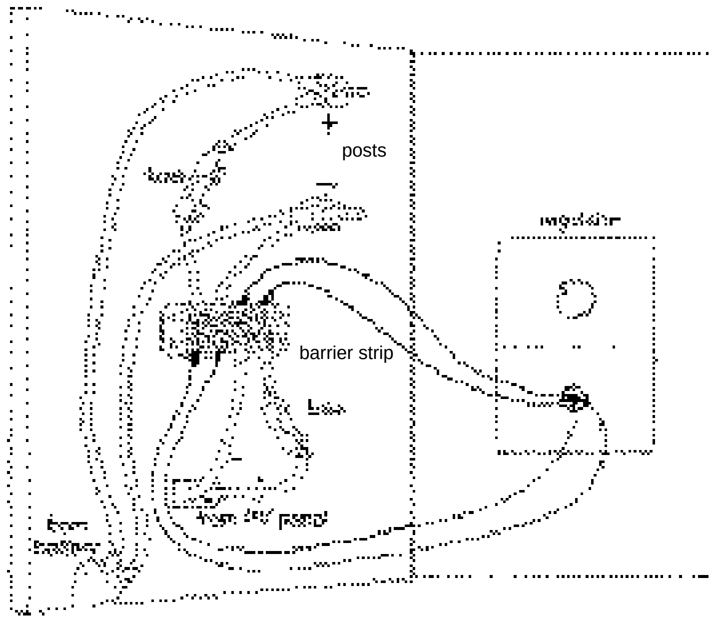
Not the Whole Picture

But the wiring diagram doesn't show everything! I decided to put a plug on the PV panel so I could disconnect it for travelling or maintenance. I bought a plug from Radio Shack. More soldering! I'd use a different plug next time — I had to use a piece of sheet metal to attach the female end of the plug to the plywood box. A lightswitch outlet plate makes a neat cover hiding my metal work mistakes. As far as I know, there is no set standard polarization for this plug. One side was angled which I designated positive.

The diagram also does not show how the regulator is wired. I didn't want to "hard wire" the regulator into the system — I want to be able to remove it or replace it without too much trouble. I used a barrier strip to accomplish this. A barrier strip allows the electrical connection of two ring connectors. A small plate of metal with two screws acts as a conductor between each pair of ring connectors. Since there are four wires attached to the regulator — positive and negative from the panel and positive and negative going to the battery — I needed an eight terminal barrier strip. The convenience of removing the regulator cost me a bit of soldering. There were eight ring connectors total! I arranged the barrier strip on the same side of the plywood box as the panel plug (see diagram above right).

The next step was safety! After looking at a few systems, I decided to put a fuse between the panel and the regulator and one between the regulator and the battery. I bought two fuse holders at Radio Shack, mounted them in the box, and put two 20 Amp Littlefuse fuses in them. This will protect the regulator against any short circuits. After a bit of soldering, I was set. Now the wiring diagram looked like this:





Above: What it really looks like — a close up of some of the wiring in my box.

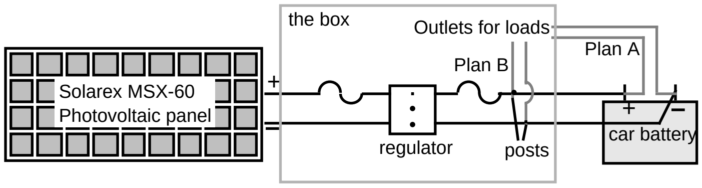
Lights and Music

Now the point of all this is to produce electricity for a 12 Volt light and my radio/tape player. I started thinking about outlets and plugs. I could use a cigarette lighter plug for the radio/tape player — it doesn't draw that much power (22 Watts max, or less than 2 Amps at 12 Volts draw). I bought a Suntronics brass outlet rated at 20 Amps. I've seen cigarette lighter outlets/plugs rated for 2 to 20 Amps; the wide range makes me wonder how hardy the connection is.

For the light, I was more concerned about a good solid connection. I wanted to experiment with different types of 12 Volt lights: compact fluorescent, fluorescent, and halogen lights. Some of these lights draw up to 50 Watts, so I thought something more heavy duty than a cigarette lighter plug was in order. At our "local" hardware store, I found a plug and outlet rated 20 Amps/250 Volts, which is more heavy duty than I need, but better safe than sorry! The plug has three prongs; the two flat prongs are not parallel like a regular 110 vac plug, but are at right angles to each other. I could have used a regular 110 vac plug and just wired it for DC, but I felt that was asking for trouble. I wanted to make sure that only 12 Volt appliances could be plugged into my socket. I bought plastic outlet boxes and started sawing holes in my plywood box.

Electricity from the Battery

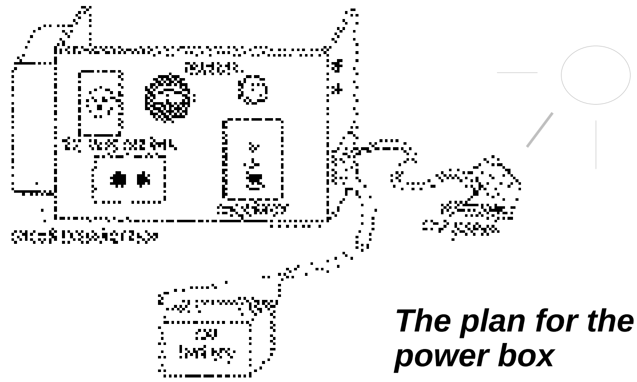
The next struggle was a design problem. I needed to get electricity to the battery from the panel and I needed to get electricity from the battery for the loads. The wiring diagram (next page) helped here.



I could use two wires from my box to the battery and two more wires (labled Plan A) from the battery back to the box — four wires total. But by looking at the electrical diagram I discovered that instead of using four wires, I could use two wires between the box and the battery! I can tap off wires to loads within my box (wires labled Plan B). The two plans are the same, electrically speaking, but Plan B will save wire and make for a much neater and simpler system. Plus, the location of posts inside my box will make it easy to add leads to a future ammeter and voltmeter.

I put two 2 inch long 5/16 inch bolts through the side of my plywood box. I arranged the "posts" vertically instead of horizontally. There is less chance of a wrench falling across the two posts sparking a huge short circuit current from the battery, but I plan to put a barrier between the two posts to be safe. I soldered ring connectors to wires leading to the battery and to wires leading from the regulator. Time to stack up ring connectors!

One stroke of luck was finding a four foot piece of #8 gauge 3-ply extension cord for a dollar at the hardware store! The size and flexibility of the extension cord was perfect for getting electricity in and out of the battery. Plus, my two wires look like one — no tangled wire, and the conductors are protected with two layers of insulation.



The plan for the power box

The best laid plans...

The trailer system is almost ready to unplug from Home Power Office & Power. But, I've already found changes to make! I will add disconnects between the battery and my outlets and think about other safety features. I just bought some surplus airplane meters and plan to get an ammeter and voltmeter on line soon. Then I'll add a handle to the box, and maybe a plexiglass lid. It's been overcast here lately — I better get to work!

Access

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HAPPENINGS

INTERNATIONAL

CANADA

SW Alberta Renewable Energy Initiative Information Centre — This group provides Canadians with information and workshops on renewable energy. For more information contact Mary Ellen Jones, Information Centre Manager at POB 2068, Pincher Creek, Alberta, Canada T0K 1W0

MEXICO

LA CARRERA FORMULA SOL, Mexico's solar, electric and hybrid car race, will take place from the 11th to the 18th of July 1993, in the state of Sonora (which borders with Arizona), covering a total of 930 miles. For information, please contact Beatriz Padilla, race coordinator, at (52 5) 281-0655 (phone and manual fax).

NATIONAL

Electric Vehicle Safety Survey: In order to establish meaningful standards, the Electric Vehicle Industry Assoc. is seeking data on the safety of EVs already in actual use. Anyone who has had any experience with EV accidents is invited to share their information. The survey takes 10 minutes to complete. Final data will be made available for publication. To participate, contact Shari Prange, Electro Automotive, POB 1113, Felton, CA 95018-1113 • 408-429-1989

Elfin Permaculture is holding a number of workshops ranging from one day to three weeks in locations around the U.S. and Canada. Contact Cynthia Hemenway, 7781 Lenox Ave., Jacksonville, FL 32221

The Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS) is a national service, funded by the U.S. Department of Energy, that provides the general public and educators with free information on renewable energy and energy conservation. They also maintain a referral network of approximately 500 organizations that provide more technical information. CAREIRS is interested in organizations that can benefit from being part of their monthly mailing list. The mailings are most useful to organizations who have direct contact with the public". For more information contact CAREIRS, POB 8900, Silver Springs, MD 20907, or call 800-523-2929

HOME ENERGY MAGAZINE is offering a free Directory of Energy-Related Graduate Programs in US Universities. Over 60 programs in the fields of energy, resources, the environment, and development. This directory was produced by the Energy Foundation, with the cooperation of Student Pugwash USA, a national educational, non-profit organization. The free directory is available via book, IBM 3.5" disk, IBM 5.25" disk, Macintosh disk, (please specify MS Word 5.0, Filemaker Pro (Mac) or delimited ASCII). Contact Home Energy Magazine, 2124 Kittredge St #95, Berkeley, CA 94704

FREE NATURAL GAS VEHICLE MAGAZINE Send SASE to Frank Rowe Circulation, NGV Magazine, 1410 Grant St Ste A-201, Denver, CO 80203 • 303-863-0521, FAX 303-863-0918

EV NETWORK - Ken Koch will search his file of 2,000 customers and let you know if there's an EV owner near you. Send him an SASE: 12531 Breezy Way, Orange, CA 92669

Public Citizen is again promoting SUN DAY 1993, an ongoing nationwide, grassroots, organizing and educational campaign to promote improved energy efficiency and renewable energy (solar, wind, biomass, solar-hydrogen, geothermal, and hydroelectric) technologies as solutions to global climate change, energy imports, acid rain, radioactive waste, and other energy-related environmental problems. The campaign was formally launched on Earth Day 1992 with activities sponsored throughout the United States. Once again, many participating organizations will be sponsoring fairs, conferences, educational programs, political actions, and other events. If you are interested in participating contact Public Citizen, attn: SUN DAY 1993, 215 Pennsylvania Ave SE, Washington, DC 20003 • 202-546-4996, FAX 202-547-7392

ALABAMA

THE ALABAMA ENERGY EXTENSION SERVICE is offering free energy consultation and literature on a wide variety of energy related topics. Contact: Alabama Energy Extension Service, The University of Alabama , Box 870201, Tuscaloosa, AL 35487 or 1-800-452-5901 (AL only) or 205-348-4523

ARKANSAS/MISSOURI

OZARK RENEWABLE ENERGY ASSOC. (OREA) is dedicated to providing RE enthusiasts regional connections and promoting the use of alternative energy in the Ozarks. OREA is working on a Networking Directory which is meant to be a vehicle for getting interested folks in touch with each other. For more info about OREA and a Directory Questionaire send SASE to Julie Courtney at RT3 Box 4305, Reed Spring, MO 65737 • 417-338-8688

CALIFORNIA

ARCATA, CALIFORNIA'S SECOND ANNUAL RENEWABLE ENERGY FAIR is April 24th, 1993 and will take place in Redwood Community Park from 10:30 a.m. to 7:00 p.m. In case of rain we will move to the Arcata High School Gym. This year's event is sponsored by Redwood Alliance, Citizens for Social Responsibility, Campus Center for Appropriate Technology, Solutions, Power 96 KFMI, Earth Options Institute, and Home Power Magazine. Speakers will include Richard Perez, editor of Home Power Magazine; Dennis Weaver, actor (invited); and emcee Wavy Gravy (invited). Enjoy live music and entertainment all day long from our Solar-Powered Sound System, and bring the kids for the fourth annual Earth Games Festival. Workshops are planned on Alcohol Fuels, Battery Storage, Bio- Gas, Efficient Lighting, Electric Vehicles, Human Powered Vehicles, Humboldt Happenings, Hydro Power, Hydrogen Fuel, Passive Solar Heating, Photovoltaic Design, Rammed Earth Homes, Solar Cookers, Solar Hot Water, Teachers' Workshop, Thermal Curtains, and Wind Power. For further information, booth space applications, or details on becoming one of our fair's sponsors or contributors, please contact us at: Renewable Energy Fair PO Box 4179 Arcata, CA 95521 • 707-822-3481

SEERs SOLAR SUMMIT! SEER is not having a public event this year, instead a SOLAR SUMMIT is planned for the renewable energy and transportation industry. Proposed topics include industry & governmental interfacing, financing, industry networking, current technology, educational programs, contract opportunities. Representatives from CALSEIA, EVA, ERA, SCCA will be present. The Solar Summit is scheduled for August 6, 7, & 8 in Willits, CA. A local resort has been reserved for the event. For more information contact Solar Summit, 733 S Main St #234, Willits, CA 95490 or call 707-459-1256

North San Francisco Bay Chapter of the Electric Auto Assoc. (EAA) holds meetings on the second Saturday of each month at the PG&E Business Center, 111 Stony Cir, Santa Rosa, CA from 9:30 AM–Noon. For information on the EAA and the chapter nearest you, send an SASE to 1249 Lane St, Belmont, CA 94002, or call 415-591-6698 (10 to 5 on weekdays).

The American Hydrogen Association's Silicon Valley Chapter is now offering access to a bulletin board system with information on solar cells, hydrolyzers, gensets, windmills, hydropower, ocean thermal energy, converters (OTRCs), bio ponds, thermal cracking and other means of converting solar energy in Hydrogen. Learn about technologies for transporting hydrogen by pipeline, storage of hydrogen as a liquid, a gas, and a hydride, combustion of hydrogen with air and by catalytic burning and how hydrogen is electrochemically combusted to produce electricity within fuel cells. Contact: The American Hydrogen Association-Silicon Valley Chapter Headquarters, 1401 Pointe Claire Ct., Sunnyvale, CA 94087, BBS@408-738-4014 Voice@408-235-1177

THE 2ND TEHACHAPI WIND FAIR AND WINDMILL HIKE will be held May 22-23, 1993. Sponsored by the Kern Wind Energy Assoc., Southern California Edison and Mountain Valley Airport, the weekend festival celebrating the success of the area's renewable energy industry will be held at the local sailplane port. The fair will again include displays of wind and solar energy as well as electric vehicles , tours of an area wind farm, kite flying, sky diving and a host of other activities. As part of the Wind Fair's activities, the annual hike among the wind turbines will be held at 9 AM on Saturday, May 22. For more info about the fair or the windmill hike call Tehachapi Wind Fair Committee at 805-822-3222, or contact the Wind Energy Assoc. at 805-822-7956.

ARROYO SECO EARTH FESTIVAL: April 24, 1993. Earth Parade, over 200 environmental exhibitors, environmental theme park featuring energy, transportation, air quality, waste & recycling, food & agriculture, children, water, recreation, housing, conservation, business, manufacturing, nature and more. Live music, clowns jugglers entertainment, food earth games and a job fair. For more info contact Timothy Brick, The Arroyo Seco Council, 16 S Oakland Ave Ste 205, Pasadena, CA 91101 • 818-792-2917

The American Wind Energy Association (AWEA), the National Renewable Energy Laboratory (NREL) and the US Dept. of Energy (DOE) is sponsoring WINDPOWER '93 on July 12-16, 1993. The meeting, AWEA's 23rd national conference and exposition, will take place in San Francisco, California at the Fairmont Hotel, Nob Hill. For more information contact Windpower '93, 777 N Capitol St NE Ste 805, Washington, DC 20002.

Siemens Solar Industries is offering its training program, Photovoltaic Technology and System Design. Siemens has been presenting this week long course since 1981. Learning begins by purchasing the two volume set of Training Manual and Technical Appendix for $175. The fee includes their award winning 30 minute videotape "The World of Solar Electricity". Step two is a 5 day training class at Siemens Solar in Camarillo, CA on April 19-23, July 19-23 and October 4-8, 1993. The training class, including the two set manual & video, is $1500 (food and lodging not included). The course offers hands-on experimentation with inverters, controllers, batteries, modules, trackers and loads. For more information contact Mark Mrohes, Siemens Solar Industries, 4650 Adohr Ln, Camarillo, CA 93011 or call 805-482-6800

COLORADO

SOLAR HOME WORKSHOPS will be held at the Sustainable Technologies International (STI). These workshops are for owner builders and persons seeking careers as solar professionals. For a detailed description of SOLAR HOME PROGRAM WORKSHOPS, costs and scholarship information, write STI, POB 1115, Carbondale, CO 81623-1115 • 303-963-0715

4th ANNUAL CRESTSTONE, COLORADO ENERGY FAIR-July 31 & August 1, 1993. The Fair committee wishes to thank all the folks who made the 3rd Annual Creststone Energy Fair such as success. Anyone interested in participating in this year's Fair should contact Citizens for Clean Energy, P.O. Box 17147, Boulder, CO 80308 • 303-443-6181

DISTRICT OF COLUMBIA

SOLAR EMERGING: THE REALITY - April 22-28th, 1993, Washington DC. Three major solar energy conferences will be held jointly—The American Solar Energy Society (ASES) Solar 93 Conference, the SOLTECH 93 Conference, organized by the Solar Energy Industries Association (SEIA), and the American Society of Mechanical Engineers (ASME) International Solar Energy Conference. For more information, contact American Solar Energy Society, 2400 Central Ave G-1, Boulder, CO 80301 phone 303-443-3130, fax 303-443-3212; Solar Energy Industries Association, 777 N Capitol St NE Ste 805, Washington DC 20002, phone 202-408-0660, fax 202-408-8536; American Society of Mechanical Engineers, 345 E 47th St, New York, NY 10017 • 212-705-7054, FAX 212-705-7674.

FLORIDA

Florida Solar Energy Center - 1993 PV System Design Workshops: Learn about solar electric technology and the proper way to design stand-alone PV systems. Registration fee: $300. May 25-27, Sept. 14-16 1993. For more info contact JoAnn Stirling, 300 State Rd 401, Cape Canaveral, FL 32920 • 407-783-0300 ext 116, FAX 407-783-2571

The 10th World Hydrogen Energy Conference is being held on June 20-24, 1994 in Cocoa Beach, Florida. Abstracts due June 1, 1993. For additional conference information, please write or call Carolyn Burby, Florida Solar Energy Center, 300 State Road 401, Cape Canaveral, Florida 32920 • 407-783-0300 extension 112.

IDAHO

Backwoods Solar Electric Systems is offering Saturday workshops on June 19 and September 4 1993. The workshops will cover photovoltaic theory, equipment & installation. Classes are limited to 10 people. The non-refundable, prepayment of $40 covers class, lunch, and textbook, or $30 per person for couples sharing the book. For more information contact Steve or Elizabeth Willey, 8530 Rapid Lightning Creek Rd, Sandpoint, ID 83864, or call 208-263-4290

MAINE

Hands-On Workshops will include: solar air heating, solar water heating, solar cookers and ovens, solar electric home, passive architecture, greenhouses and sun spaces, and the immensely popular photovoltaics workshop. The fee for each of these workshops is $25.00, which includes lunch. For information on sites and dates contact Richard Komp, Maine Solar Energy Assoc., RFD Box 751, Addison, ME 04606 • 207-497-2204

MASSACHUSETTS

NESEA — Over 50 cars, powered by the sun, will race from Boston, MA through New Hampshire, to Burlington, VT, May 23-29 1993, in the fifth annual American Tour de Sol, the solar and electric car championship. There will be free educational displays of these innovative non-polluting cars along the route. Contact: NE Sustainable Energy Assoc., 23 Ames St., Greenfield, MA 01301 • 413-774-6051

MINNESOTA

MINNESOTA SUNFEST 93, A three day renewable energy exposition will be held June 25-27 1993. Events include the finale of the SunRayce 93, featuring 36 solar vehicles designed by college students from across the US, Solar Boat Regatta at Lake Nokomis, Student Science Contest, Kids Programs, a non-polluting commuter vehicle demo, solar powered hot water exhibit, entertainment featuring strolling musicians and a live radio show, solar workshops and a variety of exhibitors featuring commercial solar products, ecological exhibits, and food booths. Most of the activities will be held at the Minnesota Zoo. For more info contact Stephen Dess, PO Box 36, Crosby, MN 56441 • 218-546-5369

MISSOURI

Earth Day Environmental Fair 10 am to 3 pm April 24, 1993. The Fair will be held at the Army Corp of Engineer Visitors Center, Table Rock Lake Dam. Over 40 environmental exhibitors featuring alternative crops, waste and recycling, renewable energy, RE and environmental organization, air and water quality, recycling, endangered species, nature and more. For more info contact Wayne Dietrich 417-546-2371 days or Debbie Redford 417-334-6016 nights.

NEVADA

Solar Electric Classes in Nevada taught at remote solar home site. Maximum of four students for more personal attention. Two day class choice on 4th weekend of April or 3rd weekend in May 1993. Classes on weekdays & other weekends upon request, minimum of 2 students. Class will be full of technical info, product evaluation, sizing systems etc. Students will build a solar system. $75 per person. Call 702-645-6571 or write Solar Advantage, 4410 N. Rancho Dr #148, Las Vegas, NV 89130

NEW YORK

EARTH MONTH 1993 - The Earth Month Coalition in Rochester, NY is again sponsoring Earth Month. Earth Month 93 will kick-off on March 20 - International (United Nations) Earth Day and wrap-up the weekend following April 22 - U.S. Earth Day. Events are too numerous to list here, but include “The Sense of Wonder” — a play depicting the life of Rachel Carson, and a weekend of Earth Day events including an Alternative Energy Fair. For more details and a copy of the Earth Month calender please call Susan Dorman 716-271-3550 or Bill LaBine 716-334-2347.

E-DAY 1993 will be held in Olean (O-lee-ann), NY at the city recreation center on Friday, April 30 and Saturday May 1 from 10 AM til 6 PM. “E” stands for energy, environment and everyone. Displays will include energy conservation, solar goodies, solid waste management, electric vehicles, school student projects, and much more. 30-40 energy related vendors will also be on hand to showcase their products and services. A nominal, but necessary fee will be charged at the door. For more info, call Don Struchen at 716-933-6175, 7-11 PM EST or write to 91 Brooklyn St, Portville, NY 14770

OREGON

The Appropriate Technology Group is a grassroots and hands-on group formed to explore how to educate, demonstrate projects, provide a community resource for designers and builders, do experimental projects involving energy, transportation, sewage, hazardous and solid waste, etc. The group meets once a month in Portland, Oregon. For more information call 503-232-9329 (evenings).

VERMONT

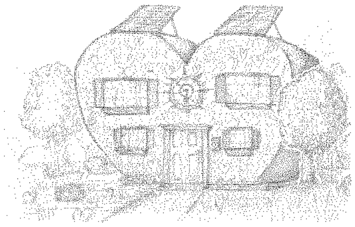
Photovoltaic Home Electric Systems: Seminar and Workshop is a one day program held at Sunnyside Solar in Gilford, Vermont. This introduction to independent solar electric systems will include a hands-on portion assembling a four module system. The dates for 1993 are scheduled for April 17, May 8, June 5, July 17, August 28, September 11 and October 9. Each date is a complete program, held on a Saturday from 9 am to 4:30 pm. The $130 fee ($90 for folks sharing materials) includes lunch, a full packet of product information and related articles and both Joel Davidson’s *The New Solar Electric Home* & Steven Strong’s *The Solar Electric House*. A $45 deposit, advance registration is required. For more information contact Carol Levin, Sunnyside Solar, RD4 Box 808, Brattleboro, VT 05301 • 802-257-1482

WISCONSIN

The 4th annual Midwest Renewable Energy Fair is June 18-20, 1993 at Amherst, Wisconsin. The Energy Fair introduces the public to a wide spectrum of renewable energy technologies and their contemporary applications. The Energy Fair is a fun and educational experience for individuals and families. At the Energy Fair you will have the opportunity to: • watch wind and solar power actually power the fair • see, handle and purchase products that will help you conserve energy, protect the environment, and save money • attend informative hands-on workshops (beginner to advanced) presented by experts from across the country • walk through a model home demonstrating energy efficient construction and appliances, and renewable energy, power and heating • see vehicles powered by alternative energy • network with others who share similar interests • dance to live music played on a solar and wind powered stage. Have fun and more! For more information about the Energy Fair contact: Midwest Renewable Energy Association, 116 Cross St., Amherst, WI 54406 • 715-824-5166.

A Permaculture Design Course, will be held June 11-29, 1993 in West Linn, WI. The course will cover the standard Permaculture Design Course with emphases on creating appropriate settlements in existing rural villages, pan-cultural experimentation, strategies for northern climate gardening, networking and accessing information & sustaining decentralized non-institutional organizations. Two days will be spent at the Midwest Renewable Energy Fair as well as smaller field trips. Tuition is $625 which includes meals and tent camping. For more information contact Dreamtime Village, Miekal or Elizabeth, Rt 1 Box 131, La Farge, WI 54639 or call 608-528-4619

Home & Heart



Kathleen Jarschke-Schultze

Bob-O and I added a 12 panel Wattsun tracker to our system. This opened up the area where the three panel racks had been. With these panels off the ground I have the space in the sun to build a dream — a solar cooker utility table surrounded by herb beds.

Spring, Hope's Eternal

The Wattsun tracker went in over a period of time. The weather fought us all along. It was either too cold to pour the cement, or it was raining, or it was snowing. Then we had a January thaw. It was wonderful! The tracker installation was finished and I began my project.

The old racks were positioned on pier blocks with the angle adjustable for seasonal elevation. When they were dismantled I had varying lengths of rack steel and more pier blocks than I needed for my project. Bob-O had given me his old Makita drill when I got him the new deluxe model for Christmas so I was set for action.

Siting

First, I took the Solar Pathfinder out and moved it around the area I wanted to use until I found the place that had no obstruction to the sunlight at any time of year. I had erroneously assumed that where the panels had been would be perfect for a solar cooker. Richard pointed out that the panels on the new tracker would shade that area at certain times of year.

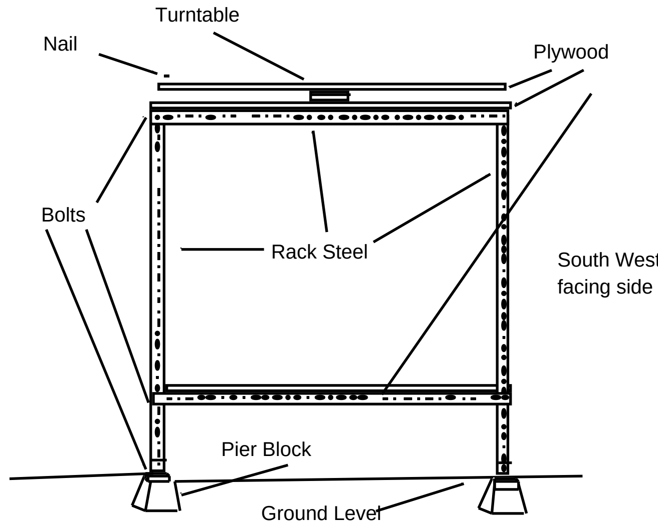
Plumb Crazy

Once I had the placement determined I dug holes to set the pier blocks in. I did not want them to be visible when I was finished. This turned out to be the most frustrating part of the project. Not only did I have to get them all level with each other, I also had to get them square to each other. Arrgh! I kept telling myself these were good skills I was learning and finally got through it.

The next step was to assemble the pieces of rack into a table with a shelf. I wanted to avoid having to cut the rack if I could. By laying out the pieces on the ground first I was able to determine that only one cut was needed. I measured and cut that piece with a hacksaw.

Assembly

I assembled the rack frame using bolts, nuts, washers and my Makita drill. The table top is waist high and made from plywood. There is a shelf underneath, also made of plywood, with enough room to store solar cookers that are not in use. Later I will enclose this shelf with hinged and latched doors. The front half of the table top has a raised plywood table on a Lazy Susan type turntable which holds the cooker and allows it to be easily turned to the sun. By drilling holes in the turntable and the table top I am able to secure the cooker from the wind by using a 20 penny nail dropped into the appropriate holes. Eyebolts on the platform and bungee cords will secure any cooker I use to the platform.

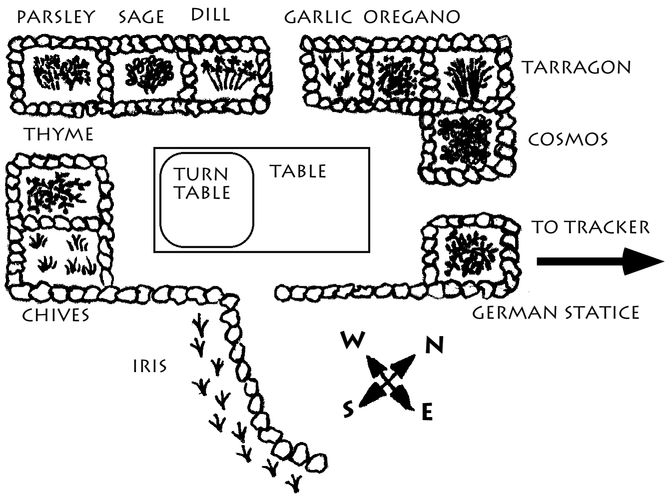


Herbs

Then came the fun part. I gathered rocks, of which we have a plentitude, and made a border around the table about two and a half feet out. There is an exit path on all four sides. Three sides are divided by more rocks into planting beds for the herbs.

I chose sage, thyme, chives, parsley, oregano and tarragon for the perennial herbs and dill for the annual. A small permanent bed of elephant garlic will be be there also. Some cosmos and German statice will provide some color in the beds, towards the back where they will not shade anything. Iris will line the path to the solar cooking area. As a preventative measure, I am planting gopher plant in all the beds, except the garlic bed. Although it has caustic roots that deter gophers it will not affect the herbs cooking qualities. I may try rosemary but I have never had much luck with that.

Eventually I will expand the beds and borders to surround the tracker pole, with room for standing and maintenance. A sundial on a pedestal would be a nice touch. Since this is my view as I stand at the sink and wash dishes I want it to be as pleasing as possible.

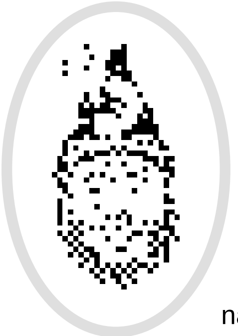


Finishing Touches

Except for some of the plants and the turntable mechanism the whole project is from recycled or scavenged on-hand supplies. The path and standing area around the table and tracker will be covered with wood chips, gathered from the road side where the chip trucks drop them. This fall I will plant some bulbs so that next spring will be more colorful.

Access

Kathleen Jarschke-Schultze c/o Home Power Magazine, POB 520, Ashland, OR 97520



the Wizard Speaks…

A New Way

There is a new paradigm of life brewing in the pot of home power users. This new life-style combines the best of high technology with a sense and style that is in harmony with the natural environment. I like to call this new paradigm TECHNO-PRIMITIVE.

Here is a standard example of those I am familiar with. A low cost, owner-built, house with wood heat and an out-house is combined with a high-tech power system. This power system can provide all electrical needs including refrigeration, entertainment, and computers. For intermediate level solutions we have propane stoves, heaters, and refrigerators.

In the future, the techno-primitive life style will combine the most advanced features of science and technology with the most non-intrusive methods of living in the natural environment. Cities may eventually disappear as may highways and power lines. There will be resources and habitats for all.

Letters to Home Power

No Meter, It's Sweeter

Thank you! You know, living off the grid isn't too common here in the Pacific Northwest and it was a moment to relish when Puget Power came up the road (nobody else lives on it), stepped out of the car and scanned the house for the meter. My housemate shut off the belt sander, greeted them, and replied that "Oh, sorry, we don't have one of those." She pointed vaguely at the sky and said that's where we got our power. Jaws agape, they backed into their vehicle, completely unable to reconcile the fact that there was no power line, no generator, no extension cord, just a woman with a beltsander in her hands. I would have loved to listen in when they finally spoke! Janet Welch, 330 Protection Ridge, Port Townsend, WA 98368

I love stories like this. It's amazing that a lot of people who work for utilities are still in the dark about RE home systems. Sometimes their enlightenment comes as a profound shock. – Kathleen

Panel Puzzle

Dear Richard; Being a faithful reader since your 1st issue of Home Power way back when, I've certainly enjoyed reading almost every printed word. And what an education I've gotten.

What I haven't seen is how a 36 cell panel relates to a panel with 33 cells. Let's compare the Solarex with the M-75. As quoted by Steve Willey, "M-75 saves money, but voltage is a little lower. The 33 cell ones CAN BE HARMED if they are put in with the 36 cell panels where the 36 cell panels outnumber them. No problem while charging, because the battery sets all the panels voltage to its own voltage. But when the controller disconnects the whole group, the 36 cell panel forces their higher 22 volts open circuit rating backwards through the 33 cell ones that are only 19 volts open circuit. That causes the 33 cell panels to heat up hotter than just being in the sun, and could melt the encapsulating glue. If the 33 and 36 cell panels are separated and each with their own charge control, no problem."

This statement is certainly something to consider by your many readers who have been mixing brands and cell count. Karim Wingedheart, POB 530, Haiku, Maui, HI 96708

Yes, Steve is absolutely right. A solar cell is really a big forward-biased diode. Current through a forward biased diode increases exponentially with increasing voltage. If the 33 cell panel's voltage rises much above its open circuit voltage, it will absorb all of the current produced by the 36 cell modules. This current shows up as heat in the 33 cell module(s). The situation gets worse as 36 cell modules outnumber 33 cell modules. As Steve says, the solution is to give all 33 cell modules their own charge controller. Or better, stay away from 33 cell modules entirely. — Chris

A River Runs Through It

Your magazine is very informative, I enjoy it very much. It is very hard to get much information on alternative energy supplies up here in Canada, so I hope you can get more advertisements from suppliers in Canada.

I have a river flowing approximately 100 feet from my house. The problem is, it is a slow moving river, and I have no drop or head available to use the turbine generators I have seen. I would like to know if it would be a good idea to build a water wheel and use the force of the moving water to generate electricity, by stepping up the rpm of the wheel, through a gear train or pulleys. Have you had any articles on this type of situation. If so, I sure would like to hear about it. Eric Dickinson, RR#4, Marmora, Ont., Canada K0K 2M0

Hiya Eric. I've heard tales of a submersible propeller-driven generator which is towed behind a sailboat that might work in your situation, but I've never seen one or know who makes it. Could be baloney for all I know. The only other option would be an undershot wheel, basically a device which sits on pontoons and is guyed in place so that the current running past it spins the wheel. A runner like that would probably have to be designed specifically for a given site, inefficient, a mechanical carnival, expensive, and a real liability during high water runoff. That being said, I'd love to see one. How 'bout it, fellow hydromaniacs? – Bob-O

Y-H, Y not PV Direct?

A firm believer in using PV power when the power is produced, I can hardly see (except for possible portability) the advantage of storing energy in the form of hydrogen produced at 50% efficiency when an old battery returns 70% of your energy input.

With regards to cooking with hydrogen: during the last three years more than 80% of my coffee has been perked and better than 90% of my hot meals have been cooked with PV energy.

Over that same period I sold my never used back-up generator and a seldom used microwave oven. I acquired instead a 650 W percolator, a 500 W cooking pot, a small

600 W frying pan and four crockpots of 47, 150, 150 and 250 Watts respectively.

Here in the Sierra foothills with good to excellent solar radiation, I do most of my cooking between 8 am and 3 pm. This is when the power output of my 16 Hoxans usually exceed the power ratings of all but my perker, which I seldom use for more than 8–10 minutes at a time. You may say I cook with PV electricity direct.

A typical daily energy use for hot coffee, breakfast or lunch and supper cooked from scratch falls between 760 and 940 Watt-hrs with some additional 100–175 W-hrs for dishwater. Reheating a refrigerated supper may reduce that amount by about 450 W-hrs.

In order to shorten cooking time and maximize energy utilization, I cover my percolator, frying pan, and crockpot with towels during cooking. For example a 3 1/2 quart of chili takes me a mere 5 1/2 hrs and 585 Watt-hrs.

Crockpots with non-removable crocks are by far the most efficient. Also, replace the Lexan lid with available glass or steel lids and do not cover the High-Low adjustment knob! I have melted two Lexan lids, one adjustment knob and a plastic leg baking potatoes or boiling laundry water.

So as for cooking with hydrogen, give me instead eight Hoxans (about 1.61 kW-hrs per day at my place), and I'll feed your gang of seven two meals a day, six days a week on equally clean PV power alone.

Toast and steaks for seven does present a problem, but if you're partial to the latter, lend me a barbecue for the occasion and I'll throw in soup, baked potatoes and chilled, cooked rice with crushed pineapples for dessert.

In general, covering the crockpots lowers the power requirement 30%. For boiling water or baking potatoes the "High" setting is more efficient than the "Low" setting.

Also, you may cook soup, bake potatoes, heat dishwater and preheat beans for overnight soaking in the same crockpot in one day. Thus you take full advantage of the crock's residual heat. But so much for cooking.

My final purchase of a 12 VDC heating pad for my feet at night and a 12 VDC space heater for my bathroom (I use a large crockpot with crock removed for that purpose at present), will turn my little house into an "All Electric Home" about eight months of the year. Sincerely, Dag (CB handle "Crockpot") Heiestad, POB 788, Soulsbyville, CA 95372

"Don't be a fool," says Hijo the mule,

"Eventhough I'm barely able, I still read **my** mailing label!"

Hey Dag, with your ingenuity, daily amount of sunshine and drive to find efficient answers to cooking power conservation you should be setting your sights on the Home Power Solar Cooking Contest! However, I do heartily congratulate you on the unique way you have made your home fit your energy lifestyle. – Kathleen

What, no roast turkey? Baked Lasagna? Pies 'n Cakes? Pizza? Ya gotta be tough...– Bob-O

On the Natch

I have every issue since #1. Me and my partner live in the Cascades, 3,000 foot elevation on a South facing ridge, one and a half miles from nearest utility line. We laugh when the town four miles away has blackouts. We have eight PV panels and we do occasionally have brownouts after watching three or four movies on our VCR but like that Motel 6 ad, we can always keep a light on if we want to. P.S. What, no Muddy Roads anymore? We live on a rutted road. Sincerely yours, Greg Conlin, Box 1825, Chelan, WA 98816

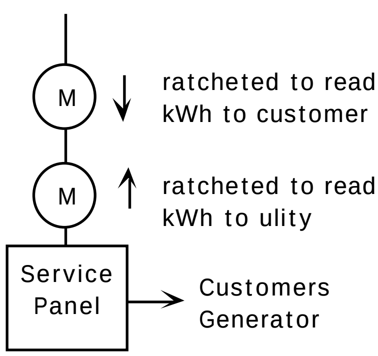
I'll tell you what Greg, we have had some of the muddiest roads this winter and it'll be till they dry out before we can look back with humor on them. Bob-O did get a picture of the garbage bag outfits everyone is sporting this season for chic outerwear at Agate Flat, that fashion capitol of RE trends. — Kathleen

Yes, we had the truck parked 2 miles away from HP Central for about 4 weeks. We backpacked for 2 weeks until we got the old Volkswagen mud buggy running again. Mud for sale, any takers? We could write up our story, but would love to hear others! — Therese

Sell Wholesale, Buy Retail

Dear Home Power; Look forward to each issue, keep up the good work. Some comments on Utility Interface Systems: Part 2 in Issue #33.

I once worked for an electric utility and developed their interconnection and metering requirements for small power producers. What we settled on was two ratcheted kWh meters connected back to back as shown below. In this way the customer used his own power as available and used utility power for any short fall. If the small power producer made more power than he could use at the time the utility would take the excess and pay the customer for it.



It is not reasonable to expect the utility to buy power back for the same price the utility sells power since generating cost is only about one third of the total cost of delivering electricity to its customers. Transmission, distribution, billing, losses and overhead make up the rest of the costs. You wouldn't expect to borrow money from the bank and pay exactly the same amount back without any interest so why would you expect to borrow electricity from the utility and pay it back without interest?

I no longer work for the utility. My present employer is considering installing a co-gen system. We will be pleased to have the same sort of metering arrangement I described earlier.

If interconnect is to be accepted by utilities it must be safe and fair to both the small power producer and the utility's other customers and the owners of the utility.

I support the work of Home Power and Mike Sagrillo. Sincerely, David Morrison, 649 Hawthorne St. NE, Grand Rapids, MI 49503

Hi David. Good to see that utility and former utility folks read Home Power, too. Your metering diagram is electrically the same as my figure in HP #33. However, I disagree with the prevailing utility perspective concerning net billing. PURPA specified that the cogenerators be paid "full avoided cost", as I stated in HP #32. This includes not only fuel costs but capital expenditures for that capacity, transmission, operation and maintenance, and even the interest owed on the utility debt for construction costs of the power plant and equipment depreciation. The intent of PURPA was to reward cogenerators for the cost of displaced capacity, not just the cost of displaced fuel. A pile of coal doesn't generate any electricity! When I generate my own electricity, the utility doesn't have any costs due to transmission, distribution, billing, losses or overhead. Eight progressive states and a variety of utilities apparently consider this arrangement fair. — Mick

Open Letter To The Friends Of SEER (Solar Energy Expo & Rally)

Dear Friends of SEER; We are happy to report to you that the rumors of our demise have been greatly exaggerated! In fact SEER is alive and growing. However we are planning something a little different for 1993. This year brings for us at SEER the opportunity for a permanent home.

REDI

For those of you who have been with SEER from the beginnings at SEER '90 you'll remember the "desert storm"-like location and have a real appreciation for how important a site can be — like the park location of SEER '91 and '92. Well you won't believe the new site that has been offered to us — over 100 acres of gorgeous ridgetop land just outside of Willits with 360 degree views of mountains, forests and ocean! What's more exciting is that not only will this site serve as a home for future SEER events but will also be the site for our next step — the Renewable Energy Development Institute (or REDI for short — who comes up with this stuff anyway?)

The plans for REDI are ambitious and far-reaching. For us, the founders of SEER it means on-going staff and office functions, a long-term R&D facility, continuing education programs and an evolution into a permanent and sustainable effort toward the development of renewable energy and transportation technologies. This effort is demanding almost all of our limited time and resources to pursue. Because we need to get our foundation firmly placed, it also means that there won't be a SEER '93 — at least as you've come to know it.

We've heard much feedback of disappointment that there won't be a SEER '93 — in fact some people have gotten downright hostile and have demanded that we forge ahead. On the other hand most of you recognize the need to establish a sustainable base in order to survive in the long run and have been supportive of our plans to take this next step. SEER has been only one of the many who responded to Home Power's call for "people's energy fairs" and we support each and every one of those groups that is working hard to find better ways for our energy future. We do plan to hold a SEER '94 and if all goes well we will be meeting at the new site!

Perhaps just as important as the securing of the site and forming REDI is the current "window of opportunity" which has opened with the new Clinton/Gore Administration. Not since the policies of the Carter years has there been the kind of possibilities of pushing forward with clean energy and transportation systems which we have all worked so hard to keep alive. Because of this shift in the power structure there is an even greater need for our industry to pull together to become more effective in influencing the growth of these industries and the policies that will secure this growth.

Announcing The Solar Summit

After brainstorming how SEER could be most effective in helping with this effort we have decided to call together our most valuable assets — You — to meet with government and public sector representatives in convening this first SOLAR SUMMIT. Participation will be limited to 300 participants so we are contacting you first in hopes that you will join us. By all of us working together we can continue to create the solutions for tomorrow's energy problems today.

SEER Directors • 707-459-1256

Lyric Al

Am I blue,
My subscription ends with #32,
Here is your fee,
Hope I see 33.

Al McVetty, POB 26, Guildhall, VT 05905-0026

Himalayan Home Systems

Have been growing with you since issue #1. Just returned from Asia. You might be interested to hear that the Govt. of India is subsidizing individual solar systems in remote areas of the Himalayas. A happy interface of ancient and modern. Very progressive action from a "backward" country. We love you here and all the good work you are doing. Aloha, Stan Skurow & Prema Dasara, POB 504, Kula, HI 96790

Yep, "backwards" is a relative thing. I met some people from Auroville, a small community in India, who were building their own inverters and controller circuity. It was impressive. Slowly but surely, solar is arriving. — Mark

Let There Be...

Home Power, I thought you might be interested in the price of this 18 watt compact fluorescent light bulb: regular price is $6.87, minus manufacturer's rebate of $3.00 = $3.87! It consists of a Q'lite ballast rated at 60,000 hours and a replaceable Lights of America triphosphor bulb rated at 10,000 hours. Larry Thompson, POB 79, Booneville, CA 95415

Wow! That is the cheapest price I've ever seen for a compact fluorescent light! When you get one, let us know how you like it. All compact fluorescent lights are not made the same! My $8 Panasonic is still holding up after two years. It may not have as warm a color as the Osram compact fluorescents, but it works for me! — Therese

No Soap

Dear Home Power; your excellent magazine has been an education for me. Though I'm still constantly learning, I am now working in Industrial PV sales. Without your technical articles I wouldn't have found enough information locally to make this happen. I think you all are doing a great job. I've even started seeing Home Power for sale at my local Walden's bookstore.

On a more serious subject: If the oil tanker wreck in the North Sea doesn't prove the stupidity of our world's oil dependence, I don't know what it will take. And here in Texas, TU Electric is about to petition the NRC to allow them to turn on the second phase of the Comanche Peak nuclear power plant. By this summer, some of us lucky Texans will be using that (cheap) nuke power. Oh yes, TU Electric also is asking for a 10% rate increase to help the pay for this new cheap electricity. Well, keep up the good work. I'm off the soapbox for now. Sincerely, Mike Kilgore, KE5F, 2046 Ash Hill Rd., Carrollton, TX 75007

Teach a Man to Fish...

First things first: Home Power is good stuff — hats off to the crew who makes it happen. (I know you're putting in some long days, and it shows.) What do I like? Count me in as a fan of the Wizard; my psyche can always use a yoga session. Things That Work! works for me. I appreciate the thorough technical testing, complimented by practical and personal evaluations. I'd like to see more reviews on energy efficient appliances and other products which enhance living in an off-the-grid environment. (What is the scoop on the Low-Keep reefers? How do they stack up against the Sun Frost?)

A big hug for Richard and Karen and the rest of the Colombian crew for your exceptional work in Tierradentro. I spent nine weeks this Fall in Papua New Guinea, working as a rock climbing specialist for a geologist who was collecting stones in hard to reach places. My side job was keeping our photovoltaic powered barometer and recorder charged and running. Our work took us deep into the jungle to villages accessible only by foot, often places where the level of technology has yet to rise above the machete. In some of the larger villages I was shown microhydro systems and, less often, photovoltaic systems which had been installed in the village health center by the PNG Institute of Technology. To further document a point made by Ken Olson regarding the repair and maintenance of energy systems installed in remote "Third World" locations (see Renewable Energies for the Paez Indians, HP #32), not a single hydroelectric system I was shown was working. In most instances the villagers were "waiting for someone to come and fix it." Judging from the accumulation of rust on many of the hydroelectric generators, I'd guess some have been down for years. The photovoltaic systems were at best funky. In one health clinic the battery, a crusty 100 Amp-hr lead acid battery, was kept in the foot space under the desk. Yikes!

By using the best possible equipment, training a local villager in system operation and maintenance, and arranging for scheduled inspection by professionals (Aprotech), I feel you have overcome perhaps the biggest problem faced by remote, Third World electrical systems: unwitting neglect. Your work in Mosoco reflects much foresight and planning — truly a model of excellence. Bien hecho. Well done. Finally, a belated thanks to Richard Perez, Allen Sindelar and STI for the all the hard work, integrity and energy you put into last Summer's Advanced PV. The course was well organized, highly informative and inspirational. Jeremy Werlin, PO Box 816, Hotchkiss, CO 81419

Hi Jeremy, glad to hear that things went well in PNG. Your eye witness report re-enforces the importance of a complete system installation including local education and periodic maintenance need. It is be a big commitment. — Mark

Mountain Bike PV

Gentlemen and Ladies: My special interests include EVs and Home brew, such as the digital Amp-hour meter. Pedal powered grinder was good, but need access information.

During a two month mountain bike tour of the Ozark Mountains last spring I carried a Solarex MSX-5L (4.5 watt "light") PV panel modified with a switch to achieve 6 Volt operation. (To limit current when charging small nicads, just switch back to 12 V operation!) I charged batteries for bike lights and horns, and lights and radio for camping. I carried that panel up and down hills clear across Arkansas and Missouri and it rained almost every day. Still, when the sun did pop out, the panel was strong enough to quickly give a stiff charge to the 6 V 3.4 A-h sealed lead acid bike battery and four 1.8 A-h nicad C cells. Lawton C. Bates, POB 802, Tustin, CA 92681-0802

Well, Lawton, the grinder cycle was home assembled using an old bike and a purchased grinder. – Kathleen

Lawton, it is pretty admirable to pedal that panel for so many miles. It is also a fitting way to spread the solar word! Your 6V to 12V panel switch would make a great simple Homebrew. For more information on the bike grinder you should check out Pedal Power *by James C. McCullagh, Rodale Press, 1977 — Mark*

Sewing Saved

Dear Home Power; Have been re-reading your HP#16 issue. Was most interested in letter about copiers and inverters.

I am a quilter and we have solar and a generator. I own a "New Home Memorycraft 6000" computer sewing machine. Runs fine on the generator, but who can afford to run it 8–12 hours a day? So we bought a 250 Watt Statpower inverter. The light came on but the computer would not. We took it back and tried it on a Trace 600 Watt inverter and also a PowerStar 200 watt inverter. All the same. Then our supplier received a copy of an ad for the Exeltech SI-250 power inverter. When it came in the electronic engineer checked it out and was most impressed. Now I'm a very happy quilter. The cost was high per watt but well worth it. This inverter has many other features: off/on switch, fuse on outside, and 2 outlet plug. My inverter is serial # 0011.

We live in the San Luis valley of Colorado, elevation 7540 feet in Alamosa and higher. The air is clean and mostly clear, ideal for PV. Many of our friends and neighbors have

PV. We would never go back on grid even if it were an option. We are three miles from power and have a cellular phone. I would be interested in info about 12 VDC refrigerators. Helen Bowers, POB 814, Alamosa, CO 81101-0814

I'm glad that you were able to find an inverter for your computerized sewing machine that works — without destroying the sewing machine. Often when it doesn't start it is because the inverter just fried the insides of your test subject. Any electronics that contain a thyristor (like most laser printers) should only be fed true sine wave power. Anything else and POOF$$. If you ever have any doubt it is a lot cheaper to check with the manufacturer. — Mark

Resource Defense

Dear Home Power; I am writing this letter in order to give another perspective to some of your editorial comments and letters from some other H.P. readers.

First of all I am a natural resource producer. I have been working in the mining industry of Nevada since 1954 and am a graduate of Mackey School of Mines, University of Nevada, Reno. I have mined or worked in larger mines that produced ores of the following metals — tungsten, copper, lead, zinc, silver, gold and mercury. All of these metals are used by you, your readers and me.

In your article "Good Manners," Issue #31, I guess by your definition I am the ogre in caulk boots. I state this irrefutable fact: without the mining, petroleum and timber industries, most of us could not function. Your business could not function. Everything around you that is man-made came from a mine, oil well or the forest. All of the plastics in your house and car came from an oil well or coal mine. Your toothbrush, case on your computer, insulation, medicines, tires, fan belts, clothes on your back (except cotton and wool), toys and many other items about us start from an oil well. Your computer and TV sets have fifteen to twenty different metals in them including gold, silver, platinum group metals and rare earth minerals (to give picture tubes color). The same is true with your car, truck, boat, airplane, bicycle or whatever your conveyance might be. They are composed of metals, minerals and wood products that come from the earth.

I worked at a copper mine in Eastern Nevada in 1957. To get copper started, it goes to a fabricator who in turn makes it into the products that we use. First the ores that contain the copper minerals such as chalcopyrite or cuprite must be found by exploration crews. At the mine I worked at the ore contained about 0.75% to 1.0% copper per ton of ore. That is 15 to 20 pounds of copper in one ton of ore. The stripping ratio at this mine was about 3 to 1, so 3 tons of waste had to be removed to get to the one ton of ore.

The ore went to the concentrator-smelter complex where it was crushed, ground in ball mills and fed to flotation machines which produce a sulfide concentration which contains the copper along with iron, sulfur and other impurities. The concentrates go to the smelter where fluxes are added (limestone, silica) and fed to coal-fired reverbatory furnaces and the charge is melted.

This copper is about 90% pure, is drawn out of the bottom of the furnace. This blister copper was then shipped to a refinery in New Jersey where the metal is dissolved in acids and electrolytically deposited on sheets of pure copper. This is finally the product that goes to a fabricator to make the products we use. In other words, it just doesn't appear in a hardware store. Now, if copper had to be produced without making a hole in the ground, only the very rich could afford it. Waste heat from the furnaces above is used to generate electricity.

It is the same story with all the other metals we use. The aluminum foil you use in your solar cookers or solar mounts probably started its journey to you from a Bauxite mine in Jamaica, transported to the Northwest where there is cheap hydro-power and melted in large electric-arc furnaces and processed into "pigs" of aluminum metal.

Each year, each citizen of the United States requires 40,000 pounds or 20 tons of newly-mined minerals and metals. This includes sand and gravel products, metallic and non-metallic minerals. At this rate of consumption, the average child in America will need a lifetime supply of 800 pounds of lead, 750 pounds of zinc, 1500 pounds of copper, 3593 pounds of aluminum, 32,700 pounds of iron, 26,550 pounds of clays, 28,213 pounds of salt and 1,238,101 pounds of stone, sand, gravel and cement. These figures are from the U.S. Bureau of Mines.

To mine, process, transport, fabricate and get to market the products we use takes huge amounts of energy. To melt silica for your solar panels takes temperatures of 1100° C.

What is the total energy flow in the United States to make the system work? For 1991 the total energy consumption was 81.51 Quadrillion BTUs. I wonder how many hundreds or possibly thousands of square miles of solar panels it would take to provide this sort of energy. A "Quadrillion" is beyond me.

I can relate to metals though. Take lead, for example. If there were 50,000,000 households in the United States (250,000,000 divided by 5) and 10% of these had a home-power system with 2000 pounds of lead-acid batteries in each system, that would require 10,000,000,000 pounds of lead. It sure would keep the lead miners busy. Lead is mostly obtained from the mineral galena (PbS) and has to go through processes similar to the copper ores to obtain lead.

It seems to me that with present technology, only a few of us can have these home power systems.

I read an article in a mining publication about twenty years ago and it stated that there was not enough iron ore on the whole planet to provide each family on earth with a car, refrigerator, stove, etc. By 2050 the U.S. population will be 350,000,000 so we must use our resources wisely and recycle all we can — lead, copper, aluminum, iron, paper, and tires.

What of the future? Better energy systems, whether it be solar conversion, hot or cold fusion or things that we have not even dreamed of yet. To get there will require tremendous expenditures of time, resources and energy. Maybe someday we will have "free" power. Hopefully, we can get more of our young people interested in science and technology to help us get there. Best regards, Don Jung, POB 69, Austin, NV 89310

Don, thank you for this letter, I really learned a lot here. Your points are true and well taken. It is always good to get a reality check. We do face some serious problems. Chris figured out that it would take solar panels covering 145,000 square kilometers (56,000 square miles), or about half the state of Nevada, to provide the 81.5 Quadrillion BTUs Americans used in 1991. Assumptions for this figure: 300 days of sun a year, 7 hours of sun per day, and 8% efficiency converting the sunlight energy (1kW/m^2) into electricity. Currently we are told that it takes between a year and a half and four years for a panel to make back the energy that it took to produce it, depending on the manufacturing process. And then there is the wiring and storage and... Nothing is free. Tough questions and even tougher answers. — Mark

Rule of Thumb Renewables

Dear Sir: A sign of maturity in any industry is spec standardization. The solar industry should do some effort to get to that stage.

With more and more people and manufacturers getting into PVs, it will be a blessing if the manufacturers could get together and agree on a meaningful set of tests that a particular product should conform to. The results of these tests will go into a common format that will constitute the specification for that product.

Standardization helps both the industry and the consumers.

The "apples to apples" comparison will be easier, and the good products will be recognized, because all will be measured with the "same stick."

Right now we have too many specs that are a page or two pages of plain literature, instead of two columns of hard data on pre-established test runs, common to everybody.

For example, there are manufacturers that will give mechanical, electrical and reliability (MTBF) data for some models of their product line, but not for all of them. Why? Operating temperature range seems to be unimportant or a secret only to be disclosed to those who ask for it.

Have you seen de-rating data for output power vs. operating temperature for converters? And how about de-rating of output power vs. operating temperature for PV panels? Either the coefficient is too low to be practical, or you get a set of high temperature curves that, in some cases, only goes to 47° or 48° Celsius. Do they want us to play with tiny little graphs to come up with a meaningless de-rating factor? By the way, have any of them heard about the desert areas in Northern Mexico, the American Southwest or some areas in Latin America? They have the tendency to be rather hot places, 48° C could be the temperature the panel gets to in the shade.

The best way to complement the standardized format is to have notes in the spec sheet and to offer Technical or Application Notes on request. That is where the good literature should be! We are not so dumb. We can read, ask questions, and get educated. That's all folks! Hector L. Gasquet El Paso, TX

Hector, we agree with you that there should be easy to read and understand yardsticks for consumers. Not that it can't be better, but in reality, those manufacturers who cater to the AE industry are better than most in that regard. All PV manufacturers give output curves at the industry STC (Standard Test Condition) of 25° C and most (but not all) give them at 50° C and 75° C as well. Temperature deration curves or continuous duty ratings for inverters and controls on the other hand, would be welcome. MTBF (Mean Time Before Failure) data is meaningless on products operated over a vast range of varying input voltages and currents, output wattage, and temperature swings. That pretty much covers most of the usual AE machinery. Ever seen the kind of industry standards you suggest for refrigerators?, toasters?, blenders? Me neither. — Bob-O

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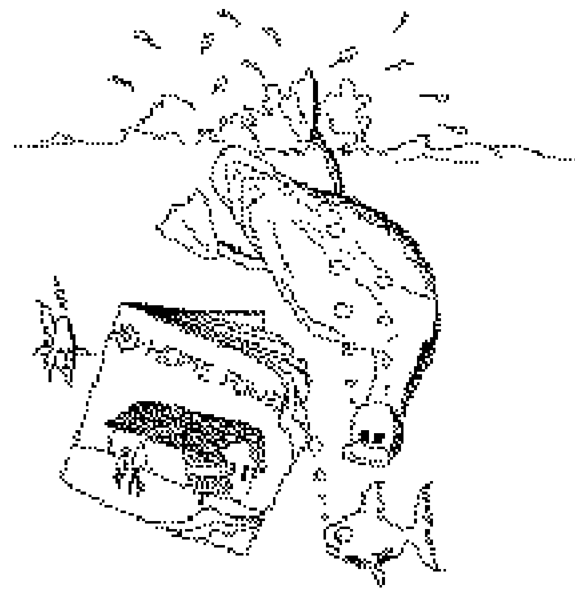

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Q & A

Stainless Coil

In a recent article, Steve Heckeroth mentions a stainless steel coil in his fire box. I have been trying to locate a source for a coil for some time. The only company I could locate was out of business. Could you help me out? Scott A. Wilson, POB 2773, Big Bear City, CA 92314

I cannot tell people how to find a hot water coil for a woodstove (to heat domestic water for household use) without first discussing a couple important items for installing this device properly. In my mind it's analogous to giving someone a gun without the proper knowledge of how to use it — mixing fire and water can be a dangerous proposition. There are some laws that must be followed to have a safe wood-heated hot water system. Even a competent Do-It-Yourselfer may be biting off more than he/she can safely chew tackling a project like this. I'm not trying to discourage anyone, but beware of the "fudge-factor." We are talking about thermosiphon systems — pumped systems are significantly different and require other techniques for installation.

• Always install a pressure-temperature relief valve on both the inlet and the outlet of the coil in the stove. These must not be any further than two feet from the stove, less than one foot is better. Plumb the exhausts of these valves to the outside where you can see the pipes' end.

• Use either stainless steel or schedule 80 steel galvanized pipe inside the stove. If you use anything else, you'll be taking an unnecessary risk.

• From the coil in the stove to the tank you're using to store your hot water, run the "hot pipe" (higher outlet from coil) such that there is never a "high spot" where an air pocket could collect (heed these words!). Even if you have to travel across, say, some ceiling joists, shim the pipes so they will rise at least 1/4 inch per 12 inch run. If you have an air pocket in your system, you won't have any hot water. The "cool" pipe (lower outlet) should, after the pressure-temp. relief valve, drop at least 6 inches, and then follow the same criteria as the "hot" pipe. This is far from a complete description of a woodheated hot water system. But at least if you do these things you won't blow up the stove and the cat under it. I'll describe a complete system in the next issue. Go to your woodstove dealer or plumber experienced in woodstove coils. Many people in this field do not know how to do this kind of installation. Find someone who has experience to help you. If you send away for a coil, ask if you can call those people for help during installation. Or hang on till next issue and I'll be back. — Bill Battagin

Common Ground

Home Power: I finally did it. I made myself a drafting/drawing table and I'm in the continuing cycle of designing my futuristic PV system.

As I draw a line from point A to point B, and after I have referenced numerous back issues these are the questions I have.

1.) In an ungrounded Low Voltage system (under 50 Volts) do the negative and positive both have to be disconnected in lines coming from PV panels before controller?

2.) In ac-DC system, with ac side having system ground: From what I understand you connect all grounds together. My initial instincts say ac will flow into DC side of ground in case of mishap. If you could shed some light here.

3.) What are methods of making connections with large 4/0 wire to say #2 etc.?

4.) How does Oregon's Low Voltage License affect small PV users and Installers?

A little info on shunts would be helpful. And small wires sensing large current draws. Example: an Amp-hour meter sensing current off negative Battery lead. Is this true or did I read something wrong?

P.S. I graduated from an Energy Center in Red Wing, MN in '86. Any of you Red Wingers keeping up with the latest, drop a line. The school is now closed. John Viner, 1362 W. 8th St., Eugene, OR 97402

Hi John. Whew! That's a bunch of good questions. Some of them will take a full scale article to treat effectively, but we'll try to give you a thumbnail sketch of each.

1) Section 690-13 of the NEC states that "Means shall be provided to disconnect all current-carrying conductors of a photovoltaic power source from all other conductors in a building or other structure." That's clear enough until we read on to Section 690-15. It states that "Means shall be provided to disconnect equipment, such as a power conditioning unit, filter assembly, and the like, from all ungrounded conductors of all sources." Confused? Join the Club. This would seem to say that both the negative and positive wires from the PV array AND the battery must have a disconnecting means from the controller in an ungrounded DC system. That's FOUR switches! OK, that's the way it's written — here's the reality check. Nobody I know does it that way, none of the currently available power distribution panels for AE systems do it that way, and I've never heard of an inspector requiring it — yet. If you ground the DC side, you only need have a disconnect in the positive legs.

2) I assume we're now talking about a grounded DC side? Your ac overcurrent or ground fault protection should open the faulted circuit before anything comes to grief. No ac fusing? Uh-oh. The reason that NEC gives for bonding both the ac and DC grounding electrodes is that it's possible for currents from an uninterrupted ac fault to go through the ground to the DC electrode and impose a higher ac voltage on the PV array frame or whatnot. Not bloody likely, but possible.

3) Twisting and soldering the wires, using split bolt connectors, or using crimped and soldered lugs bolted together, all of which are covered with copious amounts of tape and/or heat-shrink tubing work fine. See HP #2, p33; #7, p.36; #14, p.36; and #18, p.35 for more details. Take your pick, but remember that the splice has to be in an approved enclosure to be legal.

4) I'm a little fuzzy on the Oregon low voltage license, but my understanding is that it is designed for radio and alarm systems installers and is generally limited to power outputs of 100 watts or less. Might work for a system with just a few PVs and no inverter, but no good beyond that.

5) A shunt is simply a hunk of metal or length of wire with a known resistance between point A and B. Passing a current through a shunt causes a voltage drop (caused by the resistance) between point A and B. Using the Ohms Law formula $I = E/R$, we can calculate the current flow without having to break the wire and insert an ammeter. Ampere-hour meter manufacturers put the shunt in the negative leg because it's much easier to be accurate at the negative battery terminal. However, an instantaneous amperage measurement could be made with a shunt anywhere in the circuit. — Bob-O

Steam Dream

Our home is on 45 remote acres heavy with brush and black oak. We are gradually clearing out pockets of this and planting Ponderosa pine, Douglas fir and other trees. The clearing activity leaves us with large supplies of burnable material — more than we need for the house but not good enough quality to transport or sell. Normally, our only alternative is to burn this in brush piles which is wasteful. Is it at all possible to use this fuel source to generate steam; drive a turbine, and generate small amounts of electricity? Some preliminary ideas and calculations would be appreciated.

We have asked this before and do not mean to belabor the point, perhaps the idea is far too impractical for "home power". We very much appreciate your publication. *(Name & Address misplaced due to operator space cadet-edness... Oops! KP)*

To answer your reader re: steam turbine electricity generation, I believe the problem with turbines such as those used by electric power plants or ocean liners is that they are not efficient in small sizes.

However, there are many reciprocating steam engines available (both new [yes, castings & plans are available] and used) that would run an electric generator just fine. And there are also plenty of boilers available to power engine — and, of course, one could easily be built new by a welder.

Home-based steam-generated electricity is not all that common since the boiler needs to to monitored and (especially in the case of wood or coal firing) serviced with considerable attention. Those who do use steam (such as Terry Williams, Steamboating Issue #44) generally use it to recharge batteries and to run power equipment (saws, washing machines, etc.) for a few hours at a time, maybe a couple of times a week.

Of course the rpm of a steam system could easily be adjusted by varying the sizes of the pulleys of the engine shaft and the generator shaft. The horsepower rating of a steam engine cannot easily be compared with the hp of an electric motor or an internal combustion engine since full torque of a steam engine is available at all speeds. In other words, a steam engine can handle a much higher load than a typical internal combustion gas engine of equal horsepower.

By the way, I saw a classified ad (I think in TMEN) for info on home steam engined electricity. I hope the above is helpful to you.

Bill Warren Mueller, Editor & Publisher, Steamboating*, Rt. 1 Box 262 Middlebourne, WV 26149-9748 • 304-386-4434 • FAX 304-386-4868*

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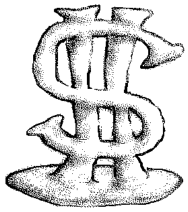
Whose issue got dropped in a bucket
The label came off
It was soggy and soft
But she read it before she chucked it



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the *Home Power* Crew

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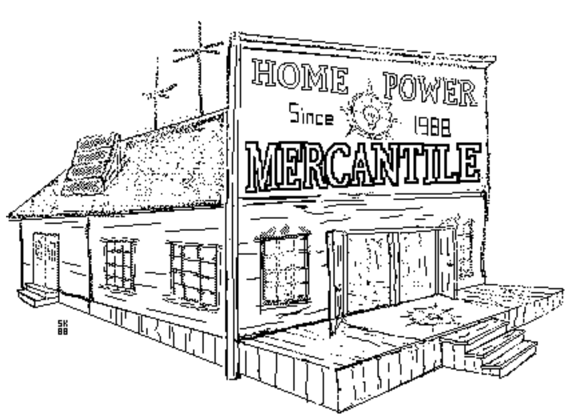

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