A Working MicroHydro at Journey's End Forest Ranch

Harry O. Rakfeldt

We make our own electricity with a MicroHydro power system. When we were looking for our acreage, our list of requirements contained self-sufficiency. Surface water was a prime ingredient on our list. And we found it. The project to design and install our MicroHydro power system spanned four years. Our goal: to live in a "normal" electrical way, without any commercial power.

Setting the Scene

Our homesite, at 4,300 feet elevation, is located on a corner of a half mile wide, 80 acre, steep mountain property. We are located about 1 mile from commercial electricity. One of the two year round creeks (really a stream) enters our property at the NE corner from the BLM (Bureau of Land Management) land behind us and flows SSW across our land for about 1800 feet. From top to bottom there is a total head of 300 feet. The creek's average seasonal flow varies between about 34 to 50 gallons per minute. But during heavy rains and snow melt, flow will go well above 100 gallons per minute. For practical hydro purposes, it is LOW flow, HIGH head.

Our Considerations

• We like our creature comforts. We wanted our new home to be in all appearances the same as Dick & Jane's in the city.

• Because our maximum output would be low this meant a mixture of electric and propane appliances to reduce electrical needs.

• Our stream flow is heavier in the winter when needed the most.

• To produce a respectable output, the turbine would have to be located at some distance from the homesite. Thus, line loss from transmission of low voltage would be a factor.

• Output from the turbine would not meet PEAK CONSUMPTION (maximum amount of electrical energy needed at any one time). To meet peak consumption, a battery bank and inverter would be required.

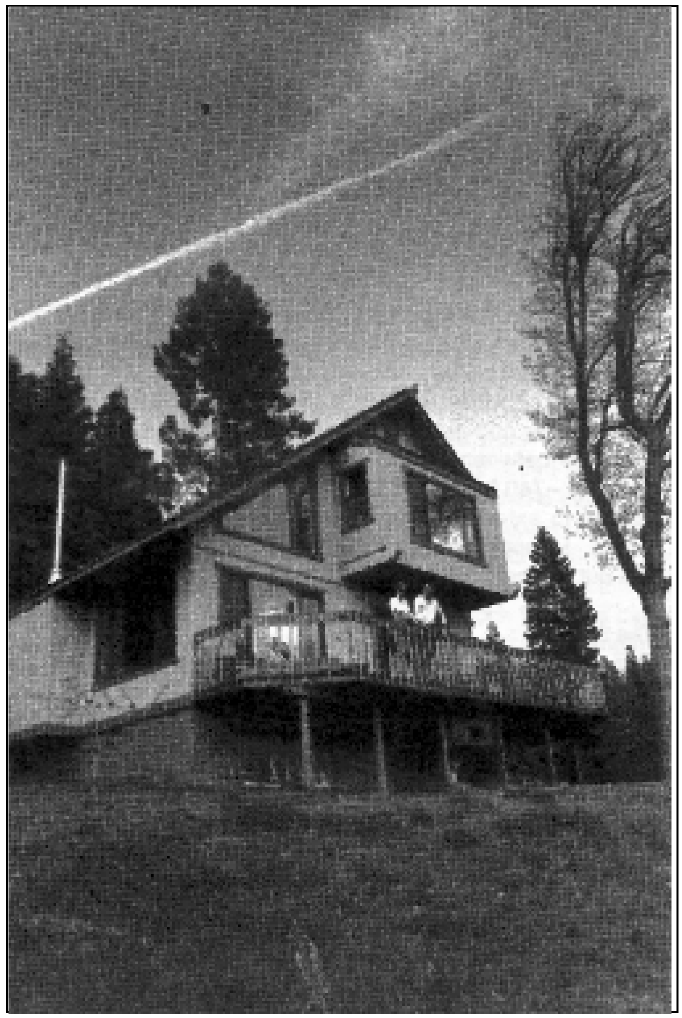
• The system should meet our need for TOTAL CONSUMPTION (the number of kiloWatt-hours (KWH) used in a given period of time, most commonly KWH per month).

• And money... How much would a system cost? What compromises did we have to make? There wasn't going to be any money for a second shot if the first try didn't score -- we were going to build a home at the same time. And THIS made me nervous.

• To make a major decision such as this about which I only had "book" exposure put me on the spot with my wife and the few others who knew what was being attempted. With respect to this hydro thing, I felt something like a paraphrased Truman quote, "The flow stops here."

Research and Design

During the four years until our house was built, I had a number of opportunities to observe the creek. Flow was measured a number of times. On this small creek, measuring was simple -- build a small dam and time the overflow into a 5 gallon bucket.



Harry & Marlene on the deck at Journey's End Forest Ranch

I measured potential head to three different turbine sites on the creek, three times each with two different sighting levels. Starting at the lowest point considered as a potential turbine site, I worked up to the proposed intake site, recording along the way the number of times I sighted through the level and then climbed to that point to sight again. The total figure was multiplied by the 5 foot-6 inch distance from the ground to my eye level to arrive at the total head. Using this method, the final spot decided on for the turbine measured out at 103.5 feet of head. And the site selected offered a fairly straight line for the majority of the penstock's length from intake to turbine and generally followed the creek's SSW direction.

In reading material related to hydro, I came across a number of potential suppliers of hydro equipment and systems. I made contact with one of these firms because the system seemed reasonable in price, was small but looked well made and offered site-selected options. I discussed with Ross Burkhardt of Burkhardt Turbines the variables -- flow and head. Ross and his partner John Takes did much to help me select a system. Ross has a computer program which predicts outputs on the systems he sold. We plugged in my variables and came up with a set of predictions for a 12 Volt system. Then as we fine tuned the variables (different flows and different heads), the 24 Volt system evolved.

What followed at a rapid pace were decisions on an inverter (to match the 24 Volt output), batteries, transmission cable and other related supplies. The size of the penstock -- 3" PVC pipe -- had already been a factor in the discussions with Ross and used in his computer predictions. This size presented a comprise between head loss due to friction over such a long distance --740 feet-- and a nominal size for later expansion if I wanted to extend the penstock further downhill for increased output. I planned for and incorporated this option into the way I laid out the penstock.

The System

Our hydro power system consists of an impulse-driven alternator that produces direct current (DC) to maintain a battery bank. 24 Volts DC is changed by an inverter to 117 volt alternating current (ac) that is passed into the home's electrical circuits through the distribution panel.

For the powerplant, a Harris Turbine system was bought from Burkhardt Turbines. It is a vertical axis, 24 Volt DC Pelton wheel generating setup. A 37 AMP Delco alternator modified for 24 volt output is mounted on an aluminum housing and is direct-coupled through the housing to a silicon bronze Pelton wheel. My setup has two jets (one to four jets can be ordered, depending on your water flow -- a site designed option). These jets hold Rainbird® nozzles which are available in a number of different-sized openings. My system also included a PHOTRON voltage regulator, a 500 watt 24 volt water heating element, a rheostat control to adjust power output at the turbine, a heat sink mounted diode (to control voltage flow direction), a panel with dual meters - VOLTS and AMPS, an extra alternator and detailed instructions.

The battery bank is made up of eight Trojan J-250, 6 Volt, 250 AMP hour units. These batteries are true deep cycle -- listed by Trojan as, "Motive Power-Deep Cycle." The batteries are wired in a series of four to develop 24 Volts and then paralleled to double their Ampere-hour capacity for a total of 500 AMP hours storage.

A model HF24-2500SXW inverter from Heart Interface changes the 24 Volt DC from the batteries to 117 volt ac for use in the home. This inverter is wired directly into the home's electrical panel. The inverter was selected for its high surge capacity -- needed for our induction motors: water pump, refrigerator and washer -- and a built-in 40 AMP battery charger. When connected to an ac generator, the inverter operates as an automatic battery charger while transferring all the loads to the incoming ac power. We keep a 4,000 watt ac gas generator on standby, and we have to use it once in a while.

Getting It Together

The hardest part of putting the system together was the penstock. Not that it was technically difficult, but labor and time intensive. It starts above ground from the intake barrel alongside the the creek. About 40 feet later it enters the ground, a very rocky area that proved somewhat slow and difficult to dig with the backhoe. Shortly after this point, it takes a 45° turn to the right (through an elbow) and continues for some distance underground before exiting to cross above a spring's streambed. On the other side of the streambed, it goes deep underground, up to 6 feet at one location, to maintain grade and follows a straight course for several hundred feet. Then it takes a rapid drop down a 30% grade before relaxing its descent. About 60 feet later it makes a 90° turn to the left through two 45° elbows spaced four feet apart to reduce the sharp transition. The 90° turning point here is intentional. It allows the option to continue the penstock downhill at a later date, giving more head for increased power at a new turbine site. The 90° turn would be eliminated to allow the penstock to continue in a straight line to the new site.

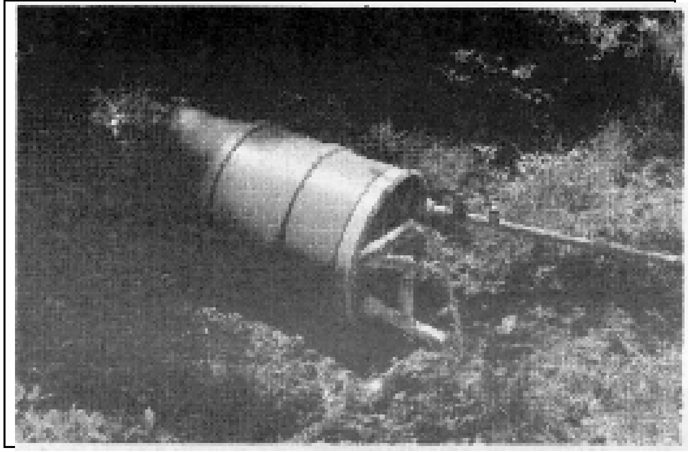
After this turn, the penstock exits the ground again and plunges down an embankment 40 feet toward the creek. At the bottom of the embankment, there's another 45° elbow to level out the penstock before it enters the powerhouse.

Digging the trench took a day and a half in itself. Then the PVC pipe was placed above the trench on crossboards and carefully cemented together and left to dry for a full day before it was gently lowered into the trench and covered.

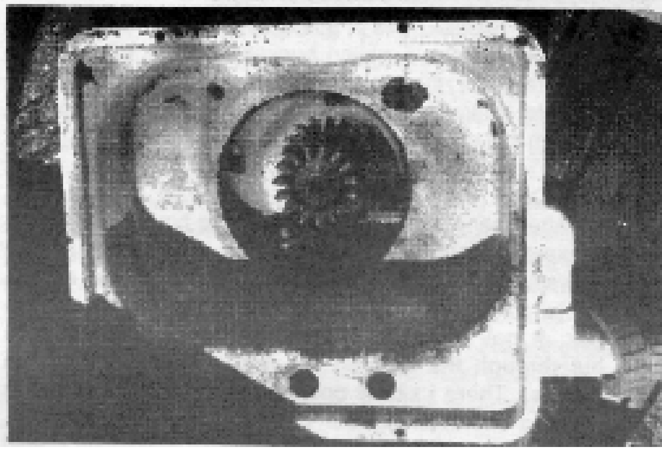
At the intake end of the penstock is a 55 gallon polyethylene drum. It is connected to the small dam via 4" drain pipe. This barrel is used as the intake because it:
- Filters the debris not trapped behind the dam
- Prevents turbulent water from entering the penstock
- Allows the sediment to settle out
- Can be located as needed with respect to the dam and penstock
- Is easy to work with
- Will last for a very long time

When I put the connections together, I arranged the air vent and gate valve assembly so that it could be removed from the barrel and penstock easily. At the barrel the PVC pipe is threaded into the barrel and a collar is threaded onto the coupling inside the barrel. The short section of pipe on front of the air vent is only slip-fitted into the penstock. Because I only have a low flow stream to work with, building a small dam was straightforward. The end of the drain pipe that extends into the dammed water is also protected with a trash collector made of screening. At the other end of the penstock is the simple powerhouse.

The powerhouse sits directly over the streambed on railroad ties. There is easy access to the turbine components via a removable roof. It's here I really got a chance to be creative -- I even used a kitchen sink! It makes a great base to mount the



A barrel on the penstock keeps the system free of silt and dirt.

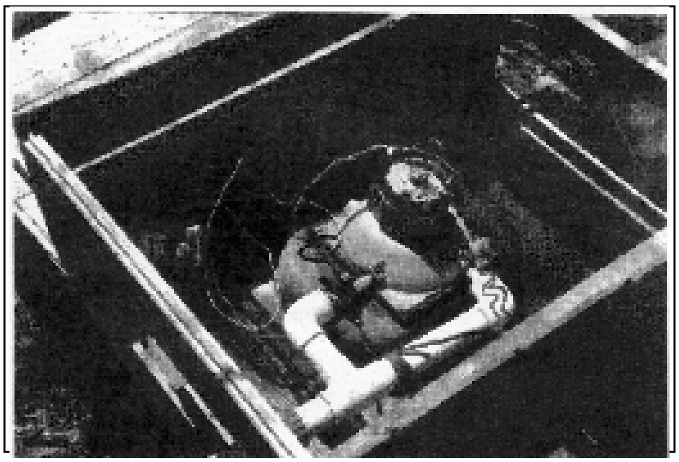


The underside of the turbine & sink showing the turbine's cups

trubine, permitting much easier access to the Pelton wheel and pipe connections.

Laying the transmission cable wasn't difficult but required some "engineering." The terrain from the homesite to the powerhouse falls steeply downhill. The cable was buried from the house to within 45 feet of the powerhouse in a channel dug with the backhoe. The aluminum cable I chose for the transmission line between the powerhouse and homesite is very large -- 4/0 (1/2" diameter plus insulation). It came on a 1,000 foot spool and was heavy.

I placed a long pipe through the cable spool and lifted this combination onto the back of my pickup truck with the backhoe. The pipe rested on the top of the pickup bed sides and was prevented from rolling off. The truck was parked alongside the house, facing uphill. I then grabbed the end of the cable and walked it downhill, unrolling the cable easily from the elevated spool. When I retraced my steps from the powerhouse back to the homesite, I sprayed this section of the cable every 10-15 feet with red spray paint to denote this leg



The Harris turbine at home in the kitchen sink.
Note the loading control for the alternator on the left,
and the valve to shut off the water to the second jet.

as the POSITIVE side of the line. At the truck I cut the cable and then unrolled the second leg of the pair. The length of each leg is 451 feet.

The final step was to install the components at the homesite. We had planned for the equipment by having our building pad cut into a "stepped" pad with a bulldozer. This resulted in a generous 54" crawlspace across the front half of the home where the inverter, control panel and batteries are kept.

Because of the good instructions, the components went in "by the numbers." One of the items connected was the 500 watt water heating element. It serves to use the "excess" output from the turbine. "Excess" is the electricity not needed when the battery bank is fully charged. The voltage regulator senses the state of charge on the batteries and when the batteries are full, it diverts the continuously incoming power from the turbine to a "dump." In this case, the dump is a water heating element immersed in a 5 gallon bucket filled with water. An air heating element could be substituted for the water heating element.

I didn't think I would have a great deal of excess power to dump, so I chose the 5 gallon bucket initially. While I was getting a "feel" for the way the system performed, I could always go to a larger container of water to hold the heating element. I'm still using the 5 gallon bucket.

It's A Turn On

Finally. After many hours of research, long hours of planning and double and triple-checked installation, the day came to try out the system. The gate valve at the powerhouse was closed. At the intake site, I opened the gate valve to let water into the penstock. It took some minutes to fill and let air inside work its way out through the opened air vent. Then back to the powerhouse. There I slowly opened the gate valve and after some hissing and belching, the water began to flow steadily. As I continued opening the valve the turbine picked up speed and then suddenly dropped off slightly -- but at the same instant the AMP meter began to climb! I continued to open the gate valve and brought the system up to full output. It's working, it's working!

And for me it was a special thrill to know I had just crossed into the world of renewable energy -- from and because of my resources!

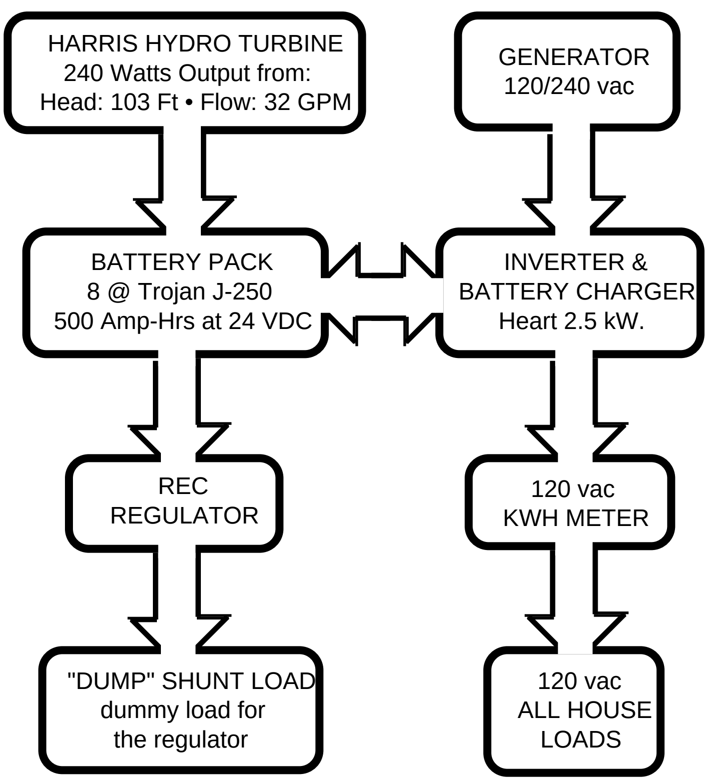
That was early October 1985. Except for a period in November 1986, when I purposely shut down the system to have a modification made to our inverter by Heart Interface, our micro-hydro power system has been running continuously.

Our "Normal" Home

It's a modified saltbox design that originally appeared as a cabin style post and beam plan in HOME magazine. It's now a passive home with 1,435 square feet, six inch walls, required insulation, two baths, two bedrooms, woodstove heat, and nine feet high thermal mass (brick) in the woodstove alcove.

Propane is used for the range/oven, hot water heater and clothes dryer. 117 volts single phase electricity is used for: an 18 cubic foot, self-defrosting refrigerator (4.3 amps); 1/3 HP jet pump on the water pressure system (8.3 amps); clothes washer (9.6 amps); 500 watt ignitor on the dryer; ignitors on the range/oven; and electric motor to turn the dryer. We also have or use: AM/FM stereo, AM/FM portable radio, 19" color TV, VCR, typewriter, desktop calculator, 1200 watt hair dryer, small TI computer, vacuum cleaner (3.2 amps), electric broom, Dremel hand tool, electric stapler, 500 watt slide projector, electronic flash unit, small B&W TV (Tube type), electric mixer, 4 cup coffee maker, 30 cup coffee pot, electric griddle, blender, waffle iron, hand iron, electric knife, 3/8" electric drill, tape deck, skilsaw (10 amps), ceiling fan, electric clock, battery charger (portable), range hood, soldering gun, our special radio phone, electric meter and lights.

For lights we have fixtures in the dining room (300 watts), downstairs bath (240 watts) and a 480 watt guzzler in the master bath. Our light inventory is rounded out with: two 2-tube, 4 foot fluorescents, one 2-tube, 2 foot fluorescents, a PL-Type (small twin tube) fluorescent (9 watts + ballast) and various single lamp, varied wattage incandescents.



Block Diagram of the MicroHydro System

The Need to Estimate

When I was researching a system design, I kept coming across the statement that in order to develop a properly-sized system, I had to "estimate" my projected usage. Now, for those of us who are coming from a "just-throw-the-switch" type of public power environment, to estimate our usage is difficult, at best. Just how much does a refrigerator run in a 24 hour period? How long do I use lights while shaving on a winter's morn? How long... And the list goes on and on.

But now I can give you some real help...because I kept track of ACTUAL electrical usage and PATTERNS of usage with a commercial KWH power meter wired to the home's mains panel. But before we look at what has been used, let's look at what I had to work with. Total head is 103.5 feet and dynamic water pressure at the powerhouse is 46 PSI.

In the summer, I use one 3/8" diameter nozzle in the turbine. This nozzle runs about 32 gallons of water through the turbine per minute. This results in 9 Amperes at 24 VDC, or 216 watts turbine output. This amounts to about 5.1 KWH of electricity produced daily. In the winter, increased stream flow allows me to use two nozzles 5/16" in diameter. These nozzles run about 45 GPM of water through the turbine. This ups the turbine's output to 12 Amperes at 24 VDC or about 6.9 KWH daily.

In the 916 days, that the system has been running, we have consumed an average of 4.32 KWH per day as measured by the KWH meter. The system produces a daily average of about 5.0 KWH of usable electricity once inefficiencies in the batteries, inverter, power transmission and other factors are considered. The main thing to be noted from the comparison of output to usage is that there isn't a whole lot of leeway. There isn't much "excess" electricity to worry about.

The interior of the homestead, looking South into the Siskiyous

Even though our turbine output in the summer is lower, so is our average daily consumption. We're not using lights as much, may not be watching TV or using the VCR as often and clothes can now be hung on the line to dry rather than tumbled in the dryer. These all help to cut a little off our usage.

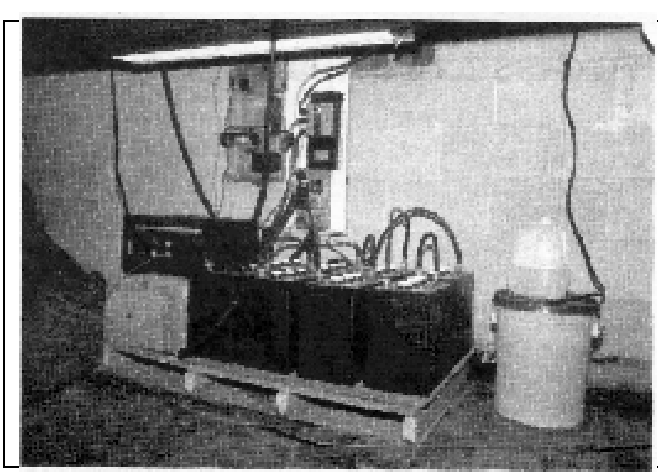
In the winter time, or any time for that matter, we have formed the habit of not leaving lights on indiscriminately. When we leave a room, off go the lights. But we don't walk around in a blackout either. We just watch our consumption through closer attention to usage. And we improved over the first months after moving into the house. And now I think we have ourselves trained.

An area that we MUST watch is how much load we put on the inverter at one time. When you compute the watts used by the washer, water pump and refrigerator (117 volts x AMPS = watts), the total EXCEEDS the rated output of the inverter: inverter = 2500 watts; combined usage of item = 2597 watts. When using the washer and water pump, we could turn off the refrigerator. But we don't have to. The inverter surge capacity, so far, covers us when all three of the items happen to be on at the same time. So we do our washing during the day time when lights aren't needed. And we only use the dryer after the washing is done. The surge capacity of our inverter permits it to operate for a period of time even though the normally-rated load has been exceeded. The LENGTH of time that the inverter will continue to operate is directly related to the AMOUNT the load exceeds rating. This may be minutes to only several seconds. The surge capacity for us was a must -- and well worth the few extra dollars.

Standby Power

Yes, we've had to use our gas generator backup. Especially when we have guests who aren't "trained" like we are. Lights left on in the bathrooms; hair dryers going much more often; more flushing of the toilets (our captive air tank has a 36 gallon capacity but reaches its automatic turn-on when 11 gallons have been used) -- just plain more use in a short time frame. Fortunately, our guest stays have not been too long -- but they are noticed with respect to the system.

When our system reaches its low point of 21.9 volts in the batteries, it self-shuts down to prevent damage to the batteries. Even a few minutes wait will sometimes bring the batteries back to a safe limit and the inverter can be reset without resorting to the ac generator. But if the load on the system at the time it shut down is high, I usually choose to start the ac gen and run it for a while to boost the batteries enough to meet the need. As our desire to use more power increases, our next move will be to increase our microHydro's output. The efficiency of my system -- as it operates today -- ranges from 30% to 38%. Not very good. BUT I knew this in advance because the Delco alternator doesn't reach its efficiency in the 24 volt output until it is used at a much higher head. Because of my low stream flow, I have only one way to go -- increase head for more output.



The batteries, inverter, regulator and dummy load are all housed in the crawl space under the house.

I planned for a future increase in head with the manner in which the penstock was installed. I've replaced the first voltage regulator with one much more powerful. The PHOTRON regulator that came with the system had only a 15 AMP capacity. The new regulator has a 40 AMP capacity and the float voltage level can be user adjusted. This new regulator is made by Renewable Energy Controls, owned by Ross Burkhardt. Ross sold out his interest in Burkhardt Turbines to his former partner, John Takes.

What it all Cost

The total cost of the system has been $5,421.37 to date. The expenditures are detailed in the pie chart below. The MicroHydro has been operational for 916 days and during that period has generated 4,671 KWH of electricity. At this point in time, this calculates to an electricity cost of $1.16 per kiloWatt-hour. Over the ten year expected lifetime of this system, the electricity should cost about $0.29 per KWH.

Now, consider that the local commercial utility (PP&L) wanted $5.35 per foot to install 1 mile of line to our homesite. This amounts to over $28,000. for the privilege of paying a monthly power bill. The money we've spent on our MicroHydro system is less than 20% of what the power company wanted just to hook us up!

Some Comments on Components

PVC PIPE - Easiest to use for the penstock. It has a very low head loss due to friction. Take time to cement the sections together -- and to let the cement dry properly. Originally, I tried a 90° PVC CURVED elbow used in electrical conduit. It didn't mate properly and "blew" off quite easily when the system was turned on. Had to shut down for a day to repair with the two 45° elbows.

BATTERIES - The J-250's I'm using don't allow too much storage capacity in my situation. The next sized battery, the L-16, has 40% MORE storage capacity. As I expand my system, and it becomes time for me to replace my present battery bank, I plan to upgrade to the Trojan L-16W.

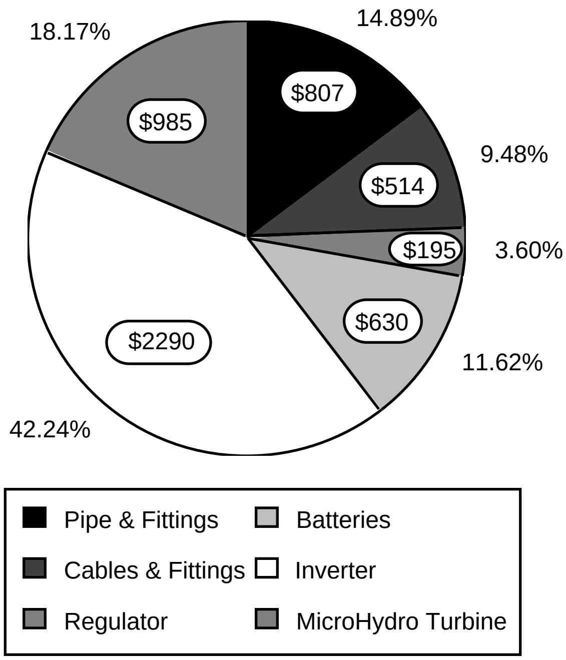
INVERTER - For those who haven't used one before, there is some adjustment necessary. For the most part, forget using the AM portion of your AC-powered radio. The hum from the lines overshadows all but the strongest stations. Stereo and video equipment may also hum depending on make and type.

BATTERY CABLES - Have all connections SOLDERED. My cables came unsoldered. For a while they worked fine. Then deep into the first winter I begin noticing lights blinking especially when a large appliance was on. The blinking disappeared after the cables were soldered.

VOLTAGE REGULATOR - This is an essential piece of equipment in a MicroHydro system. It will sense the correct voltage level needed to properly bring your batteries up to charge and then maintain them there. Without a regulator you'd have to personally monitor the system and then either shut off the turbine when the batteries are full, or flip a switch to shunt off the excess electrical output not needed for the fully

charged batteries.
FAITH - Place faith in a reputable dealer. He has feedback from all sorts of installations. He continues to stay in business by knowing what is happening.

Closing Thoughts
FIRST We feel like a "normal" household. Nothing has drastically changed in the way we live.
SECOND Although the list of electrical items mentioned earlier sounds impressive, we don't use many of these at any given time or the larger ones for any length of time.



THIRD For the two of us, we have what we need. We can curl up in front of the VCR for a double feature, fill our 80 gallon bathtub (meaning, that every 11 gallons the water pump comes on) and other things without the system shutting down. We are careful but not fanatical about our usage.
FOURTH We made some adjustments that are now habits.
FIFTH It's not perfect. The system does work well. And so can yours. Do research, consult with distributors and have faith that you can do it TOO!

EDITOR'S NOTE: When we visited Harry Rakfeldt to take the photos you see here, he had just finished moving his powerhouse some 50 feet lower than described in his article. While this change is too new to give much data yet, turbine performance has increased. The dynamic pressure at the powerhouse is now 76 PSI. The turbine's output has increased some 50% with no increase in water consumption. Harry is now considering a big time electric hot water heater to use his additional energy.

Those wishing to communicate with Harry and Marlene Rakfeldt can write them at 1211 Colestin Rd., Ashland, OR 97520-9732.

Access to Equipment Sources

HEART INTERFACE
811 1st Ave South
Kent, WA 98032
206-859-0640
INVERTERS

DON HARRIS
632 Swanton Road
Davenport, CA 95017
Maker of Harris Turbines

BURKHARDT TURBINES
1372 A South State St
Ukiah, CA 95482
707-468-5305
Supplier of Harris Turbines (packaged systems)
RENEWABLE ENERGY CONTROLS
POB 1436
Ukiah, CA 95482
707-462-3734
Voltage Regulators

TROJAN BATTERY COMPANY
12380 Clark St
Santa Fe Springs, CA 90670
800-423-6569 (outside CA) • 213-946-8381 (CA)

PHOTRON, INC.
149 N Main St
Willits, CA 95490
707-459-3211
Voltage Regulator

UNITED STATES PLASTIC CORP.
1390 Nuebrecht Rd
Lima, OH 45801
419-228-2242 (info)
Polyethylene drums (15-55 gal) Comply with FDA regulations for potable water and food storage (pg 110 of 1987 catalog)
and
CONSOLIDATED PLASTICS CO. INC.
1864 Enterprise Pkwy
Twinsburg, OH 44087
Page 18 of 1987 catalog
Both catalogs may be of value to anyone in need of a variety of plastic containers and connectors/hoses.

ELECTRON CONNECTION LTD
POB 442
Medford, OR 97501
916-475-3179
"The Complete Battery Book", a compilation of information about batteries and their upkeep. This firm also designs, sells and installs complete home power systems.

HOMESTEAD ELECTRIC
POB 451
Northport, WA 99157
509-732-6142
Dave Johnson owner/consultant
Hydro and solarpower systems, inverters, radiotelephones