

Above: Abe Lewisburger cleans out the trash racks of prototype "Portable" low head hydroelectric plant. Turbine Specs: 22 inches of head drives a 24 inch diameter C.M.C -Fitz vertical axis francis turbine developing 3 Amperes at 130 Volts DC or 9,360 Watt hours per day. This turbine discharges 520 cubic feet of water per minute at 70 RPM. Photo by Cameron MacLeod.

## Ultra-Low Head Hydro

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**O**ne hundred years ago low-head hydro wasn't just an alternative; it was the best alternative. Unlike high-head sites, low-head sites are everywhere, and often closer to population centers where the power is needed. Power sources were valuable and sought after, because cheap power wasn't delivered through silent wires down every street. Local wars were fought over water rights.

### The History of Low Head Hydro

Times have changed, but the weight of water and gravity remain the same. Once we had over two hundred makers of small water turbines in the U.S.A. Some of them built, by 1875, equipment that was 80% efficient. They built and inventoried turbines as small as four inches in diameter that made one horsepower on ten feet of head. Turbines that ran on two feet of head and made from one to fifteen

horsepower were common. Some were excellent machines that ran with little maintenance for years. The know-how and hardware were everywhere. In the eastern part of America, the power of the small streams near populated areas was developed and put to work. All the way from the hills to the sea, this water was used over and over again wherever topography supplied enough head. One large stream in the east had dams and still has

pre-revolutionary deeded water rights wherever early settlers found three feet of head.

When ships landed on the east coast, surveyors and mapmakers headed inland to discover natural resources. All the old maps denoted power sites as "Mill Seats" long before settlers arrived. This was before the successful use of stationary steam engines, so we know that they were referring to hydro power. Later, towns grew because of this power. Virtually every sort of agricultural and industrial work was once aided by the water. It is sad that the water source of power is often blamed today for the mess that industry left behind. In this age of environmental awareness, we should not throw out the turbine with the wash water.

Back when power was valuable, men moved hundreds of tons of earth and rocks with just their backs, mules or oxen. Often they made this investment & did this work with their bodies for the sake of one or two horsepower. Wow! Think about it. Something was going on there. If you think they were nuts, then look at the size of the manor houses and mills that were energized with those one or two horsepower. Then think about what clean renewable power in your backyard is really worth to you - and your children - and your grandchildren - and on and on - forever.

Of course power has gotten cheaper and cheaper in the last hundred years. By burning non-renewable fossil fuels at the expense of the earth and our futures, they practically give it away. I can hear you now - what's this jerk talking about. The only ones that really know the value of power are the people who have tried to make power for themselves. If your goal is to supply your daily energy needs; you either know how cheap commercial power is or you're going to find out. My position is not to discourage you, just to warn you. Pursue your dream. If you can't visualize it it will never happen.

Over the past ten years, I've helped to develop twenty or so small hydro sites. I've gone on to bigger megawatt hydros now, because I need to make a living. The small sites range in power from 300 Watts to 100 kW. Almost all of this work has been under fifteen feet of head. The power has

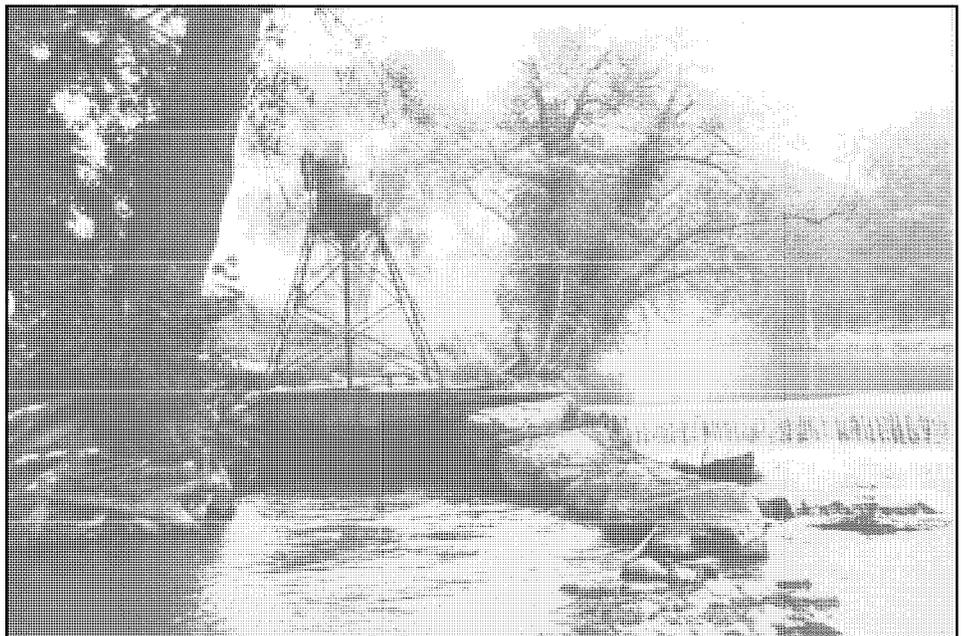
been utilized to run homes and small businesses or more commonly, large farms. All the projects were former sites with dams in one state of repair or other. The legal aspects of these undertakings have been handled by the owners and often represent the greatest problem.

### Hydros and Red Tape

If your home power system isn't on federal land, doesn't hook to the grid, and doesn't make power from a navigable stream; then you may not need a federal license. There is no legal way to avoid dealing with a state agency. Watch out - often this destroys dreams. You had better base your work on an existing dam or a pile of rocks no more than 36 inches high called a diversion wier. Remember not a dam, but a wier. That diversion had better not be long in either case if you hope to stay within environmental laws. In all cases you had better own both sides of the stream. These problems will vary from state to state. You must learn through research. Have enough sense to keep your own council (keep your mouth shut about plans) until you figure out which way the water flows.

### Low-Head Hydroelectric Turbines

My goal here is to let home power people know that under just the right circumstances low head hydro is possible. Practical - that's your judgement. It will depend a lot on what you consider to be valuable. That is to say, your values. How much your alternatives cost matters too.



Above: a 30 inch Trump turbine operating at 36 inches of head. This turbine produces 35 Amps at 130 Volts DC or 4,550 Watts of power. It has been in operation since 1981. Photo by Cameron McLeod.

Despite all this red tape nonsense many people have successfully established low-head hydro systems. I'll detail a couple of sites to whet your imagination. First, you should understand that very little has been written about low-head hydro in the last fifty years. By 1915, development had shifted from small diverse sources of power to large centralized systems based on alternating current and high voltage distribution. Giant government-backed utilities were beginning to carve up the country into dependent territories. Starting with the cities and industrial areas they stretched their wires out into the country. By the 1930s, rural electrification was well under way. Many utilities forced their customers to take down their wind machines and remove their turbines before they could hook up. Big customers were bribed with no cost changeovers from D.C. to A.C.. Along with the gradual loss of public self-reliance, the end result for the hydro power machinery business was that the market for small turbines disappeared. So did the manufacturers. Several companies made the transition to giant utility grade equipment into the 1950's. Now they are gone too. None of the biggies are U.S. owned.

There are a few crazies like myself who still build small machines. Most backyard operations concentrate on pelton and crossflow turbine which are only suitable for high head (depending on power requirements). I build Francis and Propeller type turbines. They are expensive, hand-built machines that don't benefit from mass production. They will, however, last a lifetime with only bearing changes. This is a tall order because everything must be constructed just right. I approve all site designs before I'll even deliver a turbine. I personally design most systems.

Often a better way to go involves rehabilitating old equipment. Some hydros were junk the day they were built. Other makers really knew their stuff. Their quality and efficiency are tough to match even today. These machines are usually buried under mills or in the banks of streams. Go look, you'll find dozens. The trick is to know which one you want, so do your homework before buying an old turbine.

### **A Low-Head Hydro System**

One site that depends on a rehabilitated machine belongs to a farmer named George Washington Zook. George decided not to use commercial power in 1981. He had deeded water rights and the ruin of a dam on his property. Best of all he had lots of water, and incredible determination, common sense, and know-how. He only has thirty-six inches of head. I supplied him with a thirty

inch diameter vertical axis Francis type turbine. This turbine was built by Trump Manufacturing Co. in Springfield, Ohio around 1910. One of the good ones. George was 25 years old when he finished the project.

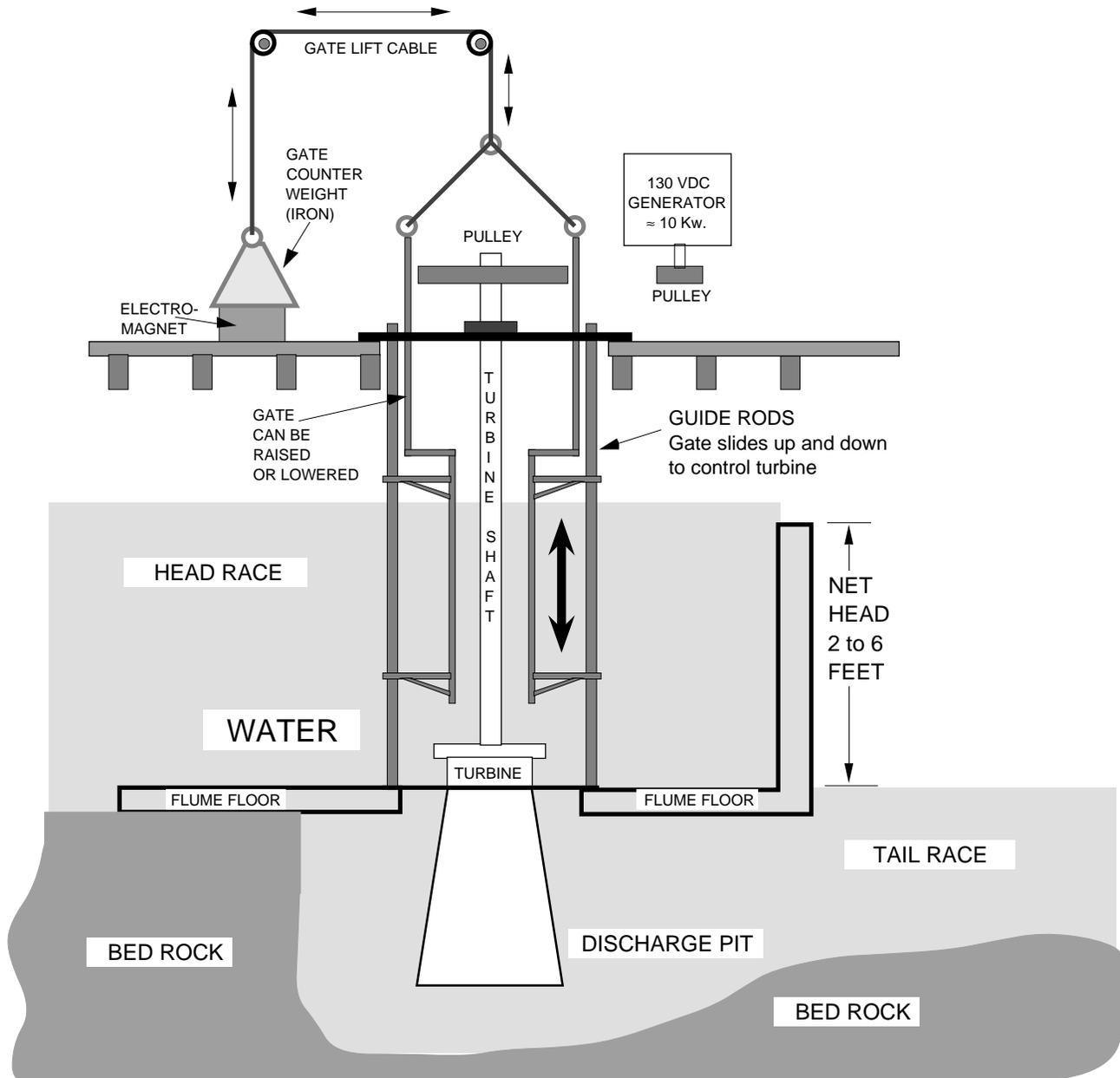
George got all the required permits and built a sixty foot long, 36 inch high, log dam with a wooden open flume for the turbine at one end. He installed the turbine with a generator mounted on a tower to keep it dry in high water (never underestimate high water). Four months later his dam washed out. One year later he re-built and started generating 130 Volt D.C. power. Yes, high voltage D.C.. His machine develops 35 Amps @ 130 Volts or 840 Ah/day or 109.2 kWh/day. Discharge is 2358 c.f.m. (lots of water) @ 96 r.p.m.. He has a 90 series cell, 240 Amp-hr. nicad battery pack. This represents an incredible amount of power for any home power system. That is 32,760 kWh a month. Hey, that's enough power to run three to five average American homes. All of this on 36 inches of head. Yeah, that's right, and his battery pack lets him meet 20 kW peaks. Here is what his load looks like : three freezers( two for the neighbors),a refrigerator, refrigeration to keep the milk from twenty cows cold, a vacuum system to milk these cows, two hot water heaters, all lighting in home, barn and two shops, occasional silage chopper use, wringer washer, water pump, iron and farm workshop machines. I'm afraid it still goes on, his nephews put in a complete commercial cabinet shop two years ago. They have all the associated equipment including a 24-inch planer. Well, now what do you think about low-head hydro?

There are a few key differences between George's system and most you read about. There isn't an inverter on the property. At 120 volts D.C., line losses are at a minimum (We have some 220 volt three wire systems operating). All of the equipment and machinery on the farm was converted to 120 volt D.C. motors, including refrigeration. The high efficiency of this approach makes all the difference.

### **AC versus DC Hydros**

Stand alone A.C. is a possibility, but it requires a larger turbine and more year round water to meet peak loads. The cost of an electronic load governor and the inefficiency of single phase induction motors are two of the drawbacks to consider. Backup generator cost is also a factor. You'll need a big one to meet A.C. peak loads. With batteries to meet peak a small generator will suffice.

Remember, if you can meet 20 kW. peak loads with batteries it only takes one horsepower 24 hours a day to run the average American home. This is a tiny turbine that



uses little water when compared to the 40 horsepower turbine on the same head that would be needed to meet the same peaks on conventional A.C.. Forget it - there is no comparison. The big machine would cost a fortune and require massive amounts of water. Hey, it is possible, I've built them.

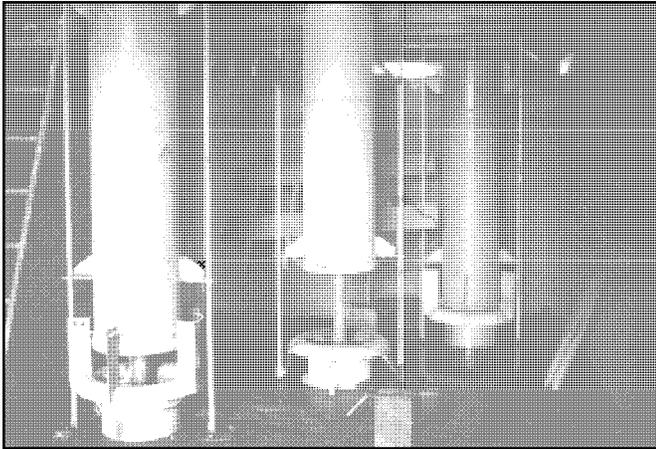
The best of both worlds would have the lighting and heavy motor loads on 120 Volt D.C. for efficiency. It would have a switching power supply running on 120 Volts D.C. putting out high-current 12 or 24 Volts D.C. to run an inverter for specialized A.C. loads like TVs and stereo systems.

**Some Low-Head Hydro System Specs**

Here are the pertinent details on some-stand alone D.C. low-head hydro sites that I've been involved with:

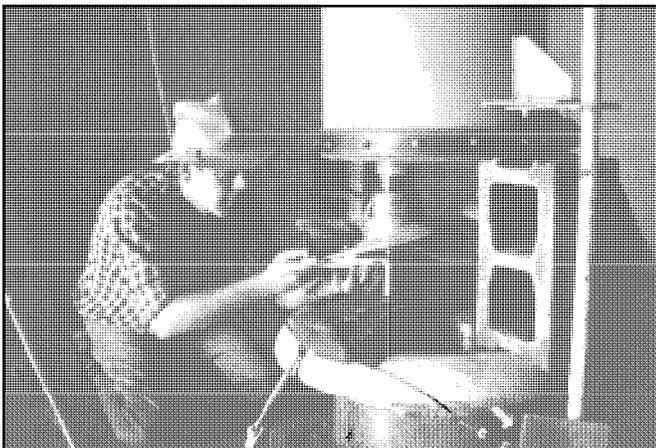
**System 1**

5 feet of head - 8 inch MacLeod-built C.M.C. vertical Francis-type turbine develops 3 Amps @ 130 Volts or 72 Ah/day or 9.36 kWh/day. Discharge is 72 cubic feet of water per minute @ 335 r.p.m.. Note: The term vertical implies a vertical main and gate shaft which extends above flood level to protect generator and electrics.



Above: three Conastoga propeller turbines that operate on 7 feet of head. Each turbine produces 5,000 Watts at 470 RPM. This photo shows the head race which is filled with water when operating. Note the Gates and Gate Rods.

Photo by Cameron McLeod.



Above: Cameron McLeod inspects the propeller on one of the Conastoga turbines.

### System 2

22 inches of head - 24 inch C.M.C -Fitz vertical francis develops 3 Amps @130 Volts or 72 Ah/day or 9.36 kWh/day. Discharge is 520 c.f.m. @ 70 r.p.m..

### System 3

Three feet of head - 30 inch Trump Vertical francis turbine develops 35 Amps @ 130 Volts or 840 Ah/day or 109.2 kWh/day. Discharge is 2358 c.f.m. @ 96 r.p.m..

### System 4

Fifteen feet of head - 8 inch MacLeod built C.M.C. vertical Francis turbine develops 12 Amps @130 Volts or 288 Ah/day or 37.4 kWh/day. Discharge is 130 c.f.m. @ 580 r.p.m..

### System 5

Four feet of head - 27 inch S. Morgan Smith vertical Francis turbine develops 28 Amps @ 250 Volts or 672 Ah/day or 168 kWh/day. Discharge is 2190 c.f.m. @123 r.p.m..

### System 6

Ten feet of head - 12 inch C.M.C. vertical Francis turbine develops 15 Amps @130 Volts or 360 Ah/day or 46.8 kWh/day. Discharge is 244 c.f.m. @ 320 r.p.m..

### Low-Head Hydro Information

Getting info on low-head hydro isn't easy. Virtually nothing of any technical merit has been published since 1940. Watch out for crazies and experts who try to re-invent the wheel. It is un-necessary and wrong-minded. It has all been done and done well. Go find the data. Rodney Hunt Manufacturing published some of the best information between 1920 and 1950. They also built great machines. They no longer build turbines. Their books are out of print. Find them in engineering school libraries or museums that specialize in early industrial technology. Turbine makers catalogs from 1880 to 1920 were in fact engineering manuals, some better than others. Look for them. I haunt the old book stores. Go for it.

### Books to look for :

Power Development Of Small Streams, Carl C. Harris & Samuel O. Rice, Published 1920 by Rodney Hunt Machine Co., Orange Mass.

Rodney Hunt Water Wheel Cat. #44 - THE BEST. Check out the Engineering section.

Any catalogs printed by : James Leffel Co., S. Morgan Smith Co. , Fitz Water Wheel Co., Holyoke Machine Co., Dayton Globe Manufacturing Co..

Construction of Mill Dams, 1881, James Leffel and Co. Springfield, Ohio. Reprint; 1972, Noyes Press, Park Ridge N.J.,07656.

### Some words of encouragement...

Well people, I hope I've opened the door to stand-alone, low-head hydro for a few of you. If you really want the details you've got some long hours of research ahead of you. If you are determined to get on line, I wish you the best. Watch out, it is harder than building a house from scratch. It can be a real relationship buster. I believe it has as much merit as any effort at self-reliance one can undertake. Good Luck!

### Access

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