# HARRIS

# HYDROELECTRIC

# SYSTEMS

12 VOLT

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**HARRIS HYDROELECTRIC**
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## HOW TO DETERMINE SYSTEM OUTPUT

System output is determined by a variety of factors:

1. Head, or drop in elevation from source of water to turbine nozzle.
2. Flow, or number of gallons per minute passing through nozzle.
3. Diameter, length, and condition of feeder pipe.
4. Turbine efficiency.

A precise output figure is difficult to determine. Silt may accumulate in dips in the pipe and reduce output significantly. Leaks, clogging at mouth, or excessive bending of pipe may do the same. Generally, single nozzle systems with under 2000 feet of feeder pipe require a 2" pipe; 2 nozzle systems need a 3" pipe; and 4 nozzle systems a 4" pipe. Longer pipes must be larger, and shorter ones may be somewhat smaller. Output and efficiency are always improved by increasing pipe diameter. Very high head systems (over 300 feet) can use pipe down to 1" diameter, but flow is greatly reduced and friction losses are high

## PROCEDURE

The following system may be used to approximate output. It assumes a relatively straight, clean plastic pipe. Steel pipe will have about twice the frictional losses.

1. Determine head.

This may be done by measuring the vertical drop with a measuring stick of known length and a carpenter's level. Place the stick on the ground at the turbine site and put the level squarely on top of it. Site along the bottom of the level to the spot where it intersects the ground and move the stick to that point. This process is repeated until the dam site is reached, and the stick lengths are all added together. Subtract one foot for the distance the nozzle will be above the ground. If a pipe is already installed, the pressure can be measured directly.

2.3 feet = 1 lb/sq inches .43 lbs/square inch = 1 foot

An alternative method is to string a number of hoses together, fill them with water, and measure the pressure. This can be done in several steps, and the figures summed. Use a pressure gauge of 30 pounds or less, 15 pounds if you can find one, to assure accuracy.

2. Determine Flow.

On small creeks, a temporary dam can be erected to divert the flow into a container of known volume and timing it. Small creeks should never be dried up, as environmental damage will likely result. On larger creeks, flow is limited only by the size of the pipe. Many creeks rise and fall seasonally and it is important to know the low figure. The nozzle size can be reduced for periods of low flow.

Example: A five-gallon bucket that takes 45 seconds to fill is 5/45 or 1/9 G.P.S., 1/9 X 60 = 60/9 or 6 2/3 gallons per minute.

The maximum <u>output</u> of a given pipe is usually obtained when friction losses are about 1/3 of the static pressure. Maximum <u>efficiency</u> is obtained with the largest pipe possible.

3. Measure the length of pipe needed or installed.

4. Determine head loss from the following tables:

## Poly Pipe Table

### Friction Loss- Polyethylene (PE) SDR-Pressure Rated Pipe

Pressure loss from friction in psi per 100 feet of pipe.

| Flow | NOMINAL PIPE DIAMETER IN INCHES | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| GPM | 0.5 | 0.75 | 1 | 1.25 | 1.5 | 2 | 2.5 | 3 |
| 1 | 0.49 | 0.12 | 0.04 | 0.01 | | | | |
| 2 | 1.76 | 0.45 | 0.14 | 0.04 | 0.02 | | | |
| 3 | 3.73 | 0.95 | 0.29 | 0.08 | 0.04 | 0.01 | | |
| 4 | **6.35** | 1.62 | 0.50 | 0.13 | 0.06 | 0.02 | | |
| 5 | 9.60 | 2.44 | 0.76 | 0.20 | 0.09 | 0.03 | | |
| 6 | 13.46 | 3.43 | 1.06 | 0.28 | 0.13 | 0.04 | 0.02 | |
| 7 | 17.91 | 4.56 | 1.41 | 0.37 | 0.18 | 0.05 | 0.02 | |
| 8 | 22.93 | **5.84** | 1.80 | 0.47 | 0.22 | 0.07 | 0.03 | |
| 9 | | 7.26 | 2.24 | 0.59 | 0.28 | 0.08 | 0.03 | |
| 10 | | 8.82 | 2.73 | 0.72 | 0.34 | 0.10 | 0.04 | 0.01 |
| 12 | | 12.37 | **3.82** | 1.01 | 0.48 | 0.14 | 0.06 | 0.02 |
| 14 | | 16.46 | 5.08 | 1.34 | 0.63 | 0.19 | 0.08 | 0.03 |
| 16 | | | 6.51 | 1.71 | 0.81 | 0.24 | 0.10 | 0.04 |
| 18 | | | 8.10 | 2.13 | 1.01 | 0.30 | 0.13 | 0.04 |
| 20 | | | 9.84 | 2.59 | 1.22 | 0.36 | 0.15 | 0.05 |
| 22 | | | 11.74 | **3.09** | 1.46 | 0.43 | 0.18 | 0.06 |
| 24 | | | 13.79 | 3.63 | 1.72 | 0.51 | 0.21 | 0.07 |
| 26 | | | 16.00 | 4.21 | 1.99 | 0.59 | 0.25 | 0.09 |
| 28 | | | | 4.83 | 2.28 | 0.68 | 0.29 | 0.10 |
| 30 | | | | 5.49 | **2.59** | 0.77 | 0.32 | 0.11 |
| 35 | | | | 7.31 | 3.45 | 1.02 | 0.43 | 0.15 |
| 40 | | | | 9.36 | 4.42 | 1.31 | 0.55 | 0.19 |
| 45 | | | | 11.64 | 5.50 | 1.63 | 0.69 | 0.24 |
| 50 | | | | 14.14 | 6.68 | **1.98** | 0.83 | 0.29 |
| 55 | | | | | 7.97 | 2.36 | 0.85 | 0.35 |
| 60 | | | | | 9.36 | 2.78 | 1.17 | 0.41 |
| 65 | | | | | 10.36 | 3.22 | 1.36 | 0.47 |
| 70 | | | | | 12.46 | 3.69 | **1.56** | 0.54 |
| 75 | | | | | 14.16 | 4.20 | 1.77 | 0.61 |
| 80 | | | | | | 4.73 | 1.99 | 0.69 |
| 85 | | | | | | 5.29 | 2.23 | 0.77 |
| 90 | | | | | | 5.88 | 2.48 | 0.86 |
| 95 | | | | | | 6.50 | 2.74 | 0.95 |
| 100 | | | | | | 7.15 | 3.01 | **1.05** |
| 150 | | | | | | 15.15 | 6.38 | 2.22 |
| 200 | | | | | | | 10.87 | 3.78 |
| 300 | | | | | | | | 8.01 |

**Numbers in Bold Indicate 5 Feet/Second Velocity**

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# PVC Pipe Table

## Friction Loss- PVC Class 160 PSI Plastic Pipe

Pressure loss from friction in psi per 100 feet of pipe.

**Bold Numbers indicate 5 Feet per Second Velocity**

| Flow<br>GPM | NOMINAL PIPE DIAMETER IN INCHES<br>1 | 1.25 | 1.5 | 2 | 2.5 | 3 | 4 | 5 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.02 | 0.01 | | | | | | | | | |
| 2 | 0.06 | 0.02 | 0.01 | | | | | | | | |
| 3 | 0.14 | 0.04 | 0.02 | | | | | | | | |
| 4 | 0.23 | 0.07 | 0.04 | 0.01 | | | | | | | |
| 5 | 0.35 | 0.11 | 0.05 | 0.02 | | | | | | | |
| 6 | 0.49 | 0.15 | 0.08 | 0.03 | 0.01 | | | | | | |
| 7 | 0.66 | 0.20 | 0.10 | 0.03 | 0.01 | | | | | | |
| 8 | 0.84 | 0.25 | 0.13 | 0.04 | 0.02 | | | | | | |
| 9 | 1.05 | 0.31 | 0.16 | 0.05 | 0.02 | | | | | | |
| 10 | 1.27 | 0.38 | 0.20 | 0.07 | 0.03 | 0.01 | | | | | |
| 11 | 1.52 | 0.45 | 0.23 | 0.08 | 0.03 | 0.01 | | | | | |
| 12 | 1.78 | 0.53 | 0.28 | 0.09 | 0.04 | 0.01 | | | | | |
| 14 | 2.37 | 0.71 | 0.37 | 0.12 | 0.05 | 0.02 | | | | | |
| 16 | **3.04** | 0.91 | 0.47 | 0.16 | 0.06 | 0.02 | | | | | |
| 18 | 3.78 | 1.13 | 0.58 | 0.20 | 0.08 | 0.03 | | | | | |
| 20 | 4.59 | 1.37 | 0.71 | 0.24 | 0.09 | 0.04 | 0.01 | | | | |
| 22 | 5.48 | 1.64 | 0.85 | 0.29 | 0.11 | 0.04 | 0.01 | | | | |
| 24 | 6.44 | 1.92 | 1.00 | 0.34 | 0.13 | 0.05 | 0.02 | | | | |
| 26 | 7.47 | 2.23 | 1.15 | 0.39 | 0.15 | 0.06 | 0.02 | | | | |
| 28 | 8.57 | **2.56** | 1.32 | 0.45 | 0.18 | 0.07 | 0.02 | | | | |
| 30 | 9.74 | 2.91 | 1.50 | 0.51 | 0.20 | 0.08 | 0.02 | | | | |
| 35 | | 3.87 | **2.00** | 0.68 | 0.27 | 0.10 | 0.03 | | | | |
| 40 | | 4.95 | 2.56 | 0.86 | 0.34 | 0.13 | 0.04 | 0.01 | | | |
| 45 | | 6.16 | 3.19 | 1.08 | 0.42 | 0.16 | 0.05 | 0.02 | | | |
| 50 | | 7.49 | 3.88 | 1.31 | 0.52 | 0.20 | 0.06 | 0.02 | | | |
| 55 | | 8.93 | 4.62 | **1.56** | 0.62 | 0.24 | 0.07 | 0.02 | | | |
| 60 | | 10.49 | 5.43 | 1.83 | 0.72 | 0.28 | 0.08 | 0.03 | 0.01 | | |
| 65 | | | 6.30 | 2.12 | 0.84 | 0.32 | 0.09 | 0.03 | 0.01 | | |
| 70 | | | 7.23 | 2.44 | 0.96 | 0.37 | 0.11 | 0.04 | 0.02 | | |
| 75 | | | 8.21 | 2.77 | 1.09 | 0.42 | 0.12 | 0.04 | 0.02 | | |
| 80 | | | 9.25 | 3.12 | 1.23 | 0.47 | 0.14 | 0.05 | 0.02 | | |
| 85 | | | 10.35 | 3.49 | **1.38** | 0.53 | 0.16 | 0.06 | 0.02 | | |
| 90 | | | | 3.88 | 1.53 | 0.59 | 0.17 | 0.06 | 0.03 | | |
| 95 | | | | 4.29 | 1.69 | 0.65 | 0.19 | 0.07 | 0.03 | | |
| 100 | | | | 4.72 | 1.86 | **0.72** | 0.21 | 0.08 | 0.03 | 0.01 | |
| 150 | | | | 10.00 | 3.94 | 1.52 | 0.45 | 0.16 | 0.07 | 0.02 | |
| 200 | | | | | 6.72 | 2.59 | **0.76** | 0.27 | 0.12 | 0.03 | 0.01 |
| 250 | | | | | 10.16 | 3.91 | 1.15 | 0.41 | 0.18 | 0.05 | 0.02 |
| 300 | | | | | | 5.49 | 1.61 | **0.58** | 0.25 | 0.07 | 0.02 |
| 350 | | | | | | 7.30 | 2.15 | 0.77 | 0.33 | 0.09 | 0.03 |
| 400 | | | | | | 9.35 | 2.75 | 0.98 | 0.42 | 0.12 | 0.04 |
| 450 | | | | | | | 3.42 | 1.22 | **0.52** | 0.14 | 0.05 |
| 500 | | | | | | | 4.15 | 1.48 | 0.63 | 0.18 | 0.06 |
| 550 | | | | | | | 4.96 | 1.77 | 0.76 | 0.21 | 0.07 |
| 600 | | | | | | | 5.82 | 2.08 | 0.89 | 0.25 | 0.08 |
| 650 | | | | | | | 6.75 | 2.41 | 1.03 | 0.29 | 0.10 |
| 700 | | | | | | | 7.75 | 2.77 | 1.18 | 0.33 | 0.11 |
| 750 | | | | | | | 8.80 | 3.14 | 1.34 | **0.37** | 0.13 |
| 800 | | | | | | | | 3.54 | 1.51 | 0.42 | 0.14 |
| 850 | | | | | | | | 3.96 | 1.69 | 0.47 | 0.16 |
| 900 | | | | | | | | 4.41 | 1.88 | 0.52 | 0.18 |
| 950 | | | | | | | | 4.87 | 2.08 | 0.58 | 0.20 |
| 1000 | | | | | | | | 5.36 | 2.29 | 0.63 | 0.22 |
| 1500 | | | | | | | | | 4.84 | 1.34 | 0.46 |
| 2000 | | | | | | | | | | 2.29 | 0.78 |
| 2500 | | | | | | | | | | 3.46 | 1.18 |
| 3000 | | | | | | | | | | | 1.66 |

5. Multiply the figure found in the table times 2.31, then times the number of 100 foot pipe sections needed.

6. From theses figures, select the pipe size necessary for available water.

7. Subtract this figure from the static head (#1). This is "dynamic" or "net" head.

8. Find output below using flow and net head.

**Delco Alternator**
**Output in Watts**

Feet of Net Head

| G.M | 25 | 50 | 75 | 100 | 200 | 300 | 600 |
|---|---|---|---|---|---|---|---|
| 3 | | | | | 25 | 60 | 125 |
| 6 | | | | 15 | 80 | 110 | 240 |
| 10 | | | 35 | 65 | 140 | 225 | 450 |
| 15 | | 40 | 60 | 105 | 225 | 350 | 580 |
| 20 | 20 | 65 | 100 | 150 | 300 | 400 | |
| 30 | 45 | 100 | 175 | 230 | 450 | 600 | |
| 50 | 75 | 175 | 290 | 400 | | | |
| 100 | 155 | 350 | 500 | 625 | | | |
| 200 | 175 | 400 | 600 | | | | |

**High Output Alternator**
**Output in Watts**

Feet of Net Head

| G/M | 25 | 50 | 75 | 100 | 200 | 300 | 600 |
|---|---|---|---|---|---|---|---|
| 3 | | | | | 30 | 70 | 150 |
| 6 | | | 25 | 35 | 100 | 150 | 300 |
| 10 | | 35 | 60 | 80 | 180 | 275 | 550 |
| 15 | 20 | 60 | 95 | 130 | 260 | 400 | 800 |
| 20 | 30 | 80 | 130 | 200 | 400 | 550 | 1100 |
| 30 | 50 | 125 | 210 | 290 | 580 | 850 | 1500 |
| 50 | 115 | 230 | 350 | 500 | 950 | 1400 | |
| 100 | 200 | 425 | 625 | 850 | 1500 | | |
| 200 | 225 | 520 | 850 | 1300 | | | |

The water that will pass through the turbine is dependent on the nozzle size, the number of nozzles, and the net head. In a given pipe the bigger the nozzle the lower the net head will be. This is significant in long, small diameter pipes. The flow through a given nozzle increases with the square root of the increase in net head.

## NOZZLE FLOW TABLE

| Head | 3 /16 | 1 /4 | 3 /8 | 1 /2 | nozzle size |
|---|---|---|---|---|---|
| 25 | 3.4 | 5.9 | 12.7 | 22.8 | G.P.M. |
| 100 | 6.8 | 11.8 | 25.4 | 45.7 | |
| 400 | 13.6 | 23.6 | 50.8 | 91.4 | |

For multiple nozzle systems, add together the flow figures for each nozzle.

If all this seems too complex, it is simpler and more interesting to try various nozzles and note the results!

## INSTALLATION

After determining head and flow and deciding the proper pipe size, a water diversion must be installed. It is prudent not to remove too much water during the dry season from a flowing creek as undesirable changes in the creek bed can result. A dam that allows a minimal flow to pass before the turbine feed pipe gets water will prevent this. This will also reduce the amount of silt in the pipe.

The variety of possible impoundment schemes is almost as one is different. Common sense and a little experimentation are the most useful tools at this point.

There are, however, a few considerations common to all collections systems:

1. The flow of water should not be interrupted enough to interfere with natural vegetation or fish life.

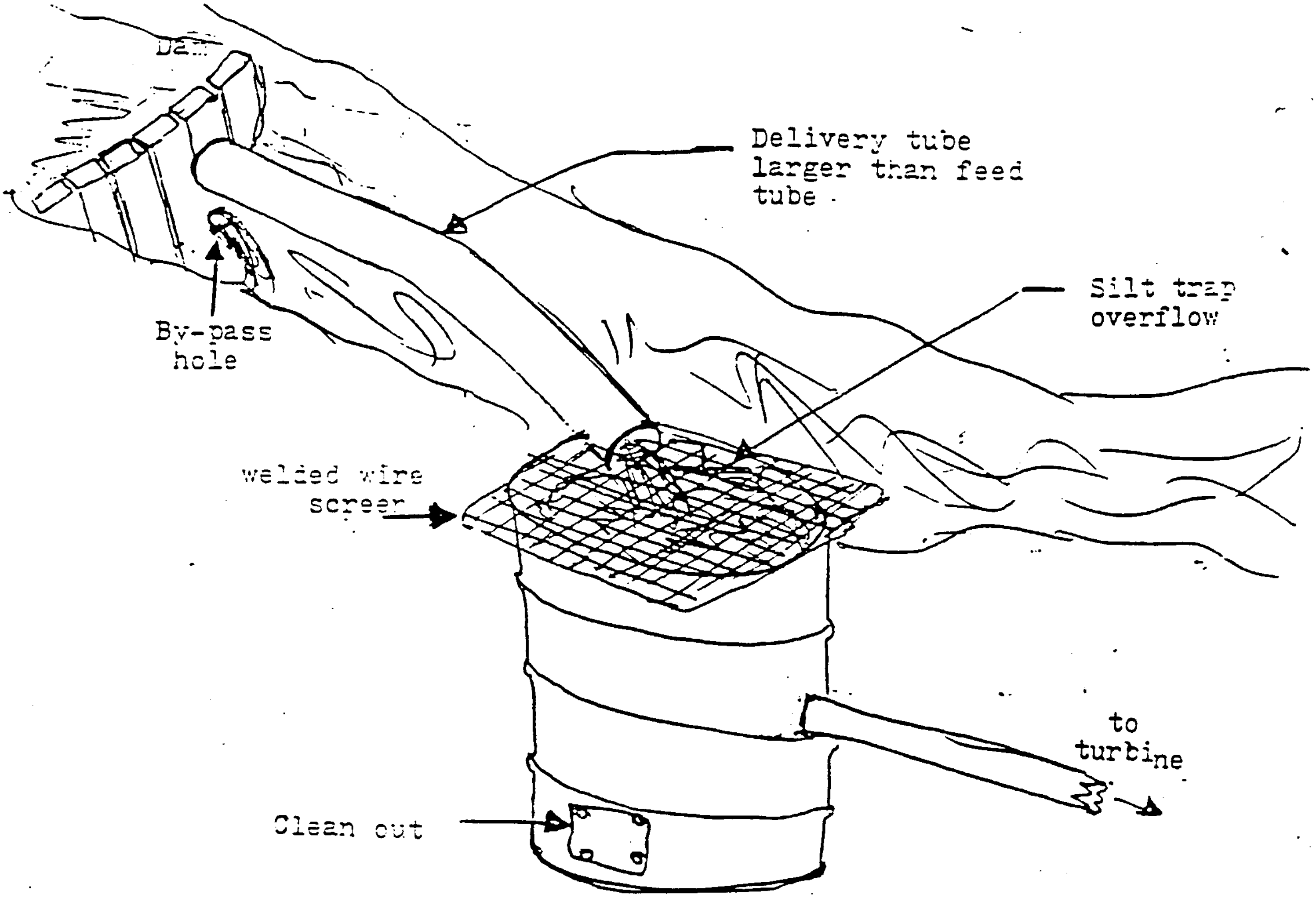
2. The dam should either be mounted securely enough to withstand the wildest winter weather, or be simple enough to be expendable and quickly repaired.

3. Water filtering is best when the screen is self-cleaning. In systems with a submerged filter, the area should be as great as possible to reduce the tendency of suction to plug it with debris.

4. Provision should be made for allowing silt that has accumulated at the dam to self-clean. This usually means being able to open (and reseal) a large opening in the dam during the wet season and allow the flow to carry the mud away. Small particles must be removed from the water to keep the nozzles clean. Silt removal becomes increasingly important at heads above 100 feet. This is especially true in water carrying decomposed granite.

If the stream becomes silty during the wet season, a silt trap should be installed. A small Dough-Boy type pool is excellent, but a 55 gallon drum will do. The larger the tank, the better.

Welded wire may be used to cover the silt trap. It should be sized to preclude anything larger than 1/2 the diameter of the smallest nozzle to be used from entering the silt trap.



In very low springs or creeks during the dry season the turbine can be run intermittently by trickling water into the pool for a day or two, then running it at a much higher rate for an hour or so. This can be made automatic with a double-acting float valve.

## LAYING PIPE

Next, the pipe must be laid, being careful not to stress the pipe excessively. If laid above ground, plastic pipe tends to deteriorate in direst sunlight. Covering pipe with a layer of eaves or applying a coat of exterior grade paint will solve this. Pipe in steep country should be well anchored, as slippery plastic pipe tends to slide downhill.

If the pipe cannot be laid at a constant angle of decent, then clean outs should be provided in dips in the pipe where silt tends to accumulate, and in long pipes air relief valves should be put at humps. Be careful to get pipe capable of withstanding the pressure you will have, plus at least 50 lbs. This is because when the system is shut down, either intentionally or by an obstruction in the nozzle, the pressure rises substantially. Valves should always be closed slowly. It is advisable to permanently install a pressure gauge in the line at the turbine end but before the gate valve. It will be invaluable in trouble shooting hydraulic problems. Select a gauge with a value of 1 ½ to 2 times the terminal pressure.

Burying the pipe is the best and most permanent solution, but be sure to provide access to all silt and air relief points. In cold climates consult with local plumbers regarding how deep to bury pipe to avoid rupture from a hard freeze.

P.V.C. pipe comes in a variety of schedules or pressure ratings. These run from a low of 62 lbs. To Schedule 80, which is rated about 600 P.S.I.

Because all P.V.C. has the same outside diameter, the higher pressure pipe has a smaller inside diameter. With pipe 2" diameter and smaller, this can make a significant difference in pipe friction. Because the highest pressure is always at the bottom (turbine end) of the pipe, it makes sense to use thinner (and less costly) pipe from the dam end, and switch to the heavier pipe at the point where the pressure has increased enough to require it.

## THE TURBINE

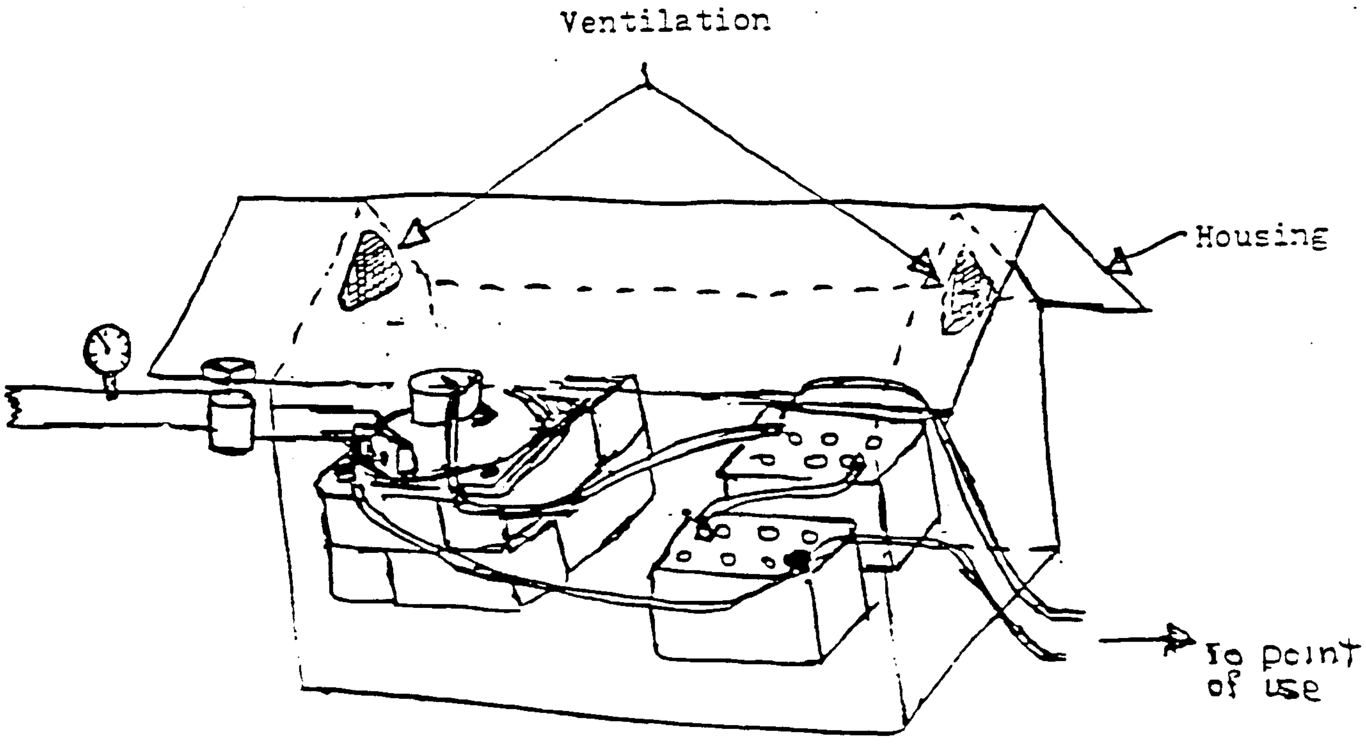
The turbine may be mounted by the four holes on the base plate to a wooden or concrete substrate. The mounting base should not protrude into the falling water pattern and should provide at least 12" clearance above the ground. Care must be taken to assure that no water splashes on the alternator or control panel. It is desirable to enclose the entire underside of the turbine except for a water exhaust area. This quiets the turbine significantly. Exhaust water may be diverted back to the creek or other intended use.

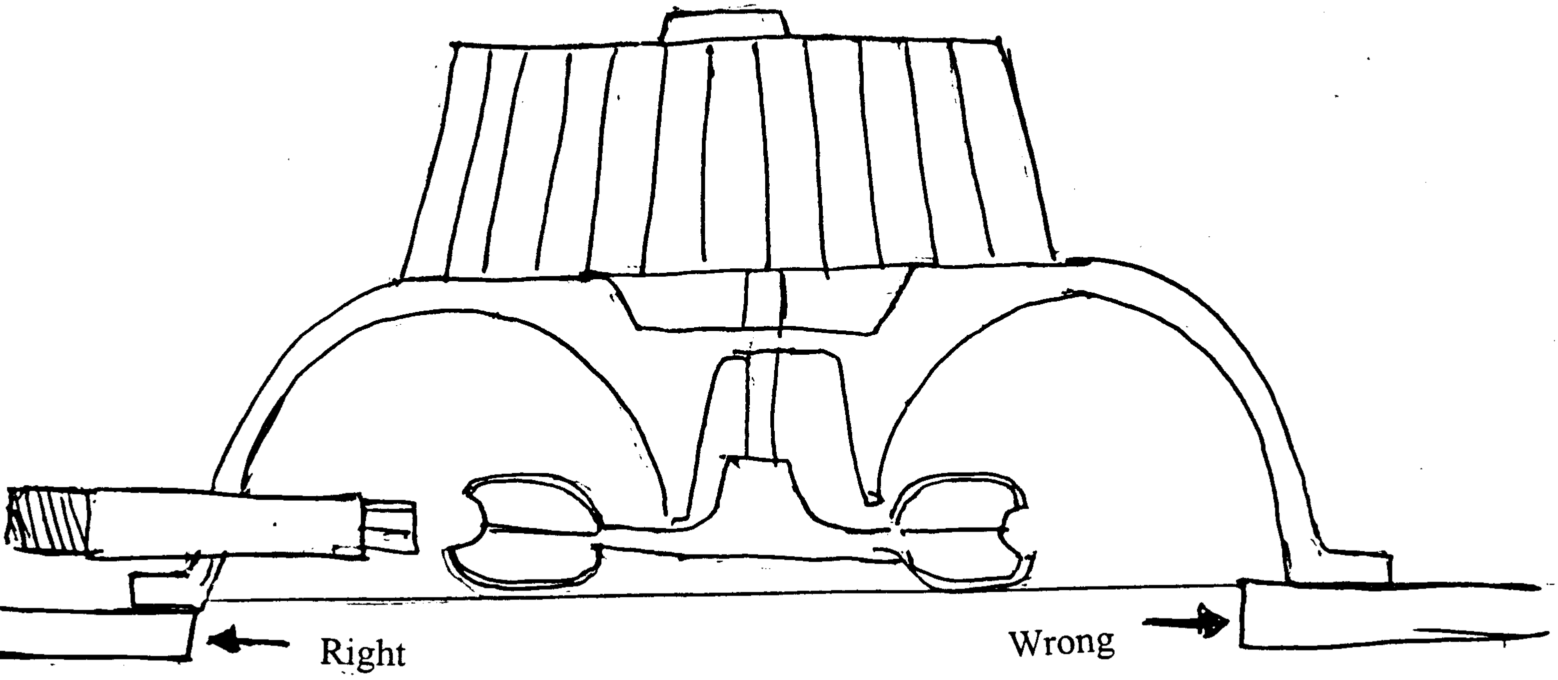
Batteries should be as close to the point of use as possible. The distance from the turbine to the batteries, and turbine output w3ill determine the wire size necessary to keep power losses within acceptable limits.

If an inverter is being used, the distance from the battery(s) to the inverter should be kept as short as possible consistent with codes and safety considerations. A 12 volt inverter starting a 1-horsepower motor under load can draw 1,000 amps for a short period of time. The wire must be short and large enough to not starve the inverter.

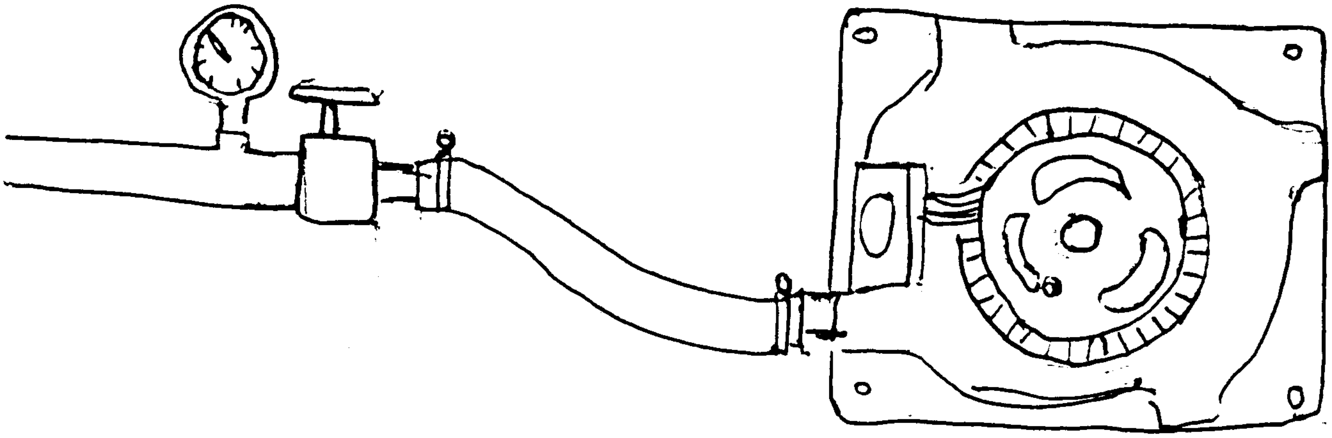
The turbine housing should be grounded with a standard 5/8" copper ground rod driven at least 8 feet into the earth. This is especially important if the open circuit voltage of the alternator can exceed 50 volts.

A housing should be installed over the entire installation including batteries (if they are at the turbine site). It should be substantial enough to protect hardware from rain and wind but provide adequate ventilation for turbine heat and battery out-gassing. Some sound proofing may be desirable if the system is close to the house or other place where noise could be a problem. Care must be exercised to insure that exhaust water cannot plug up and flood the turbine and other hardware. It is important that the battery storage area be ventilated at the highest point in its enclosure to assure that no explosive hydrogen gas can accumulate.





Water must be able to fall freely from the casting. Even a 1/16" lip can cause splash-back resulting in power loss.



Single nozzle machines can be connected to the pipe with high-pressure hose. This allows for removal to change nozzles, etc. without disconnecting the turbine from the pipe. It also reduces stress on the nozzle tube.

It should go without saying to mount the turbine high enough above the high water level of the creek to assure that it will not wash away in a severe storm. Creeks in flood stage can astonish even a seasoned back-wooder. In at least one case the ground rod and strap saved a generator from winding up in the ocean!

## TRANSMISSION

It is necessary to use large enough wire between the turbine and the batteries to keep power losses within acceptable limits. Electricity passing through a wire is much like water flowing through a pipe. Voltage resembles pressure, and amperage is analogous to water volume.

Between the alternator and the batteries, the voltage will drop. The battery bank establishes the voltage of the system. The generator must run at a voltage higher than the battery voltage to overcome this line loss. The alternator is capable under the particular site conditions of producing a given number of watts of power. Volts times Amps equals Watts. So, if the voltage rises, to overcome the wire loss, the amperage must drop; resulting in a loss of power at the batteries.

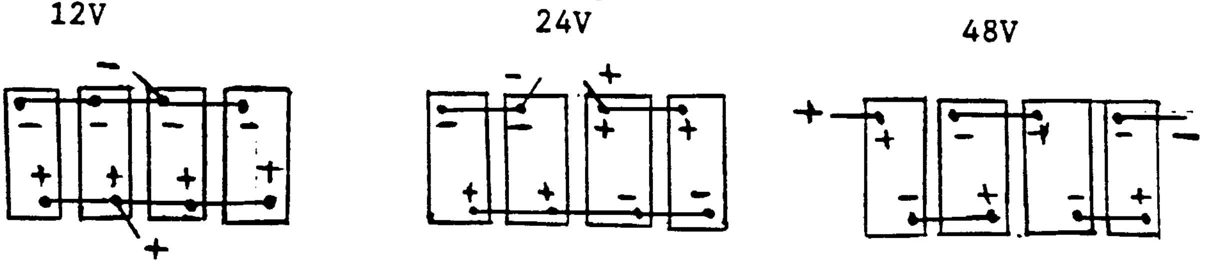
Voltage drop is dependent on four factors: System Voltage, System Amperage, Transmission Distance and Wire Size.

**System Voltage** is established by the battery bank. If the house is wired for 12-volt lights and appliances, the question is settled. If an inverter is to be used to produce 110 v., A.C. power, there are far more choices. At this time 12-v, 24-v, 32-v, 36-v and 48-v inverters are commonly available.

The effect of system voltage on line loss is extreme. The loss for a given wire and wattage varies inversely as the square of the voltage. This means that 40 watts a) will go 125 feet through a 2-way run of #10 wire with losses of 10% at 12 volts; b) will go 500 feet with the same losses at 24 volts; c) and will go 2,000 feet at 48 volts.

Changing system voltage requires changes in battery arrangement and alternator wiring.

Wiring diagram of 12v, 24v, and 48v using four 12-volt batteries:



**System Amperage** is the measure of current. Amps equals watts divided by voltage. The greater the current, the larger the wire necessary. If the current is double, all other factors constant, the wire area must be doubled to maintain the same transmission efficiency. Also, for each wire size there is a safe upper current limit called the ampacity of the wire.

| Wire Size | Copper Wire | | Aluminum Wire | |
|---|---|---|---|---|
| AWG | VDI | Ampacity | VDI | Ampacity |
| OOOO | 99 | 260 | 62 | 205 |
| OOO | 78 | 225 | 49 | 175 |
| OO | 62 | 195 | 39 | 150 |
| O | 49 | 170 | 31 | 135 |
| 2 | 31 | 130 | 20 | 100 |
| 4 | 20 | 95 | 12 | 75 |
| 6 | 12 | 75 | • | • |
| 8 | 8 | 55 | • | • |
| 10 | 5 | 30 | • | • |
| 12 | 3 | 20 | • | • |
| 14 | 2 | 15 | • | • |
| 16 | 1 | • | • | • |

Line loss is directly proportional to **Transmission Distance.** Twice the distance, twice the loss. Or, to keep the loss the same, twice the distance will require twice the copper per foot, or four times the wire in total.

**Line Loss** is inversely proportional to the cross sectional area of the conductor. The more copper, the less the loss.

The following table assumes copper wire and a loss of 10% or less. In some cases higher losses are permissable, and in others lower losses are practical. Balance the price of wire against the need for more power. Short runs or higher voltage systems often can operate with 5% or less loss.

### Twelve Volt Transmission

| watts | 25' | 50' | 100' | 250' | 500' | 1000' | Distance |
|---|---|---|---|---|---|---|---|
| 25 | #14 | #14 | #12 | #10 | #8 | #4 | |
| 50 | #14 | #12 | #10 | #8 | #4 | #2 | |
| 100 | #12 | #10 | # 8 | #4 | #2 | #00 | |
| 250 | #10 | # 8 | # 4 | #0 | #000 | ---- | |
| 500 | # 8 | # 4 | # 2 | #000 | --- | ---- | |
| 1500 | # 2 | # 0 | #000 | --- | --- | ---- | |

For 24-volt transmission, multiply the distance by 4; for 48-volt transmission multiply the distance by 16.

For extremely long transmission distances, or for moderately long distances on 12-volt systems, the alternator can be operated at a higher voltage and the power switched down to battery voltage through a D.C. to D.C. transformer called a Linear Current Booster. These systems must be carefully planned and are site specific.

**Electricity is Dangerous!** Whenever possible, the transmission lines should be buried. Consult local codes for particular requirements. Be sure to use wire rated for direct burial and/or encase the wire in poly pipe or some other suitable environmental barrier. All splices should be brought above ground, soldered with rosin core solder, and enclosed in a sealed electrical box.

The positive conductor must be fused near the battery with a rating 25% above the highest alternator amperage output, but not exceeding the ampacity of the smallest wire in the transmission line.

**DO NOT REVERSE POLARITY!** Simply touching the wires backwards will destroy the diodes in the alternator. **BE CAREFUL.**

Standard wired turbines should have a diode inserted in the positive wire near the turbine to prevent leakage of electricity into the alternator field when the system is shut down. In some cases, the field must be excited when the system is turned on by jumping past the diode with a short wire. Turbines with a starter button on the alternator are wired differently and do not need a diode.

## STORAGE

The size of the battery bank is dependent on three factors:

1. Turbine output
2. Characteristics of end use
3. Method of regulation

**ALWAYS USE DEEP CYCLING BATTERIES.**

If **Turbine output** is constant summer and winter and is the only charging source for the batteries, a C-25 charger rate is about right. There should be about 25 amp hours capacity for each amp of charging capacity. If the battery bank is much larger than this, its internal self-discharge will absorb too much of the turbine output; also, it becomes difficult to provide an equalizing charge of the battery cells.

If the turbine output varies or stops seasonally, there must be a backup muthod of keeping the batteries charged.

**End use.** If there are extreme peaks of use, such as periodic binges of shop use, or large, energy intense parties, the battery system must be sized to store enough electricity for the purpose without damage. Also, if an inverter is being used, the battery bank must be large enough to provide peak load without an excessive voltage drop. For a typical 12-volt 2,000 watt inverter this is about 700 amp hours capacity.

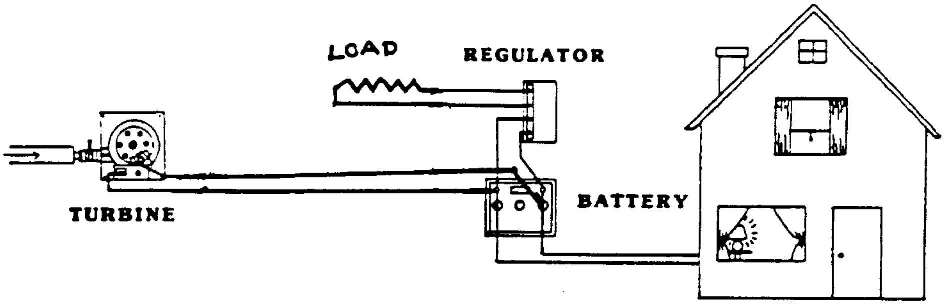
**Regulation.** Battery overcharge must be controlled. The lowest output systems can be manually controlled by monitoring battery state of charge and adjusting turbine output to match the power being use. Also, the turbine may be run intermittently to keep the batteries charged.

Several systems are available to automatically regulate battery condition. The most universal method is parallel shunt regulation. Under this scheme the alternator continuously supplies its rated power to the batteries. The regulator monitors battery condition and "turns on" enough to use up the excess electricity and keep the voltage stable. Usually the excess power is used to heat air space or water.

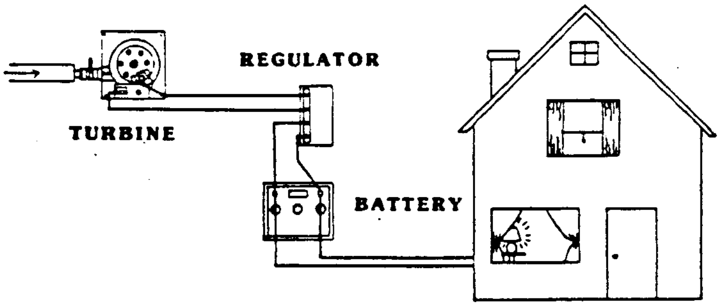
Low head turbines in dry climates can use field control regulators to shut down turbine output when the voltage is up. This method cycles both alternator speed and temperature which can create a problem in high head systems or in moist sites where condensation on electrical connections accelerates corrosion.

A third method of control is a voltage sensitive switch used to turn on and off the water to the turbine. This is especially appropriate at sites fed by ponds where the water supply is limited and cannot be wasted.

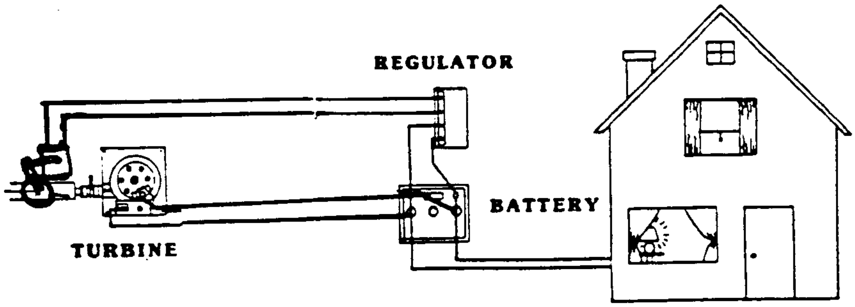
## 1. PARALLEL SHUNT REGULATION



## 2. FIELD CONTROL REGULATION



## 3. WATER CONTROL REGULATION



## OPERATION

Once the turbine pipe and wiring are connected, the water simply needs to be turned on. On Delco systems, the knob on the control panel regulates the magnetic field in the alternator. To operate at maximum efficiency, a pelton wheel should spin at exactly ½ the speed of the water hitting it. By increasing the magnetic strength the wheel slows down, and at some point reaches maximum efficiency. Simply watch the output gauge until the highest reading is obtained.

When the alternator is properly loaded, the greatest amount of energy is being extracted from the water. The turbine will usually be quietest at this setting.

Following initial start up the static and dynamic water pressure can be noted using various nozzles and combinations of nozzles. These figures should be recorded for future reference, and compared with the theoretical expectation.

Using a hand held voltmeter the turbine output voltage should be compared to the battery voltage to assure that the line loss is as computed. This too should be recorded.

If possible, turn on the maximum size and number of nozzles and operate long enough to be sure that the water is draining fast enough to not back up and flood the turbine.

## MAINTENANCE

Turbine hardware is relatively immune to damage. High head systems need frequent enough silt removal to keep the water clear. Periodically inspect the filtering screen to assure that chunks of debris cannot enter the pipe, plug nozzles or damage the runner.

The alternator should be removed and inspected **annually**. **At least** the first year the field brushes and bearing should be inspected and replaced. From their condition after 1 year in operation, you can make a judgment about how often to inspect. Different site conditions and water quality yield a wide range of hardware life . Also, the wires, connections, rheostat, amp gauge, fuse, and fuse holder should be inspected for signs of damage or corrosion.

When the turbine is not in operation in cold weather it should be drained to prevent the rupture of the penstock from freezing water. This is done by draining the entire pipe, or if this is not possible or desirable, by closing the main gate valve and opening all the individual ball valves.

Routine battery maintenance is essential for long life. Check water level weekly and add distilled water only to the proper level. All corrosion should be removed and neutralized with baking soda. If the water level drops too rapidly, check the regulator voltage set points.

## TROUBLE SHOOTING

If output has dropped or stopped the following procedure will help determine the problem.

The problem will be either:

1. **Hydraulic** - Water Delivery
2. **Mechanical** - Hardware
3. **Electrical** - Alternator; control box; transmission line

First, review the original pressure and voltage information recorded during the start-up.

1. If the **pressure is too low**, the possibilities are:
   - A. Over drafting pipe: The water source has dropped and the pipe is not being fed as fast as the turbine is using it.
     **SOLUTION:** Switch to fewer or smaller nozzles(s).
   - B. Silt has accumulated in dips in the pipe.
     **SOLUTION:** Purge pipe through clean-outs at low points.
   - C. Air is trapped in pipe (usually from overdraft).
     **SOLUTION:** After solving overdraft, purge air from pipe through air relief valves.
   - D. Screen is partially plugged.
     **SOLUTION:** Clean screen.
   - E. Pipe is ruptured
     **SOLUTION:** Repair pipe.
2. If the **pressure is too high,** the possibility is:
   One or more nozzles are partially or totally plugged.
   **SOLUTION:** Remove nozzles, purge pipe, and clean nozzles; also, check screen for ruptures, and repair, if necessary

3. If **turbine voltage is too high:**
    - A. Wire or fuse is broken.
      **SOLUTION:** Find and repair.
    - B. Corrosion has increased resistance in transmission wire at connections.
      **SOLUTION:** Inspect and check all connections with an OHM meter to find resistance and repair.

4. If rheostat adjustment makes no noticeable difference in the sound of the turbine, and it seems to be running fast, the field circuit is probably the problem.
   **SOLUTION:** Check external wires to rheostat, rheostat itself, fuse holder, and fuse. Replace fuse, if blown, with the same value fuse. If the fuse blows again, remove and repair alternator. Field brushes and rotor coil are the possible problems.

5. If rheostat adjustment does make a noticeable change, but power is low, the stator coil or diode bridge may be bad, and the alternator should be repaired.

**NOTE:** To remove the alternator, insert a 5/16" allen wrench through the center of the pelton wheel into the end of the alternator shaft and **twist the wheel** counter-clockwise against the wrench. Be sure to note the sequence of spacers and washers, and replace in the same order when re-assembling.

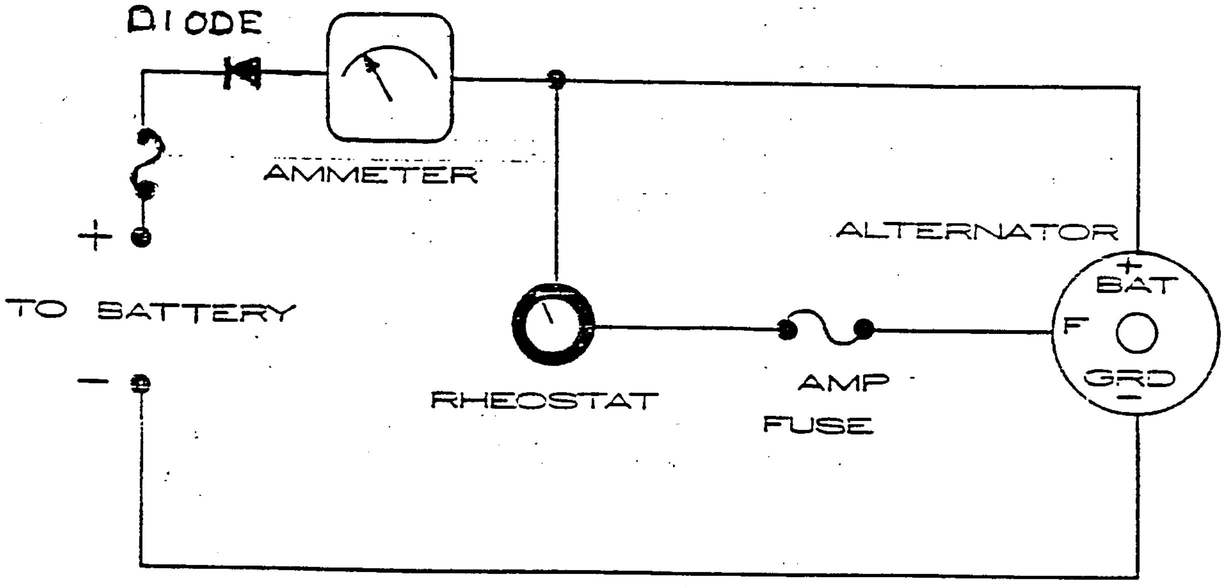
## A FEW WORDS OF CAUTION!!

1. **Never disconnect batteries when turbine is running. Disconnecting the batteries when the turbine is running can produce lethal voltage spikes.**

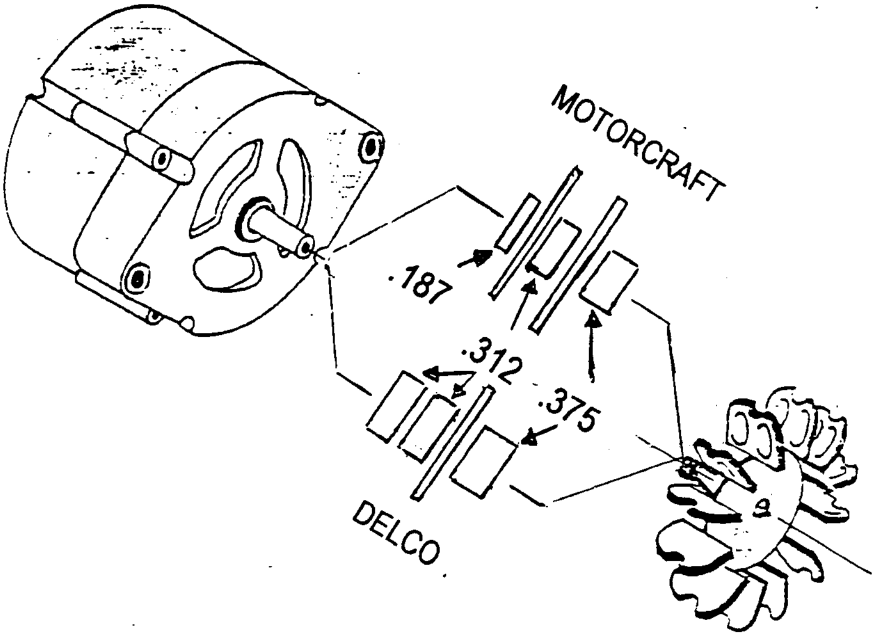
2. **Never operate turbine without first connecting the batteries.**

3. **Always use "Never Seize" or some similar non-seize grease on all threads during re-assembly.**

## HAPPY GENERATING!!



WIRING DIAGRAM



SPACER AND SLINGER ASSEMBLY