Welcome to the world of hydro power! The concept of generating electricity from water has been around for a long time and there are many large hydro-electric facilities around the world. What is new to most people is the idea that this same concept will work on a smaller – and even individual – scale. With the rising costs of utility power and refinements to micro-hydro systems, it is now not only possible, but also very practical, to look at water as the source for your electricity.

This booklet will provide you with a basic understanding of small-scale hydro-electric power generation. The information will help you determine the power generation potential for your site, acquaint you with the various components necessary for a small scale hydro-electric system, and explain the basic differences between common micro-hydro turbines so that you can choose the best one for your system.

This booklet is a basic overview of micro-hydro power generation and systems. It is not intended to be a detailed system design manual. Here at ABS Alaskan, Inc. we have a friendly staff trained and experienced in small-scale hydro-electric systems who can assist you with any additional questions you might have regarding micro-hydro or systems design.

Whether you have an existing application with known electrical requirements or just want to know if that stream running through your property can be used to generate electricity, this booklet will provide you valuable insights into the world of small scale hydro-electric power generation. We hope that you find it informative and enlightening.

— Jim Norman
President
ABS Alaskan, Inc

Got water, need power?

If you could choose any renewable energy resource to use, hydropower would be the way to go. With the right location, hydro systems can produce many times the power a similarly priced wind or solar system could generate. With special precautions, they can be used virtually year-round, summer or winter. Even a modest output from a hydro system, producing steadily 24 hours a day, will add up to a large cumulative total.

Often, peak power use is in the evening when the sun isn't shining and the wind is not necessarily blowing. Batteries can be completely drained by morning with a solar or wind system. With a hydro system located on a year-round creek or river, power is produced steadily around the clock. These are just some of the benefits of hydropower ...

Richard DeMur's home hydropower site, powered entirely by 1 waterwheel, 2 PowerPals, and 1 Nautilus water turbine.

What is Micro Hydropower?

Micro Hydropower (from *hydro* meaning water and *micro* meaning small scale) refers to electrical energy that comes from the force of moving water used to power a household or small village.

The fall and flow of water is part of a continuous natural cycle. The sun draws moisture up from the oceans and rivers, and the moisture then condenses into clouds in the atmosphere. The moisture falls as rain or snow, replenishing the oceans and rivers. Gravity moves the water from high ground to low ground. The force of moving water can be extremely powerful, as anyone who has been whitewater rafting knows! Micro Hydropower harnesses some of this power to create electricity.

Hydropower is a renewable energy source because it is replenished by snow and rainfall. As long as the rain falls, we won't run out of this energy source.

How Does Micro Hydropower Work?

Hydropower plants capture the energy of falling water to generate electricity. A turbine converts the energy of falling water into mechanical energy. Then an alternator converts the mechanical energy from the turbine into electrical energy. The amount of electricity a hydropower plant produces is a combination of two factors:

1. **How far the Water Falls (Head):** Generally, the distance the water falls depends on the steepness of the terrain the water is moving across, or the height of a dam the water is stored behind. The farther the water falls, the more power it has. In fact, the power of falling water is 'directly proportional' to the distance it falls. In other words, water falling twice as far has twice as much energy. *It is important to note we are only talking about the vertical distance the water falls* – the distance the water travels horizontally is consequential only in expense of the system and friction losses. Head is usually measured in 'feet'.

2. **Volume of Water Falling (Flow):** More water falling through the turbine will produce more power. The amount of water available depends on the volume of water at the source. Power is also 'directly proportional' to river flow, or flow volume. A river with twice the amount of flowing water as another river can produce twice as much energy. Flow volume is usually measured in 'gallons per minute', or 'GPM'.

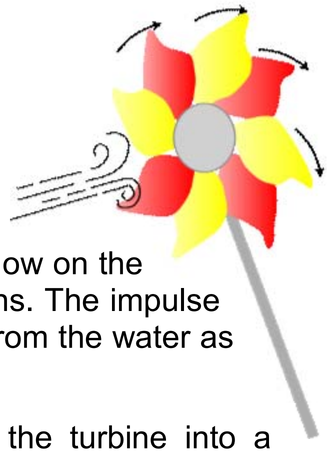
For Micro Hydro systems, this translates into two categories of turbines:

For high head and low flow volume sites, impulse turbines are the most efficient choice. The power produced by an impulse turbine comes entirely from the momentum of the water hitting the turbine runners. This water creates a direct push or 'impulse' on the blades, and thus such turbines are called 'impulse turbines'.

For low head and high flow volume sites, a reaction turbine is the best choice. The reaction turbine, as the name implies, is turned by reactive force rather than a direct push or impulse. The turbine blades turn in reaction to the pressure of the water falling on them. Reaction turbines can operate on heads as low as 2 feet, but require much higher flow rates than an impulse turbine.

Impulse Turbines

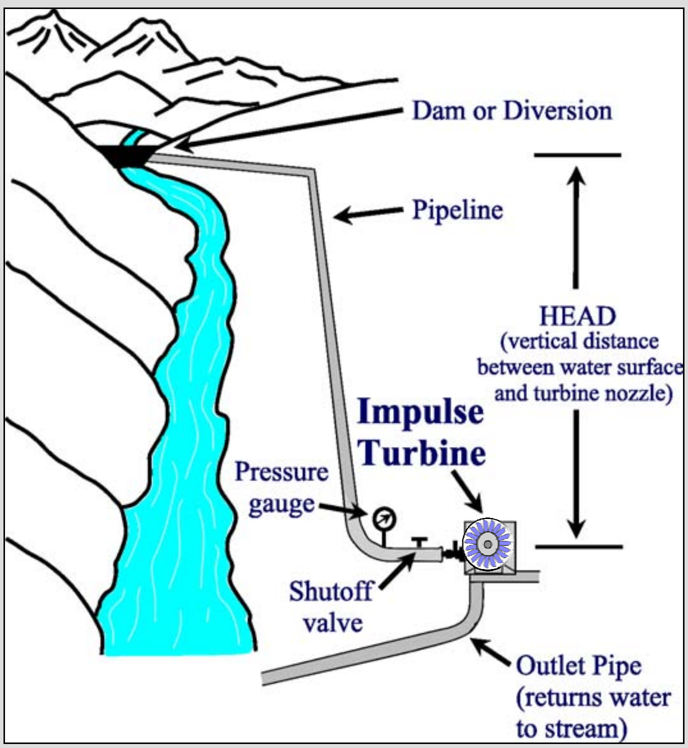
(High Head, Low Flow)



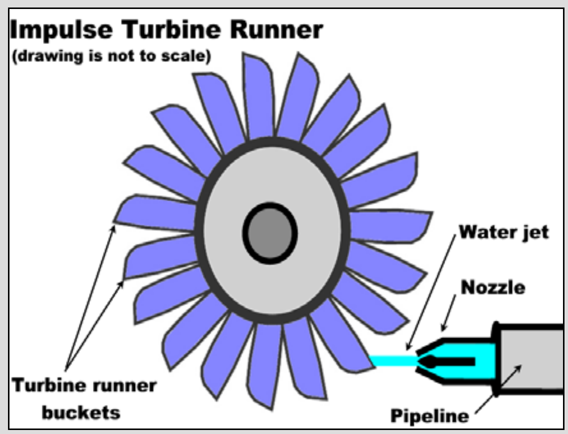
Do you remember playing with toy pinwheels as a child? They are a good illustration of the principles behind an impulse turbine. When you blow on the rim of the pinwheel, it spins rapidly. The harder you blow, the faster it turns. The impulse turbine operates on the same principle, except it uses the kinetic energy from the water as it leaves the nozzle rather than the kinetic energy of air.

In a system using an impulse turbine, water is diverted upstream of the turbine into a pipeline. The water travels through this pipeline to a nozzle, which constricts the flow to a narrow jet of water. The energy to rotate an impulse turbine is derived from the kinetic energy of the water flowing through the nozzles. The term 'impulse' means that the force that turns the turbine comes from the impact of the water on the turbine runner. This causes the attached alternator to turn, and thus the mechanical work of the water is changed into electrical power.

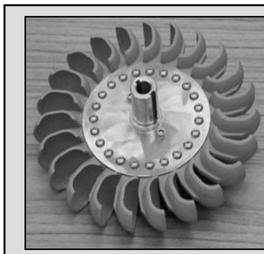
Most sites with a head of at least 25ft now use impulse turbines. These turbines are very simple and relatively inexpensive. As the stream flow varies, water flow to the turbine can be easily controlled by changing nozzle sizes or by using adjustable nozzles. Common impulse turbines are the Pelton and the Turgo turbines.



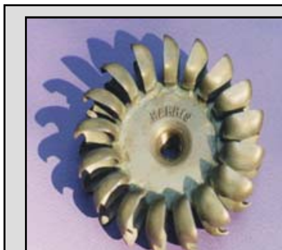
Basic Components of an Impulse Turbine System – ***Notice how important the closed pipeline is to producing the pressure (potential energy), which is translated into kinetic energy at turbine nozzle***



The Impulse turbine in action, with the water jet hitting the runner 'buckets' and spinning the turbine wheel



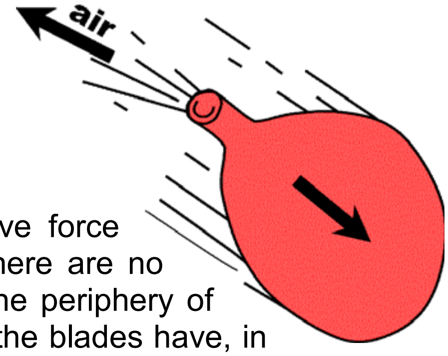
Turgo Impulse Turbine Runner



Pelton Impulse Turbine Runner

Reaction Turbines

(Low Head, High Flow)



The reaction turbine, as the name implies, is turned by reactive force rather than by a direct push or impulse. In reaction turbines, there are no nozzles as such. Instead, the blades that project radially from the periphery of the runner are formed and mounted so that the spaces between the blades have, in cross section, the shape of nozzles.

You can use a balloon to demonstrate the kickback or reaction force generated by the nozzle blades. Blow up the balloon and release it. The air will rush out through the opening and the balloon will shoot off in the opposite direction.

> **Newton's Third Law:**
> ***For every action, there is an equal and opposite reaction***

When the balloon is filled with air, you have potential energy stored in the increased air pressure inside. When you let the air escape, it passes through the small opening. This represents a transformation from potential energy to kinetic energy. The force applied to the air to speed up the balloon is acted upon by a reaction in the opposite direction. This reactive force propels the balloon forward through the air.

You may think that the force that makes the balloon move forward comes from the jet of air blowing against the air in the room, not so. It is the reaction of the force of the air as it passes through the opening that causes the balloon to move forward.

The reaction turbine has all the advantages of the impulse-type turbine, plus a slower operating speed and greater efficiency. However, the reaction turbine requires a much higher flow rate than the impulse turbines.

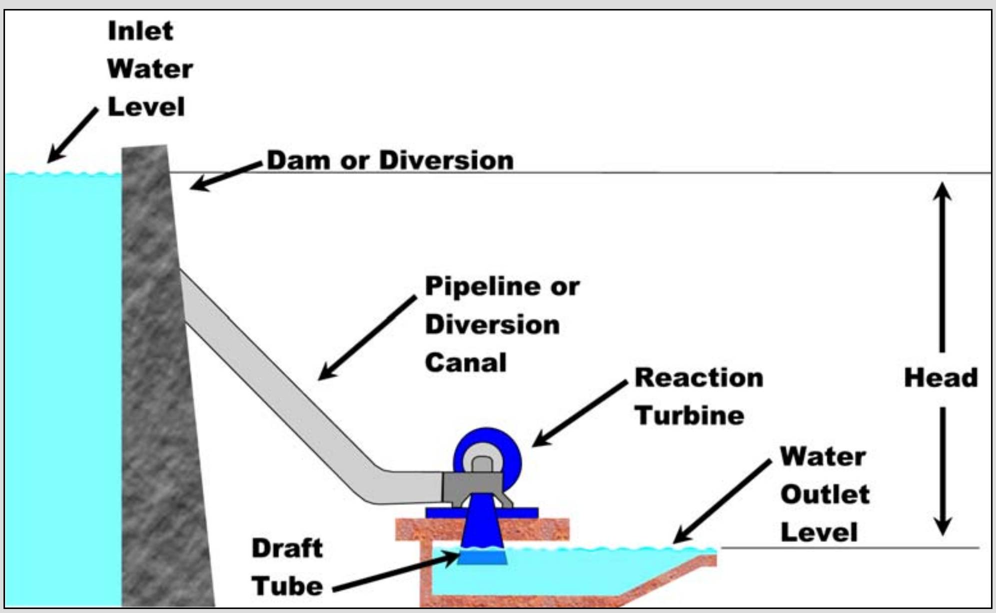
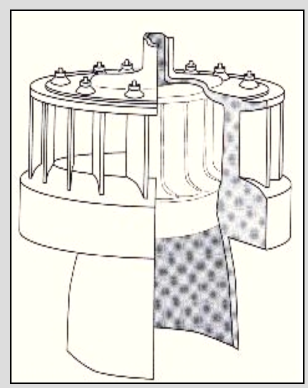


Diagram showing the components of a reaction turbine system with a combination diversion system.



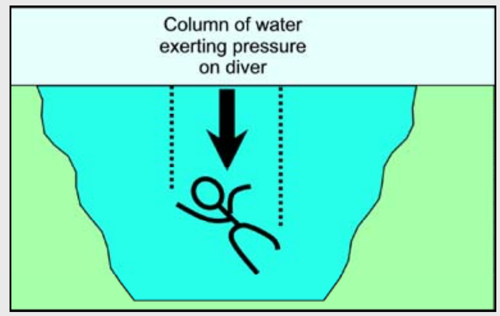
A reaction turbine runner, with the outer guide vanes guiding the water flow into the runner blades, which act as nozzles

Developing Head Pressure

We've already defined 'head' as the vertical distance water falls once it enters our hydro system. This is probably the single most important factor in determining the amount of power you can generate from you potential hydro site, and thus we should delve a little further into how head is measured and developed.

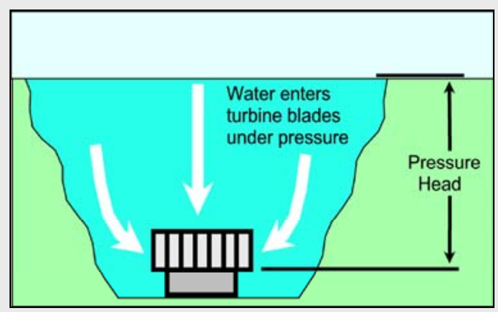
There are many different ways to measure head at your hydro site, and a couple of the most common methods are outlined in appendix 2. You'll find methods of determining the available flow volume of your hydro site in appendix 2 as well. In this section, we will discuss how head is developed at a hydro site and how it is transferred into power.

Have you ever swam down to the bottom of a deep swimming pool and felt your ears pop? That's caused by the water pressure, which is created by the weight of the water above you. We measure water pressure in pounds per square inch (PSI). That's the weight in pounds of the water on a one-square-inch area.



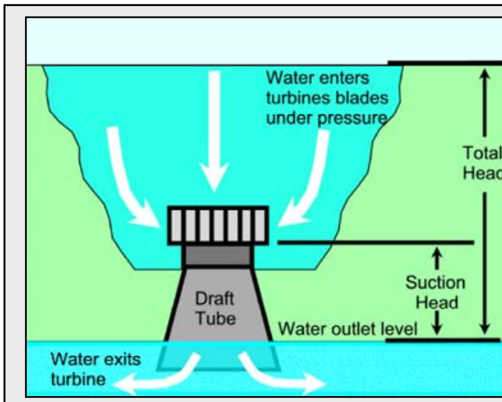
Water Pressure exerts force on a diver

A reaction turbine uses "pressure head" in the same way to produce electricity. If you substitute the diver in the picture for a submerged reaction turbine, you can imagine how the pressure of all that water under pressure falling through the turbine blades creates the force to turn the blades and produce electricity. This 'pressure head' accounts for most of the power output of a reaction turbine.



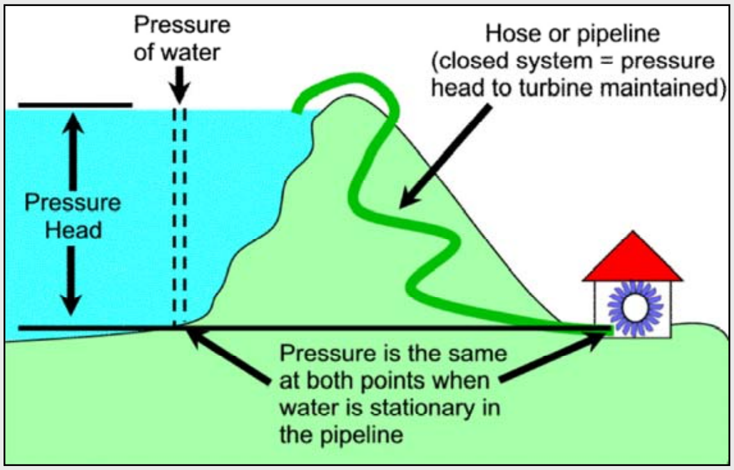
'Pressure Head' for a Reaction Turbine

In addition, many reaction turbines also have a water discharge tube called a 'draft tube', which can increase the head by producing a vacuum between the turbine runner blades and the level of the exit water. This is called the 'suction head' and can increase power output of the turbine by up to 20% if it is set up properly. It is important that it is completely submerged in the tail water with no air leaks, maintaining a closed system and thus the vacuum suction. With this system, the total head is a combination of the pressure head and the suction head.



'Suction Head' for a Reaction Turbine

Another important characteristic of water is that it is essentially a non-compressible liquid. This means it exhibits the unique trait of transferring pressure horizontally when in a confined space (what we define as a closed system). This becomes very important in hydro systems where a pipeline is involved, which is always the case with impulse turbines and is occasionally used with reaction turbines as well. Water that enters a pipe exhibits the same pressure at the bottom as it would if the pipe were perfectly vertical, even if the pipe itself isn't. The best way to demonstrate this is with a picture.



'Pressure Head' for an Impulse Turbine System

As long as the water is not flowing through the pipeline, the pressure of the water at the lower end of the pipe is exactly the same as the water pressure at an equivalent level directly below the inlet. This is true no matter how long the pipe is. Because the water is a non-compressible liquid it transfers the pressure horizontally along the pipe route for any distance without any loss of pressure. This is called the "static pressure" (or "static head") of the water.

If this system were completely frictionless, the pressure would remain the same when the water was flowing as well. However, there is friction between the water and the inner surface of the pipeline, causing the pressure to drop once the water is moving (called "friction loss"). The usable force of the water when it reaches the turbine is called the "dynamic pressure" (or "dynamic head"), and is calculated by subtracting the friction loss caused by the pipeline from the amount of static head. The total length and diameter of the pipe you use becomes important in planning your system, because you always want to minimize your friction losses.

Impulse turbines are not submerged in the water, and thus the water exits the closed system when it exits the pipeline at the turbine nozzle. Hence there is no suction head and in an impulse turbine the total head is equal to the pressure head.

What we are beginning to see is that in a hydro system, it's not just important how much head and how much flow you have available in a theoretical sense, it's also really important to consider how you can get that water to your turbine location with as little loss as possible.

An analogy could be made with driving your car. Your car has a certain potential amount of power it can produce. But the amount of power you use at any given time has a lot to do with the road you are traveling on. A twisting, winding road will not allow you to move as fast as a straight one. A muddy road will not let you move as fast as nice smooth pavement. In the same way, it's not just the amount of power (from head) that you can theoretically get from your water source, it's also the 'road' you build to get your water to the turbine. We call this road a '**diversion system**', and just like with a road, water prefers nice straight diversion systems without abrupt turns and smooth walls.

Types of Diversion Systems *(Open and Closed)*

"Diversion System" refers to the means that you use to "divert" water from the source and transport it to your turbine. There are various methods for diverting and transporting the water, but diversion systems can be grouped into two basic types – "open" and "closed" systems. Matching the correct type of diversion system to a particular style of micro-hydro turbine is critical to the optimal performance of the turbine. In general, impulse turbines (which produce power primarily from head pressure) will utilize a closed diversion system. Reaction turbines (which produce power primarily from water volume) will normally work best with an open diversion system.

Whether a Diversion System is classified as "open" or "closed" depends on the point in the diversion system at which gravitational forces directly impact the water.

In a "closed" diversion system (such as a pipe), the system is sealed and water is isolated from direct gravitational forces while in the pipe. The water surface at the inlet to the pipe is the point at which gravity directly affects the water, and is, therefore, the starting elevation for the system head. Since the water exits the closed diversion system at the turbine, the turbine elevation becomes the ending elevation for calculating system pressure head. Closed diversion systems work well for developing high pressure head with relatively low water flow volumes.

In an "open" diversion system (such as a canal), the water along the entire diversion system is directly exposed to gravity. In an open diversion system, then, the last point at which gravity directly impacts the water is the water surface directly above the turbine inlet. Hence, the starting elevation for the pressure head is often the water surface directly above the turbine. The ending point for pressure head is the turbine impeller. Open diversion systems work well for supplying large volumes of water to the turbine with low friction losses. Some disadvantages of the open diversion systems are that they may involve more work to set up initially and, in cold climates, the slow moving water is more subject to freezing.

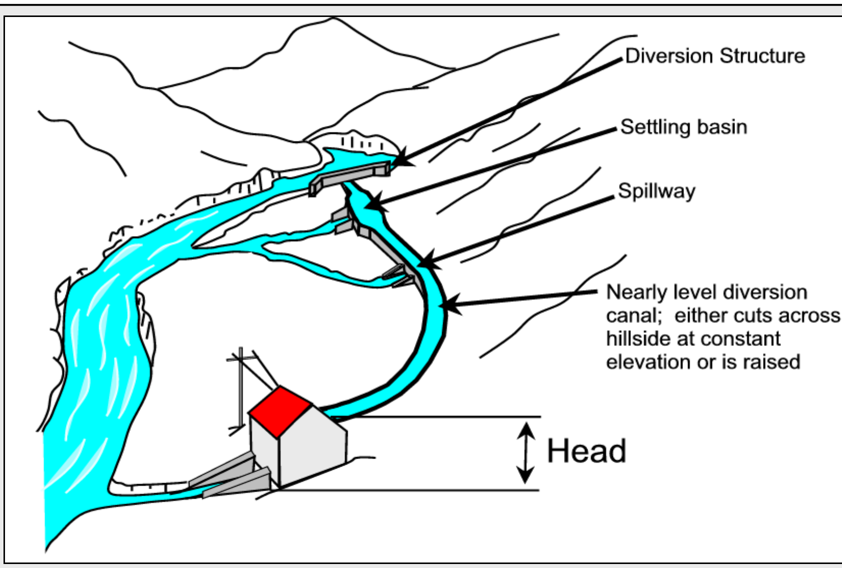
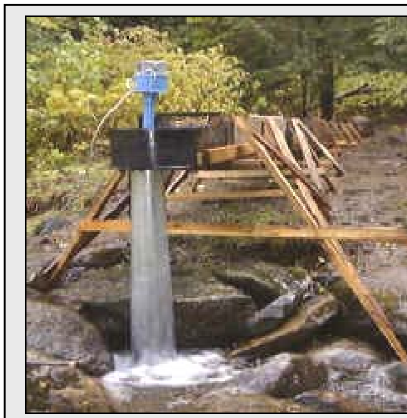


Diagram of the main elements in an open diversion system: In this case, the useable head is the elevation difference between the level of the river water and the level of the water in the open diversion canal at the turbine location.

Some reaction turbines (such as the Nautilus) may utilize a combination of open and closed diversion systems, with the open system leading to a



Example of a raised open diversion canal

closed system (such as a pipe). The open segment diverts a large volume of water close to the turbine site, while the closed portion allows development of the necessary pressure head for the turbine without the expense of long lengths of piping. In these combination systems, the starting elevation for the pressure head is the water surface at the point where the water enters the closed system.

Now, a comment on static and dynamic pressures. In both instances we are talking about the pressure at the bottom of the column of water. Static pressure refers to the pressure when the water in the column is static, or not moving. Dynamic pressure refers to the available pressure when the water is moving, and is the static pressure less system pressure losses due to friction and turbulence. Since hydro turbines draw their power from moving water, dynamic pressure is the important pressure.

In closed diversion systems, there can be significant system pressure losses due to friction on the pipe inner wall, bends in the pipe, valves, etc. and turbulence due to incomplete filling of the pipe. Thus, in closed systems there can be a substantial difference between static and dynamic pressure. It is imperative that the closed diversion system be designed to optimize the dynamic pressure and that the dynamic pressure is calculated and utilized.

In open diversion systems, the larger system capacity and slower water speed tend to minimize system friction or turbulence losses. System friction and turbulence losses are still an issue but are less critical for open diversion systems since there is far less difference between static and dynamic pressure.

Optimizing both the static and dynamic pressures are a cost-benefit analysis. The baseline is meeting the minimum turbine pressure and flow requirements. Beyond that minimum, the site and diversion system selections center on achieving the best power-to-cost ratio. More information regarding the design of closed diversion systems can be found in Appendices 7 and 8. More information regarding the design of open diversion systems can be found in Appendix 9.

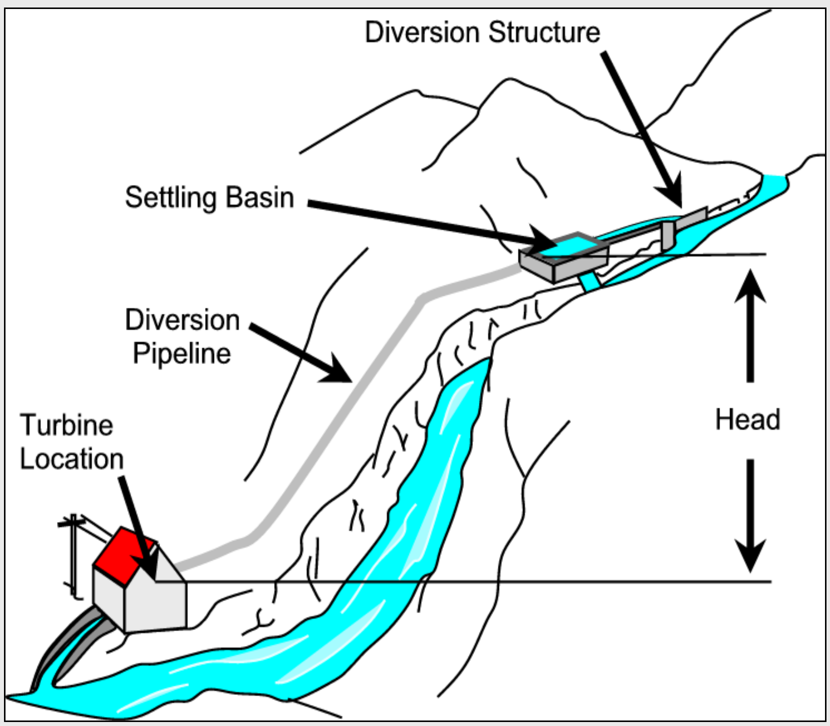


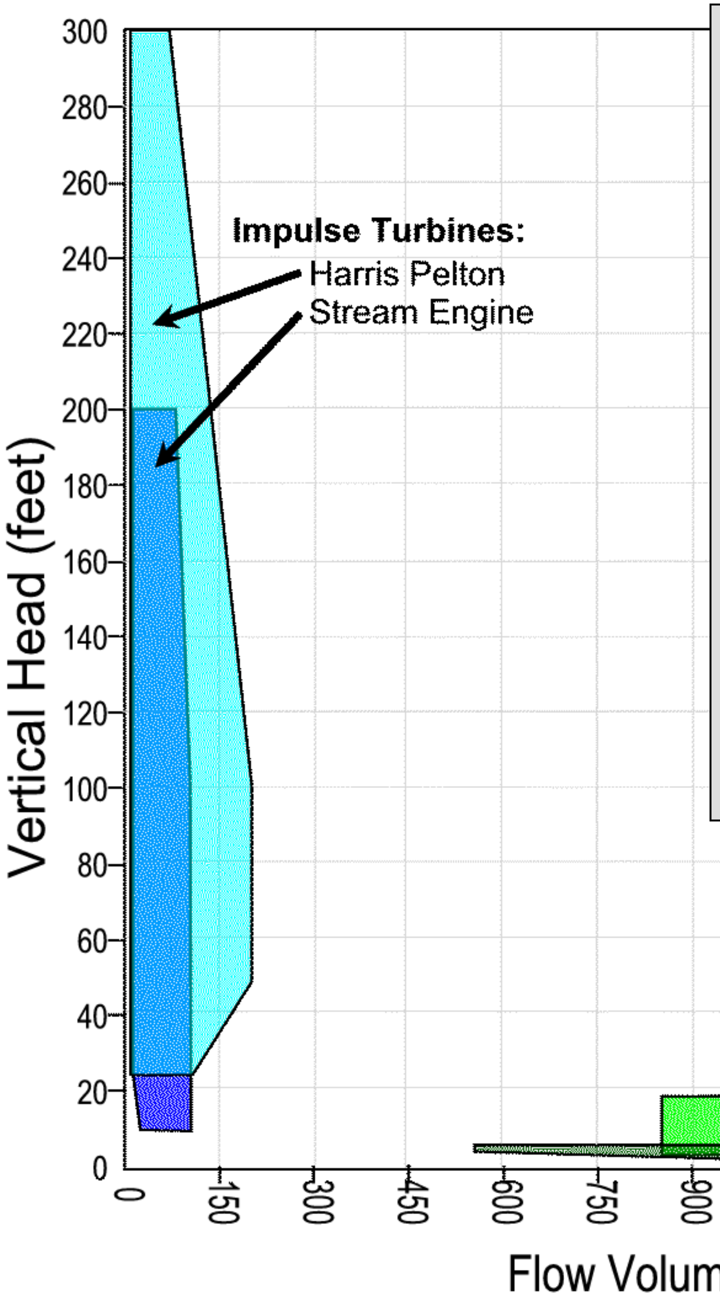
Diagram of main elements in closed diversion systems: In this case, the useable head is the elevation difference between the water level at the pipeline intake and the turbine nozzle, after friction losses are taken into account.

Micro Hydro Turbines ...

On the next few pages, you will find detailed information about each turbine we carry, but on this page we have included most of them in a graph depicting the optimal performance ranges for each one. You can clearly see the difference between the impulse and reaction turbines. Impulse turbines can operate over a wide range of vertical head, but narrow flow range. Reaction turbines operate over a wide range of high flow, but low head.

Use an Impulse Turbine

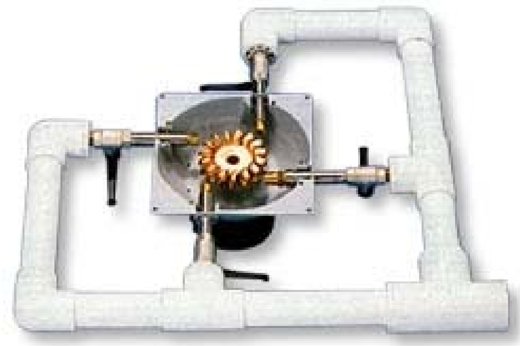
Use a Reaction Turbine



ABS Alaskan Inc. introduces …

The Harris Pelton

Hydro Turbine



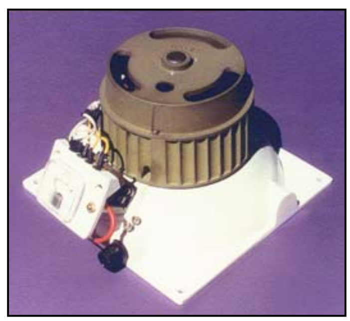
- **Can produce over 1.5kW of power**
- **Operates most efficiently on high head (above 25ft)**
- **Effective operation with ultra low flow (3GPM and greater)**
- **Reliable, year-round electricity at low cost**

Water is collected upstream from the turbine and channeled in a pipe down to the turbine location. At the turbine, the water passes through a nozzle, where it accelerates, strikes the turbine runner, and turns a brushless permanent magnet alternator.

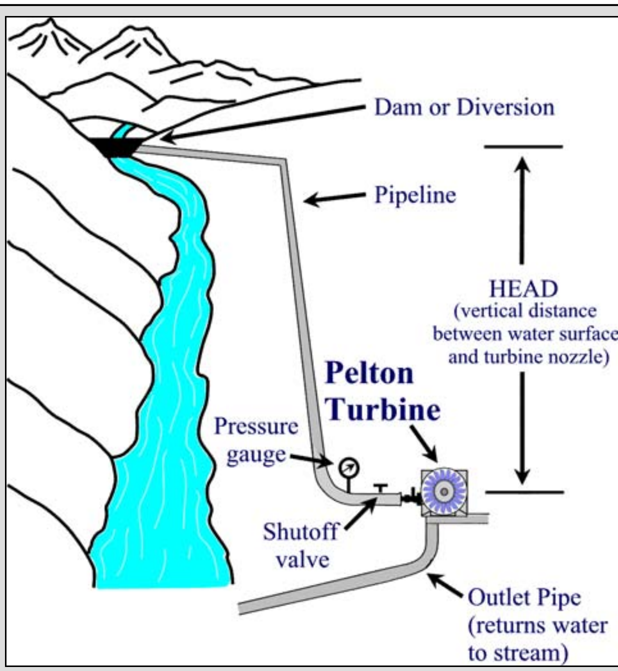
These turbines need very little water flow to run efficiently and produce significant power output. The standard configuration uses one nozzle, which is sized to match the water supply. Additional nozzles can be added (up to 4) with a maximum flow at each nozzle of 30 GPM.

Typically, the turbine generates DC electricity – 12volt, 24volt or 48volt – which is then either stored in a battery for future use or used directly to power DC appliances. An inverter can also be incorporated into the system to convert the DC electricity to standard household AC electricity.

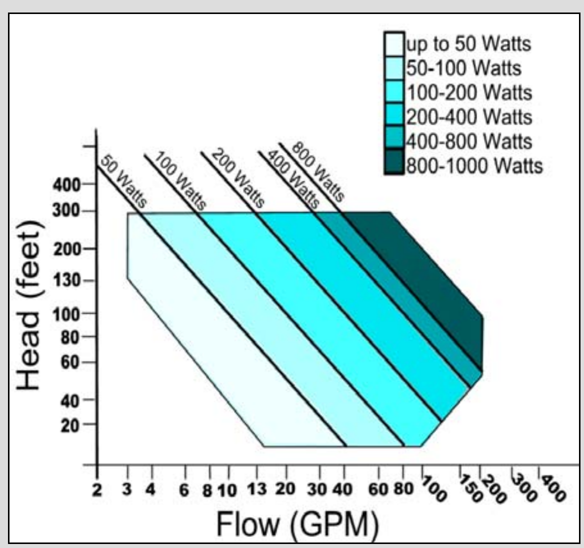
Close-up of the Harris Pelton Turbine runner



The Harris Pelton Hydro Turbine



Typical Harris Pelton Setup



Harris Pelton Optimal Power Output
(graph is in logarithmic scale)

ABS Alaskan, Inc. introduces …

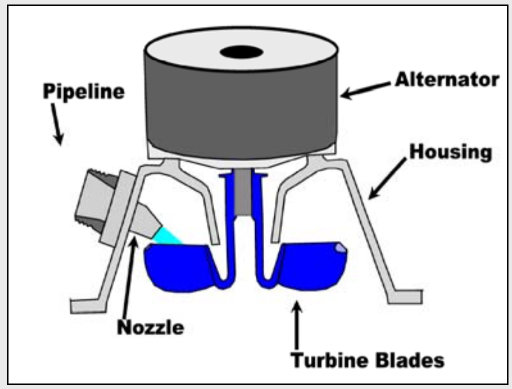
The Stream Engine
Hydro Turbine

- **Can produce over 1kW of power**
- **Operates efficiently on low head (down to 5 ft)**
- **Easy installation and low maintenance**

Water is collected upstream from the turbine and channeled in a pipe down to the turbine location. These turbines don't need a lot of elevation change to run efficiently and produce significant power output.

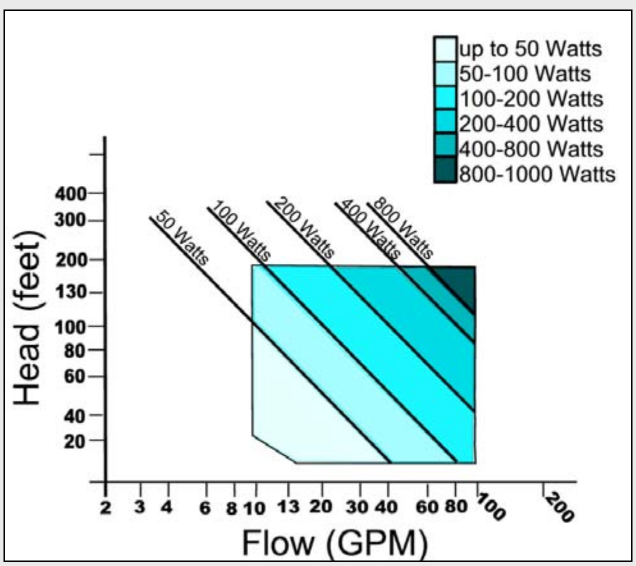
This means you'll get about the same amount of power from 6ft of head and a flow of 400GPM as from a flow of 6GPM and 400ft of head.

The Stream Engine has a brushless permanent magnet alternator driven by a 'Turgo' runner. In micro-hydro applications, the Turgo style runner is better suited to higher flow rates than the 'Pelton' runner, due to a design more efficient at removing large quantities of water from the system with minimal loses from back pressure.



Cross Section of Stream Engine
(Drawing is not to scale)

The standard configuration uses two nozzles, which are adjusted on-site to match the water supply. These turbines generate DC electricity – 12volt, 24volt, or 48volt – which is then either stored in a battery for future use or used directly to power DC appliances.



Stream Engine Optimal Power Output
(Graph is in logarithmic scale)

The Stream Engine with the Turgo runner housed in the white casing, the permanent magnet alternator on top and the controller in the foreground (silver box)

ABS Alaskan, Inc. introduces ...

The Water Baby

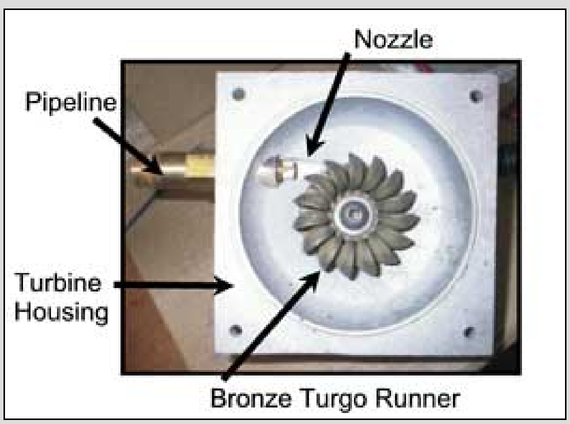
Hydro Turbine

- Operates efficiently on ultra low flow (3 GPM)
- Super lightweight and compact design
- High quality turbine at a low price

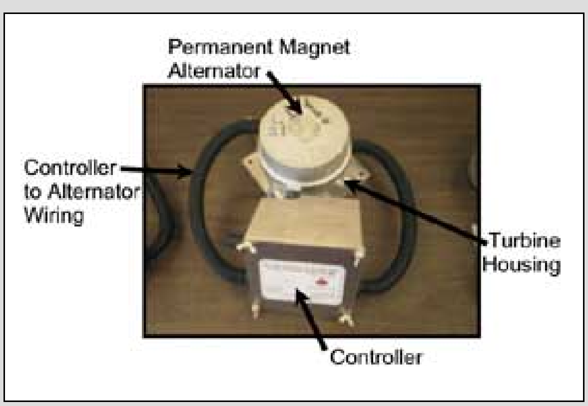
This turbine is a smaller ('baby') version of the Stream Engine. It is a lightweight and compact device which converts energy in water under pressure into electricity. It can operate on flow rates as low as 3 GPM, on heads from 50-500ft. To compare, 3 GPM is only slightly greater than the amount of water flowing out of a typical water faucet in your home. The Water Baby's bronze turgo runner is only 2 inches in diameter, making this one of the smallest turbines on the market. It the perfect hydro turbine for a site with low flow rate but a large 'drop' in elevation, such as a spring coming out of a hillside or a mountain stream.

The Water Baby uses a maintenance free, highly efficient permanent magnet alternator. This alternator is specially designed to allow adjustments in output to be made while the turbine is spinning. This feature greatly simplifies optimization of power output for each hydro site.

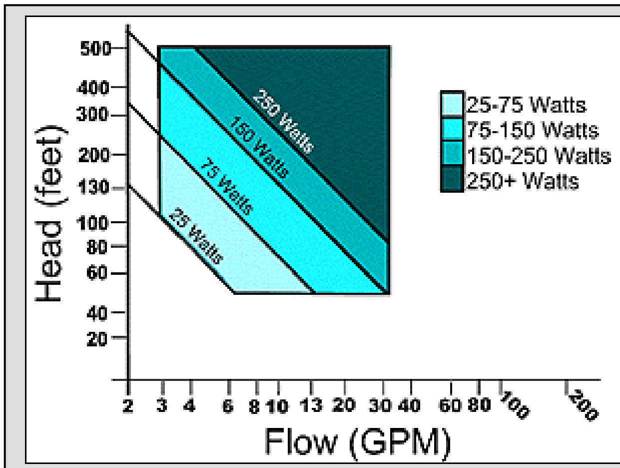
The Water Baby comes standard with 12V, 24V or 48V DC output. It can also be outfitted with additional nozzles (up to 4) to accommodate higher flow rate. A high voltage option is also available for longer transmission distances.



Bottom View of the Water Baby



Components of the Water Baby



Optimal Water Baby Power Output

ABS Alaskan, Inc. introduces …

The LH-1000

Hydro Turbine

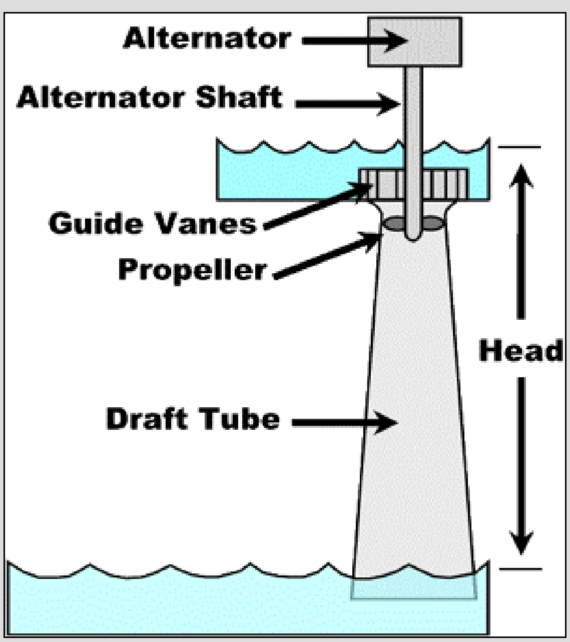
- Produces up to 1 kW of electricity
- High quality turbine at a low price
- Ultra low head (2 ft to 10 ft)

The LH1000 is an exciting hydro turbine that produces DC electrical power at sites with sufficient water flowing across relatively level terrain. The LH1000 uses a durable, low-head bronze propeller to produce power on a head of 2 to 10 feet. At 10 ft of head, the output from this turbine is <u>one kilowatt</u>, which is enough to supply the electrical requirements for an average household.

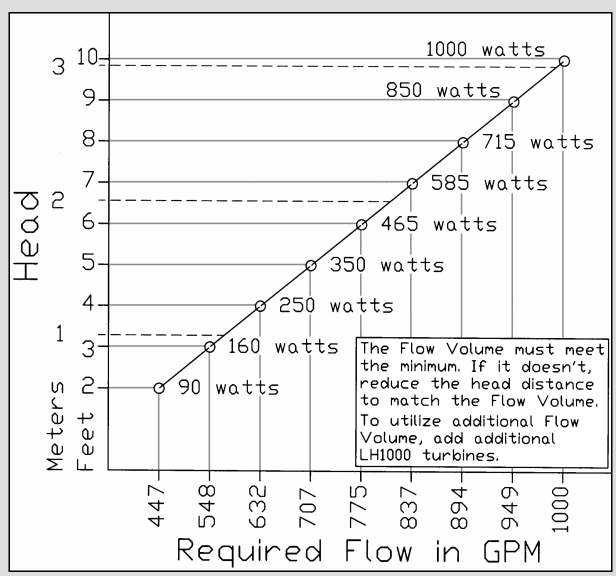
The LH1000 uses a permanent magnet alternator, which increases efficiency and performance while greatly reducing maintenance. This alternator is specifically designed for DC electrical output, eliminating the extra cost and inconvenience of an external turbine speed controller.

Water enters the LH1000 through the top guide vane assembly. As it falls through the turbine it turns the propeller, which spins the alternator, creating electricity. The water then exits the turbine through the draft tube, which is a sealed, tapered tube immersed in the tailwater. The draft tube creates a suction effect in the turbine, greatly increasing the turbine capacity.

The LH1000's light weight and small size allow for easy installation, portability, and quick removal during adverse conditions.



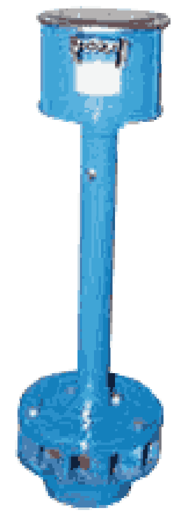
Basic Components of the LH1000



Optimal LH1000 Power Output

Required Water Flow Volume & Power Output in Watts for Various Head Distances.

ABS Alaskan, Inc. introduces ...



The PowerPal

Propeller Hydro Turbine

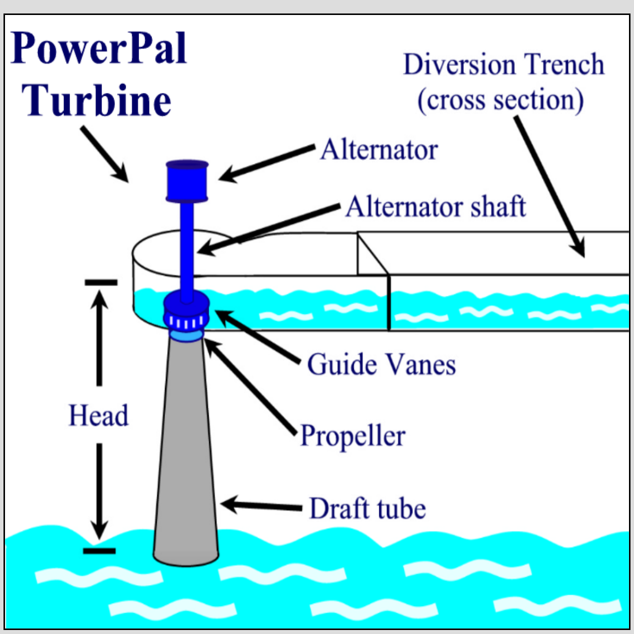
- **Power Production at 200W, 500W or 1000W (3 models to choose from)**
- **Operates efficiently on ultra low head (2 to 5ft)**
- **Designed for simple operation & low maintenance**

The PowerPal was designed for families in remote areas to produce power for their households easily and inexpensively. These units have been incredibly successful and today thousands are installed throughout the world.

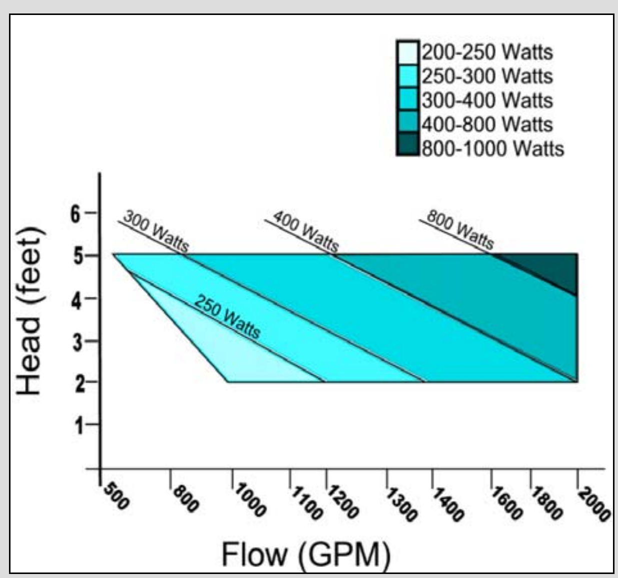
The PowerPal is a propeller turbine whose small size and light weight allows it to be installed virtually anywhere. It is the perfect hydro turbine for slow moving rivers and streams. Small, natural waterfalls or dams provide the ideal setting for the PowerPal.

Water enters the turbine from the top and drops into the propeller, spinning the blades. It exits the turbine through a sealed draft tube that is submerged in the outlet water, creating suction and increasing power production.

It can be quickly and easily moved to a new location, or removed temporarily during flooding or other adverse conditions. The PowerPal is designed to operate on a head (vertical distance between inlet water surface and the outlet surface) of 2 to 5 ft.



Typical PowerPal Setup



Optimal PowerPal Power Output
(graph is logarithmic scale)

ABS Alaskan, Inc. introduces …

The Nautilus

Hydro Turbine

- **Produces over 3kW of power**
- **Operates efficiently on low head (4-18ft)**
- **High quality design with expected life of 50 years**

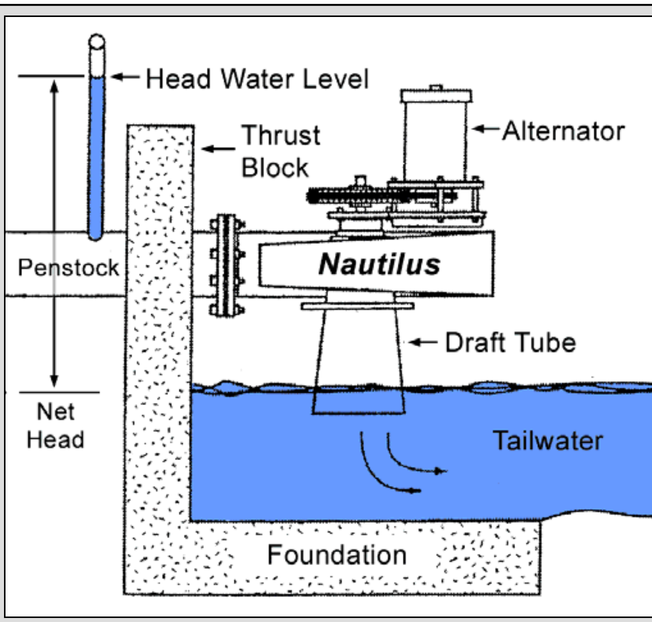
The Nautilus is a Francis-style turbine capable of tremendous power output in a compact design. It will power your home and shop for generations on as little as four feet of head. Water is channeled to the turbine via a 'Penstock', or large diameter pipe. The Nautilus is unique in that it uses both a 'closed' water diversion system prior to the turbine (providing substantial 'pressure head'), while also using a 'Draft Tube' from the turbine to the tail water (producing 'suction head').

The Nautilus Turbine in action

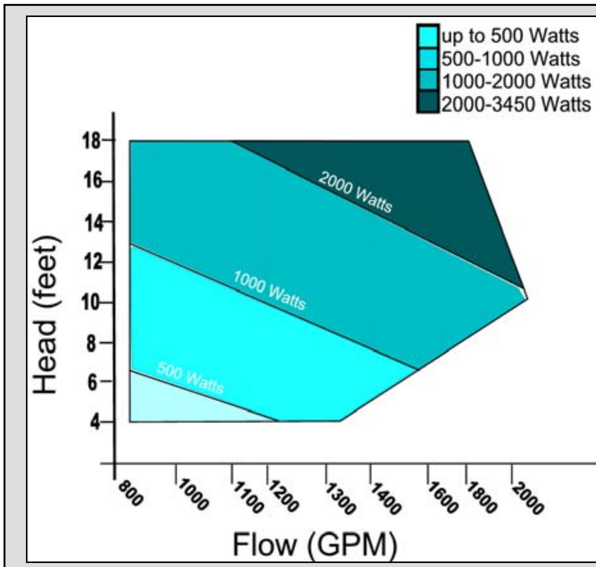
The Nautilus has an expected life of over 50 years. All components are made of laser-cut stainless steel to insure smooth water surfaces that will never rust. Massive taper roller bearings and carbon/ceramic face seals will last 7-10 years between refits.

The Nautilus can be disassembled and easily transported into the most remote areas as no single component weighs over 95 lbs. (44 kg.). The total assembled weight (without the alternator) is under 230 lbs. (105 kg.).

The Nautilus turbine is available with either an 8 inch (203 mm) or a 10 inch (254 mm) stainless steel runner. Using the 8" runner (shown in graph), 1800 GPM and 18 ft (5.5 m) of head will produce almost 3500 watts of power. With the 10" runner, 2100 GPM and 10 ft (3 m) of head will produce over 2200 watts of power.



Basic components of a Nautilus hydro system



Optimal Nautilus Power Output
With 8 inch runner option
(graph is in logarithmic scale)

ABS Alaskan, Inc. introduces …

The Neptune

Hydro Turbine

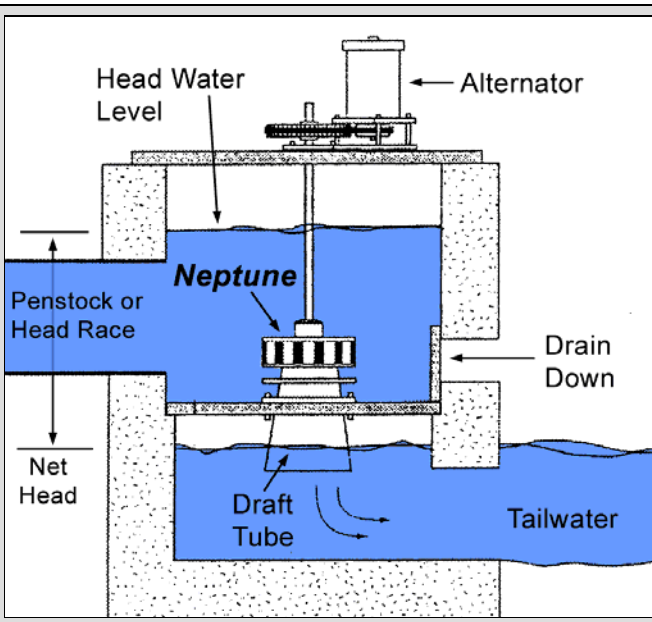
- **Produces over 2.2kW of power**
- **Very effective low head (3-10 ft) turbine**
- **High quality design and long service life**

The Neptune is a Francis-style turbine capable of tremendous power output in a compact design. It will provide power for generations on as little as four feet of head. It is essential the same as the Nautilus turbine, except that the water, whether channeled to the turbine via pipe or open canal, empties into an open chamber in the turbine. This 'open' water diversion system prior to the turbine means that the 'pressure head' is limited to the depth of the water directly above the turbine. Like the Nautilus turbine, it uses a 'Draft Tube' from the turbine to the tail water, also producing 'suction head'. The Neptune turbine is ideally suited for low head applications. For heads over 8 ft (2.5 m), the Nautilus turbine is recommended.

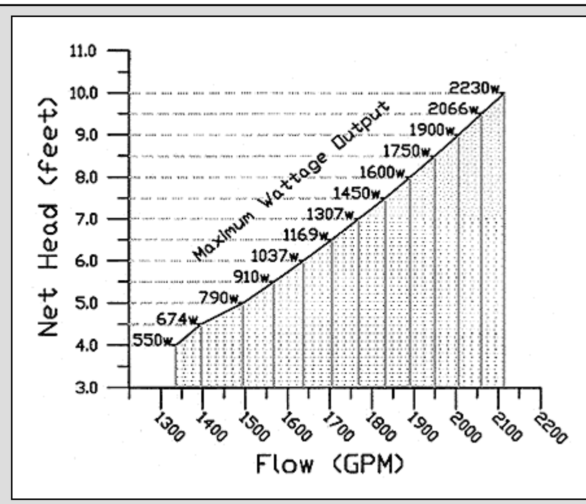
The Neptune has an expected life of over 50 years. All components are made of laser-cut stainless steel to insure smooth water surfaces that will never rust. Massive taper roller bearings and carbon/ceramic face seals will last 7-10 years between refits.

The Neptune can be disassembled and easily transported into the most areas. There are several permanent magnet alternator choices, available in both direct-coupled and timing-belt driven configurations, and with 24VDC, 48VDC, and high voltage DC output.

The Neptune turbine is available with either an 8 inch (203 mm) or a 10 inch (254 mm) stainless steel runner. Using the 10" runner (shown in graph), electrical output will vary from 550 watts at 4 ft (1.2 m) of head and 1350 GPM of flow to over 2200 watts with 10 ft (3 m) of head and 2100 GPM of flow.



Basic components of a Neptune hydro system



Optimal Neptune Power Output
With 10 inch runner option

ABS Alaskan, Inc. introduces …

The Niade

Hydro Turbine

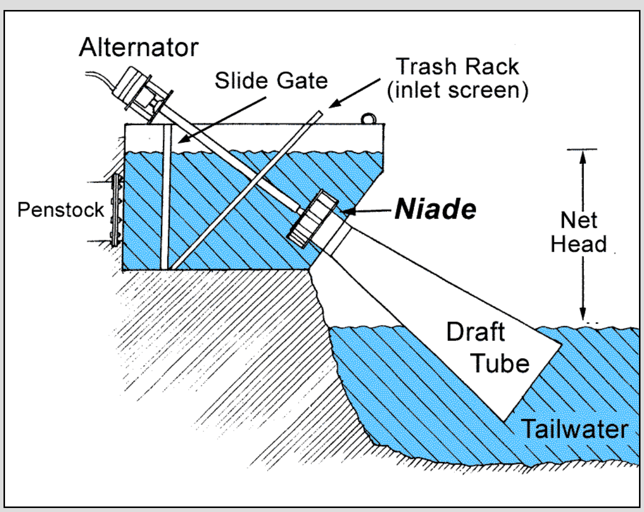
- 700 watts peak output (9 in. model)
- Produces power from 2 – 4 feet of head
- Shipped complete, easy install, no hidden costs

The Niade is an ultra-low head propeller style turbine in a complete housing for ‘drop in’ installation in almost any low-head site. Like the Nautilus and Neptune turbines, it uses a ‘draft tube’ from the turbine to the tail water, also producing ‘suction head’ to maximize output. The Niade turbine is the first micro-hydro turbine in the world to produce usable power with less than 4 feet of head.

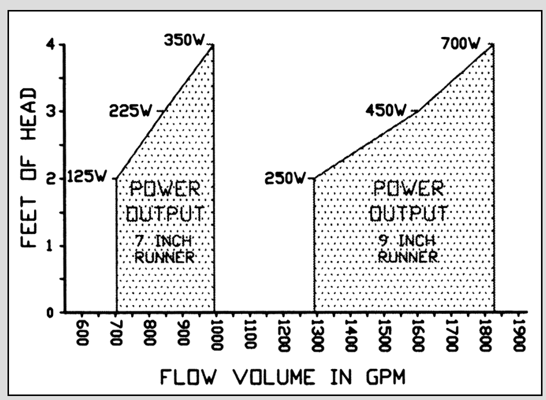
The Niade is delivered as a complete package, including the cast-iron propeller turbine and housing, draft tube, slide gate (to shut off water flowing into the turbine), a protective trash rack/inlet screen and the alternator. The complete package is ready to install, with no hidden costs or extra accessories needed.

The Niade can be lifted with a small front-end loader, or even by hand with enough man power, weighing in at 300-400 lbs. It is a rugged, durable design, intended for user installation in nearly-level sites where other turbines cannot develop enough head to produce usable power. The Niade should be installed with the housing/flume level with the surrounding land, allowing the draft tube to angle downwards into the tail race excavation. After attaching the flume inlet to your installed penstock, and backfilling the excavation to stabilize the turbine, the Niade is ready to wire into your power system.

The Niade turbine is available with either an 7 inch or a 9 inch cast iron runner. Using the 9” runner, electrical output will vary from 250 watts at 2 ft of head and 1293 GPM of flow to over 700 watts with 4 ft of head and 1828 GPM of flow. With the 7” model, the Niade will produce from 125 watts at 2 ft. of head with 704 GPM flow, up to 350 watts with 4 feet of head and 994 GPM of flow.



Basic components of a Niade hydro system



Optimal Niade Power Output

ABS Alaskan, Inc. introduces …

The Aquair UW
Submersible HydroTurbine

- **Produces up to 100W of continuous power**
- **No pipeline or diversion channel necessary**
- **Effective operation in as little as 18 inches of water**
- **Simple installation and low maintenance**

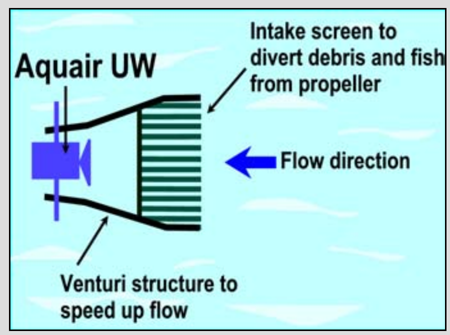
The AQUAIR UW is a propeller turbine of simple design and rugged construction. It was originally developed for use aboard seismic sleds towed behind oil exploration vessels. We like the AQUAIR UW because unlike other micro-hydro units where head, flow volume and nozzle pressure are factors, this unit simply requires _fast_ moving water from a flowing stream, creek, river or sea.

The propeller is lowered into the water and held into place with a steady mount (not included). Power output is directly related to water speed, and at a flow of 6mph output will be around 60W, while at a flow of 9mph power generation will increase to 100W.

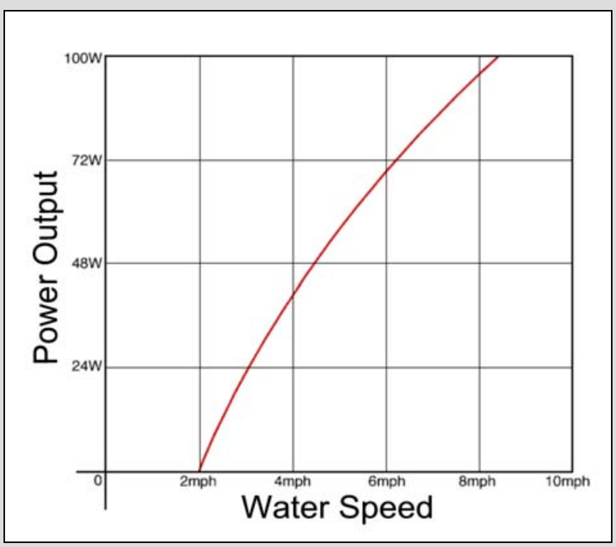
Water speed can be increased somewhat by use of a venturi pipe in the water upstream of the propeller, or by taking strategic advantage of the natural venturi effect created behind a large rock or submerged log.

The AQUAIR UW submersible generator is a rugged permanent-magnet low-speed high-output alternator sealed in an oil-filled waterproof housing.

It is ideally suited for use as an alternative power source for remote cabins when connected to storage batteries and an inverter. The AQUAIR UW Submersible Generator is warranted for three years.



Aerial view of Aquair and venturi structure



Aquair UW Power Output (in Watts)

Aquair UW with 4m of cable, heat sink and manual, all included

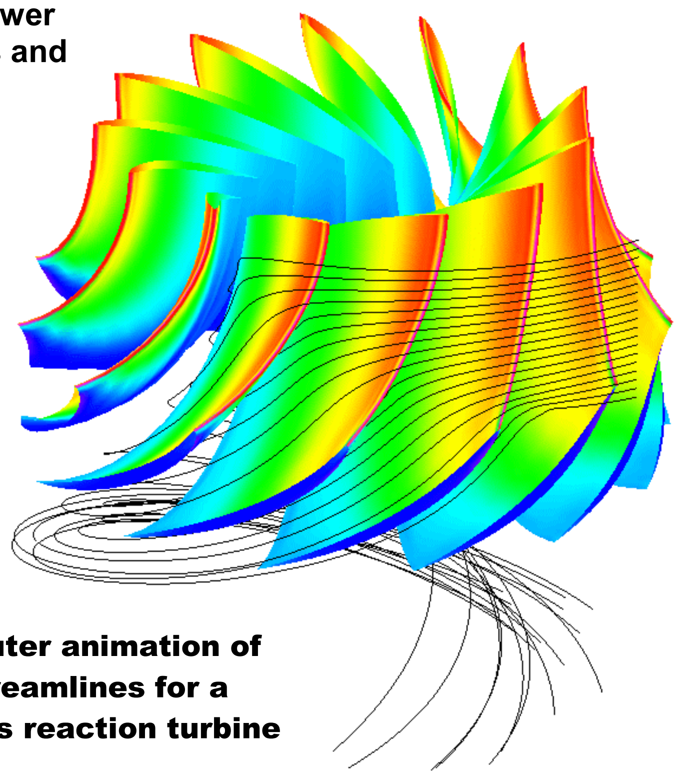
Appendix 1: *Developing your Hydro Site*

The purpose of the appendices on the following pages is to walk you through the steps in determining whether you have a potential hydro site, and if so, what type of hydro turbine and other system components you should use. By the time you get to these pages, you should have read through the general hydropower and turbine theory on pages 3-11. Listed below are the basic steps to developing your hydro site. This list forms only a basic framework to follow; many of these steps are interchangeable.

1. Determine the available head and flow you have available at your potential hydro site. (see appendix 2)
2. Determine your household power requirements (see appendix 3)
3. Determine whether you will use a stand alone hydro system or a hybrid system (see appendix 4)
4. Consider the other elements you want to include in your electrical system (see appendix 5)
5. Determine what sort of turbine fits your available head, flow, and power requirements (see appendix 6)
6. Design your diversion system
    a. For a closed diversion system, reference appendix 7 and 8
    b. For an open diversion system, reference appendix 9

In addition, several other appendices are included at the end of this book, which include some additional information on hydropower you may find helpful. These include:

Appendix 10: History of Hydropower
Appendix 11: Important formulas and Conversion factors
Appendix 12: Glossary of terms



Computer animation of the streamlines for a Francis reaction turbine

Appendix 2: *Determining Available Head & Flow*

Measuring Head: *Closed Diversion Systems*

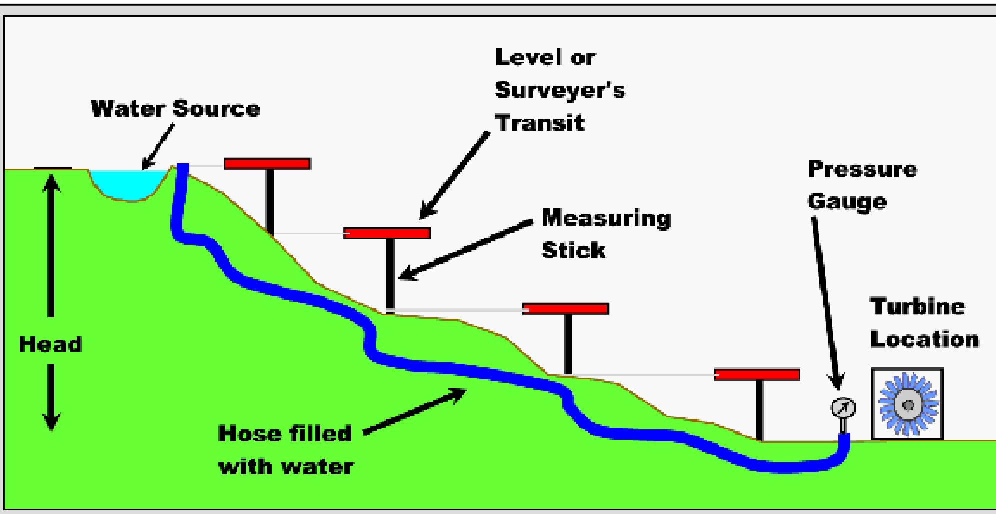
Selecting The Water Source Site

There may be several potential water source points, particularly if the water source is a river or stream. Each one will have a different elevation and linear distance from the hydro turbine. In selecting the best site, several factors to consider are water availability, site access, topography of the site, elevation (potential static head), linear distance from the turbine, head pressure required for the turbine, and the volume of water required for the turbine. The best site will usually be the one that has the best cost-benefit ratio (the least cost per kWh of electricity produced). The site with the highest elevation may not be the best, as that site may also have the highest incremental cost of diverting and transporting the water to the turbine.

Measuring The Available Head

Head is a vertical distance. It's starting point is where the water begins to impact the pressure at the hydro turbine and it's ending point is where the water ceases to affect the pressure at the hydro turbine. With closed diversion systems, head is the change in elevation from the water surface at the inlet to the closed diversion system and the elevation at the turbine nozzle. Head is the most important factor in determining if your site is adequate for an impulse type turbine. There are a couple of commonly used methods of measuring head for a closed diversion system:

1. Use a transit or level and a measuring stick of known length to measure the vertical elevation change in successive steps down the slope. The cumulative total of the vertical measurements is the head in feet.
2. Assemble a temporary piping system (a series of connected garden hoses works well for this) and, with a water pressure gauge, measure the static pressure (in pounds per square inch or PSI) at the lower end of the hose system with the hose filled with water. Convert the static pressure to vertical feet of head, using the formula 0.43 PSI = 1.0 foot of head. This method can also be done in successive steps to measure total head over a longer distance. This method is quite accurate.



Determining head for a closed diversion system

Note: The expected error range of ± 50 ft on GPS altitude readings prevents GPS from being an accurate method for determining head.

Measuring Head: *Open Diversion Systems*

Selecting The Water Source Site

Water source site selection and head calculation for open diversion systems requires a different approach. The minimum head requirements for reactive turbines and open diversion systems are much less than the requirements for impulse turbines and closed diversion systems, and they are much easier to attain.

All of the water source site selection criteria for closed diversion systems also apply to open diversion systems. However, the cost-benefit analysis for open diversion systems focuses on water volume, instead of water pressure, as the benefit.

Measuring The Available Head

With open diversion systems, you are not as concerned with high heads (high pressures) as with large volumes of water. The turbine (usually a reaction turbine) is submerged in the water at the end of the open diversion system.

With impulse turbines the water exits the closed diversion system at the turbine so we are only dealing with the head prior to the turbine, or pressure head. With reaction turbines there can also be a closed system for the water exiting the turbine, creating suction head.

The pressure head for open diversion systems is the vertical distance between the water surface above the turbine and the turbine impellers. This distance is usually less than ten feet and is easily measured. If a draft tube is used (see page 8), there is also suction head for these turbines. The suction head must also be measured. The total head is the pressure head (prior to the turbine) plus the suction head (after the turbine).

Measuring Flow

Note: The term 'Flow' as used in conjunction with micro hydro represents volume, not speed. It is the volume of water, stated as Cubic Feet Per Second (ft^3/s) or gallons per minute (GPM), that flows past a specific point in a specific amount of time.

Method 1:

The simplest way to measure flow is via a four-step process:

1) Measure the speed of the water (in feet per second)
2) Determine the cross-sectional area of the water source (in square feet) by measuring and multiplying the average water depth (in feet) X the average water width (in feet)
3) Calculate the flow (in cubic feet per second) by multiplying the water speed X the cross-sectional area.
4) Convert the flow in cubic feet per second to flow in gallons per minute by multiplying by the flow in ft^3/s X 450.

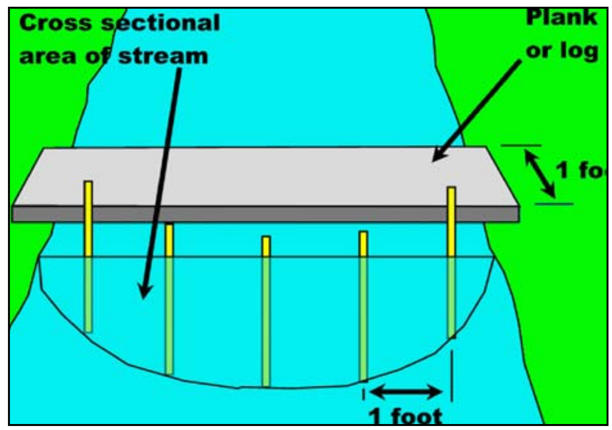
Water Speed

Determining the water speed is easy. Pick a representative segment of river or stream close to the expected water diversion point. Place two stakes 50 feet apart along the bank, marking the upper and lower limits of this segment. Drop a ping-pong ball (or other lightweight, floating object) into the current opposite the upper stake. Time (a wrist watch with a second hand works great!) how long it takes for the ping-pong ball to travel the 50 feet.

Take this measurement several times and calculate the average time (add all times and divide by the number of trials). This is the speed of the water through the segment *at the surface*. Not all water moves as fast as the surface because there is friction at the bottom and along the banks. To calculate the overall average speed of the water, multiply the surface speed X .80.

Cross-Sectional Area

Now we can measure and calculate the cross-sectional area of a 'slice' of the water. In the segment used above for determining water speed, select a spot that will provide a representative water depth and width for the 50 ft segment.



Measure and record the water depth at one foot increments along a cross section (water-edge to water-edge) of the river or stream at this spot. Laying a log or plank across the river or stream from which you can take these measurements is convenient.

You can also wade (or boat) across but take care that you are measuring the actual water depth and not the depth of water affected by your presence in the water. Calculate the average depth of the water (as explained above during water speed).

Measure and record the width of the river or stream (in feet and from water-edge to water-edge). Multiply the average depth **X** the width. You now have the cross-sectional area (in square feet) of that 'slice' of the river or stream.

Calculating Flow

You can now use the following equation to calculate your Flow.

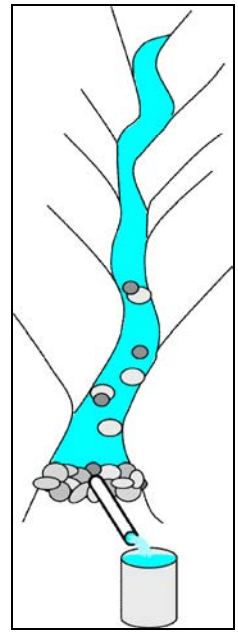
Water Speed (ft/sec) X Cross Sectional Area (sq ft) = Flow (cu ft per second)
Flow (cubic feet per second) X 450 = Flow (gallons per minute)

Calculate the flow in cubic feet/second first by multiplying the average speed (in feet per second) **X** the cross-sectional area (in square feet). Then convert the flow from cubic feet per second to gallons per minute (GPM) by multiplying the cubic feet per second **X** 450.

Method 2:

Sometimes with small, intermittent, or steeply dropping streams, it is difficult to accurately measure the average depth, width, and/or water speed. This is fairly common with water sources for impulse turbines, since they can operate with low water volumes. In these instances, it is possible to temporarily 'gather' the water by using sand bags, rocks, wood, etc. to create a temporary dam.

Insert a short length of pipe in the middle of this dam, preferably the same diameter of pipe that you later plan to use for your diversion system pipeline. The inlet to this pipe must be completely submerged in the water behind the temporary dam.



Fill a container of known volume (in gallons) with the water exiting the pipe, timing (in seconds) how long it takes to fill. Like above, conduct this measurement several times and calculate the average. Using the 60 seconds = 1 minute relationship, calculate how many gallons would exit the pipe in one minute. You now have your flow in GPM.

Example:

The container holds 5.5 gallons

The average time to fill the container is 15 seconds

$$5.5 \text{ gallons} \times \frac{60 \text{ seconds}}{15 \text{ seconds}} = 20 \text{ gal./minute (GPM)}$$

Seasonal Changes In Water Availability

When taking flow measurements for both closed and open diversion systems, evaluate any seasonal deviations in the source water level, such as low water during dry spells or flooding, and take these into account when determining the potential flow, diversion system size, and hydro turbine output.

Remember, though, that the requirement is to keep the pipe full or keep enough water in the diversion canal to supply the turbine. Any flow capacity at the water source that is in excess of the turbine requirement, even during dry spells and low water, is immaterial.

Appendix 3: *Household Power Requirements*

So how much power do your appliances use? The table below shows approximate power requirements of some common appliances. However, the actual power consumption of your appliances may vary considerably from these figures. Check the power tag, or better yet measure the ampere draw with a multimeter. Multiply the hours used on the average day for each appliance by the Watts per hour listed below. This will give you the Watt-hours consumed per day, which can then be plugged into your load calculation sheet on the next page.

Remember, some items are used for only a fraction of an hour per day. A 300 Watt item used for 5 minutes per day will only consume 25 Watt hours per day.

Appliance	Watts/Hour
Air Conditioner	
Room	1000
Central	2000-5000
Blender	300
Blow Dryer	1000
CB radio	5
CD player	35
Ceiling fan	10-50
Chain Saw	1100
Cloths Dryer	
Electric	4000
Gas heated	300-400
Coffee pot	200
Coffee maker	800
Freezer	
Conventional 14cf	440
Sunfrost 19cf	112
Vestfrost 7.5cf	50
Frying pan	1200
Garage Door Opener	350
Heater	
Engine block	150-1000
Portable	1500
Waterbed	400
Stock tank	100
Hedge trimmer	450
Hot plate	1200
Iron	1000
Compact fluorescent Incandescent eq.	
40 Watt equiv.	11
60 Watt equiv.	16
75 Watt equiv.	20
100 Watt equiv.	30

Appliance	Watts/Hour
Lights	
100W incandescent	100
25W compact flour.	28
50W DC incandescent	50
40W DC halogen	40
20W DC compact flour.	22
Microwave	600-1500
Popcorn Popper	250
Radio telephone	
Receive	5
Transmit	40-150
Refrigerator/Freezer	
Conventional 20cf	540
Conventional 16cf	475
Sunfrost 16cf	112
Sunfrost 12cf	70
Vestfrost 10.5cf	60
Sander	
9” disk	1200
3” belt	1000
Satellite dish	1200
Saw	
14” Band saw	1100
7-1/4” circular saw	900
8-1/4” circular saw	1400
Vacuum Cleaner	
Upright	200-700
Handheld	100
VCR	40
Waffle Iron	1200
Washing Machine	
Automatic	500
Manual	300
Weed eater	500

Load Evaluation Form

Name:

Date:

Appliance	AC	DC	Qty.	Watts (V x A) W x 1.15 for AC	Hrs./Day	Avg. Watt Hrs/Day
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00
			0	X 0	X 0.0	= 0.00

Calculators

Find the Wattage of an appliance from the listed Amps and Volts

Volts: x

Amps: =

0.00 (Watts)

Adjust the Wattage for an AC appliance to adjust for estimated inverter loss.

Watts: x

1.15 =

0.00 (AC Watts)

Erase Form

Highest AC Load in Watts	Total AC Connected Wattage at One Time	Total Watt-Hours Per Day
		0.00

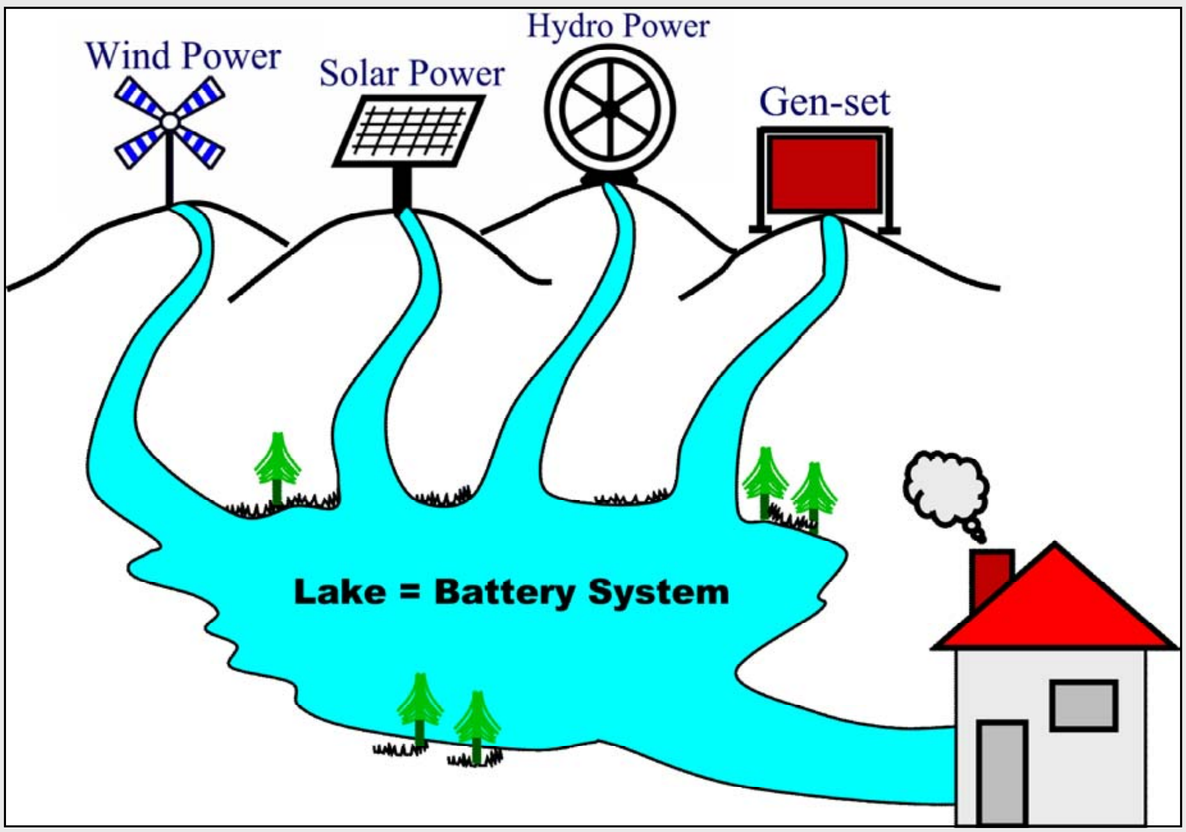
Total Watt-Hours Per Day		Load Correction Factor*		Corrected Watt-Hours/Day
0.00	/	0.70	=	0

*Load Correction Factor compensates for losses in the system. Batteries and other power system components are not 100% efficient. We have found that increasing load value by 30% adequately factors in these losses.

Appendix 4: *Hybrid Power Systems*

Remote Power Systems can be likened to a reservoir system supplying water to a house or town (see drawing). The battery is the lake (or reservoir). The house represents the 'consumer', a house (or even a whole city) drawing water from the reservoir. The power generation source(s) replenish the water in the reservoir. The reservoir (battery) performs a very important function in that it stabilizes the system, storing excess capacity when the supply exceeds the demand and supplementing when the demand exceeds the supply.

Often, one renewable energy source cannot provide enough power for the demand and multiple sources of power generation are utilized. These are called 'hybrid systems'. Hybrid systems can also be more reliable as the power generation is not dependent on one renewable energy source (water, solar, or wind).

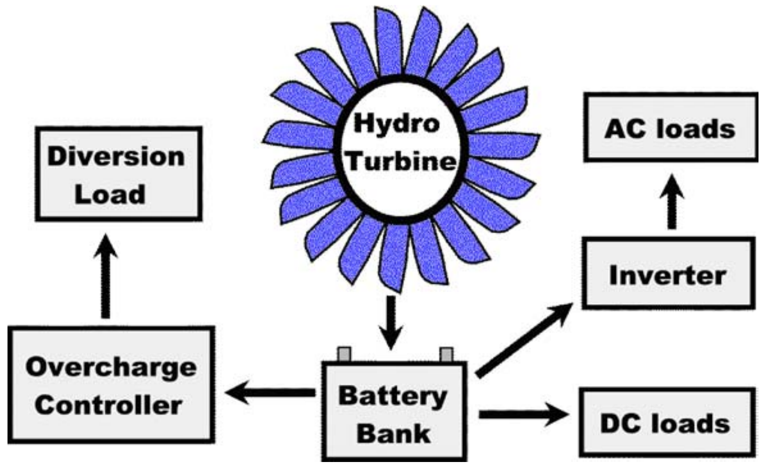


Hybrid systems may use two or more sources of power which are tied together through a battery bank to supply household power.

If you suspect that a hydro turbine system alone will not be sufficient and want to explore the use of a hybrid system, please contact our technical staff. A well-designed alternative energy hybrid system can be very effective. However, there are a few key points to address when designing the system that will ensure the system works as planned and provides ample power.

Appendix 5: *Other Components of your Power System*

Thus far, this booklet has focused on hydro power and generating electricity from water. Now we need to consider how to put that electricity to good use. The diagram on the right shows the other key elements in a complete hydro power system.



Diversion Load: Hydro turbines are 'active' power producers. When the water is flowing and the turbine is spinning the hydro turbine is producing electricity. That electricity must be used up – it needs somewhere to go. Otherwise, the electricity will be converted to heat within the turbine and ruin the turbine. In a 'balanced' situation, all of the electricity generated by the hydro turbine will be consumed by the electrical loads and recharging of the battery. Often, though, even when the battery is fully charged, there is excess electricity being produced by the hydro turbine. The function of the Diversion Load is to provide an outlet for this excess power. The excess power can be put to beneficial use such as heating water or it can be simply 'used up' as waste heat. It is important that the Diversion Load is sized to utilize all of the power produced by the hydro turbine in case there are no electrical loads and the battery is fully charged.

Charge Controller: The Charge Controller shunts the excess power (not used by the electrical loads and battery charging) to the Diversion Load. The Charge Controller must have sufficient capacity to handle the entire diversion load. Some controllers are a simple voltage-controlled relay that alternates between the main system and the Diversion Load. Others use proportional diversion, diverting only that portion that is in excess of the main system requirements.

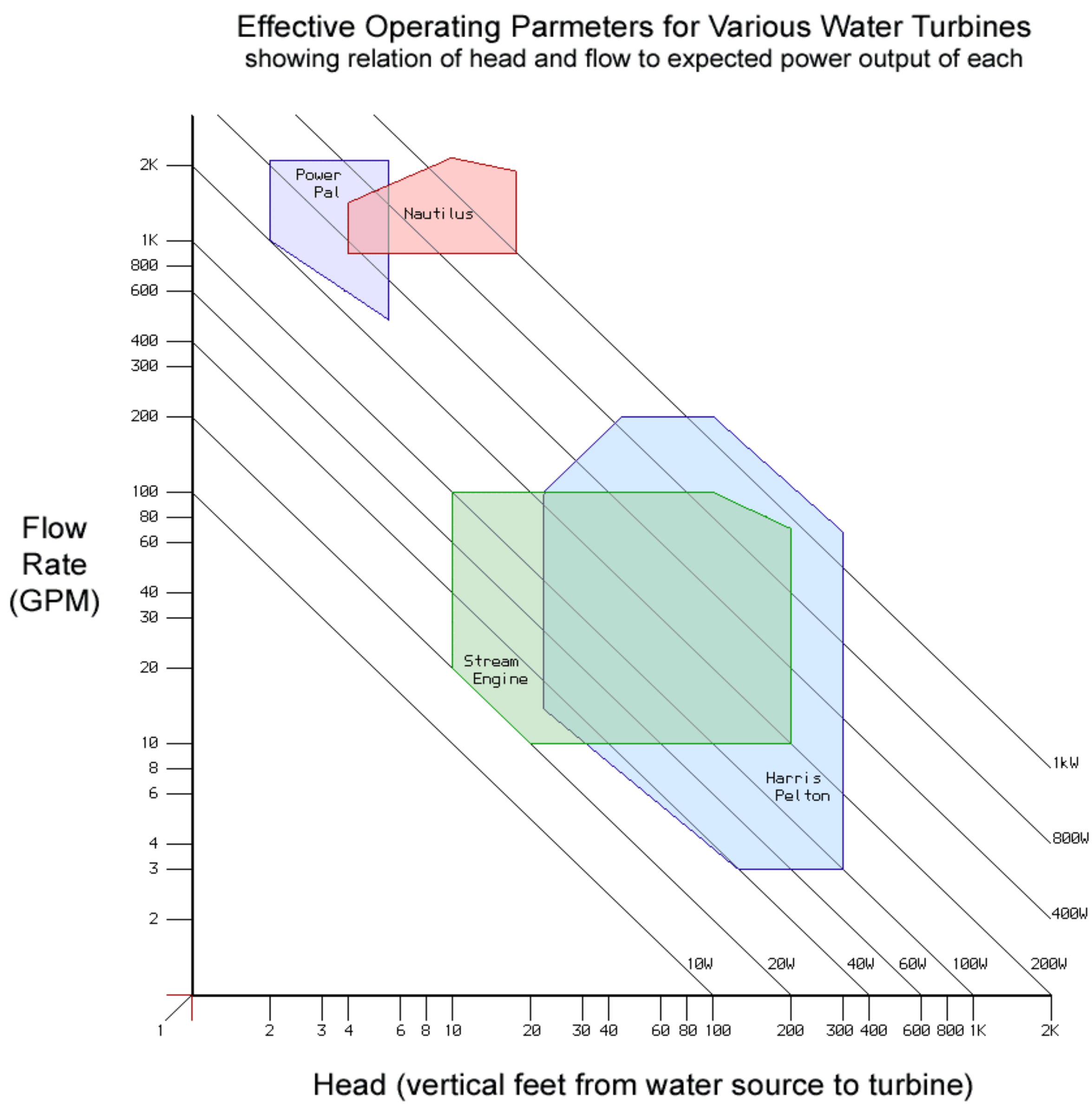
Batteries: Batteries are an integral part of the self-sufficient energy system. One of the benefits of hydro systems is that fewer batteries are required than with wind or solar systems because of the reliability of hydropower on a day-to-day basis. There are no cloudy or calm days to contend with! Storage batteries come in many different styles and sizes, but all home power models are "deep cycle" batteries, meaning they can charge and discharge repeatedly for years. Make sure your battery bank has enough amp hour capacity for your needs, and is the right voltage for your system.

Inverters: A battery bank does not enable users to live with all the conveniences of modern living, as most appliances use high voltage AC (alternating current) while batteries can supply only DC (direct current). Inverters are used to convert DC to AC so that stored battery power may be used as needed by appliances and other loads. Modern inverters are available in virtually any wattage capacity, in recreational and commercial grades, in a variety of DC voltages, and with the 120VAC 60 Hz output for North American applications and 220-240VAC, 50 Hz output for the rest of the world.

Appendix 6: *Choosing the Right Turbine*

A graphical representation of the power output of the hydro turbines in our product line is shown below. Once you have determined your site's head, flow, and your household power requirements, you can use this graph to assist in determining which turbine suits your situation. It is important to note that this is a logarithmic graph and thus the scale is not linear. You can find the power output on a third axis at 45 degrees to the flow and head axis. Power generated from any hydro turbine is a function of the amount of head and flow available.

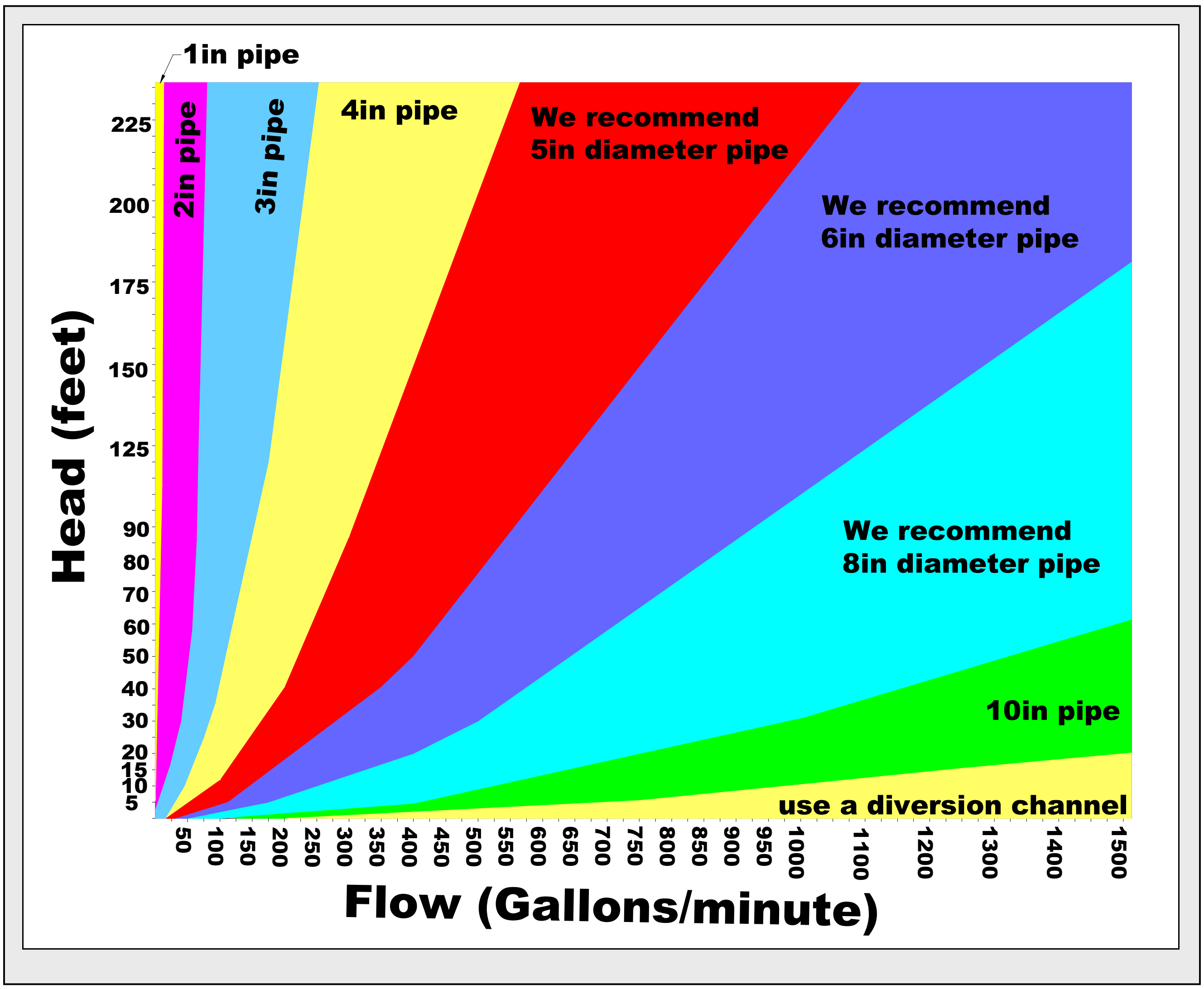
Net Head (ft) X Flow (GPM) / 10 = Output Power



Appendix 7: *Choosing Pipe in a Closed Diversion System*

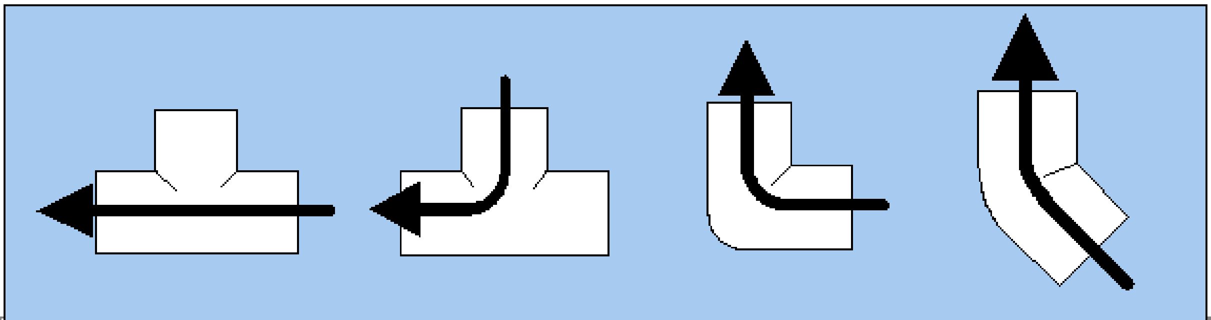
Once you have determined the water source inlet and measured the static head (vertical change in elevation) from the water source inlet to the turbine, measure the lineal distance for the path that the pipe for the diversion system will follow. You now want to select the optimal pipe diameter for your diversion system. The larger the pipe diameter, the less the friction loss will be. However, larger diameter pipes also cost more. You need to meet the hydro turbine's dynamic pressure and flow volume requirements. Beyond that, the optimal pipe diameter is the one that gives you the best cost-benefit ratio – the least cost per PSI of dynamic pressure. In the graph below we have provided a simple means of determining which pipe diameter to use, based on static head and flow information.

This graph is based on the assumption that your pipeline will have no turns or fittings with a radius greater than 22 degrees, and that it's overall length is under 500ft. If you do have additional friction losses from these elements, you will need to size your pipeline larger than what we have recommended here. In this case, we strongly recommend you contact our engineering staff to help you in designing and planning your system. Keep in mind that your flow must be adequate to keep the pipeline full even at low water levels to maintain a closed system and prevent cavitation and turbulence caused by air drawn into the system intake.



Appendix 8: *Other Pipeline Friction Losses*

Another major cause of head loss is in any fittings you might use. Avoid sharp corners in planning your pipeline, because sharp corners will cause turbulence and hence increase friction. The table below lists friction losses associated with various common plumbing fittings. It shows how many feet of pipeline length the fitting is equivalent to, in terms of friction loss. For example: A 'T' in a 4-inch pipeline represents 22ft of head lost – OUCH! Your goal in planning your pipeline is to keep it as straight as possible. Bends and curves should be less than 22 degrees. This is best accomplished with smooth, flexible hose sections making gradual curves where necessary, or by carefully heating and bending straight pipe sections to your needs.



Pipe Diameter	Tee-Run	Tee-Branch	90° Ell	45° Ell
½	1.0 feet	4.0 feet	1.5 feet	0.8 feet
¾	1.4 feet	5.0 feet	2.0 feet	1.0 feet
1	1.7 feet	6.0 feet	2.3 feet	1.4 feet
1¼	2.3 feet	7.0 feet	4.0 feet	1.8 feet
1½	2.7 feet	8.0 feet	4.0 feet	2.0 feet
2	4.3 feet	12.0 feet	6.0 feet	2.5 feet
2½	5.1 feet	15.0 feet	8.0 feet	3.0 feet
3	6.3 feet	16.0 feet	8.0 feet	4.0 feet
3½	7.3 feet	19.0 feet	10.0 feet	4.5 feet
4	8.3 feet	22.0 feet	12.0 feet	5.0 feet

Some other sources of potential head loss to be aware of:

- **Trash-rack/screen – clogged or poorly designed**
- **Pipe inlet – clogged inlet or inlet not properly submerged**
- **Valves – use gate, butterfly, or ball valves only in hydro systems as they allow unobstructed flow when open**
- **Size transitions in pipeline diameter, both increase or decrease**
- **Poorly sealed joints which allow air to be sucked into the pipeline**

Appendix 9: *Planning an Open Diversion Canal*

There are many factors in planning a diversion canal and it is not the intention of this appendix to delve into great detail. Instead, we are presenting a brief overview of the important elements and considerations in planning the route and components of your diversion canal.

Important factors:

- Flowing water in the river will always carry silt and sand particles, which can be very abrasive to the turbine. Although it is impossible to eliminate these particles entirely, including a silt settling basin in your design will help to greatly reduce the amount of these particles reaching your turbine. This will significantly increase the life of your turbine runner.
- It is important to remember that while a hydro installation is designed to handle constant flow, rivers are variable in their flow rates throughout the year. Therefore it is important to create a diversion weir or dam to maintain channel flow at low water. The intake structure should be high enough to prevent excess water from entering your channel, and a spillway should be in place to allow excess water in the channel to escape.
- The channel should always be planned with flooding in mind. Floodwaters can cause a lot of damage to a poorly planned diversion channel. It is worthwhile to research past flooding records before beginning construction.
- Another factor demanding attention is the potentially destructive effect of turbulence in the flow of water through the channel. This can be erosive and lead to silt buildup. It also allows particles to remain suspended in the water.
- Remember that since the power delivered by the turbine is strongly influenced by the head of water at the entry to the turbine, the channel should not drop any more than necessary along its length. The more level the channel is, the slower the water also moves through it allowing silt particles to drop out and reducing turbulence. The ideal water speed at the turbine is less than ½ foot per second.

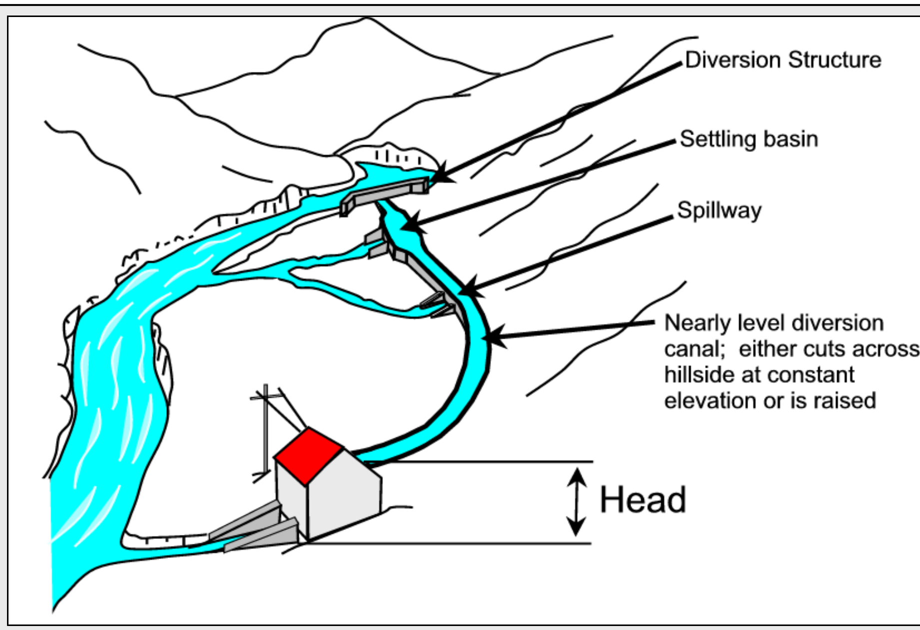
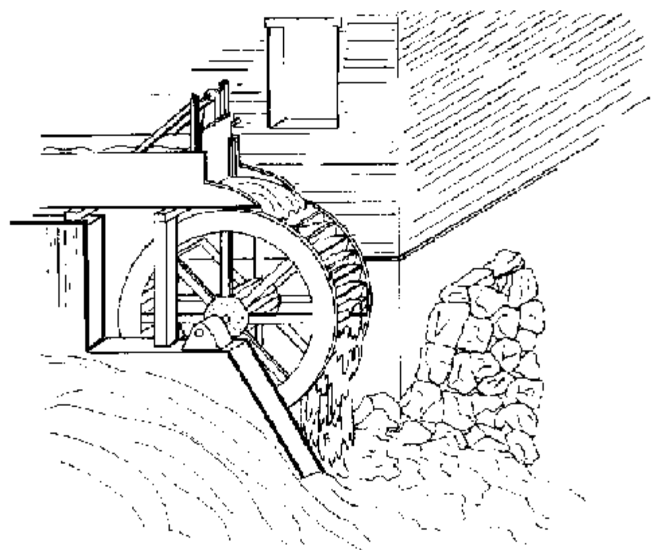


Diagram showing the main components of an open diversion system

Appendix 10: *A Brief History of Hydropower*

The mechanical power of falling water is an age-old tool. It was used by the Greeks to turn water wheels for grinding wheat into flour more than 2,000 years ago. In the 1700's mechanical hydropower from water wheels was used extensively for milling and pumping.

In 1826, The Frenchman Jean-Victor Poncolet proposed a machine involving a fully enclosed waterwheel, where water would flow into the wheel rather than along the wheel. Following this concept, the American Samuel Howd patented the first turbine in 1838. James Francis later perfected it by curving the blades. Known as the Francis turbine, this became the foremost water turbine in use.



Turbines slowly replaced the waterwheel in driving sawmills and textile mills. The turn of the century in the US was a golden era for hydropower. Thousands of small-scale hydro sites were scattered about the countryside, with hundreds of turbine manufacturers in existence. By the early 1900's, a new use was found for the water turbine: producing electricity. Hydroelectric power grew quickly, and accounted for more than 40% of the electricity generated in the US during the 1920s. With the increase in development of other forms of electric power generation and the rural electrification program, hydropower's percentage has slowly declined and today provides about 10% of the electricity in the US. One by one, the micro hydro turbine builders went out of business, watermills went silent and turbines were abandoned as power lines raced across the country. However, today hydropower is being revived as a clean and renewable energy source. Modern hydro plants range in size from the “micro-hydro” turbines that power remote cabins or small homes, to the giant dam systems like the Hoover Dam, providing electricity to millions of people daily.

Cease your work, ye maidens, ye who labored at the mill,

Sleep now and let the birds sing to the ruddy morning;

For Ceres has commanded the water nymphs to perform your task;

And these, obedient to her call, throw themselves upon the wheel,

Force round the axle tree and so the heavy mill.

First known reference to a water wheel, written by Antipater of Thessalonia sometime in the 1st century B.C

Appendix 11: *Formulas & Conversion Factors*

Conversion Factors:

1 US gallon = .8327 Imperial gallons
231.0 in^3 (cubic inches)
.1337 ft^3 (cubic feet)
3.785 liters
8.34 lbs
.00378 m^3 (cubic meters)
1cu. ft. = 7.48 US gallons
1 ft^3/s = 448.83 US gallons
646,317 US gallons per 24 hours

1 inch = 25.4 millimeters
2.54 centimeters

1 foot = 0.3048 meters

1 mile = 1.609 kilometers

1 centimeter = 0.3937 inches

1 meter = 39.37 inches

1 kilometer = 3281 feet

1 foot of head = 0.43 psi of pressure

Geometry Equations and Constants:

π = 3.1416
Circumference of a circle = π x diameter
Area of a circle = π x $(\text{radius})^2$
Volume of a sphere = 0.5235 x $(\text{diameter})^3$
Volume of a cylinder = area of base x height

Pipes:

Doubling the diameter of a pipe increases its volume 4 times

Volume of water in a full pipe =
π x $(\text{inside pipe diameter})^2$ x length

Electrical Formulas:

Ohm's Law: R = V/I
Resistance (Ohms) =
Voltage (Volts)/Current (amps)

Power (Watts) = Volts x Amps

1 horsepower = 746 Watts

1 kilowatt = 1000 Watts

1 kilowatt = 1.341 horsepower

Hydro and Physics Equations:

Newton's 3^{rd} Law: For every action, there is an equal and opposite reaction

For a Hydro Turbine:
Net Head x Flow /10 = Output Power

Flow = speed x cross-sectional area

Average stream speed =
80% of surface speed

Appendix 12: *Basic Hydro Power Terminology*

Buckets: In an impulse turbine, the buckets are attached to the turbine runner and used to 'catch' the water. The force of the water hitting the buckets turns the turbine runner and generates power.

Cavitation: Air bubbles in a closed hydro system, greatly reducing efficiency.

Cubic feet per second (cfs): A unit of measurement for flow. Flow equals the volume of water (cubic feet) passing through an area in a given time period (per second). 1 cfs is equal to 7.48 gallons per second.

Diversion (water): Redirects water from its natural course. There are two types of diversion systems: open diversions such as a ditch or canal, and closed diversions such as a pipeline.

Diversion Load: An electrical load to which excess energy from the hydro turbine can be diverted once the battery bank is fully charged. This is a necessary component of a hydro system, and requires a stable load such as a heating element.

Draught Tube: Used in reaction turbine systems, a draught tube is a flared cylindrical tube below the turbine runner, which maintains a closed system between the runner and the tail water. The draught tube recovers additional kinetic energy in the water leaving the runner in the form of 'suction head'.

Dynamic Pressure: The pressure in a pipeline when the water is flowing. This is equal to the static pressure minus pressure loses due to friction, turbulence or cavitation in the pipeline or fittings.

Flow: Flow is the volume of water passing through an area in a given time period. Flow is measured in gallons per minute (GPM) or cubic feet per second (cfs)

Flume: Conducts the water to the turbine

Forebay: A closed tank which acts as a settling basin and feeds water into the penstock.

Francis Turbine: A type of reaction turbine, a Francis turbine has a runner with nine or more fixed vanes. The water enters the turbine in a radial direction with respect to the shaft, and is discharged in an axial direction (90 degrees change). Francis turbines will operate from 4 feet to 2,000 feet of head and can be as large as 800 megawatts.

Guide Vanes: Used in reaction turbines to change water direction by 90 degrees, thus causing the water to whirl and enter all buckets of the turbine runner simultaneously. This increases turbine efficiency.

Head: The total vertical distance influencing the water pressure at the turbine. The amount of energy potentially available in a hydro system is proportional to the head.

Head Losses: Factors which reduce the effective head, caused by anything that obstructs or limits the ready flow of water. Examples include roughness of the inner pipeline wall, and fittings which change the direction of the flow of water or increase the pipeline diameter.

Hydrology: The science dealing with the waters of Earth – their distribution and movement on the surface and underground; and the cycle involving evaporation and precipitation.

Impulse Turbine: The power produced by an impulse turbine comes entirely from the momentum of the water hitting the turbine runner. Impulse turbines are usually most efficient for high head micro-hydro systems (above 20 feet). Common impulse turbines include the Pelton and Turgo turbines.

Intake: The point at which water is diverted from the river to the turbine via either a closed pipeline or an open diversion channel. A trash screen and a settling tank are often set just in front of the intake to prevent debris and excess sand or silt from reaching the turbine.

Kinetic Energy: Energy due to motion. Water in motion has kinetic energy, which is being converted to electrical energy in a hydropower system.

Micro-hydro: Hydro power installations with a power output of less than 100kW

Potential Energy: Energy that is in a stored form. Batteries store electrical potential energy. Water behind a dam also has potential energy, because the water is stored for future power production.

Pelton Turbine: A Pelton turbine is a type of impulse turbine that has one or more jets of water hitting the buckets of a runner. This runner looks much like a miniature water wheel. The Pelton turbines are used for high-head sites (20 feet to 6,000 feet) and can be as large as 200 megawatts. It is a very efficient turbine and often used in high head micro-hydro applications.

Penstock: A closed pipeline through which the water flows to the turbine.

Propeller Turbine: A propeller turbine is a type of reaction turbine that has a runner with three to six fixed blades, like a boat propeller. The water passes through the runner and drives the blades. Propeller turbines can operate from 2 feet to 300 feet of head and can be as large as 100 megawatts.

Reaction Turbine: The reaction turbine, as the name implies, is turned by reactive force rather than by a direct push or impulse. The turbine blades turn in "reaction" to the pressure of the water falling on them. Reaction turbines can operate on heads as low as 2 feet, but require much higher flow rates than an impulse turbine.

Run-of-the-River: A hydro system which does not stop the river flow, but instead diverts part of the flow into a channel or pipeline to the turbine

Runner: A wheel to which buckets are attached in an impulse turbine. Looks similar to a miniature water wheel.

Scroll Case: A device used in a reaction turbine system that conducts the water from the penstock around the turbine vanes. This increases the efficiency by ensuring the water enters the runner at a 90 degree angle thus imparting the most force to the runner.

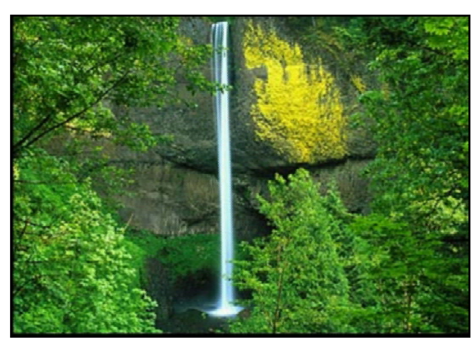
Static Pressure: The pressure produced by an unmoving column of water. This pressure is caused only by the vertical height of the water column and is unaffected by any horizontal displacement of the water. Therefore, a pipeline where the inlet is 10 ft above the outlet has the same static pressure at the outlet irregardless of whether the pipe is 10ft long or 1000ft long.

Suction Head: Additional energy reclaimed in the draught tube of a reaction turbine after the water leaves the turbine blades. While the inlet pressure head can be thought of as "pushing" the water through the turbine, the suction head can be thought of as "pulling" the water through the turbine. Generally, 80% of the power produced comes from pressure head and 20% from suction head.

Tail Race: Channel or pipe carrying the water from the turbine outlet back to the stream in any hydro system.

Trash Screen: A series of bars or mesh just before the system inlet designed to stop wood and debris from entering and choking or damaging the turbine.

Turgo Turbine: Variation on the Pelton turbine with differently shaped buckets which are tilted in such a way to allow for removing water from the system very efficiently after it hits the runner. Therefore a larger diameter water jet can be used which allows for greater power production. The Turgo runner is more difficult to manufacture, and therefore costs more than a similar diameter Pelton runner.



Watershed: The region draining into a river, river system or body of water; the total land area, regardless of size, above a given point on a waterway that contributes runoff water to the flow at that point; all the land that serves as a drainage for a specific stream or river.

Weir: A low dam over which a river flows, but when water is in short supply nearly all of it can be redirected to the turbine or waterwheel