

# Small & Micro Hydropower

DoradoVista, Inc.

## Hydro History:

### From Waterwheels to Turbines

In the late 1700s, inventors applied waterpower to the developing textile industry in England. The increased productivity of water-powered machines led to the development of bigger and stronger waterwheels to power these machines. This quest for more efficient waterwheels led to the development of the modern turbine. The earliest turbines were simply smaller, stronger, faster waterwheels and merely replaced their larger predecessors in the turning of gears to power machines.

The town of Lowell, Massachusetts, begun in 1822, was a planned textile community with a canal system designed to turn more than a hundred waterwheels which powered several textile mills.



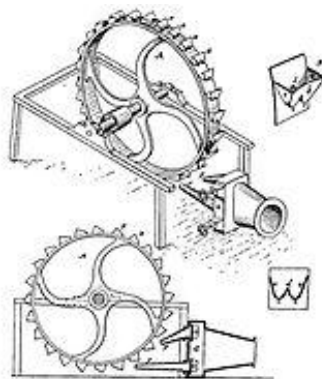
A Turbine Waterwheel (Horizontal)  
From The United States Miller, April 1883

In the 1840s, James B. Francis, the chief engineer of the company which owned and maintained the canal and lock system supplying the water to Lowell's mills, turned his attention to improving the efficiency of the waterwheels powering the mills. Working with Uriah Boyden, Francis developed a turbine that was 88% efficient. Applying science and math to the design process, Boyden and Francis experimented with methods of reducing friction and calculating the water's trajectory. To reduce the friction, Boyden suspended the turbine from above. Boyden and Francis also calculated scientific formulas so that turbines could be built and improved by craftsmen rather than engineers.



Francis Turbine at Grand Coulee Dam 9/1941

While craftsmen were producing more efficient Francis turbines, other creative minds were also devising new approaches for harnessing the power of water. Samuel Knight and Lester Pelton each improved on the concept of the water wheel by designing a turbine driven by jets of water. Although Knight's Wheel was developed first, Pelton's was determined to be the more efficient in a 1883 test of the two.



Pelton Wheel Drawing from Original 1880 Patent

In 1913, Viktor Kaplan produced a propeller-type turbine called the Kaplan turbine.

The first turbines were used before electricity was applied to machines, but when technology was ready, turbines were in place to power the generators and produce electricity. The Francis turbine, Pelton wheel, and Kaplan turbine, though larger and more refined in design today, still produce the majority of the world's hydroelectric power.

10/28/2009

Volume 9, Issue 4

[www.smallhydro.com](http://www.smallhydro.com)

#### Inside this issue:

<i>Hydro History: From Waterwheels to Turbines</i>	1
<i>Getting Practical: Choosing a Turbine</i>	2
<i>Ask Jess</i>	3
<i>About DoradoVista</i>	4
<i>Let Us Hear From You</i>	4
<i>Addition References</i>	4



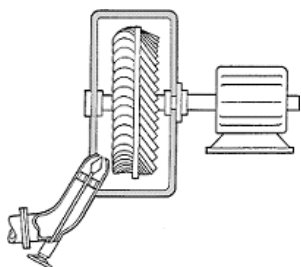
Kaplan Turbine at Bonneville Dam  
after 61 years in service

## Getting Practical:

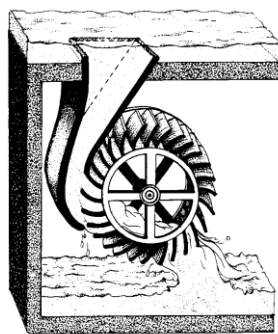
# Choosing a Turbine

### What's a Turgo? —

The Turgo was originally patented by Gilkes in 1919. It is a modified Pelton wheel designed to operate at lower heads. Unlike a Pelton, the water strikes the plane of the Turgo wheel at an angle of approximately 20°. This angle has a significant impact on overall efficiency. The water flows over the wheel and exits on the opposite side. The Turgo wheel can be smaller than a Pelton wheel for the same power.



Turgo Turbine  
from the British-Hydro Web Site



Crossflow Turbine  
from ec3wd.com

### Narrowing Your Options

A turbine is a device that transforms moving wind or water into rotary mechanical energy. In hydropower projects, water is diverted from a stream or river, channeled through a pipe or penstock, and directed into a turbine. As it passes through the turbine, the flow of water causes the turbine to spin. This spinning turbine turns the moving part of a machine and produces mechanical energy.

If all water sources were identical, only one type of turbine would be needed. However, each hydro project has its own unique characteristics. In some cases, there is a high rate of water flowing through a potential site. In other cases, the volume may be less but there is a significant drop in elevation, or head. Usually, the water flow increases or decreases seasonally. These varying factors have led to the development of turbines which require more or less head or water flow.

In general, impulse turbines require higher head (H) and a lower rate of water flow (Q), while reaction turbines are the opposite. By and large, low head is less than 50m and low flow is under 2m<sup>3</sup>/s. However, engineers have improved turbines so that there are a variety of overlapping options for almost any hydro site.

As you can see from the Turbine Application Chart on the next page, both the Kaplan and the Francis turbines utilize low to medium H and a higher Q. Both are reaction turbines, which need to be placed directly into the water or sealed into a housing. Reaction turbines use the suction created by water pressure in turning the turbine blades.

The Pelton, on the other hand, requires H above 30m but functions at a Q less than 2 m<sup>3</sup>/s. The Pelton is an impulse turbine which utilizes the velocity of the water, delivered by jets directly into buckets, to turn the wheel. Impulse turbines require higher H but lower Q. The cross-flow is an impulse turbine that works at a lower H, making it an option for sites that could also employ a reaction turbine.

If choosing a turbine was as easy as graphing H and Q on a chart like this and picking a turbine that lies at the intersection of these two lines, turbine choice would be simple. But, as with most important decisions, there are other factors to consider, also. Think of a turbine application chart as the first cut in selecting your turbine. It helps you rule out obviously impractical choices and allows you to focus on the turbine classes nearest to your site's particular characteristics.

Having ruled out unworkable turbines, you can begin looking at the remaining choices. Now you need to consider peak, minimum and average flow. Since there are usually seasonal variations in water flow, these cannot be ignored. Putting a Francis turbine in a stream with a flow rate that is above .5m<sup>3</sup>/s only in the spring would not be as practical as a Kaplan or possibly a cross flow variety on that site.

Once you have determined the type of turbine or turbines you will consider, you need to compare the flow data for your site to specific models of turbines. Each turbine model has its own power curve, which can be obtained from the manufacturer. To help decide which model will best meet your site's characteristics, match your minimum, average, and peak flow numbers to the power curve for each turbine you are considering. This will enable you to narrow down your turbine choices to a practical range for further research. Then you can consider factors such as the cost of the delivery system, state and federal regulations which might affect your water source, depth of water needed for the turbine to function properly, and whether the turbine you are considering has the necessary power production potential to meet the needs of your site.

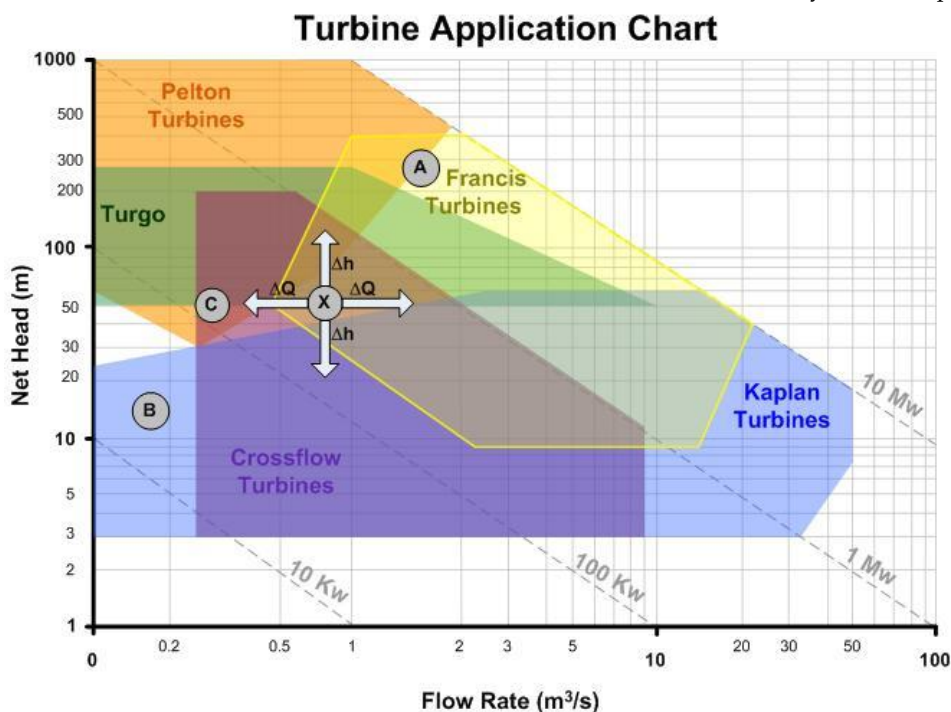
Future issues of this Newsletter will delve into how these other factors impact turbine choice. Now, however, you can gather flow data and compare it to the turbine diagrams and specific turbine power curves to become familiar with your turbine options. Choosing a turbine requires careful study and deliberation, since choosing the wrong turbine can sink your small or micro hydro project.

## Using the Chart

Let's look at some examples. Point A on the chart is well within the Francis turbine range in both H and Q but it is also on the border of the Pelton turbine range. With these numbers, you would probably rule out the Kaplan, crossflow and Turgo turbine classes. However, it would be wise to revisit your H and Q data. Is your head measurement based solely on the elevation drop of your water source or is it what we call net head? Overestimating the head value could lead to purchasing a Pelton turbine and then discovering that you lack sufficient head for optimum function. Is your flow data based on seasonal variations or is it only peak or low flow data? The most accurate numbers available will enable you to determine whether a Francis or a Pelton best suits your site requirements.

At first glance, Point B looks like an easy choice. Head and flow rate data are well within the range of the Kaplan and outside the ranges of the other four turbine classes. However, as you consider a Kaplan, you will still need to verify your head and flow rate data in order to investigate various models of Kaplan turbines. Where do your low, average, and peak flow rates fit on the turbine power curve of the models you are considering?

Now look at point C on the chart. It lies on the border of the crossflow, and the Turgo and within the Pelton ranges. Here again you will need to start by obtaining the best data possible on head and flow. Then you must begin looking at the turbine power curves for various models of the turbine classes you are considering. You will likely have more options from which to choose, but that means more research to determine the best fit for your site requirements.



### Net Head—

It is important to keep in mind that the actual head at the turbine input termed "Net Head" is less than the head at the top of your water stream where your intake is located. This is due to friction as the water traverses your penstock. Be sure to account for this loss in head when using the diagram as the loss can account for as much as 25% of your total power.

For those not encumbered by a logical measurement system ☺

$$1\text{m}^3 = 35.3\text{ft}^3$$

$$1\text{m} = 3.28\text{ft}$$

## Ask Jess:

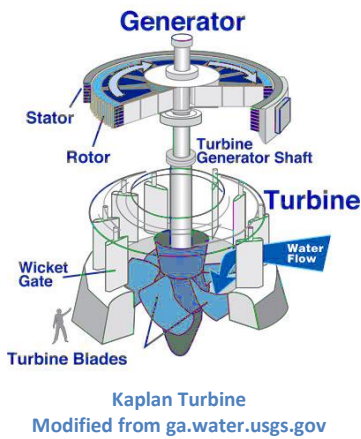
I have just acquired a property with flowing water and a drop in the range of 50m over the course of 300m. We measured the flow rate this spring, when the snow was melting, and found it had a flow of  $.8\text{m}^3/\text{s}$ . We have been offered a good deal on a used Kaplan turbine. Would it work for us, or what other turbine do you recommend? Sincerely, Dreaming of Hydropower

Although you have provided some important data, we still need to know more about your property before we could make a recommendation. However, for starters, let's compare your data to the diagram of the five most common classes of turbines. We've

plotted your information on the Turbine Application Chart above (point X). Based on your data, the Kaplan would probably not be your best option, but don't rule it out yet. You could look at a crossflow, a Francis, a Turgo and the Kaplan, but first you need more accurate head and flow rate data. Some basic

### Something New—

In April of 2009 DoradoVista began operating a web site called [www.smallhydro.com](http://www.smallhydro.com), which is dedicated to fostering hydropower communication and learning about how to develop Small & Micro Hydropower projects. As a new addition to the newsletter, we will periodically take user submitted questions from the site and address them here.



information on measuring these can be found in [Volume 9 Issue 2 of our Newsletter](#).

Since you measured the flow during the spring, at what we would expect to be a high water point, we need to know the seasonal variation in flow. To find this, research historical flow patterns for this region and for your site. The horizontal arrow on the chart demonstrates how the flow rate can impact your turbine options. If your average flow is more than you've expected, a Kaplan may work for you, depending on the power curve of the particular model. If your flow rate is less, you should probably rule out the Kaplan.

Now let's look at your head measurement. The numbers you've given are probably not very accurate. The vertical line on the chart demonstrates how head measurement impacts your turbine options. If you have more head

than estimated, you might want to look at a Turgo, but if you have less, you should probably be investigating a Francis or a crossflow.

With accurate head and flow data, you can rule out some turbine classes and begin looking at the power curves for others. Checking your flow data against the power curves for some specific models will help you decide what types and models of turbine you want to investigate further. But this should get you started.

So, Dreaming, it's time to put your boots on and head to your site. You have a good start, but you need to have answers to these and other questions before you can make a wise decision on your turbine. Good luck, and have fun!

## About DoradoVista

DoradoVista is a hub for several entrepreneurial efforts. One of our key efforts is helping people with their Small & Micro Hydropower needs and questions. Our goal is help you better understand what is required to analyze and then develop a small or micro hydropower site.

This newsletter and our support web site our primary tools to help you understand what is required to develop your site.

In addition, I am glad to discuss your specific issues through email where I can

Sincerely,  
Jess

## Let Us Hear From You

Email concerning this newsletter can be sent to:

[smallhydronewsletter@doradovista.com](mailto:smallhydronewsletter@doradovista.com)

To contact Jess directly by snail mail:

Jess  
DoradoVista, Inc.  
Small & Micro Hydropower  
PO Box 147  
Newbury Park, CA 91319

Or for email use:

<mailto:AskJess@DoradoVista.com>

To send email concerning the Small & Micro Hydropower BLOG use:

<mailto:smallhydroblog@smallhydro.com>



## More Power:

# Increase Your Knowledge

Previous Issues of the Newsletter	<a href="http://www.DoradoVista.com/ReadersCorner.html">www.DoradoVista.com/ReadersCorner.html</a>
BLOG Site	<a href="http://www.smallhydro.com">www.smallhydro.com</a>
DoradoVista web site	<a href="http://www.DoradoVista.com">www.DoradoVista.com</a>
Low Cost Development of Water Power Sites	<a href="http://www.cd3wd.com/cd3wd_40/vita/wtrpowr/en/wtrpowr.htm">http://www.cd3wd.com/cd3wd_40/vita/wtrpowr/en/wtrpowr.htm</a>
Turbine Types	<a href="http://www1.eere.energy.gov/windandhydro/hydro_turbine_types.html">http://www1.eere.energy.gov/windandhydro/hydro_turbine_types.html</a>