The Pelton Impulse Water Wheel

Water wheels have been used to power mills and pumps for centuries. However, the traditional water wheel was inefficient: water hitting a bucket would splash back against the next bucket, slowing the wheel. This is especially true when water is delivered to the buckets under very high pressure.

Millwright Lester A. Pelton worked in the Mother Lode region during California's gold-mining era, where innovative miners had learned to concentrate a stream of water under very high head, through a nozzle and against banks of dirt and gravel in a process called hydraulic mining. Pelton experimented with high-head nozzles and water wheels, tinkering with at least 40 different configurations until he developed a split bucket water wheel.

Pelton's impulse water wheel was a key to tapping the vast water power of the mountainous American West. The Pelton wheel is still used throughout the world for generating power where sources of high-head water are available.

The amount of power that a water wheel can generate from a stream of water is dependent on several variables, including: 1) the efficiency of the water wheel; 2) the volume of the stream of water; and 3) the pressure, or head, under which the water is delivered to the wheel. Thus, a high-head, low-volume hydropower facility can theoretically generate as much power as a low-head, high-volume facility.

By splitting the stream of water from the nozzle into two parts, he was able to eliminate inefficiencies caused by water splashing back against other buckets. He also learned that by changing the angle of the water's impact against the buckets, he could control the speed and power of the water wheel.

Within 15 years of its first serious demonstration at the Idaho-Maryland gold fields in 1880, 850 companies were using the Pelton wheel and many more were vying for orders.

At the North Star Mine powerhouse in Grass Valley, California, an 18-foot Pelton Wheel, weighing 10,000 pounds, ran for 30 years pumping 1,000 gallons of water every minute from the mine.

The wheels are typically used where water is under high heads, generally 1000 feet or more. They develop efficiencies up to 90 percent while utilizing small volumes of water compared to that which are used in turbines.

Although there are some Pelton wheels operating under heads of even more than 2,000 feet, there are also many operating at heads of only several hundred feet.

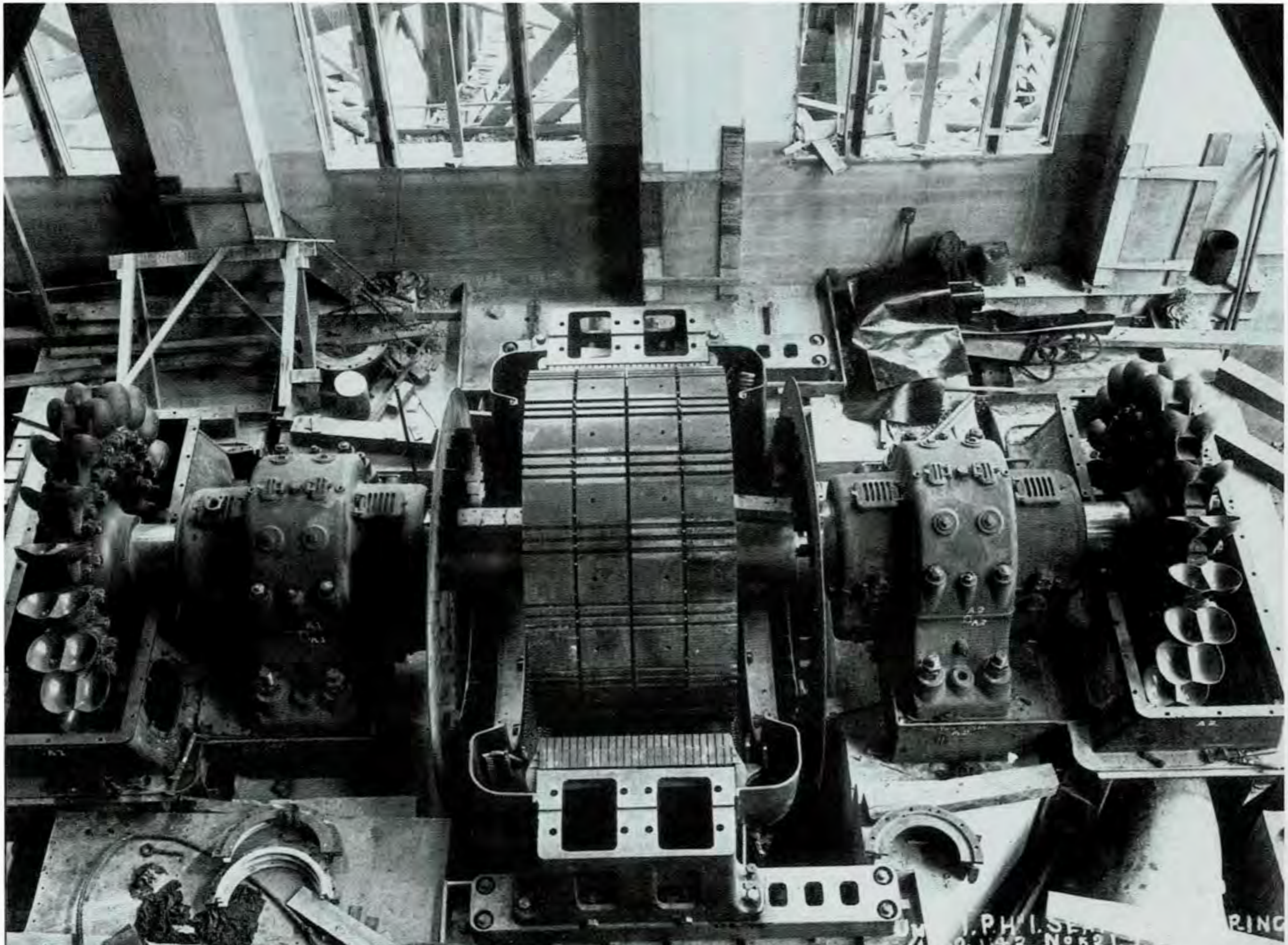
Pelton's hydraulic prime mover, known as a Pelton turbine, is still being manufactured at a scale and in sizes far beyond the original machines.

Pelton patented his wheel as well as his novel design of the double cup runner, and in 1888 formed the Pelton Water Wheel Company in San Francisco to supply the growing demand for hydropower and hydroelectricity throughout the West and world-wide.

Lester A. Pelton was born September 5, 1829, in Vermillion, Ohio, and died March 14, 1908, in Oakland, California, at the age of 78. He was awarded the the Elliott Cresson Medal, the highest award given by the Franklin Institute, in 1895, and was inducted posthumously in 2006 in the National Inventors Hall of Fame.

An example of the Pelton wheel at work can be seen in David H. Redinger's book, "The Story of Big Creek".

Following are several pictures taken from the book (invoking the Fair Use Doctrine) showing a generator in Big Creek Powerhouse No. 1 in 1913.



This view of Unit No. 1 in Powerhouse No. 1 shows how each generator was flanked by two "Pelton" water wheels. This was done to equalize the tremendous forces placed on the common shaft joining the water wheels to the generator. At this time, Big Creek's two powerhouses employed the largest Pelton-style water wheels ever built.
Stone and Webster Photo, from the Edison Collection

The initial development utilized the water from Huntington Lake through a total fall of nearly 4,000 feet. Subsequent development increased the fall to upward of 6,000 feet. It may be of interest to see how the water performs. Let us follow its course from the reservoir through screens, or rack bars, into the large intake tower, thence through the twelve-foot tunnel, three-quarters of a mile long. The screens, which are necessary and common for all such structures, prevent the passage of moving debris. Connecting with the tunnel today are two pipes of 84-inch and 60-inch diameter, called flow lines, which are each a little over one mile in length. The high-pressure pipelines, or penstocks, are connected to the lower end of the flow lines, and extend down the steep mountain side to Powerhouse No. 1. They terminate at the powerhouse in eight nozzles, each six inches in diameter, one for each water wheel, and two water wheels for each unit, from which the water discharges at a velocity of about 350 feet per second. These jets, almost like bars of steel, discharge across an open space of a few inches to strike the buckets of the water wheels. A tremendous impact might be expected, but the shock is relieved since the part of the bucket, when first touched, is nearly parallel to the jet. The water's course over the surface of the buckets is momentary, and without much pressure and velocity it falls into the tailrace. For the drop of 2,100 feet, the pressure at the water wheels is between 900 and 1,000 pounds per square inch. The control of pressure and the economical use of water at varying loads is provided for, each wheel having a governor, so that maximum efficiency can be obtained from a unit by using one or both wheels according to load demand. The size of the jet, or the amount of water being discharged, is regulated by a needle valve controlled by the governor, and excessive changes in pipeline pressures are relieved by bypass openings back of the nozzles, also controlled by the governor. After reaching the tail-race, the water, instead of continuing unchecked down the natural canyon, must repeat its first performance because its job is only half done—and is again impounded, this time by Dam No. 4 across Big Creek just below Powerhouse No. 1. The water passes through a four-mile tunnel and into the high-pressure lines, through which it is carried to the wheels in Powerhouse No. 2.

The high-pressure pipe for the four units installed during the initial development—two in each of the two plants—was made in Germany. When it was laid, the work was started at the powerhouse and the sections placed uphill, the lines being kept full of water as they grew in length. The water allowed a lower and more even temperature to be maintained, and in warm weather would hold the pipe movement in the trench to a minimum. It is amazing how pipelines will react to temperature changes—crawling around like snakes if care is not taken. The practice of providing expansion joints was adopted in later years, but since there are none in these older lines they were backfilled—that is, covered with earth. The lap-welding process for making the longitudinal seams had been developed and used extensively in Germany in the manufacture of pipe for such purposes.

Big Creek Powerhouse No. 1 arose at the junction of Pitman Creek and Big Creek, on exactly the site proposed by John Eastwood a decade earlier. By April 1913 work was well under way. This view looks west down Big Creek Canyon, with the town of Cascada (Big Creek) just out of the picture at the right.
Stone and Webster Photo, from the Edison Collection

The most difficult engineering problem encountered during the initial development of Big Creek was the design and manufacture of steel pipe having sufficient strength to withstand the tremendous pressures generated by the water during its final precipitous fall into the powerhouses. This "penstock pipe" was built in Germany by the famed Krupp Works, using metallurgy similar to that needed for cannon barrels. This dramatic view shows the penstock being laid up the 80 percent grade above Powerhouse No. 1 during August of 1913.
Stone and Webster Photo, from the Edison Collection

At the bottom end of the pipelines from the reservoir high above lies this complex casting, the "needle-valve housing." Inside this pipe, a long, slender "needle valve" travels back and forth to regulate the flow of water onto the water wheel, thus regulating the electrical output of the generators. This photo of one of the four needle valve housings in Powerhouse No. 1 gives an idea of the small hole through which the water must flow.

Stone and Webster Photo, from the Edison Collection

THE STORY OF
BIG CREEK

REVISED EDITION

By

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David H. Redinger was graduated from the University of Kansas with a civil engineering degree in 1911. He immediately accepted a commission from the U. S. Government to go among the hardy Alaskan sourdoughs and investigate the vast coal deposits in our future 49th state.

On his return from the north, he heard about the large hydroelectric development being planned for the High Sierra in California. At that time Redinger knew nothing of hydro-electric development, and had never been to the Golden State. Nevertheless, he accepted the job in 1912 and spent the next few years helping to plan and construct the project.

Redinger remained on the job for the rest of his life. He was fortunate enough to see his great plans for the Big Creek Project materialize, then write about them in this once-in-a-lifetime adventure for all of us to share.