Lester Pelton and His Water Wheel

The development of the tangential water wheel took some intriguing twists and turns. The story of Lester Pelton and his role in hydro development shows how being in the right place at the right time and knowing what to do with knowledge can be as important as the knowledge itself.

By Robert W. Shortridge

At the age of 21, Lester Allen Pelton left his native Ohio in 1850 to join the California gold rush. It was in the California gold fields that the miners developed a crude water wheel to provide power for mining operations. This was the "hurdy-gurdy" wheel, so called because of its general resemblance to the musical instrument of the same name. Pelton improved this early water wheel and his basic design is still being used in power plants throughout the world today.

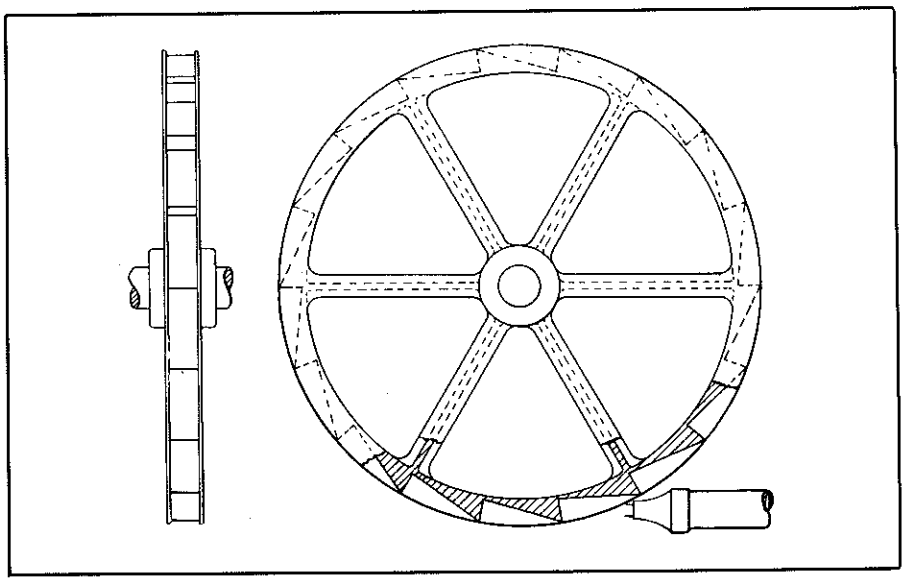


Figure 1: Illustration showing the simple construction of the early hurdy-gurdy wheel. Taken from the *Journal of the Franklin Institute*, 1895. This wheel was cheap and easy to manufacture; its performance and speed of rotation were adjusted by varying the jet size, the head, and the wheel's diameter. This type of hurdy-gurdy provided the most common source of power for the gold and silver fields of California and Nevada in the 1850s and early 60s. (Courtesy of Linda Hall Library.)

Background

The original hurdy-gurdy wheels, as shown in Figure 1, were made of blocks of wood about four inches thick. These blocks were cut so that, when mounted in place, each one formed a tooth like that of a circular ripsaw. These teeth were mounted between a pair of circular wood casings. Four wood spokes led from the casings to a log, which served as an axle. Pins at each end of the axle were fitted into live-oak bearing blocks.

Water was directed to the wheel tangentially. The water jet came from a hole bored into the end of a wooden block at the end of a sheet-iron or wood pipeline. If wood, the pipeline consisted of square wooden boxes, either bolted together with iron rods or clamped together by means of wooden frames, cleats, and wedges.

With this arrangement, heads of 40 to 50 feet were commonly used. The wheels drove small quartz-mills. Later, with higher heads and tapered brass nozzles, the wheels powered small stamp-mills. The efficiency of the crude hurdy-gurdy wheel, at best no more than 40 percent, was not adequate to provide power for large stamp mills. The efficiency of the wheels had to be improved.

The Improvements Begin

During the period of the hurdy-gurdy wheel in its purest and most primitive form, Lester Pelton confined himself to mining. It was not until 1864, after more than a decade of observing hurdy-gurdy wheels in use and working with them as a miner, that he turned his attention to waterwheels. At this time, Pelton became interested in improvements in waterwheel design and construction to

Robert W. Shortridge, Ph.D., is a technical information consultant and a contributing editor to Hydro Review. *He previously served as Director of the Technical Information Center, the University of Missouri.*

obtain increased efficiency and power.

It was generally thought at the time that the low efficiency of the hurdy-gurdy wheel was due to the shape of the buckets. With its flat-surfaced buckets closed in on both sides and on the bottom, water from the jet could not drain freely. The buckets remained full most of the time that the jet was impinging on them. Once a bucket filled with "dead water," the added water from the jet would merely slide off the face of the dead water rather than entering the bucket. Early design efforts centered on obtaining more rapid and complete drainage from the buckets so that the dead-water problem would be minimized or eliminated. Gradually, designers realized that the low efficiency of the hurdy-gurdy wheel was largely caused by the failure to reduce the residual velocity of the waste water. The eddies and fluid friction on the planar and rough surfaces of the buckets also contributed to low efficiency.

In 1866, the Pacific Iron Works in San Francisco built a cast-iron tangential wheel with center-discharge buckets designed to allow dead water to drain more rapidly. Their shape also diverted the direction of the stream somewhat. Thus, by reaction, this arrangement recovered a portion of the energy which had been wasted by the hurdy-gurdy wheel.

Major Improvements

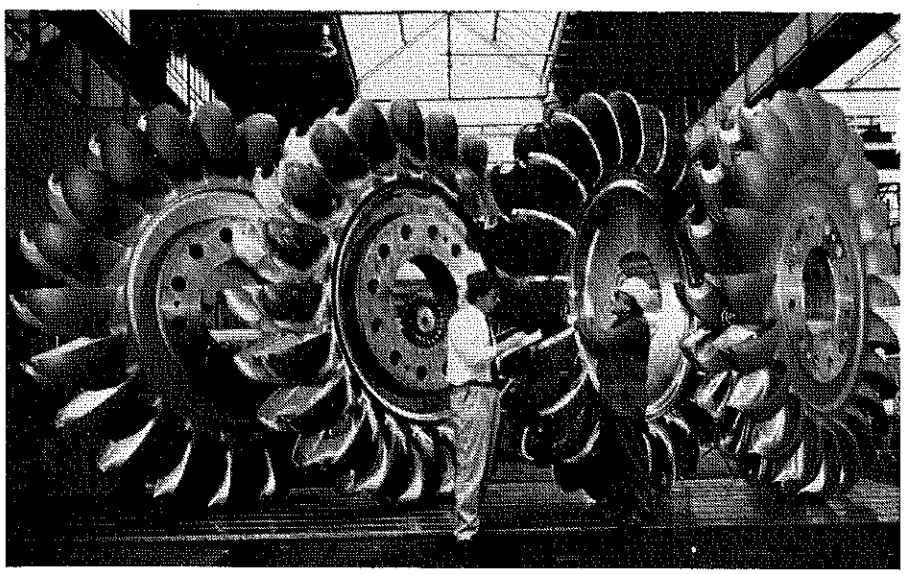
The first major improvement in the tangential wheel was probably the cup-shaped bucket designed by S.N. Knight in the early 1870s; it discharged both to the side and inward. Its truly distinguishing feature was the shape of the jet nozzle. It was a slit, so that the cross-section of the jet itself was in the form of a long, thin rectangle.

The next major improvement in this type of wheel was the development of the jet-splitting wedge. This development is usually credited to Lester Pelton, who received a patent on it in October 1880. In actuality, it seems that several workers happened upon this idea independently of one another.

The first patent on the jet-splitting wedge was issued seven years before Pelton's, and the idea was in practice three years before that. In 1870, Nicholas J. Colman built a stream-splitting bucket for a tangential wheel, and in 1873 he received U.S. Patent 135,891 on his invention. The patent specification describes the action of the water jet as striking the wedge and the back of the bucket. The wedge divides the water stream, which then follows the curve of the discharge passage, and sweeps upward and outward, finally discharging at the periphery of the wheel.

This patent clearly anticipated Pelton's. Unfortunately for Colman, he seemed unable to promote his invention, and there is no record of any of his wheels being put into use. There is also no indication that Pelton ever heard of the Colman patent until several years after his own had issued. The U.S. Patent Office did not cite the Colman patent against his application, as it did against a later related patent application by W.G. Dodd.

An almost contemporary reference, dated 1899, lists at least twenty other names involved in the development of various aspects of the tangential water wheel during this time, as well as seventeen patents dated between 1882 and 1898.



Four Pelton turbine runners and the Guavio hydropower station in Colombia. Each unit will produce 260 MW under a head of 1,140 meters. (Courtesy of Sulzer Escher Wyss.)

Pelton's Contributions

Lester Pelton arrived in California in 1850 and devoted himself almost continuously to mining until 1864. At this time, he began to work as a millwright as well as a miner. He soon found that the style of bucket had a major effect on the efficiency of the hurdy-gurdy wheels, ranging upward from 40 percent. His crucial experiment was with a Knight wheel, in which the key holding the wheel to the shaft became loose enough to allow the wheel to be displaced a few inches sideways. In this position, the jet of water, instead of striking the centers of the buckets, struck them on their inner sides. This out-of-position wheel drove its load, a stamp-mill, distinctly faster than it did when it was in its proper position.

Pelton realized that there would be an undesirable sideways thrust on a wheel specifically designed for the water jet to strike one side of the buckets. He first thought to neutralize this thrust by placing the offset buckets alternately to the left and to the right of the position of the jet. It was but a short step to the idea of a single bucket centered on the jet axis, with a wedge down the center of the bucket. The wedge would split the jet into two parts, one part coursing into and along the inner surface of the left-hand portion of the bucket, the other similarly down the right-hand portion.

Pelton received U.S. Patent 233,692 (dated October 26,1880) on this invention. The drawings for this patent are shown in Figure 2. As stated above, Pelton very likely had no knowledge of the prior Colman patent of 1873; and the Patent Office must have missed it in its search for prior art. At any rate, Pelton attempted to market his product after he received his patent.

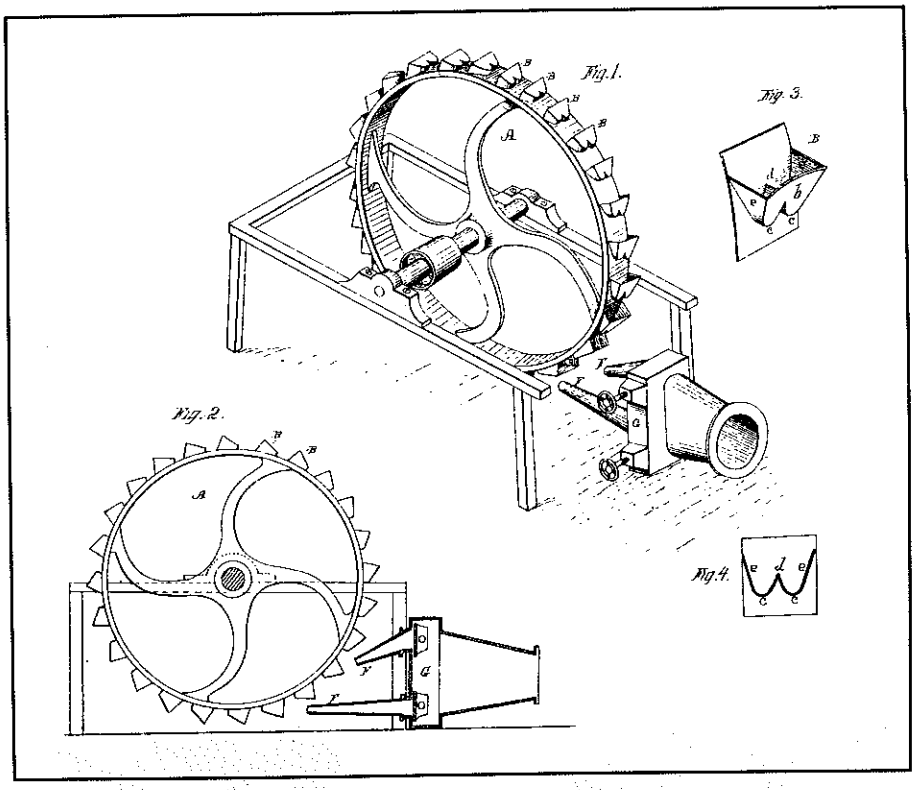


Figure 2: The miners who worked with the early hurdy-gurdy wheels soon made modifications to improve efficiency. A miner, Lester Pelton, registered these drawings with the U.S. patent office in 1880 and received U.S. Patent No. 233,692. (Courtesy of Linda Hall Library.)

Pelton's Wheel and Deals

In the fall of 1880, Pelton visited the plant of Rankine, Brayton, & Company in San Francisco and presented himself to W.G. Dodd, foreman of the shop. (Incidentally, these are neither the Rankine nor the Brayton who gave their names to the well-known thermodynamic cycles.) Pelton showed Dodd a model of his newly-patented invention, and talked with him about it. Dodd was quite impressed with the form of Pelton's bucket and considered it a great improvement over other forms in use. He asked Pelton to wait until Brayton, the general manager, arrived, so that they could have further discussions.

From Dodd's standpoint (this story stems from an interview with him which was eventually summarized in a 1939 publication)[1] some kind of double-dealing went on at this point. At the very least, there was a serious misunderstanding. Dodd thought that he and Brayton had agreed to either buy or license Pelton's patent and then go into the business of manufacturing wheels under that patent together. Instead, Brayton and Pelton made their own arrangements, effectively freezing Dodd out, and formed the Pelton Water Wheel Company. A drawing of their product is shown in Figure 3.

Dodd had his chance for revenge some years later, however, when he began to develop a water wheel of his own design. In the course of the development, he invented a form of bucket on which he received U.S. Patent 401,484, dated April 16, 1889. During the application process for that patent, the Patent Office cited the 1873 Colman patent that they had missed during the processing of Pelton's application. Upon receiving a copy of the Colman patent, Dodd and his attorney quickly recognized that some of the claims of this patent were being infringed by the wheels that were made under the Pelton patent.

Acting on this information, Dodd visited Colman and bought his patent outright for the very nominal sum of $500. He then notified the Pelton people that he now owned the Colman patent and that they had infringed and were infringing on that patent with every Pelton wheel they made. The upshot of the entire affair was the purchase by the Pelton company of the Colman and the Dodd patents, the Dodd water-wheel business, and royalties for past infringements for a very substantial sum. The record does not indicate what, if anything, poor Mr. Colman got out of all this.

Later Improvements

Pelton himself received a second patent on August 27, 1889, in which he claimed essentially minor improvements in the shape of the buckets of the wheel, and the manner in which they were attached to the wheel. This patent was assigned to Brayton.

The final major improvement in the Pelton wheel was made, not by Pelton or anyone else in the Rankine, Brayton firm, but by a competitor, the Abner Doble Company. This company, formed about 1850, manufactured and sold mining equipment and tools, as well as tools and equipment for general contracting. The principals in the company were Abner Doble and his sons, Robert and William A. Doble. Some time after 1889, William A. Doble, while visiting a mine that the company owned, saw a small Pelton wheel, which powered an electric plant. He noted that the buckets of this wheel showed rapid wear on account of the scouring action of the sand in the water jet. Wondering whether this was a condition peculiar to this particular wheel, or more general, he surveyed several mines in the area. He found this rapid-wear condition to be widespread in the Pelton wheels that were in use at that time.

He studied the problem for some time, and conjectured that the abrasion was a consequence of excessive turbulence in the water striking the buckets and flowing along their surfaces. The abrasive action of sand suspended in the water would be expected to be localized in areas where turbulent flow occurred. The obvious remedy was to design a bucket shaped to minimize turbulent flow. Doble's studies resulted in a series of three patents issued in 1899, two on February 7 and one on September 19. The final patent in the series claims a bucket formed of two side-by-side ellipsoidal cavities joined by a stream-splitter, with the leading edge cut away to clear the incoming jet. This bucket is quite similar to those used today in tangential-flow water wheels.

With this bucket, the jet of water touches only the splitter, and divides

cleanly into two halves. The water flows through the bucket with minimal turbulence, thus reducing abrasion by any material in suspension in the jet, and also reducing losses in efficiency due to turbulence.

The Abner Doble Company thus went into competition with the Pelton Water Wheel Company. About 1900, just after issuance of the Doble patents, a water company by the name of Blue Lakes Water Company asked the Pelton Water Wheel Company to bid on the installation of a number of their wheels to run a power plant. Apparently because of disagreements over price and other contract terms, Blue Lakes became unhappy with the Pelton Company before construction had begun. They asked the Doble Company to undertake the job. With their patent position as a foundation, Doble was only too happy to oblige. They furnished Blue Lakes with wheels which were clearly superior to the Pelton Company's wheels, both as to efficiency and as to resistance to abrasive wear.

The Pelton Company and the Doble Company from then on until their merger in 1912 were competitors for customers and patent rights, which were litigated continually. In 1912, with the merger of the two companies under the name of the Pelton Water Wheel Company—with William A. Doble as chief engineer—all patents plus the designs and manufacturing practices of each company were pooled together, and Pelton water wheels from then on incorporated the best of each organization.

In Conclusion

Lester Pelton himself had died March 15, 1908. Although most, if not all, present-day standard biographical and engineering references give Pelton's date of death as 1918, engineering-news-type publications of the era contain obituary notices giving the correct death date of 1908.

William Doble went on from bucket design to the design of improved methods of controlling the water jet of the Pelton wheel, taking out many patents on the use of retractable needles in the nozzle to regulate water flow onto the wheel.

Today, Pelton wheels are used with water heads as high as 3,000 feet, and can develop as much as 40,000 horsepower per wheel at efficiencies ranging upward from 88 percent. While Lester Pelton did not invent the wheel that bears his name, he did contribute much to its development. He was at the right place at the right time with the right combination of business and engineering acumen to justify its being called the Pelton wheel. □

Dr. Shortridge can be reached at 4409 West 78th Street, Prairie Village, KS 66208; (913)642-2881.

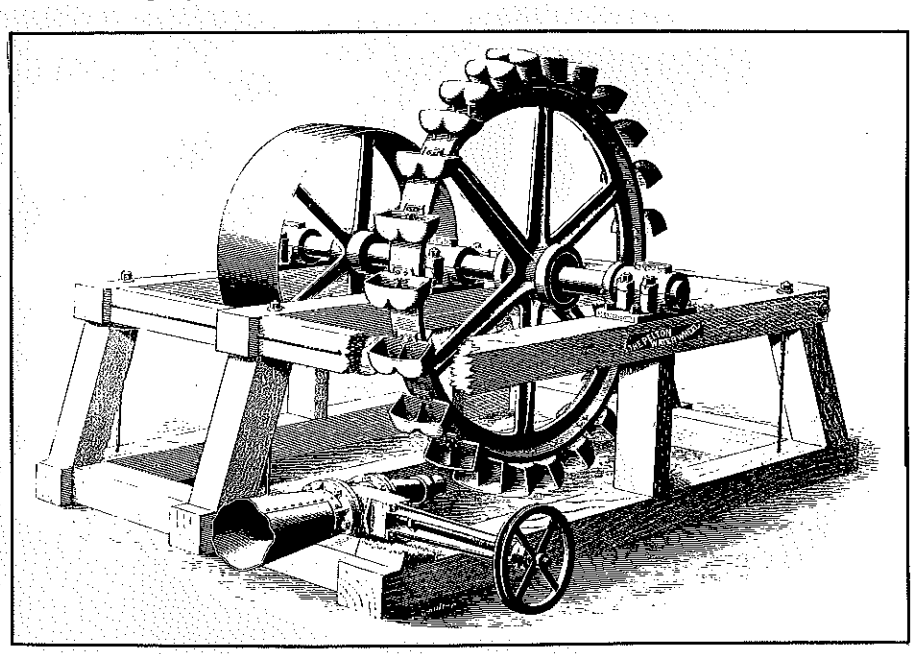


Figure 3: A drawing of the Pelton Wheel, taken from the *Journal of the Franklin Institute*, 1895. (Courtesy of Linda Hall Library.)

Notes:

[1] Durand, W.F., "The Pelton Water Wheel," Part 1, Developments by Pelton and Others Prior to 1880, *Mechanical Engineering*, vol. 61, pp. 447-453, 1939.

References:

Abbott, David, Editor, "Biographical Dictionary of Scientists: Engineers and Inventors," P. Bedrick, New York, 1986, pp. 117-118.

Doble, W.A., "The Tangential Water-Wheel," American Institute of Mining Engineers, Transactions, vol. 29, pp. 852-894, 1899.

Durand, W.F., "The Pelton Water Wheel," Part 1, Developments by Pelton and Others Prior to 1880, *Mechanical Engineering*, vol. 61, pp. 447-453, 1939.

Durand, W.F., "The Pelton Water Wheel," Part 2, Developments by Doble and Others, 1880 to Date, *Mechanical Engineering*, vol. 61, pp. 511-518, 1939.

"Engineering News," vol. 59, no. 16, p. 428, April 16, 1908.

"Engineering and Mining Journal," vol. 85, p. 919, May 2, 1908.

Mason, Martin A., "The Pelton Water Wheel," *Mechanical Engineering, vol. 61, pp. 755-756, 1939. Letter commenting on the two Durand articles.*

National Cyclopaedia of American Biography, vol. 13, p. 602, 1906.

Pelton, Lester A., U.S. Patent 233,692, October 26, 1880 (Claim and drawing). Official Gazette, U.S. Patent Office, October 26, 1880, p. 949.

Schodeck, Daniel L., "Landmarks in American Civil Engineering," MIT Press, Cambridge, 1987, pp. 316-318.

Smith, Norman, "Man and Water: A History of Hydro-Technology," Peter Davies, London, 1976.

Wilson, Joseph M., et. al., "The Pelton Water Wheel," *Journal of the Franklin Institute*, vol. 140, pp. 161-197, 1895.

Acknowledgment

Much of the material for this article was taken from vintage books and magazines in the collection of the Linda Hall Library of Science and Technology in Kansas City, Missouri. Grateful acknowledgment is given to Linda Hall Library.