# THE PELTON WATER WHEEL AND ITS HISTORIC MINING ROLE

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The Pelton Water Wheel, an 1880 patented device to convert high pressure water into mechanical energy, was developed in the northern California mining industry at a time when high pressure water was abundant and the need to run high energy machinery great. Lester A. Pelton, working in Camptonville, California, a center of hydraulic mining, was impressed by the enormous energy of high pressure water used in the attack of gold bearing gravel of the ancestral Yuba river. He was familiar with the older overshot and undershot water wheels and familiar too with the attempts of harnessing high pressure water streams with

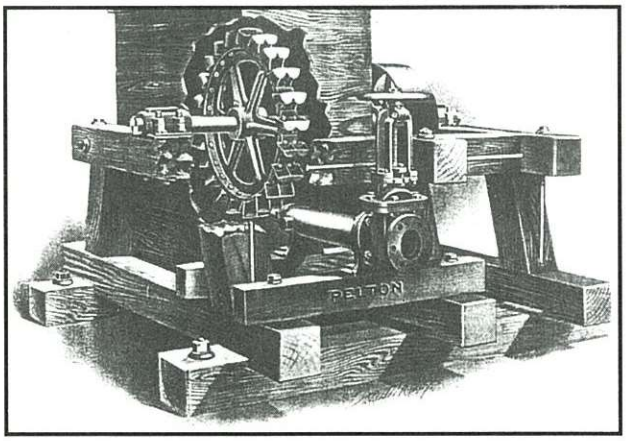



Figure 1. Standard Pelton Wheel mounted on wood frame, 1880 design.

the Hurdygurdy wheels of his time which were plagued by the inefficiencies of splash buildup as the high velocity water would strike the wheel. Hurdygurdy wheels were usually designed with flat paddles at the periphery of the wheel meant to engage a high velocity water stream. The spinning wheel would transfer energy to attached machinery. The classic overshot and undershot water wheels used for centuries are classified as reaction turbines. They take the force of moving water or gravity of water to turn the wheel. Impulse turbines as in hurdygurdy, Pelton, Knight or Tutthill wheels attempt to transfer the kinetic energy of the high velocity water into the slower moving cup at the periphery of the wheel.

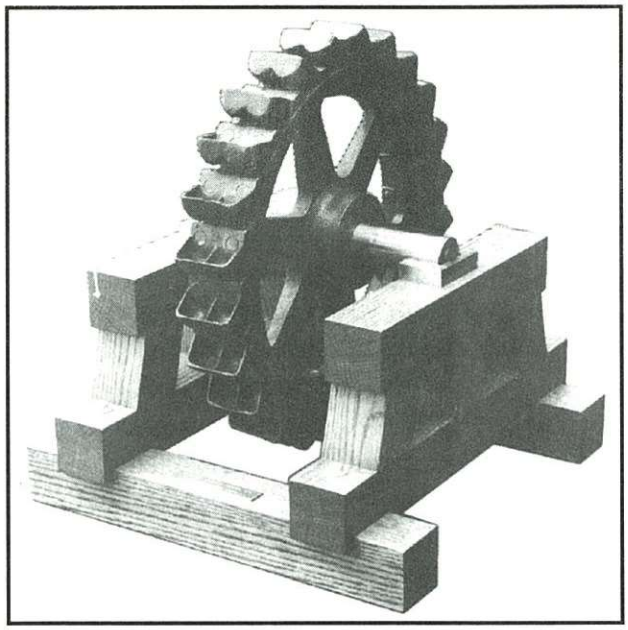


Figure 2. Pelton Wheel. 18 inch diameter, with 1880 design cups. Collection of authors. Photos by Robert Cross.

The brilliant breakthrough of Pelton's design was the division of the water cup into two chambers divided by a wedge or splitter partition. The high pressure jet of water, sometimes exceeding 200 miles per hour, was aimed at the splitter dividing the incoming stream into two portions directing them laterally and at least partially reversing their direction. This achieved two goals:

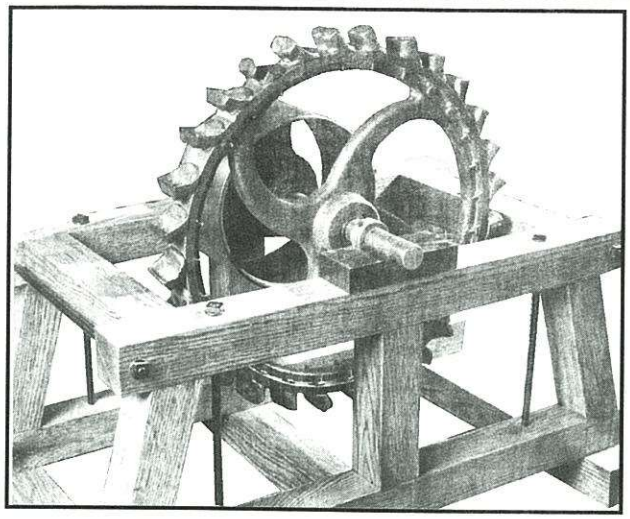


Figure 3. Pelton Wheel, 16 inch diameter, with 1880 cup design and early curved spokes. Collection of authors

1) The clearing of water from the cup to prevent splash buildup and

2) The reversal of the incoming stream imparting more energy to the wheel.

The nozzle velocity of the incoming water was considered to be roughly twice the spinning cup velocity.

Many competitors of the Pelton wheel tried to match the efficiency of this patented concept but few if any succeeded. The Knight wheel of Sutter Creek, California, was a major local competitor and actually predated the Pelton by several years. The Leffel wheels, also earlier than Pelton, were primarily designed for lower water head pressures. The Tutthill wheel used alternating left and right cups to achieve the same efficiency concepts of the Pelton. Other foundries such as Risdon and Joshua Hendy were able to manufacture divided cups similar to the Pelton either through franchise agreements or design changes skirting the Pelton patent.

The Pelton proved to be the dominant water wheel in the market place both by scientific testing and marketing efficiency. The Idaho mine, Grass Valley, California, experiment of 1883, using a head pressure of 368 feet, showed an efficiency superiority of Pelton over Knight, Fredenburr and Taylor wheels. The sales of Pelton wheels in California, western United States and throughout the world grew at a phenomenal rate from 1880 to 1910. The manufacturing was moved from the Miners Foundry in Nevada City, California, to San Francisco in 1888 with the creation of the Pelton Water Wheel Company. The facility was relocated and enlarged in San Francisco after the earthquake and fire of 1906. The plant closed in 1963.

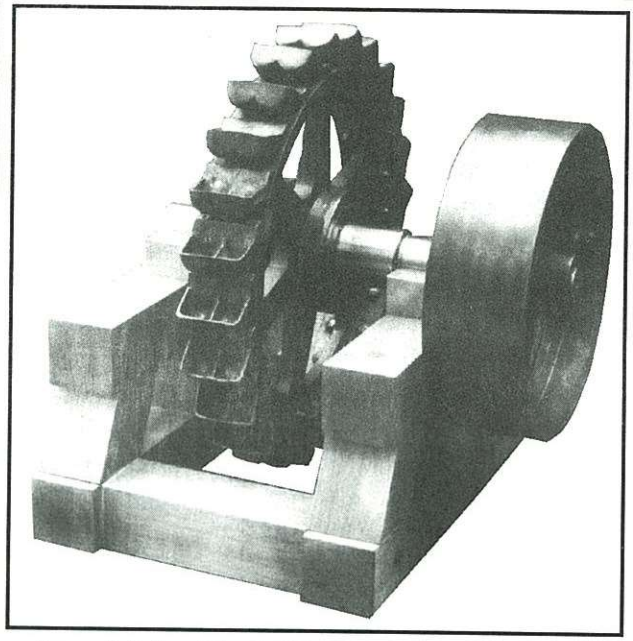


Figure 4. Pelton Wheel, 18 inch diameter, with 1880 patent cup design and flat belt pulley

By 1890, 280 Pelton wheels had been installed in the western United States and another 200 throughout the world. By 1898, 900 Peltons were listed in the United States and another 500 throughout the world. The number of Peltons in use by 1909 worldwide was over 12,000 of which over 10,000 were in the western United States and Alaska. Over 1000 were located in Mexico, Central and South America.

The majority of Pelton wheel installations were tailor-made, based on water head and water volume available, horsepower requirements and types of machinery to be driven. The average

installation would call for a steel wheel and a single fixed nozzle. More than a single nozzle, sometimes up to five, would be used for high water volume and limited water pressure. With variable work loads, a governor, jet deflector, needle nozzle and nozzle deflector would be added to protect against a runaway unloaded wheel and even worse, water hammer of the pipeline if the nozzle flow was suddenly reduced. Needle nozzles, with an adjustable brass or steel contouring needle in the center of the nozzle, were widely used in high pressure systems where hand adjustments or governing were essential. Needle nozzles, controlled by governors were frequently used for RPM control in the generation of electricity. Quintex wheels with five nozzles directed at the same wheel were only recommended for installations below 50 feet of head and were not equipped with needle nozzles or governors. In extremely variable workload installations such as saw mills, air compressors or mine hoists, the water hammer prevention apparatus would consist of a jet deflector (intercepting the jet so that it does not strike the cup), a water escape valve, a nozzle deflector (aiming the nozzle away from the cup) or even a second needle nozzle (not aimed at the wheel) which would open synchronously as the real needle nozzle closed by action of the governor. All of these would reduce water energy striking the wheel without water hammer damage to the riveted steel piping. It should be remembered that some of these high pressure systems exceeded 1000 pounds per square inch static pressure, much higher when moving water was stopped and ten times greater than most fire hose pressures. Pelton also sold off-the-shelf wheels, known as their "D" wheels, and self-contained encased water motors, known as their "C" wheels. These were less expensive and would serve the purpose of many generic water wheel tasks. The classic Pelton cup design of the 1880 patent was rectangular with a center splitter partition. Many modifications of this followed with the greatest change in approximately 1900 known as the Pelton Doble cup with

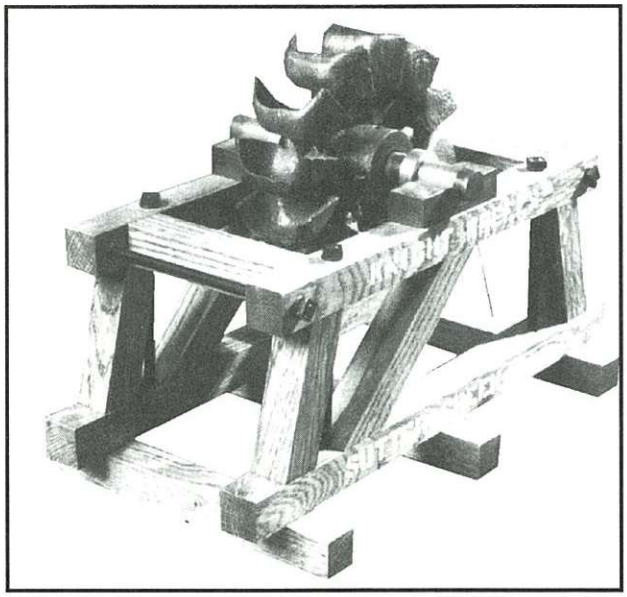


Figure 5. Knight Wheel, 6 inch diameter, one piece cast iron. Non-divided cup.

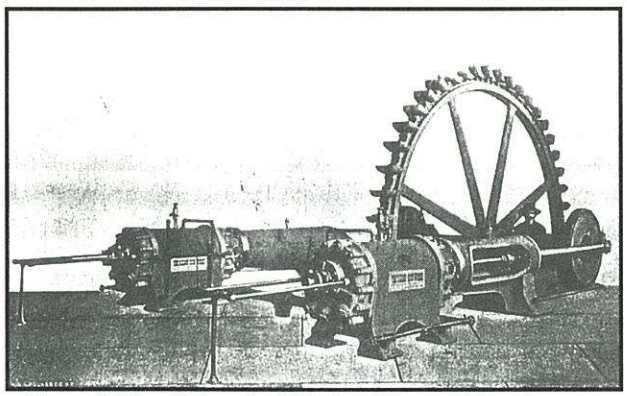


Figure 6. Twenty four foot Risdon Wheel driving air compressors, 500 H.F.

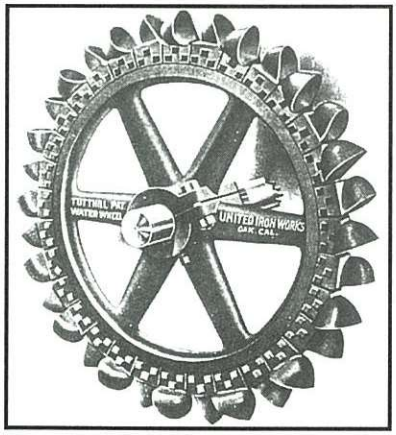



Figure 7. Tutthill Wheel with alternating left and right cups.

rounded corners in an ellipsoidal configuration. The center partition remained in all Peltons.

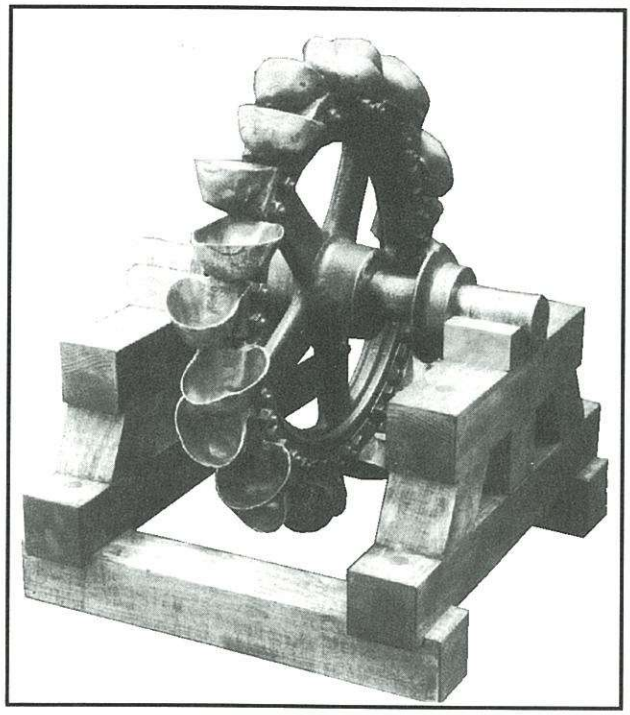


Figure 8. Tutthill Wheel, 20 inch diameter. Alternating left and right bronze cups. Collection of authors.

The Pelton water wheel and other tangential impulse systems arrived on the mining and industrial scene at a time to replace steam engines. Many mines had already stripped their local forests for mining timbers and fuel for steam engines and were happy to find an alternative energy source. The earliest use of impulse water wheels was to convert high pressure water energy into mechanical energy. This conversion was particularly useful in western mines where mountainous terrain provided the high pressure water and the mechanical energy for machinery was greatly needed. The electric motor soon replaced the Pelton wheel at the mine location if electricity could be provided at these remote sites. Since the Peltons and other wheels were well suited for electricity production, many mining and industrial sites, generally by 1900, converted to electricity and the Peltons at other locations became the primary producers of this power.

The history of the Pelton wheel could therefore be summarized as direct powering of machinery during the decade of the 1880's and production of electricity beginning in the decade of the 1890's. From approximately 1885, for at least 60 years, Pelton and other leading tangential water wheel manufacturers were at the forefront of the pioneering hydroelectric industry. The tangential wheels slowly gave way to the turbine designs where water flow is parallel to the axis of the runner. Pelton Francis turbines and Leffel turbines were early prototypes of these machines.

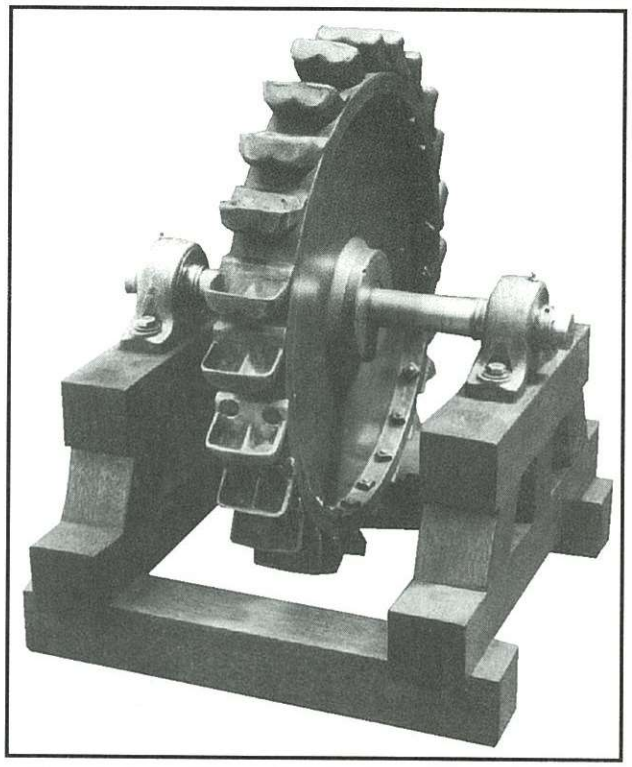


Figure 8. Pelton Wheel, 21 inch diameter, solid disc wheel with 1880 design cups.

By 1890, several hundred western mines were using Pelton water wheels for a primary energy source. Examples are listed here:

| | |
|---|---|
| Idaho Mine | |
| Grass Valley, CA | 16 Peltons |
| Empire Mine | |
| Grass Valley, CA | 6 Peltons |
| North Star Mine | |
| Grass Valley, CA | 10 Peltons |

| | |
|---|---|
| IXL Mine | |
| Nevada County, CA | 3 Peltons |
| Kennedy Mine | |
| Jackson, CA | 7 Peltons |
| Amador Gold Mining Co., | |
| Jackson,CA | 10 Peltons |
| Plymouth Mine | |
| Plymouth, CA | 7 Peltons |
| Treadwell Mine | |
| Douglas Island, AK | 5 Peltons |
| Anaconda Smelting Works | |
| Montana | 1 Pelton |

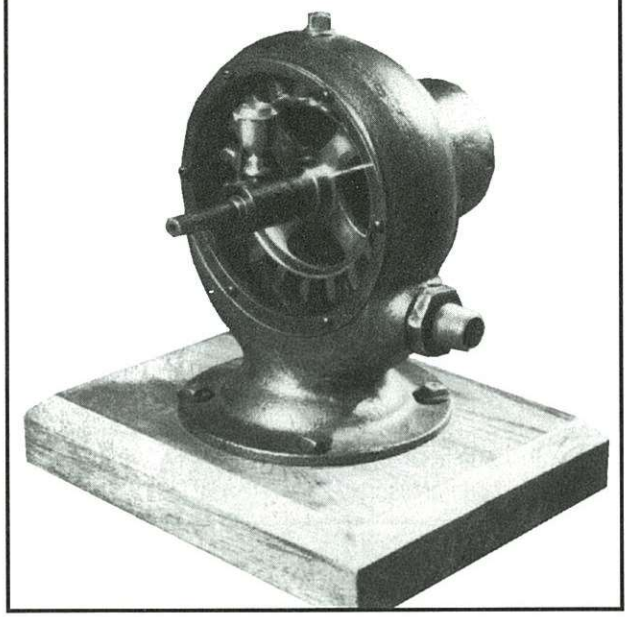


Figure 10. Pelton Motor No. 1, 6 inch bronze wheel. Side panel replaced with a window.

The largest Pelton wheel created, during this period, served the North Star Mine, 30 feet in diameter, turning at 65 RPM, developing 1000 horsepower, water delivered from a 1¾ inch nozzle attached to a 20 inch diameter penstock with 735 feet of head and driving two air compressors. The compressed air ran most of the machinery of the mine. A 33 foot Pelton was created later.

The Empire Mine in Grass Valley, just up the hill from the North Star, stopped using steam engines to drive its machinery in 1886 and converted entirely to Pelton wheels for its stamp mill, air compressors, water pumping, hoists and machine shop. This lasted only five years and the conversion to electricity became more convenient. By 1900, most major mines in the West were electrified. By 1890, over 300 Knight water wheels, a major competitor of Pelton, were in use in the western United States. The earliest installation of a Knight wheel was at the Lincoln Mine in Sutter Creek, California, in 1875, five years before the Lester Pelton patent. The water-powered Knight's Foundry in Sutter Creek became a California historic site after continuous operation from 1873 to 1995, a facility covering 16,000 square feet. In the 20th century the Knight wheel was only one of several wheels competing against the much more successful Pelton. These competitors included such names as Hendy, Tutthill, Risdon, Leffel, Chicago, Syracuse and Backus.

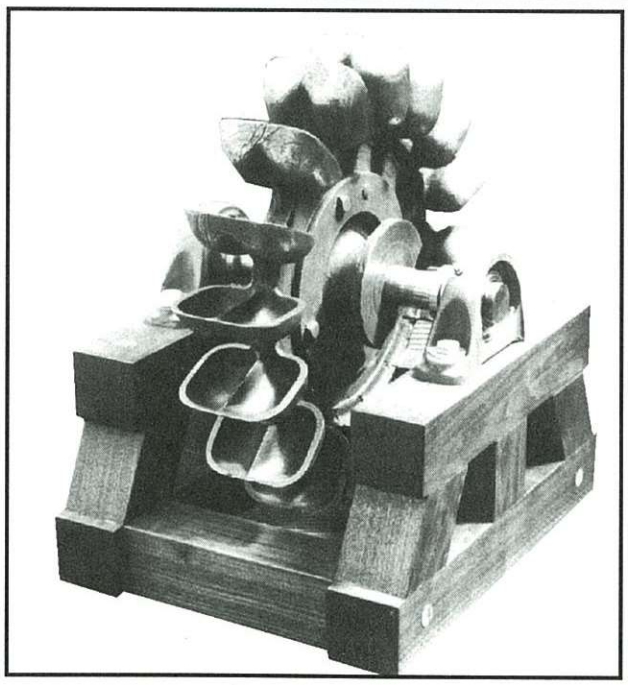


Figure 11. Pelton Wheel, 18 inch diameter. Modified cup design

One of the earliest major hydroelectric installations was in Aspen, Colorado, a mining town of 7000 inhabitants, where in 1889, a mile long 14 inch steel pipe delivered

water to eight 24 inch Pelton wheels turning at 1000 RPM producing an aggregate 1400 horsepower. This was the electric power for the entire town of Aspen as well as many mills and mines in the vicinity. A mile away at Castle Creek, two 300 horsepower double nozzle five foot Peltons were generating electricity. In 1896, Fresno, California, was electrified through a Pelton water wheel plant on the North Fork of the San Joaquin River 35 miles away. A 4000 foot steel pipeline delivered water with a vertical head of 1410 feet to three 57 inch, 500 horsepower Pelton generator pairs and two 20 inch Pelton driven exciters. The city of Salt Lake City in 1898 was electrified by a Pelton powerhouse installation on Big Cottonwood Creek 14 miles from the city. Four 60 inch Pelton wheels, 650 horsepower each, running at 300 RPM under a water head of 380 feet drove four three-phase generators. Other Pelton wheels were used for field exciters. Water was brought to the Peltons through a 2400 foot 50 inch riveted pipe.

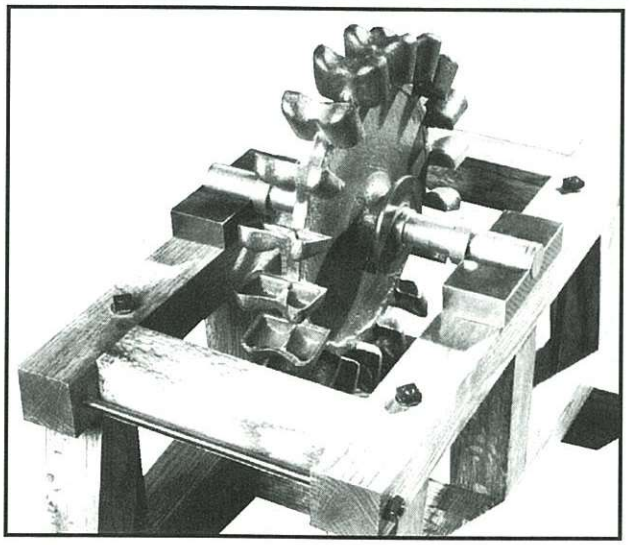


Figure 12. Pelton Wheel, 12 inch diameter. Modified cup design. Author's collection.

In 1878, Lester A. Pelton produced a mechanical device which changed mining engineering techniques throughout the world. It can also be said that the Pelton wheel and the competitive engineering of other water wheel companies were the nucleus around which today's hydroelectric industry was built. The 1890 Pelton Catalog boasted that the Pelton Wheel was California's most illustrious invention.

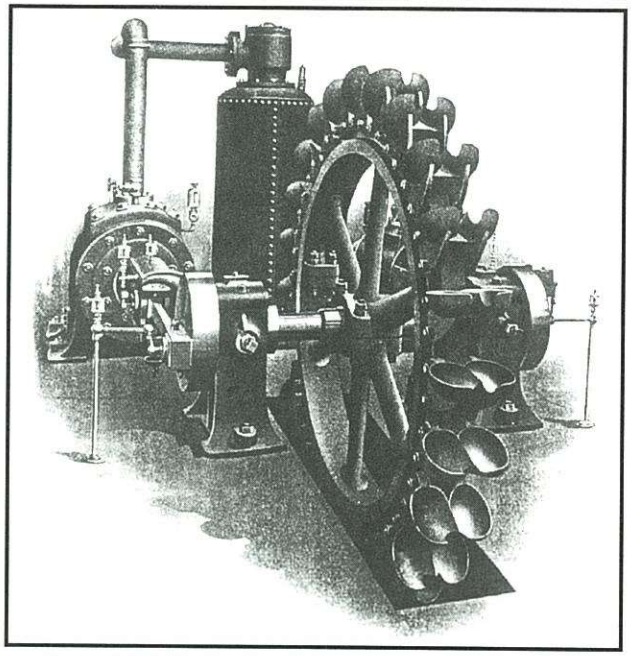


Figure 13. Pelton - Doble Wheel driving two air compressors.

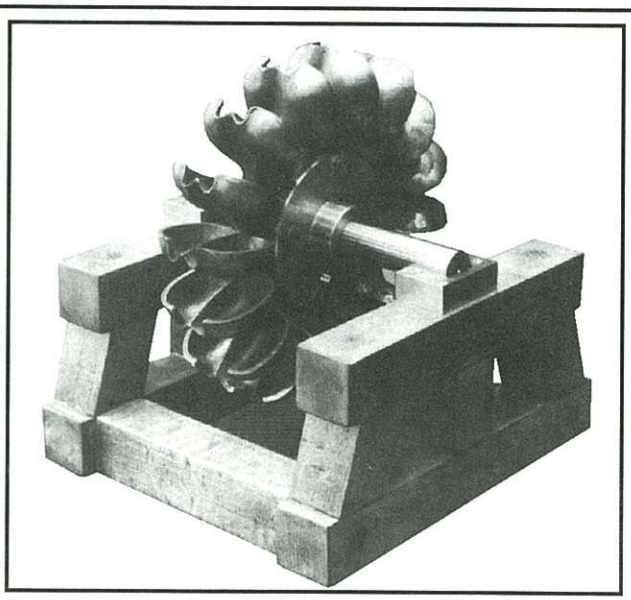
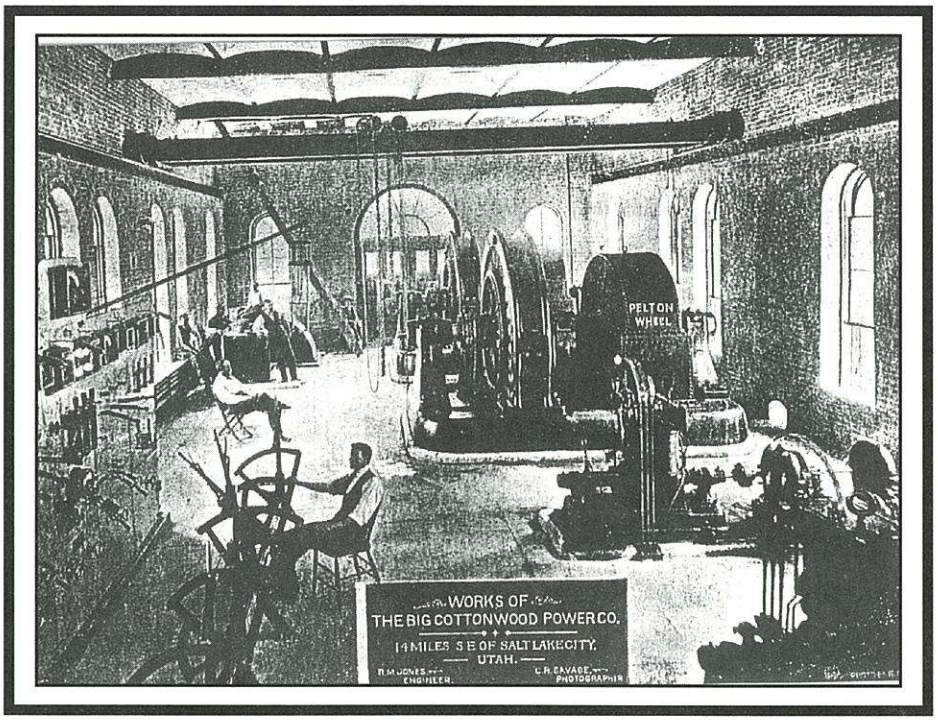


Figure 14. Pelton - Doble Wheel, 13 inch diameter, post - 1900 design.




Big Cottonwood Power Plant Supplying Salt Lake City, 1898.

Figure 15

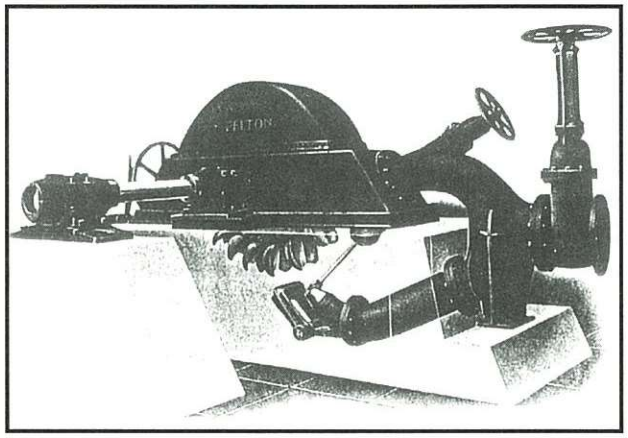



Figure 16. Double nozzle encased Pelton Wheel. A needle nozzle, (upper), jet deflector on lower nozzle.

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