Hydro Hall of Fame: Honoring the Foundations of Hydropower

In 1995, Hydro Review *introduced the Hydro Hall of Fame, inducting three hydropower plants that had been in service for 100 years. Here, we recognize and honor the contributions of the three newest inductees into the Hall of Fame.*

Industrialists in the United States are generally credited with harnessing the power of rivers, and converting that power into mechanical energy. These pioneers found that by using waterpower in their mills and factories, they could increase their output and improve the efficiencies of their operations.

It was industrialists such as these who were responsible for developing the three hydropower plants that are honored as this year's inductees into the *Hydro Review* Hydro Hall of Fame.

These projects were originally developed more than 100 years ago to improve working conditions and the quality of life for people in the communities where they are located.

The Vulcan Street plant in Appleton, Wisconsin, is credited as being the very first hydroelectric plant in the world, providing lighting to residences, mills, and businesses. The Bridge Mill project in Pawtucket, Rhode Island, is located on the Blackstone River, which earned the nickname as the hardest working river in America because of the number of mills and industries along its banks. The Columbia Canal project in Columbia, South Carolina, provided power to the first textile mill to operate on electricity, rather than waterpower.

Each project carries a unique history.

The 1.7-MW Bridge Mill project could have become a part of history in the 1970s. As the equipment aged and became more expensive to maintain, the Blackstone Valley Electric Company decided to put the project out to pasture. That thinking, however, reversed only a few years later, as planners began looking for ways to reduce the consumption of oil. A rehabilitated Bridge Mill project fired back up in 1985, featuring two modern 850-kW generators, automatic remote control, and automated trash-cleaning equipment. Although 100 years old, the project today features all of the modern conveniences of hydropower generation.

This Year's Inductees:
— Vulcan Street Hydroelectric Central Station, Appleton, Wisconsin
— Columbia Canal Hydro Plant, Columbia, South Carolina
— Bridge Mill Power Station, Pawtucket, Rhode Island

The original vision for the Columbia Canal, which serves as the waterway for the hydropower project of the same name, was not electricity generation, but navigation. After numerous attempts to sell the canal to any willing takers, the state of South Carolina finally gave it away — to the city of Columbia, South Carolina. The Columbia Water Power Company built a 1-MW project on the canal, to provide electricity to a textile mill some 600 feet away. When the station began operating in April 1894, the mill became the first electrically operated mill, revolutionizing the use of water power. Today, South Carolina Electric & Gas (SCE&G) Company continues to own and operate the project, now a 7-unit 10.6-MW plant, the oldest generating plant in SCE&G's operating system.

As mentioned earlier, the Vulcan Street Station holds the distinction of being the first hydroelectric station in the world — a feat it accomplished in September 1882 when it began illuminating electric light bulbs in Appleton, Wisconsin. The project had the direct influence of Thomas Edison himself, whose company sold the original generator — a "K" type dynamo — for the project. The Kimberly-Clark Corporation built a second generation Vulcan plant in 1908, after the original plant burned in the early 1900s. That second generation Vulcan station provided power to Kimberly-Clark mills until the mid-1970s, when economics could no longer justify the operations and maintenance expense.

All of these projects experienced major changes throughout their history. The Vulcan Street station, for instance, was built — and rebuilt — several times after it first produced the glow of an electric lamp in 1882. Newer, bigger, and better equipment was installed. Over the years, new powerhouses were built to provide more room for generating equipment, and once after fire destroyed the building.

The strong desire to improve these projects and keep them operating helps to show the value that the owners placed on hydropower — then and now. The fact that these projects operated — and two of them continue to operate — for more than a century is a testament to the value of clean, renewable hydropower as a generating source.

Vulcan Street Hydroelectric Station:

World's First Hydroelectric Plant

The Fox River has been a Wisconsin attraction since the first explorers paddled upstream from Green Bay to cross the portage to the Mississippi River. In 1882, this river inspired a group of industrialists to establish the first hydroelectric central station in the world.

The residents of Appleton, Wisconsin, were familiar with the power of the Fox River, and its ability to drive machinery in the local mills. Based on the efforts of a group of businessmen and an engineer with the Edison Light Company, Appleton's Vulcan Street hydroelectric station began generating electric power in 1882, finding a new use for the power of the Fox River.

The hydropower plant was first the inspiration of H.J. Rogers, the owner of an Appleton paper mill. A friend of Rogers', who represented the Western Edison Light Company of Chicago, told Rogers about an electric lighting plant that was being built on Pearl Street in New York. Rogers decided that the 12,000-horsepower strength of the Fox River could power a lighting plant as well as any steam-powered plant in New York.

Rogers then convinced A.L. Smith, H.D. Smith, and Charles Beveridge to support the hydroelectric plant. The four men formed the Appleton Edison Light Company, Ltd., and signed a contract to purchase two generators — 12.5-kilowatt (kW) Edison Type "K" dynamos. Within several weeks, the plant was built and the equipment installed. The first generator was connected to the water wheels at Rogers' pulp beater mill. Several buildings had been wired to receive the electricity produced by the new lighting plants, including Rogers' home and one of his mills — the Appleton Pulp and Paper Mill. On September 30, 1882, the project began feeding power to electric lamps in Appleton.

Within a couple of months, operators had decided the generator should be connected to a separate water wheel to improve operations. So, by November a new powerhouse had been built and the dynamo was connected to a separate water wheel. This feature improved the constancy of the voltage. By this time, the plant had five customers: Rogers, two additional residences, a blast furnace, and a local hotel.

During this period of operation, voltage regulators did not exist, so the powerhouse operator judged the voltage based on pilot lamps in the powerhouse. If the lights flickered and dimmed, the operator opened the gate on the water wheel for a little more power.

A new 190-kW plant was built in the

Kimberly-Clark operated the Vulcan project from 1908 through 1974. Among the properties that received power from the project was Kimberly-Clark's Atlas Mill, shown in the background of this photo.

Also 100

Hydro Hall of Fame inductees have been selected based on their length of service — at least 100 years of service. This year's Vulcan plant was taken out of service a few years before it reached the century mark. It was selected owing to its place in history as the first hydroelectric station in the world. We are aware of one additional plant that will observe 100 years of operation during 1996.

The 1.1-MW **Granite** project has operated on the Big Cottonwood River since 1896, and today supplies power to the Brighton Ski Resort near Salt Lake City, Utah. The project began operating only after several months of sabotage between the developers of Granite and the nearby Stairs Station. While the two plants were early-day competitors, today, the projects operate in tandem. Utah Power and Light Company modernized and automated the Granite station in 1980, after generator windings burned at the plant. (*Editor's note: The Stairs Station was inducted into the Hydro Hall of Fame in 1995. For more information on the operations of the Stairs and Granite stations, see the October 1995 issue of* Hydro Review.—SB)

PacifiCorp's Granite Station turns 100 years old this year. This photo shows the 1.1-MW plant in 1915. (Photo courtesy PacifiCorp)

If you are aware of other facilities 100 years old or older, or plants anticipating a 100-year celebration in the near future, we'd appreciate you alerting us.

mid-1880s. This new plant included regulating equipment, fuses, and a three-wire distribution system. This plant operated for about 15 years, before the plant burned in the early 1900s.

In 1908, a new plant, just downstream from the original site, acquired the Vulcan name. Kimberly-Clark Corporation built the second generation Vulcan plant on bedrock that had once held Kimberly-Clark's Vulcan and Tioga paper mills. The plant was built to serve several Kimberly-Clark paper mills. The project featured two vertical 62-inch Sampson turbines, geared to transfer the mechanical power to a horizontal shaft, which in turn was connected to a generator. The generator was a Fort Wayne Electric Works machine, with a 940 kVa capacity that was originally intended to be used with four turbines. The generating equipment was removed in 1916 and was replaced with two 45-inch Leffel Type "Z" turbines, connected to 450-kW, 6,600-volt, 25-cycle generators made by Electric Machinery Company. Generating capacity at the plant varied between 1.35 and 1.45 MW during its operation.

That site operated until 1974. When it closed, it supplied 25-cycle power to Kimberly-Clark's Atlas and Kimberly mills. Conversion to 60-cycle equipment and increasing costs of maintaining and operating the plant convinced Kimberly-Clark to close the hydropower plant after six and a half decades of operation.

Today, this site of the world's first hydroelectric plant consists of the old stone foundation and the ruins of the plant. The site will be incorporated into the Vulcan Heritage Park, a collaborative effort among the city of Appleton, Wisconsin Electric Power Company, and the Corps of Engineers. The park will include a series of viewing platforms, connected by an elevated boardwalk system through the natural area of the site. Interpretive signage along the walkway will identify the Thomas Edison connection to the historic ruins.

Site of Vulcan Street Hydroelectric Station, the very first hydropower plant. (Photo courtesy City of Appleton, Wisconsin, Department of Community Development)

While the Vulcan project no longer produces electricity, the power of the Fox River continues to be utilized for hydropower. Within a 10- to 15-mile stretch of the Fox River are at least half a dozen small hydropower projects, contributing more than 20 MW to the cities along the Fox. Among those projects is the Appleton Hydro Plant, a 2-MW site operated by Wisconsin Electric Power Company. The Appleton plant is located on a peninsula just across from the old Vulcan plant.

And, like Thomas Edison, the Vulcan plant has preserved its place in history. Through the Vulcan Heritage Park, hydropower's role in developing not only Appleton, but numerous other cities across the nation, will be remembered.

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Columbia Canal Hydroelectric Plant:

Dreams of Water Travel Lead to Electricity

In 19th century South Carolina, canals were a civic mania. River travel was supposed to bestow great riches wherever boats could float. The Columbia Canal was one of the greatest visions of that time. For years, dreamers and entrepreneurs sought to connect Columbia, South Carolina, with the Atlantic Ocean more than a hundred miles to the south. While these visionaries never achieved any measure of success in navigation, the canal and a small hydroelectric facility eventually made history in a major, but different, way.

The Columbia Canal, parallel to the Congaree and Broad rivers, had a history as turbulent as the surrounding rapids. It was hotly debated on the village square, in the legislature, and in the courtroom. It was the subject of speeches, statutes, and lawsuits.

The State of South Carolina began construction of the canal in 1819 in an attempt to pass boats around the Congaree rapids — an objective that frustrated planner after planner. A canal of sorts, with four locks, was completed in February 1824 at a cost of $206,000. But the canal, at the mercy of dams and other canals upriver, was often unusable, carrying either too much or too little water. The canal closed for several years in the 1830s and then reopened in 1840. However, for all practical purposes, an effective, functional Columbia Canal basically remained a vision.

Over the decades, various developers tried and failed to exploit the waterway. Almost yearly, lawmakers approved acts to authorize the canal's sale so that it could be developed for waterpower. It passed through several ownerships but proved profitable to none, and each time reverted back to state ownership.

During 1863, the South Carolina General Assembly passed an act vesting part of the canal in the Confederate Government for its use in manufacturing gun powder. At the close of the War Between the States, the canal was again returned to South Carolina.

Finally, in 1887, after more than 40 years of passing the canal from one owner to another, South Carolina handed the property over to the city of Columbia. Engineers built a dam about three miles upstream and enlarged and extended the upper half of the old canal to take full advantage of the flow from the Broad River.

By this time, however, railroads had usurped most of the market for river transportation. The canal, however, had another destiny: waterpower.

A group headed by New Hampshire textile titan Aretas Blood formed the Columbia Water Power Company to build a mill to produce textiles. The group decided to place the plant, called Columbia Mills, on a bluff about 600 feet east of the canal. This seemed to create a virtually impossible problem if power were provided in the conventional way — by using a water wheel and a system of shafts and belts.

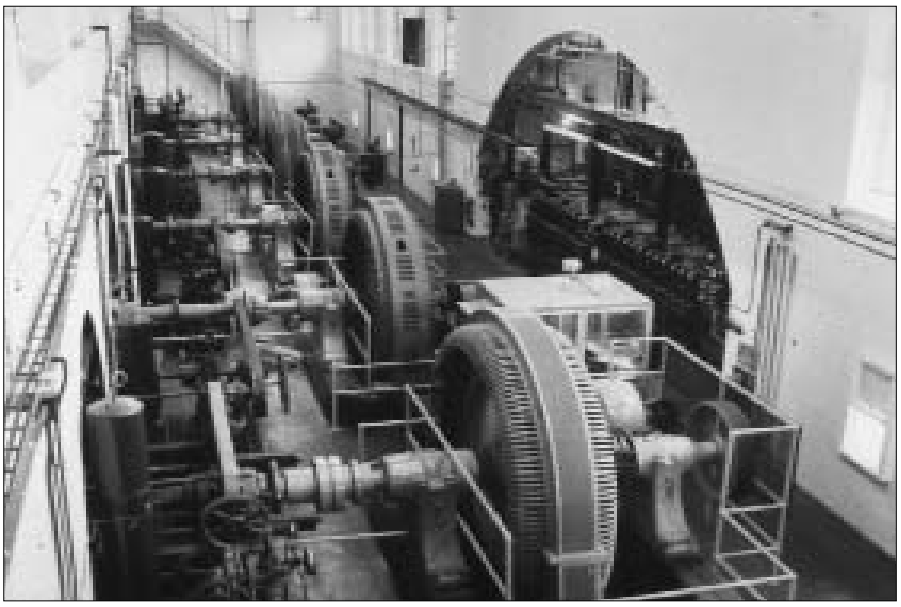
But innovation triumphed. Electric motors would power the mill, and the electricity would be generated by a powerhouse located on the canal 600 feet away. General Electric accepted a contract to provide 17 alternating current motors, each rated at 65 horsepower, even though the largest motors General Electric was building at the time were only 10 horsepower.

The powerhouse was completed in 1894 by the Columbia Water Power Company. Equipment included two 500-kilowatt (kW), three-phase generators directly connected to two pairs of 48-inch water wheels. Current was transmitted by insulated wire about an inch in diameter at low voltage. The transmission line crossed a bridge over the canal, went underground through a wooden trough to the mill switch room, and electricity then was relayed to the 36-cycle motors. The distance of transmission was 700 feet.

World history was made on April 25, 1894. With the flip of a switch, the world's first electrically operated textile mill whirred to life, forever changing the textile industry and revolutionizing the use of water power.

On July 24, 1894, *Manufacturer's Record* wrote, "The time has come when it is economically possible not only to put a mill on a hilltop and its primal motive in a valley upon the banks of some stream, or have its fac-

The state of South Carolina began construction on the Columbia Canal in 1819, in an effort to create a navigable waterway around the Congaree Rapids. The canal never did become a successful navigation route, but it did become home to the Columbia Canal Hydro Plant, which powered the first electric textile mill. A new powerhouse was built in 1896 and today still operates, contributing 10 MW to South Carolina Electric & Gas Company.



The Columbia Canal Hydro Plant entered service in December 1896 with three turbines, with a capacity of 2.25 MW. Today, the project has seven turbines and generators and an installed capacity of 10 MW.

tory and its power miles apart, according to convenience, but to manufacture climate to suit the conditions of manufacture. There is a new development for the South ... the water powers have a new importance."

Two years later Columbia Mills expanded and a second, larger powerhouse was built. The current Columbia Canal Hydro went into commercial operation on December 31, 1896, with three 750-kW units completed. Additional units were installed in 1901, 1903, 1904, and 1927. Other significant improvements continued throughout the years as well, with improvements to the dam in 1928 and 1929.

In 1905, the plant became part of a conglomerate put together by one of Columbia's most active businessmen. His firm, the Columbia Electric Street Railway, Light & Power Company, was one of several major ancestors of SCANA Corporation, the parent company of South Carolina Electric & Gas (SCE&G), which continues to own and operate the project today.

The modern-day Columbia Canal Hydro is a run-of-river plant used for peaking operations, except at times where water flow allows for around-the-clock operation. The Broad River and its tributaries are made up of 5,330 square miles of watershed area in upper South Carolina and extending into the foothills of North Carolina.

The dam across the Broad River measures 1,021 feet long, 20 feet wide at the base and 14 feet above the river bed. The dam is located approximately 3 miles above the plant itself and is a rock-filled, timber crib design.

The canal serves as a small storage capacity reservoir of 265 acres. It is approximately 150 feet wide, 10 feet deep and extends southward paralleling the river for three miles. Water enters the powerhouse through seven generating units equipped with trash racks, and into covered water pits adjacent to the one-story, masonry and brick powerhouse. Each water pit contains a horizontal water turbine that is connected to the generator shaft.

As it celebrates its 100th year in operation, Columbia Canal Hydro today remains the oldest plant in SCE&G's operating system, with a generating capability of 10 megawatts. The plant also holds another honor to its credit: In 1979 the plant and the Columbia Canal were added to the National Register of Historic Places. And in the mid-1980s, the old Columbia Mills building was turned into the South Carolina State Museum. That museum will include exhibits that explain the plant's operations and its historical significance. So in a way, Columbia Canal Hydro Plant celebrates its 100 years of history every day.

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Technical Information
Columbia Canal Hydro Plant

General Information

Location: Downtown Columbia, South Carolina, on the Broad River at the Gervais Street Bridge

Owner: South Carolina Electric and Gas Company

Capacity: 10.6 MW

Head: 29 feet

Average Stream Flow: 6,000 cubic feet per second

Type of Project: Run-of-river

Average Annual Generation: 54,000 megawatt-hours

On-Line Date: December 31, 1896

Equipment

Turbines (7 units)

Camel-back, five rated at 1,600 kW, two rated at 1,300 kW

Five units manufactured by Leffel

Two units manufactured by S. Morgan Smith

Generators (7 units)

Four units manufactured by Allis-Chalmers

Two units manufactured by Westinghouse

One unit manufactured by General Electric

Air-cooled

164 rpm

4,600 V

New exciters manufactured by Rapid Power

New governor gate actuators manufactured by Cross

New vacuum generator breakers manufactured by Westinghouse

Manual control system to be replaced by computer-based system in 1996

Construction

Intake

Forebay pond/canal

Vertical slide gate for each turbine

Powerhouse

Concrete walls

Wood truss gable-type roof

181 feet long by 30 feet wide

Draft Tubes

Vertical steel draft tubes in an open race

Transmission

34.5-kilovolt overhead line to South Carolina Electric & Gas Company's system

Bridge Mill Power Station:

Linking the Industrial Revolution to Modern Technology

Pawtucket, Rhode Island, in the heart of the Blackstone River Valley, is considered the birthplace of the American Industrial Revolution. It was here that America's first factory, Slater Mill, began spinning yarn from raw cotton in 1793. The force of the Blackstone River powered many mills and small industries throughout the 1800s, a time during which the river earned its nickname — the hardest working river in America.

In the 1890s, just 300 yards downstream from where Samuel Slater built his cotton mill a century earlier, industrialists Lyman and Darius Goff began construction of the Bridge Mill Power Station. The Goff brothers were continuing work begun by their father, who owned a large braid and plush mill.

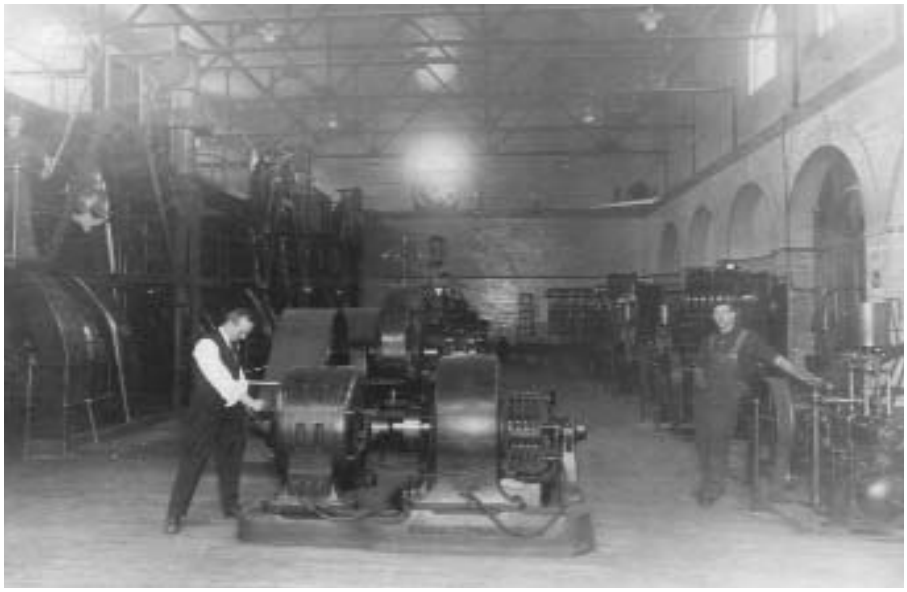
The Goffs, however, were unable to obtain a charter to do business as an electric company due to opposition from the Pawtucket Gas Company. Rather than fight the competition, the brothers joined with the gas company to form the Pawtucket Electric Company. Bridge Mill became part of the electric system serving the city of Pawtucket.

Bridge Mill officially began operation on May 1, 1896, using water, steam, or a combination of both to generate electricity. Engineering publications of the time called it the "finest water-power electric station in New England," citing both the combined utilization of water turbines and steam engines and the building's architectural design.

The plant's first customer was the Interstate Street Railway, and it soon became the main source of power to the city of Pawtucket. And, by 1915 it provided 75 percent of the power to nearby Woonsocket as well.

Bridge Mill's five original generators had a total capacity of 750 kilowatts (kW). Water from the Pawtucket Falls traveled 130 feet through a 17.5-foot-diameter, brick-lined, inlet waterway tunnel to the station.

During most of its life, Bridge Mill Power Station remained relatively unchanged. Direct current continued to be provided for many years to power several elevators in the city, and street lights were turned on and off manually from the station. A partial switch to alternating current was accomplished in 1910, and five new generators were installed in 1922, increasing capacity to 1,000 kW.



The Bridge Mill Power Station began delivering power to the city of Pawtucket, Rhode Island, in 1896. The plant's original generators were replaced during a rehabilitation project that was completed in 1985.

Ownership of Bridge Mill evolved over the years. The Pawtucket Electric Company merged in 1912 with the Pawtucket Gas Company and the electric and gas companies in Woonsocket to form Blackstone Valley Gas & Electric Company (BVG&E), serving seven communities. In 1964, the gas division was divested, leaving Blackstone Valley Electric Company as the owner of Bridge Mill. The leaders of BVG&E could be considered local folk heroes. David Daly served as the company president from 1924 to 1963. During his nearly 40-year reign, he was an ardent advocate of industrial expansion. His vice president, Captain William McGregor, worked for the company and its predecessors for 72 years, retiring in 1956 at age 92.

Bridge Mill was the hub of the electric company in the early and middle part of the 20th century. While electricity was generated in one part of the building, line crews were dispatched, appliances repaired, trucks fixed, and stock inventoried in other parts of the building.

Men who worked at the plant in the 1940s and 1950s recently shared several memorable tales: fishing in the forebay during coffee breaks; the days when the textile mills dumped dyes in the river, turning it green and blue and red; and the day that one of the 18-inch-wide leather belts broke, tearing a hole through the front door and landing in the parking lot.

But the most memorable stories of the "good old days" seem to revolve around the trash racks. Cleaning the steel grates that kept debris from reaching the turbines was considered the worst job in the company.

The upper racks, located at the falls where the water first entered the inlet tunnel, were accessed by an outside catwalk above the river. Between Bridge Mill and the upper racks was a theater and restaurant, where it was common practice for dishwashers to throw broken china out the window and into the river. On many occasions, Bridge Mill employees had dishes rain down on them as they maneuvered along the often-icy catwalk.

The lower racks are inside the station, so the smell of the river and the accumulated debris was overpowering. Workers cleaned the racks with a 20-foot-long rake. While trash and vegetation were the most common debris found, it was

Bridge Mill Power Station's first customer was the Interstate Street Railway. By 1912, the hydropower project served as the main source of power for the city of Pawtucket, Rhode Island.

Technical Information
Bridge Mill Power Station

General Information

Location: On the west side of the Blackstone River in downtown Pawtucket, Rhode Island

Owner: Blackstone Valley Electric Company, Lincoln, Rhode Island

Capacity: 1.7 MW

Head: 16.53 feet

Expected Annual Generation: 7,200 megawatt-hours

On-Line Date: May 1896

Equipment

Turbines (2 units)

Inclined Kaplan-type

Manufactured by Voest-Alpine

200 rpm

Generators (2 units)

General Electric induction generators

3-phase, 4160 V

Construction

Intake

17.5-foot-diameter, brick-lined penstock

Draft tube

10-foot-diameter, mild steel tube

Powerhouse

Brick and granite

175 feet by 90 feet, virtually unchanged from original construction

Transmission

4,160-volt lines to distribution feeders in Pawtucket

not unusual to remove animal remains — even a human one — from the racks.

Bridge Mill was deactivated in 1971 due to the high cost of maintaining the aging equipment. The station had supplied power continuously for 75 years.

As fuel costs escalated following the 1973 oil embargo, the utility renewed its interest in the plant. In 1980 Blackstone Valley Electric announced plans to rehabilitate Bridge Mill and started the work in 1983. The two-year rehabilitation project was completed in 1985. During the rehabilitation, the plant was cited by the National Register of Historic Places as "one of the earliest surviving electric power generating plants," and "perhaps the finest 19th century example of this building type remaining in Rhode Island." In 1986, the region — including the power plant and the historic Slater Mill — was designated by Congress as the Blackstone River Valley National Heritage Corridor.

The rehabilitation project included the installation of two modern 850-kW generators. Operation of the plant is now automatic and can be controlled either from control panels in the station or at Blackstone Valley Electric's Operations Center eight miles away in Lincoln. The dreaded cleaning of the trash racks has been automated, too.

Today the plant generates 7,200 megawatt-hours of electricity annually, displacing about 10,000 barrels of oil per year. The plant's primary role is to provide power at peak hours of electrical demand while contributing to Blackstone Valley Electric's efforts to diversify its fuel mix.

Bridge Mill Power Station's 100th anniversary was celebrated on May 1, 1996, with the grand opening of the Bridge Mill Power Museum, located in the original generating room. Among the museum's exhibits are the original generating equipment — some restored to working order by a local antique machinery expert — including governors, generators, turbines, and control panels.

Other exhibits include: photos and artifacts illustrating the early days of the electric utility industry in Rhode Island; an extensive collection of turn-of-the-century meters; and a graphic history of "Three Centuries of Water Power on the Blackstone River." Additional exhibits are planned.

The Bridge Mill Power Station and Museum is one more chapter in the lengthy industrial history of northern Rhode Island. It is an important link between the Industrial Revolution and the modern industrial age.

And at this rate, it may still be around to see the next revolution.

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This photograph, taken in 1894, shows construction of the Bridge Mill Power Station on the Blackstone River. When it was developed, engineering publications called the project the "finest water-power electric station in New England."