William Birch Rankine Generating Station: Powerhouse in the Park

The 74.6-MW William Birch Rankine generating station sits on the Niagara Parkway, one of Canada's most scenic drives, and just a few feet from Niagara Falls. While millions of tourists have passed the site, most have no idea that the beautiful stone building is an electrical generating facility. Rankine, which has generated power continuously for 100 years, is a good example of how scenic beauty and electrical technology can co-exist.

By Norman R. Ball

On July 27, 2005, the William Birch Rankine generating station in Niagara Falls, Ontario, Canada, reaches a milestone — it will have generated and delivered hydroelectric power to customers for a century. The station sits within the Queen Victoria Niagara Falls Park, close to Niagara Falls. Yet, few of the countless tourists who pass the long, elegant, cut-stone building with the glazed green terra cotta tile roof suspect it is a hydro generating station. There are no telltale banks of insulators, transformers, power lines, or towers.

But Rankine is no ordinary power station. The station is named after one of the earliest supporters of electrical development at Niagara Falls and a founder of Canadian Niagara Power Company. Its historical significance goes beyond the fact that, when new, its five 10,250-horsepower (hp) turbines and five 7.5-MW generators were the largest in the world. Above all else, Rankine was created to preserve the beauty of one of the world's great natural wonders.

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Protests, technology give birth to a powerhouse in a park

The Rankine station is the offspring of two developments in the late nineteenth century. The first was the international outrage over unsightly industrial development dominating the Niagara Falls tourist area. This outrage, expressed most clearly in the Save Niagara Movement, led to the creation of parks on both sides of the Niagara River. The New York State Reservation at Niagara and the Queen Victoria Niagara Falls Park in Ontario were remarkably different. On the American side, the state bought the property for the park, and funded it generously. By contrast, the Canadian park was virtually destitute from the day it was formed; both major political parties of the day vowed that not a penny of public funds would go to the park. The commissioners of the Queen Victoria Niagara Falls Park had to issue bonds just to buy property. Aside from renting out concession rights, the Queen Victoria Niagara Falls Park had no real income. That's where electrical technology comes into the picture.

In the late 1880s and early 1890s, the detailed shape of the electrical future was still unclear, but large-scale electrical generation seemed to be the coming thing. And Niagara Falls seemed to have unlimited hydroelectric power. In 1892, the government of Ontario approved an agreement between the newly formed Canadian Niagara Power and the Queen Victoria Niagara Falls Park commissioners. The company received power development rights and the park got a significant source of income, including two years' rent in advance. Because the use of hydroelectricity was still very new, just to be on the safe side, the legislation allowed Canadian Niagara to harness and transmit the power of Niagara's mighty waters either electrically or by compressed air. Nicola Tesla's pioneering alternating current (AC) patents, which were developed by Westinghouse, secured the electrical future of the site. On both sides of the river, electrical power from Niagara Falls was generated primarily for use at a distance. Buffalo, the main target market, was about 20 miles away. Only AC power could be economically transmitted over such distances that today seem pitifully short.

Delayed development at Niagara Falls, Ontario

Canadian Niagara Power was founded in 1892. Under the terms of the legislation and franchise agreement — which gave the company the legal right to generate power from the Niagara River, Canadian Niagara was supposed to generate 10,000 hp (7.46 MW) of either electric or pneumatic power by 1897. It is unlikely that the company ever intended to

Technical Information

William Birch Rankine Generating Station

General Information

Location: Niagara River, Niagara Falls, Ontario, approximately 600 feet upstream from the crest of Horseshoe Falls (Canadian Falls)

Owner: FortisOntario Inc.

Capacity: 74.6 MW, 25-cycle

Development Cost: C$5,199,827.78

On-Line Date: July 27, 1905 (first unit), 1924 (last unit)

Equipment

Turbines (11 Francis)

Units 1, 2, and 3:

10,250 horsepower (hp)

Vertical double runners

250 revolutions per minute (rpm)

Operate at 133-foot head and 885 cubic feet per second (cfs) of flow

Spiral wheel case

Manufactured by Escher-Wyss

Units 4 and 5:

10,250 hp

Vertical double runners

250 rpm

Operate at 133-foot head and 885 cfs of flow

Spiral wheel case

Manufactured by I.P. Morris and Escher-Wyss

Unit 6:

12,500 hp

Vertical double runner (single runner supplied)

250 rpm

Operate at 133-foot head

Spiral wheel case

Manufactured by Bethlehem Steel Co.

Unit 7:

12,500 hp

Vertical double runner (double runner supplied)

250 rpm

Operate at 133-foot head

Spiral wheel case

Manufactured by Bethlehem Steel Co.

Units 8, 9, and 10:

12,500 hp

Vertical single runner

250 rpm

Operate at 136-foot head

Spiral wheel case

Manufactured by Wellman-Seaver Morgan Co.

Unit 11:

12,500 hp

Vertical single runner

250 rpm

Operate at 136-foot head

Circular section plate steel spiral case

Manufactured by Allis-Chalmers

Generators (11)

Units 1-5:

12,000 volts (v)

360 amps (nameplate)

8,800 kVa

7,500 kW

25 cycle

Manufactured by Canadian General Electric

Units 6-10:

12,000 v

500 amps (nameplate)

10, 400 kVa

9,375 kW, 25 cycle

Manufactured by Canadian Westinghouse

Unit 11:

12,000 v

550 amps (nameplate)

11,400 kVa

10,300 kW

25 cycle

Manufactured by Canadian Westinghouse

Construction

Penstock

Riveted construction steel

130 feet long

10-foot, 6-inch diameter

Powerhouse

Limestone building

Glazed clay tile roof

570 feet long

2 floors

Wheelpit: 171.3 feet below generator floor; 566.84 feet long by 20.5 feet wide

Tailrace Tunnel

Underground

Brick-lined

Inverted "U" shape

25 feet tall

18.8 feet at widest point

2,164 feet long

Exits at face of Niagara gorge at side of Horseshoe Falls

Construction Contractors

Tunnels and Shaft: A.C. Douglas

Wheelpit and Canal: Dawson and Riley

Forebay and Cofferdam: James Barry

Intake to Niagara Falls Park and River Railway Powerhouse: Fraser and Emery

Railway and Highway Bridges over Canal: Queenston Quarry Company Ltd.

Contract for Steelwork for Powerhouse: Hamilton Bridge Works Co.

Contract for Powerhouse: William Grace Company

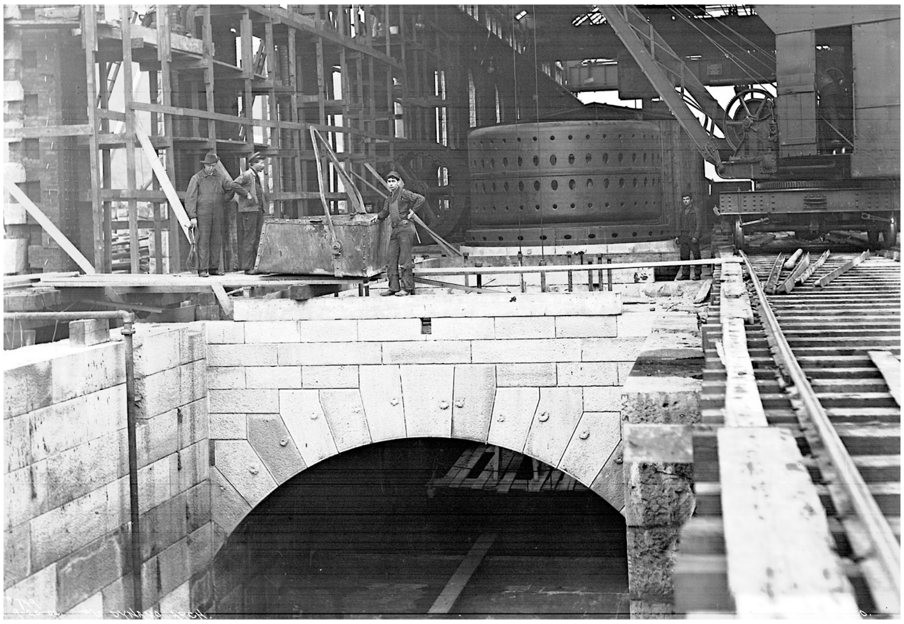
meet that schedule, and it wasn't until January 2, 1905, that Canadian and American dignitaries officially opened the still-incomplete Rankine power station.

The years of delay had eroded popular and political support for the company, and cost it the exclusive right to generate power on the Canadian side of the Niagara River and limited the amount that could be generated at the site to 100,000 hp (74.6 MW). However, the delays gave the company and its investors what they needed most — time for rapidly changing electrical technology to mature to the point at which it made better sense as a long-term investment.

Canadian Niagara Power's parent company, the Niagara Falls Power Company, was completing the Adams Generating Station in Niagara Falls, New York, and learning a great deal in the process that it hoped to apply at its Canadian generating station. When installed, the Adams station's 5,000-hp turbines and "dynamos" were the largest in the world. On October 26, 1893, the Westinghouse Electric and Manufacturing Company guaranteed that the dynamos would have "an output of 5,000 electrical horsepower at an effective potential of from 2,000 to 2,400 volts when driven at a speed of 250 revolutions per minute… the total electrical and magnetic losses in each generator not to exceed 2½ per cent of its rated output."[1,2]

In many ways, the Adams plant was a giant research and development project and the Rankine plant the resulting application for new knowledge as well as newly developed technology.

Rankine went on-line July 27, 1905. At that time, the plant's 10,250-hp turbines and 8,800-kilovolt-ampere (kVa), 7,500-kW generators were the largest in the world. Within a month, Rankine became a net power exporter to the United States. During its earliest years, the generating station was about half of its present 600-foot length and had only five turbines and generators. Expansion continued until 1924, when the eleventh generator brought theoretical installed capacity to 120,500 hp (89.9 MW). However, this figure is both misleading and operationally meaningless, as is that in a 1963 Ontario Hydro publication which lists the Canadian



The Rankine generating station features 11 generator arches made of stone and heavy cast-iron structural elements that span the wheelpit. The generator in the background of the photo is resting on a completed arch. Floor plates between the arches are removable to allow turbines and other equipment to be raised up from the wheelpit to floor level for maintenance and repairs.

Niagara Power Company at 94,700 kW.[3] Under the legislation and legal agreements governing the Rankine generating station, the plant's owner is not allowed to generate more than 100,000 hp (74.6 MW).

A powerhouse above Niagara Falls

More modern Niagara powerhouses such as 498-MW Sir Adam Beck No. 1 and 1,483-MW Sir Adam Beck No. 2 are miles downriver from Niagara Falls, where the combined heights of the drop over the falls, plus the precipitous drop in the river as it roars through rapids on its way to Lake Ontario, give a much larger head that produces more power per unit of water than a site that uses only the drop over the falls. However, Canadian Niagara and the Toronto Power Development Company (originally known as the Electrical Development Company) built just above the falls because that eliminated the need for more expensive surface and subsurface excavated water channels to deliver water to the generating site.

For the Rankine station, surface water is diverted from the Niagara River by an arm-shaped weir about 1,500 feet above the falls. It flows under a five-arch bridge and directly into the forebay and powerhouse. There, the water plunges down 136 feet through penstocks to the turbines in a turbine pit cut into the sedimentary rock.

After leaving the turbines, the water travels for 2,200 feet through a 25-foot-high underground discharge tunnel to the rock wall of the gorge beside the face of the Canadian, or Horseshoe, Falls. Tourists who board the boat, Maid of the Mist, to be thrilled by the mock danger of being close to the base of the falls also get a good view of the discharge outlet.

The pit and discharge tunnels were major mining tasks — the product of dynamite, steam power, compressed air, raw horsepower, and plenty of human muscle power. The construction was quite straightforward, but jobs of this size usually have some incidents. There was a simultaneous short-lived strike at all three generating station construction sites of Canadian Niagara, Ontario Power Development Company, and Electrical Development Company. When the liquor ran out and the soldiers arrived, things petered out. And to this day no one knows who was behind what the newspapers called the "Fiendish Attempt to Blow Up the Canadian Power Tunnel" before it was even finished.[4]

During construction, engineers waited to see if horizontal rock slippage, or displacement, would push the walls of the pit inward. This happened during construction of the Adams station. Not unexpectedly, the same thing happened at Rankine. Massive cast-iron reinforcements placed between the walls stopped the walls from moving inward.

As mentioned earlier, in order to reduce initial construction costs, Rankine was built upriver from the falls. This meant that in order to get a respectable and useful head of water, the company had to dig a deep pit to house the turbines. How, then, was a turbine to be coupled with its generator? In many installations, the two pieces of equipment are close coupled, joined by a short shaft. At Rankine, this was a theoretical

The wheelpit for Rankine had to be excavated to a depth of 171 feet below the generating station floor, with an opening almost 567 feet long. Unlike conventional open-pit or quarrying operations, the sides had to be close to vertical. Compressed air from a steam-powered compressor plant at the surface powered the drilling and cutting equipment.

The Rankine generating station looks much the same today as it did in 1913, as shown here. Both Canadian Niagara and the commissioners of the Queen Victoria Niagara Falls Park worked hard to get the aesthetics right for the powerhouse in a park. For example, to maintain the scenic integrity of the park site, there are no above-ground cables or wires running to or from the generating station.

possibility, but a practical impossibility. It would have required a far more massive excavation … and much more expense … to put the 11 generators and all of the associated switches, relays, exciters, governors, and other equipment down at the turbine level. Moreover, a larger excavation might have been more at risk from rock slippage, perhaps even collapse. In addition, engineers also worried about possible operating problems, shorting, and electrical malfunctions with generators and other equipment in the damp atmosphere at the bottom of the closely confined pit.

The need to put the generators at ground level far above the turbine level led to one of the most dramatic visual and mechanical components of the Rankine generating station: a line of 11 vertical steel shafts, each running from a turbine in the deep pit to a generator 130 feet above. Babbitt thrust bearings carry the vertical load, but the tremendous mass of the system puts the bearings at great risk whenever a unit is started up or shut down. The trick is to get the water into the turbine so quickly that it raises the entire unit slightly. In this way, the bearing surfaces are separated by a film of oil and not rubbing metal on metal. Shutting down must be done equally quickly to get the speed to drop from 250 to 100 revolutions per minute (rpm), the point at which it is safe to activate the pulsating wooden brakes that grip the 40-inch-diameter,130-foot-long rotating shaft.

The power station that doesn't look like a power station

Under the terms of the agreement with the commissioners of the Queen Victoria Niagara Falls Park, Canadian Niagara had to seek the commissioners' approval for all design and construction work. Both parties worked hard to get the aesthetics right for the powerhouse in a park. The company, for example, chose a more expensive green terra cotta tile roof, because it looked better than orange tile, which was cheaper. It was a sound decision; the gleaming green roof is striking and the building has been reroofed only once in its 100 years.

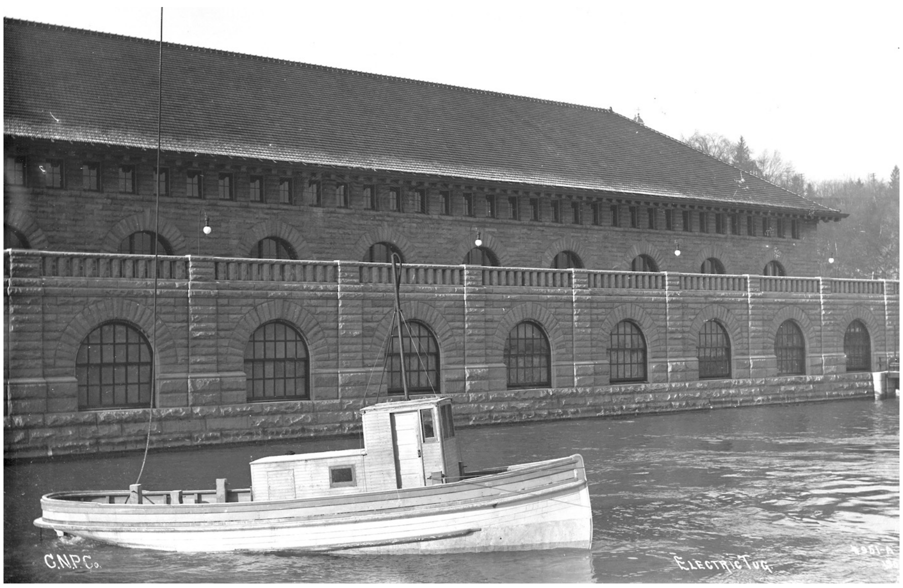
To maintain the scenic integrity of the park site, there are no above-ground cables or wires to or from the generating station. The transformer station outside the park is linked to the generating station by underground cables. Outside the confines of the park, Canadian Niagara uses conventional poles or towers.

Power destined to flow directly from Rankine to Niagara Falls, New York, also follows an invisible path within the park boundaries. When the station opened in 1905, power traveled through underground cables beneath Niagara Falls, Ontario, to the Upper Arch Steel Bridge that crossed over the Niagara Falls, New York. Cables attached to the underside of the bridge, also known as the Falls View Bridge or Honeymoon Bridge, carried power between the two countries. In 1938, a massive ice jam tore the bridge down. Its replacement — the Rainbow Bridge — also carries power transmission cables between Ontario and New York State.

The Niagara Parkway, one of Canada's most scenic drives, passes between the Rankine generating station and the river's edge. In order to keep the roadway level where it crosses over the forebay entrance, the company designed and built an innovative flat arched bridge. The visible parts of the forebay walls are also covered with the same locally cut stone as the generating station. The cut stone extends below the surface of the water, because engineers felt it offered better resistance to ice scouring.

The Canadian Niagara 'Navy'

Ice played an important role in the design and operation of the Rankine station. Although the effect of severe



This wooden electric tug/icebreaker, commonly referred to as The Canadian Niagara Power Company Navy, was vital to combat ice buildup in the forebay of the Rankine generating station in the early 1990s.

storms is beyond the scope of this article, one piece of generating station equipment should not be passed by without comment.

The swiftly moving Niagara River does not freeze over, but it carries a huge ice load from Lake Erie. Although there is an ice weir to divert much of the ice from the forebay at Rankine and a sluiceway in the forebay to remove the ice, ice buildup in the forebay was a severe problem from the earliest years of the station. Under the worst conditions, ice completely blocked the penstocks, and very little water could get through to the turbines. But most of the time, what some people called the "Canadian Niagara Navy" managed to deal with the ice. The "navy" had only one boat, but it was unusual: steel-hulled with a wooden cabin, electrically driven by streetcar motors drawing power from an overhead trolley. It was owned by Canadian Niagara and stayed in the forebay of the Rankine station.

When ramming and riding up on the ice didn't work, Canadian Niagara employees tried dynamite. Sometimes the dynamite moved the ice and sometimes it seemed to do little more than heave the boat up. During bad weather, working on the boat was every bit as exhausting as being a lineman.

Two important developments reduced the severity of the ice problem. On September 28, 1957, the opening of the International Control Dam allowed water and ice to be more carefully controlled and directed, but did nothing to reduce the total volume of ice in the river. The most significant development came in 1964 with a joint project by Ontario Hydro and the New York Power Authority. The project started as an experiment and quickly graduated to become an annual event. Every year, the two utilities stretch an ice boom across the Niagara River where Lake Erie drains into the river. The boom holds back much of the heavy winter ice loads until the ice that has not melted can be safely released in the spring, at which time the boom is taken in for the year. The ice boom has so dramatically reduced the ice problem at the Rankine generating station that the "navy" has been phased out.

Improving efficiency: share the water

Unlike many older generating plants, the Rankine station still features its original turbines and 25-cycle generators. The main modernization efforts have aimed at reducing the manpower requirements in the station. As part of this effort, North American Hydro installed automation equipment, including innovative oilless governors.

During the 1950s, the provincial government encouraged a massive Ontario-wide conversion from 25-cycle power to 60-cycle power. Canadian Niagara converted much of its transmission and distribution to 60 cycle in 1957-58. However, it continued to generate at 25-cycle, exporting some power to the U.S. and selling the rest to Ontario Hydro as part of an arrangement that gave Canadian Niagara the 60-cycle power it needed. This is still the situation today.

At the same time, Canadian Niagara started allowing Ontario Hydro to use some of its water allotment. This meant that Ontario Hydro with its generating facilities further downstream could generate more power than Rankine could with the same amount of water. Continuing today, Canadian Niagara and Ontario Hydro (now Ontario Power Generation, OPG) have a flexible water exchange agreement. The agreement provides for OPG to get more water when it is mutually convenient, but still leaves Rankine as an active generating station.

What will the future hold?

Canadian Niagara Power, wholly owned by FortisOntario since 2002, does not hold water rights in perpetuity. Under the terms of the recently signed Niagara Exchange Agreement, FortisOntario will hand the Rankine Generating Station over to the Niagara Parks Commission on May 1, 2009. Under a separate agreement, water rights go to OPG.

Celebrating a century of achievement

On July 27, 2005, FortisOntario, the current owners of the Canadian Niagara Power Company and the Rankine generating station celebrate 100 years of generating and supplying electric power to customers. But there is more to the 100 years than supplying electricity. The celebration commemorates a century of co-existence of a scenic park and a hydroelectric generating station. Rankine is the oldest operating generating station on the Niagara River. It was part of the great pioneering efforts that harnessed the power of Niagara and ushered in "The Electrical Age" that dramatically altered almost every facet of modern life. ■

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Notes

[1]Adams, Edward Dean, *Niagara Power History of the Niagara Falls Power Company 1886-1918, Evolution of its Central Power Station and Alternating Current System,* Volumes 1 and 2, The Niagara Falls Power Company, Niagara Falls, New York, 1927.

[2]Irwin, William, *The New Niagara: Tourism, Technology, and the Landscape of Niagara Falls, 1776-1917,* Pennsylvania State University Press, University Park, Pennsylvania, 1996.

[3]*Power From Niagara: Generating Stations of Ontario Hydro on the Niagara River,* Ontario Hydro, Toronto, Ontario, 1963, page 5.

[4]"Fiendish Attempt to Blow Up the Canadian Power Tunnel," *Niagara Falls Gazette,* Niagara Falls, New York, April 26, 1902, page 1.