HISTORY OF THE HYDRO-ELECTRIC DEVELOPMENT AT NIAGARA

BY

CARL GORDON CLINE, C.E. M.E.I.C.

INTRODUCTION

The whole development of the modern system of generating and distributing three-phase, alternating current occurred during the seventy-five year history of the *Engineering Institute of Canada.* The men who designed and built the plants on both sides of the Niagara River; the men who designed and made the machinery and equipment for them and the transformer stations and transmission lines; the operators of the plants and distribution systems; all these played an important part in this development. Needless to say, many of the engineers who contributed to this progress were or are members of this *Engineering Institute of Canada.*

This is a short history of the various power plants on both sides of the river, omitting the small overshot wheels used to saw the lumber and grind the grain in the early settlements. Particular emphasis has been placed on the Adams plant which was the pioneer in developing a large-scale system of generating and transmitting polyphase, AC power.

The world's first central station for the general distribution of DC electricity for lighting was that of the New York Edison Company, which began operation in New York City in September 1882. The use of low voltage DC in this plant serious limited the distance to which the current could be supplied. By that time, street railways were operating, both in Europe and in America, on 500 or 600 volts DC, which permitted operation for several miles from the power station.

The first AC central station in America began operation in Buffalo on 30th November 1886. It generated power by steam for supplying a few hundred incandescent lamps. The primary voltage being 1,000, it was possible to supply service over a radius of four or five miles.

Ten years later, on 15 November 1896, the Niagara-Buffalo transmission lines, 22 miles in length, brought Niagara power to Buffalo as three-phase AC from what later became known as the Adams station of the Niagara Falls Power Company, so that both AC and DC power could be supplied, thereby inaugurating universal electric service from the same circuit by means of suitable transformers and converters. Many difficult decisions had to be made before this achievement became possible and the best choice was not always found at the first attempt. In addition, many improvements were required since 1896 before large amounts of power could be transmitted over the much longer distances now in vogue.

Adams Plant

The hydraulic features of the Adams plant consisted of a short intake canal to withdraw water from the river above the Cascades; a wheel-pit slot 180 feet deep for the turbines; a tail-race tunnel 7,000 feet long to carry the used water under the city and return it to the river below the Falls. Because of the length of the tunnel and the steep slope necessary to carry the large volume of water contemplated in a tunnel of moderate cross section, the net head was only 135 feet. The construction work was done for the Niagara Falls Power Company by its subsidiary, the Cataract Construction Company.

By May, 1893 water was flowing through the tunnel. Before that, it was necessary to decide how it was to be used. One proposal was to sell water to private companies who would install their own turbines and discharge the used water into the tunnel. Indeed, the International Paper Company, a neighbor of the Adams plant, did make such a contract and developed 7,000 h.p. in six Jonval turbines. This was used for many years as mechanical power for making pulp and paper.

However, the economic advantage of developing power in a single central station soon became evident. There were two main sources of customers; mills to be built at Niagara Falls within a few miles of the station and at Tonawanda, nine miles away; the city of Buffalo, some 20 miles distant, where 50,000 h.p. of steam power was already in use. In 1890 the population of Niagara Falls was less than 5,000 whereas that of Buffalo was 250,000, so that the prospects at Buffalo looked more promising.

Within a few years the availability of cheap, 24-hour power at Niagara made possible the starting of important new industries using electro-chemical and allied processes which soon were using many times the total power taken for lighting and motors. In this way, the enterprise of the promoters of the Adams plant was rewarded many years sooner than seemed probable when the plant was started. The first contract was for 1,500 h.p. with the Pittsburg Reduction Company (later Aluminum Company of America) for the manufacture of aluminum from bauxite. Delivery started in August, 1895. Some years later, aluminum produced at Niagara was used instead of copper to make conductors for transmission lines.

The company proceeded with the preparation of plans for using hydraulic turbines, with units of at least 5,000 h.p. each and rotating at 150 rpm. The expectation was that, as soon as the main electrical problems were solved, the company would call for proposals for the construction of electric generators of similar power and speed, to be coupled directly to the turbines as single units on perpendicular shafts. This would require some method of supporting the weight of the long shaft and the rotating parts of the turbine and generator.

The first turbines in station No. 1 were designed by Faesch and Riccard of Geneva, Switzerland, and were built by I.P. Morris Company of Philadelphia. Each unit had two Fourneyron-type runners, the upper one being reversed so that it could help to carry the weight of the rotating parts and the thrust of the lower runner. These runners discharged outward into the wheel-pit without any draft tube, so that there was considerable loss of head.

The turbines for station No. 2 were designed by Escher, Wyss and Company of Zurich. The runners were of the Francis, single-wheel, inward-flow type and discharged into a draft tube. Balancing pistons on the lower end of the shaft, operating under water pressure, supported much of the rotating weight, the rest being carried by oil-pressure thrust bearings. These turbines performed so well that the original turbines in station No.1 were replaced gradually during the years 1910 to 1913 by similar Francis units.

The amount of water entering each unit was regulated by a cylinder gate which moved up and down outside the runner. The motion of the gate was controlled by a governor according to the amount of power required from the unit. In the first three original units in station No. 1, there were mechanical governors designed and built by Faesch and Piccard. The other eight units had governors with electric clutches which applied power from the main shaft to move the gate.

In station No. 2, the Escher, Wyss governors operated by high-pressure oil acting on one side of a piston opened the turbine gate; counterweights acting in the opposite direction closed the gate. The flow of oil into and out of the cylinder was controlled by a regulating valve operated by the fly balls through a pilot valve. This servo-motor type of governor became standard at Niagara, but with a double-acting cylinder to eliminate the counterweight.

1866 to 1896

During this decade great progress was being made in the design and construction of electrical machinery. New types of equipment, such as the induction motor and the rotary converter, were being developed and great improvements were made in generators and transformers. However, the maximum size single-phase, AC generators was about 1,000 h.p. and the size of transformers only 10 h.p. There were no polyphase plants in commercial operation of sufficient size to be a guide as to what equipment to use at Niagara.

Apparatus exhibited at the World's Columbian Exposition at Chicago in 1893 showed how polyphase AC could be transformed and converted for supplying every kind of electrical service. In units of a few hundred horsepower, these exhibits presented in miniature what was proposed at Niagara on a scale of 100,000 h.p. Niagara plants and AC machinery developed simultaneously; in less than a decade they contributed mutually to the inauguration of modern hydroelectric service.

In 1892 the Cataract Construction Company instructed its Board of Engineers to provide for two power stations, one on each side of the intake canal, each for 50,000 h.p. to be developed by turbines in each case but to be distributed in one case by electricity and in the other by compressed air, which was being used then in a small way in Paris, France. However, the advances being made in electrical equipment encouraged the management to proceed with the electrical side of the enterprise first, awaiting further developments, if any, in the use of compressed air. On 6 May 1893, the long controversy between DC and AC was officially ended in favour of polyphase AC. By 1899 the electric system operating in station No. 1 had proved its reliability and advantages and the company dropped the idea of using compressed air and announced its commitment to electricity exclusively. This was one decision that never needed to be reversed.

The selection of polyphase current made necessary a choice between two-phase and three-phase systems. The Westinghouse Company proposed two-phase generators; the General Electric and the Oerlikon Company of Switzerland both favoured three-phase but offered to accept either. Two-phase generators were simpler to wire but the extra phase gave the transmission line greater carrying capacity. However, it was found that, by using extra taps on the transformers, two-phase current could be converted to three-phase. Thus, although some of the earlier generators were two-phase, the transmission lines were always three-phase.

There was also the question of what frequency to use and here the outcome was not so fortunate. In the fall of 1892 the Westinghouse Company had adopted the two standard frequencies; 60 cycles per second for lighting; 30 cycles where power in large units and rotary converters were to be used. At Niagara, what was required was electric power with incidental lighting rather than electric light with incidental power.

It was hoped that the flicker in the lights due to the low frequency would not be objectionable , or that some way would be found eventually of eliminating it. Vain hope.

As mentioned above, the speed of the turbines had been set at 250 rpm. Finally it was agreed that the generators should have 12 poles and this gave 25 cycles per second. This same frequency was adopted at all the earlier plants at Niagara whereas 60 cycles was adopted gradually elsewhere. The result was that in time Niagara became a 25-cycle island in a 60-cycle continent. Finally, the introduction of fluorescent lighting tipped the scale. The change to 60 cycles for all domestic lines was made first on the United States side of the river and this was followed later by the Hydro-Electric Power Commission of Ontario (Ontario Hydro). However, many of the large electro-chemical plants still use 25 cycles and are supplied either from the remaining 25-cycle generators or by converters.

The electrical system which the Westinghouse Company proposed was adopted in 1892 and in October 1893 this company was awarded a contract for the manufacture of three two-phase, 2,000 volt generators of 5,000 h.p. each for station No. 1. Subsequently the same company furnished the other eight alternators for this station. Contracts for the 11 generators in station No. 2 were awarded to General Electric. These were of 5,500 h.p. each, of which six had external revolving fields similar to those in station No. 1, and five had internal revolving fields. This latter type was used thereafter in all power stations.

The switching devices, indicating and measuring instruments, bus-bars and other auxiliary equipment had to be designed and constructed on lines departing radically from previous practice because of the great increase in the amount of power to be handled and the higher voltages. With low-voltage DC, the main circuit could be carried directly to the switchboard but with high-voltage AC, it became necessary to introduce instrument transformers which pass to the switchboard only a fraction of the main current and that at greatly reduced voltage.

Nowadays this first transmission line would be considered a short one, only 22 miles from the step-up station at Niagara to the step-down substation at Buffalo. The first circuit carried 10,000 h.p. at 11,000 volts, three phase. However, this line was of great historical significance because, both in the amount of power transmitted and in the importance of the service rendered, it transcended anything done previously.

The construction of the line followed the recognized practice of the period for telegraph lines, the only precedent there was to follow at that time, but of course the poles, cross arms, pins and insulators were made heavier. In 1896, lightning arrestors were inadequate, many insulators were defective, and oil switches were unknown. In fact, the experience on this line was to have an important effect on the evolution of transmission technique.

When the Adams station and its Buffalo transmission line went into service in the fall of 1896, it became the Electrical Wonder of the World. It was the pioneer, soon others followed. Today, practically all service stations everywhere in the world generate and transmit their power as three-phase AC.

Although this plant was highly successful financially, it gave only nine kW per cubic foot of water used per second. The tremendous demand for power which it started, together with the restrictions on diversion of water from the river, led finally to this plant being placed in reserve so that the water could be used in the more efficient plants. After the rockslide at the Schoellkopf plant in 1956, the Adams plant went back into service again, but on 1 October 1961, both plants were shut down permanently and the water was transferred to the new Robert Moses Niagara Power Plant.

Scheollkopf Plant

One of the first users of water for power development at Niagara was what became known later as the Hydraulic Power Company. In 1856 water was admitted to its canal intake about one mile above the American Falls. This canal extended 3/4 mile to a basin located at the tope of the gorge. It was hoped that mills would be built on the edge of the cliff and would draw water from the basin, use it in turbines at a moderate head and then spill the water over the cliff. The turbines in use at that time were not strong enough \to use the full 200-foot head.

By 1861 this canal was 36 feet wide and 8 feet deep. In this early work, gunpowder was used to blast the rock but in 1866 Nobel invented dynamite. The first mill was that of the Cataract Milling Company which developed 150 h.p. under a head of 25 feet. After the Civil War and a change of ownership, a second flour mill was built, followed in 1880 by a paper mill. In each case, power was distributed in the mill by shafting, pulleys and belts.

In 1881 the Brush Electric Light Company drove one of its generators by a belt from a mill shaft and supplied DC power for 16 arc lights in the streets and stores of the city. The railroads ran special excursion trains so people could come to see “The Lights.”

Beginning in 1881 the Hydraulic Power Company built what came to be known as station No. 1, and generated electric power for manufacturers and others at various voltages according to their needs. The city of Niagara Falls bought power for arc lighting and for the street railway. This was the first commercial hydro-electric station at Niagara Falls, NY. It had three generators developing a total of 1,800 h.p. all DC.

In 1892 the company began enlarging its canal to 70 feet in width and 14 feet deep to supply water for plant No. 2. From a new forebay, penstocks conducted water to a power house located beside the river at the foot of the cliff. This was the first installation on the canal to use the full 200-foot head. There were 16 turbines which drove 31 generators of a total capacity of 23,000 kW. About 90% of this was DC and was used for electro-chemical processes by various companies such as Pittsburgh Reduction Company, National Electro-lytic Company, Acker Process Company, etc. The other 10% was distributed as 25-cycle, three-phase AC, using the system recently developed at the Adams station.

About 1900 the original tenants of the company were induced to surrender their water rights and accept supplies of electricity in exchange. Also, plants Nos. 1 and 2 were dismantled as required to make room for the various sections of plant No. 3.

In 1904 the company began building station 3-A, which was finished in 1914. This involved another enlargement of the canal. In this plant there were 13 double-runner, 300-rpm, 10,000 hp turbines with horizontal shafts. Five of them drove pairs of 3,500-kw, 550-volt, DC generators which were owned by the Aluminum Company. The other eight were connected to 5,000-kvs, 12,000-volt, three-phase, 25-cycle alternators. The five DC pairs were replaced by alternators in 1925.

The admission of water to these turbines was controlled by wicket gates, which act as pivoted guide vanes. When these gates are rotated, they change the area of the water passages between them and can close them entirely when necessary. The gates are connected by breaking links to the shifting ring which in turn is rotated by the governor. Wicket gates were used on all the units of the Schoellkopf plant, both horizontal and vertical.

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There was some leakage from the forebay through seams in the rock and in winter this formed ice which fell on the power house roof, so the company faced the cliff with masonry.

In October 1918, during World War I, the Niagara Falls Power Company and the Hydraulic Power Company were amalgamated to form a new Niagara Falls Power Company. In December 1919 this new company completed what became known as plant 3-B of the Schoellkopf station. This had the 37,500-hp, vertical turbines operating under an effective head of 215 feet and connected to 32,000-kw alternators. Each penstock was fitted at its lower end with a Johnson valve which operated hydraulically under manual control, to shut off the flow of water to the turbine.

These were the first units at Niagara to use the new Kingsbury thrust bearings to carry the weight of the rotating parts. Bearings of this type are so designed that they scoop up oil automatically and thus constantly renew the films that carry the weight without the need of any pump to supply oil under high pressure as in the older type of bearing.

In 1921, plant 3-C was started. As the canal could not be made any larger, a tunnel was built to parallel it. This discharged into a forebay whence penstocks led to three 70,000-hp, vertical turbines driving 65,000-kva alternators. This development, with a head of 215 feet, was completed in 1925 and produced 16 kW per cubic foot of water per second.

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On 7 June 1956, leakage through the seams in the rock above the 3-C plant became greater than the drains could carry and water began to seep into the building. When the units were shut down by closing the Johnson valves, the whole face of the cliff exploded outwards, masonry and all, and fell on the roof of stations 3-B and 3-C destroying both buildings and machinery. One man was blown into the river and his body was never found but no one else was hurt. The cable ducts from 3-A were broken and the generators burned out but the building as not damaged seriously except that it was left open to the weather at one end. Eventually station 3-A was restored to service. It was supplied through the tunnel, the canal was filled in and stations 3-B and 3-C were abandoned. On 1 October 1961, this plant was closed down permanently.

International Railway Plant

The International Railway plant was the first plant to generate power on the Canadian side of the river. It was constructed in 1893 to operate the International Railway Company's 11 ½ mile trolley line from Chippawa to Queenston. This plant diverted water from the Cascades above the Falls and discharged it through a tunnel 600 feet long to the face of the cliff below the Falls, giving an operating head of only 62 feet. The original installation consisted of two 1,000-hp turbines and three belt-driven, DC dynamos. In 1905 a new 2,000-hp turbine replaced one of the 1,000-hp units. This plant was closed down on 12 September 1932 when the railway franchise expired. The intake canal was filled in and the machinery removed but the building still stands.

DeCew Falls No. 1 Plant

The first plant at DeCew Falls, two miles from St. Catharines, was built by the Cataract Power Company to supply power to Hamilton, a distance of 35 miles. It draws water from Lake Erie through the Welland Canal, with a storage reservoir in Lake Gibson. Seven steel penstocks are supported on the hillside by concrete piers. The direct-connected, turbo-generator units are mounted horizontally on a gravel foundation. The tail-water is carried downstream in Twelve Mile Creek to Lake Ontario at Port Dalhousie. The head is 260 feet.

This plant began operation with two 1,500-hp units on 26 August 1898; two 3,000-hp units were added in 1900; the plant was completed in 1912 with a total output of 44,600 KVA at 66 2/3 cycles. It supplied power to Hamilton several years before Niagara power reached Toronto. In 1930 it was bought by Ontario Hydro and converted to 60 cycles. This is the oldest Niagara plant still operating.

Canadian Niagara Plant

The Canadian Niagara Power Company is a Canadian subsidiary of the Niagara Falls Power Company. The general design of the plant is similar to that of the Adams stations except that the units are twice as big. This plant diverts water from the Cascades about half a mile above the Falls, has a wheel pit 170 feet deep and returns the water to the river below the Falls through a tunnel 2,160 feet long. One 10,250-hp unit was installed in 1904; three more in 1905; one in 1906; two 12,750-hp units in 1913; three of 10,750 in 1916; one of 12,000-hp in 1924.

This company has a transmission line to Fort Erie and Buffalo. It also has conduits crossing at Niagara to connect with the circuits of the parent company. The company distributes some of the power, some is sold in bulk in Canada and the United States.

Toronto Power Plant

The Toronto plant is similar, in general, to the Canadian Niagara. It is located close to the shore of the Cascades between the intakes of the Canadian Niagara and the Ontario plants. It has a wheel pit 22 feet wide and 158 feet deep and a tail-race tunnel 2,000 feet long which discharges under the curtain of the Horseshoe Falls. this tunnel has a concrete lining faced with brick except fort the last 300 feet at the outlet end which has concrete rings in six-foot sections so they can break off evenly as the Falls recedes.

Two 14,000-hp units went into operation in 1906' two similar ones in 1907; two 15,500-hp units in 1910; two in 1911; one each in each of the three following years: making a total generator output of 134,000 KVA. The first four units have cylinder gates, the rest wicket gates.

This plant was leased and operated by the Toronto Power Company, which built a 60,000-volt transmission line to supply the Toronto Electric Light Company and the Toronto Street Railway. In 1922 it was bought by Ontario Hydro.

Ontario Power Plant

The Ontario plant draws water from the river at the crest of the Cascades through an intake elaborately designed to exclude floating ice from the conduits. The power house is located a short distance from the Falls, on the river bank below the cliff. Water is conducted from the intake through three underground conduits about 6,500 feet long to three surge tanks located above the power house and thence in steel penstocks to the turbines. At the power house there is a valve chamber with a valve for each penstock.

The first conduit was made of steel, designed to withstand the internal pressure but when it was being emptied for inspection, part of it collapsed under a partial vacuum. It was jacked back into shape and encased in concrete. The second conduit was made of reinforced concrete; the third, during World War I, of wood staves with steel bands, later covered with concrete.

The turbines operate under a head of 180 feet and are controlled by wicket gates. The first three units of 11,600 hp each were placed in service on 1 July 1905; the fourth, on 5 November 1906; two units on 18 January 1908; one 11,600-hp unit and two 15,000-hp units in 1909; three 15,000 units in 1911; and two of 16,000-hp each, in 1913. The extension of the plant with the third conduit and two 20,000-hp units was commenced in March 1918 and both units went into operation in June 1919.

The Niagara, Lockport and Ontario Power Company contracted to take 35,000 hp; delivery to Rochester and Syracuse began in 1906. In 1910 a contract was signed with Ontario Hydro for 100,000 hp of 25-cycle power. Hydro bought the plant in 1917.

On 20 April 1922 the governor of unit 15 failed and allowed the unit to speed up so that it exploded under the excessive centrifugal force. One part went through the roof and one damaged unit 14. One unit was put back into service on 1 December 1923 but the other was never rebuilt.

Time has shown that the location of this plant is not safe. In April 1909 an ice jam formed in the upper part of the Maid-of-the-Mist pool and raised the water so high that it flooded the interior. Fortunately the machinery suffered no permanent damage and the generators were put back into service as soon as they were dried.

A second flooding occurred in 1938. Water and ice poured through the upstream windows but there was no structural damage to the building. The water drained off when the river fell, but the ice remained and a small power shovel was used to load it into trucks. Power plants do not have ordinary heating equipment but are warmed by the heat from the generators. Here was a plant full of ice and with no heat. Heavy iron rods were assembled to form gigantic electric heaters and the normal direction of current flow was reversed to supply them. A heater was enclosed with each generator to dry it out.

Hydro-Electric Power Commission of Ontario

With the single exception of the Canadian Niagara, all the power developments on the

Canadian side of the Niagara are owned and operated now by Ontario Hydro. This Commission grew out of the desire of the municipalities of southern Ontario to get low-cost power then in prospect from Niagara and to share Hamilton's advantage. In May 1906 an act was passed by the Ontario Legislature and this was amended in March 1909 and again later to create the Commission in its present form. The policy of the Commission to sell electric power at cost stimulated the industrial growth of Ontario, which was handicapped by lack of coal until this "white coal" became available.

One of the first acts of the new Commission was to build a transmission line from Niagara to Toronto. This was the first line to use 110,000 volts, which was made possible by the adoption of the ball-and-socket type of suspension insulator, in place of the upright, pin-type ones previously in use. Now the whole of southern Ontario is served by Hydro transmission lines, from the Quebec border to Windsor, and with voltages up to 230,000. Power from Niagara is an important, but not the only, source of supply.

Sir Adam Beck No. 1 Plant

The first plant built at Niagara by Ontario Hydro was named after the man who spent the last twenty years of his life in promoting the growth of the great organization which he helped to found. The total output of this plant is 500,000 KVA and at the time it was built it was the large- largest hydro-electric plant in the world.

The intake is at Chippawa, 1 ½ miles upstream from the Cascades. The power house is on the bank of the river, one mile above Queenston, where the river is practically at Lake Ontario level. Thus this plant, with a net head of 300 feet, takes advantage of the whole utilizable drop from Lake Erie to Lake Ontario, including that in the Cascades, the Falls, and also the rapids both above and below the Whirlpool.

Water is conveyed from the intake to the forebay through an open canal 12 3/4 miles in length, of which the first 4 ½ miles uses the lower part of the Welland River,[*formerly called Chippawa Creek]* enlarged and with the flow reversed. The rest of the distance is in excavated canal, most of it through rock with earth overburden, the maximum depth of earth and rock cut being 143 feet. From the screen house at the forebay, the water is carried down the cliff through steel penstocks 16 feet in diameter encased in concrete, each with a Johnson valve.

The turbo-generator units turn at 187 ½ rpm and have short vertical shafts. The turbines are single-runner, Francis type. The alternators are 12,000 volts, three phase; all were 25-cycle originally but units 9 and 10 were changed to 60-cycle later. Each unit has its own set of transformers and its own transmission circuit.

Construction work started in May 1917 and water was turned into the canal on 24 December 1921. The first unit went on commercial load on 26 January 1922; the ninth unit, on 5 December 1925; unit ten, in July 1930.

DeCew Falls No. 2 Plant

The second DeCew Falls plant, like the first, gets water from Lake Erie through the Welland Canal. An additional 5,000 cubic feet per second became available to Hydro when it built the Long Lac and Ogoki projects which divert water from Hudson Bay drainage into the great Lakes system. Construction of this new plant involved building extra intake works to divert water from the canal into Lake Gibson; raising the level of Lake Gibson by four feet to give extra pondage; excavating an approach channel from the lake to the new head-works; deepening the channel in Twelve Miles Creek to lower the tail-water by 12 feet. This increased the head to 280 feet.

This plant is only a few hundred feet downstream from the original one but it is close against the cliff on a solid rock foundation with the penstocks encased in concrete. The first unit, of 65,000 hp, was moved to DeCew from Abitibi Canyon during World War II. It began producing power in its new location in October 1943. The second unit, of 75,000 hp, went into operation in September 1947. Both were 25-cycle originally but were changed to 60 cycles later. This plant is used mainly to supply peak-load power, water being diverted steadily from the canal, except when a ship is passing, and stored in Lake Gibson.

Sir Adam Beck No. 2 Plant

The continued increase in demand makes it necessary to get as much power as possible from the available water. After the signing of the 1950 Treaty, Ontario Hydro started the construction of a second high-head plant to be known as Sir Adam Beck No. 2. With this new plant, most of the Canadian share of the water can be transferred to it from the low-head plants, which more than doubles the power output.

The intake is located 1,500 feet upstream from the Cascades. There are two tunnels, each 45 feet in diameter and 28,600 feet long, which discharge into a single canal 2 ½ miles long leading to the forebay. There is a novel level cross-over between the new canal and the old.

The power house is a short distance upstream from the No. 1 plant and is the same in general design, except that the units are about 1 ½ times as big, there are more of them, they do not have Johnson valves and all are 60-cycle. It contains 16 units of 80,000 KVA each, four extra having been added to use the pumped storage water. The first three units were in service by August 1954; three more by the end of 1955; six more were added during 1956; one in 1957; three in 1958: total capacity, 130,000 KVA.

Pumped-Storage Plant

In general, the demand for power is greater during the daytime than at night. In order to keep the tunnels and canals flowing at full capacity 24 hours per day, Ontario Hydro has built a reservoir and pumping generating station. Six reversible units have been installed in a station which is connected to the canal half a mile above the main plant. During periods of low demand, the generators act as motors to drive the turbines as pumps and deliver water from the canal into a reservoir having a storage capacity of 16,000 acre-feet. In periods of high demand, the units operate in reverse and draw water from storage, each unit having an output of 47,000 hp at a maximum discharge of 5,600 cubic feet per second. However, the great advantage of the stored water comes when it is used in the main plant under the 300-foot head.

Robert Moses Niagara Power Plant

On the United States side of the river, the first contract for the Robert Moses plant of the Power Authority of the State of New York was awarded in February 1958. The intake for this plant is 2 ½ miles above the Falls and water is carried to the forebay through four miles of underground, twin conduits, each 46 feet wide and 66 feet high. The power house is beside the river almost directly opposite the Sir Adam Beck No. 2 plant. It operates under the same head and the general construction is much the same, except that the units are nearly twice as large. There are to be 13 units, all 60-cycle, and each with an output of 150,000 KVA: practically two million KVA in all. In addition, there is a pumped-storage reservoir with 60,000 acre-feet of storage and 12 pump generating units.

On 10 February 1961, Governor Nelson Rockefeller participated in a colourful ceremony to mark the generation of first power. On 30 June, transmission started on the 345,000-volt line to

Syracuse and on 31 August this was extended to Utica. The first water was pumped into the reservoir on 26 October. The whole plant will be completed in 1962.

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