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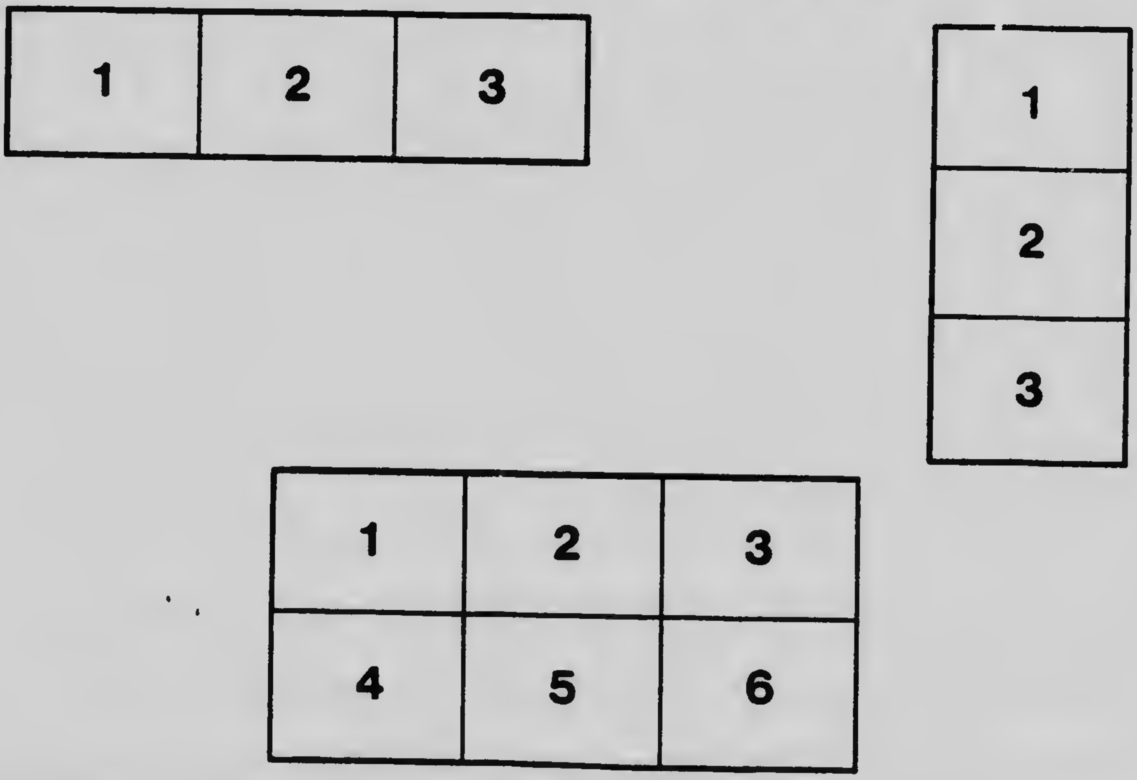
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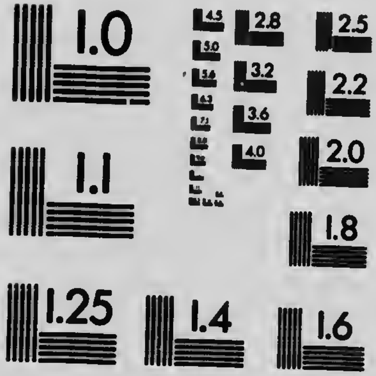

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The Institution of Civil Engineers

At Niagara Falls

September 27, 1904

19283

The Institution of Civil Engineers

At Niagara Falls

Tuesday, September 27th, 1904

Presented by the Local Committee of the Canadian Society of Civil Engineers.

NIAGARA FALLS SHOWING POWER PLANTS ON CANADIAN SIDE

Niagara River and Falls.

"In all the world there is but one Niagara, and all the world should see it."

THE Niagara River is a connecting link in the chain of Great Inland Waters of North America, and carries the outflow of Lakes Superior, Michigan, Huron and Erie down to Lake Ontario, from whence the St. Lawrence River carries it on to the Atlantic. The drainage area which it serves is over one hundred and fifty thousand square miles in extent, and owing to the Lakes acting as settling ponds, the waters of the Niagara are unusually clear.

The River is about thirty-three miles long, and in width varying from one and a half miles, a short distance above the Falls, to less than four hundred feet in the Whirlpool Rapids.

The elevation of the River at its source in Lake Erie is about five hundred and seventy-two feet above Sea Level, and at its mouth, in Lake Ontario, two hundred and forty-five feet; this giving a total drop of three hundred and twenty-seven feet, distributed as follows:—

	Distance		Drop	
Lake Erie to beginning of the Rapids	18	Miles	13	feet
Upper Rapids	1	"	46	"
Horseshoe Falls	0	"	160	"
Base of Falls to Whirlpool	3½	"	68	"
Whirlpool to Queenston	3½	"	38	"
Queenston to Lake Ontario	7	"	2	"
Total	33	Miles	327	feet

At a remote period, estimated by Geologists at from thirty to thirty-five thousand years, the Falls were at Queenston Heights escarpment, and were probably much greater, in elevation and less in volume, than at present. Owing, however, to the friable nature of the shale underlying the lime stone formation, which disintegrates rapidly when exposed to the air and falling water, the Falls have slowly cut their way back to the present location.

It may be interesting to know that the rate of recession is considered to have varied very much from time to time, owing to changes in climatic conditions and fluctuations in the flow of the River; to these causes the great variation found in the depth of the River below the Falls is attributed.

From the most recent surveys the present maximum recession, at the center of the Falls, is about five feet a year, and the average recession distributed over the whole crest line is about 2.2 feet.

There appears to be a slow earth movement going on, which it is estimated will change the drainage system of the Upper Lakes, and if not arrested will ultimately divert the out flow from the St. Lawrence to the Mississippi River Basin. This change, however, it is stated, will not occur for several thousand years, so it need not cause any present anxiety.

The volume of the River fluctuates with the level of the water in Lake Erie, but at the mean elevation of the Lake the flow is 222,400 cubic feet per second. There are several causes which affect the flow, namely,

(1). The action of the wind which raises or lowers the surface of the Lake at its outlet for a few hours.

(2). The monthly variation throughout the season, which is comparately little.

(3). A periodical fluctuation, of greater extent, which appears to be co-relative to the rainfall, temperature, etc., etc., and having a cycle varying from twelve to fifteen years.

These several changes of elevation, in Lake Erie, are so modified by the physicial characteristics of the river that at the crest line of the Falls, the rise and fall are not so noticeable.

Owing to the rapid current the Upper River does not freeze over, but large quantities of ice are carried down from Lake Erie during the winter months, and pass over the Falls, below which a jam frequently takes place, forming what is called the Ice Bridge. Above the Falls the course of the floating ice is directed by the wind, and as westerly winds prevail the ice is much more frequently driven to the American than to the Canadian side of the River, where the depth of the water is also much greater. Owing to the open river channel and the turbulent character of the rapids, anchor ice or frazil forms rapidly in severe cold weather, but the free discharge over the Falls, and the swift current leading thereto, revent it becoming as troublesome as at other places in the same or higher latitudes.

PARK SYSTEMS

The late Lord Dufferin, while holding the Office of Governor General of Canada, conceived the idea of joint action on the part of the Governments of New York State and of the Province of Ontario, to secure public ownership of all the land about the Falls on both sides of the river.

The suggestion met with public favor, and in 1880 a joint Memorial, signed by nearly seven hundred of the leading literary men of Canada, the United States and England was presented to the Governor General of Canada, and to the Governor of the State of New York, urging that their respective Governments should secure and hold, for the world's good, all the lands about the Falls of Niagara.

This Memorial bore fruit first in the United States, and in July 1885 the "State Reservation at Niagara," embracing one hundred and seven acres on the American side of the river, and including Goat Island and the smaller Islands adjacent thereto, was formally dedicated with the proper ceremonies.

Three years later the "Queen Victoria Niagara Falls Park," on the Canadian side, was opened to the public. This Park, as originally defined, extended from one mile below the Falls to the head of the Upper Rapids, about one and a half miles above the Falls, and including an area of about one hundred and fifty-four acres.

These Park Systems were placed under Boards of Commissioners, responsible to their respective Governments.

On the Canadian side additional lands have been added from time to time, by way of grant from the Crown, or by purchase, until now nearly the whole of the river bank, from Lake Erie to Lake Ontario, is under the control of the Park Commissioners, and the area has been increased to about 750 acres, not including the bed of the river adjacent to the original Park about the Falls and extending out to the International boundary line.

On the American side the State purchased the property for the Park outright, and makes a yearly grant for its maintenance.

On the Canadian side the Park system has been financed without cost to the Province, and is now self supporting.

WATER POWER DEVELOPMENT

Over one hundred years ago, the waters of the Niagara were harnessed for manufacturing purposes, and mills were erected on both sides of the river; these efforts were on a very small scale, a simple embankment of wooden cribs or of rock-work placed along the edge of the rapids for a short distance, affording the few feet of head required to run the saws of the Lumberman or the stones of the Miller, and it was not until comparatively late in the last century that any serious effort was made to take advantage of the greater head afforded by the Falls. The construction of the raceway of the Niagara Falls Hydraulic Power & Manufacturing Company, which tapped the river above the rapids and terminated on the edge of the cliff, half a mile below the American Fall, was the first important work carried out with this end in view; and several important industries were established on the brink of the Gorge, where pressure turbines, running under heads of 90 to 100 feet, furnished power, through gears or belting.

By the advance of Electrical Science, which made it possible to utilize power on a large scale at a distance from the point of development, a new and wider vista opened up for Niagara Falls as a manufacturing centre, and capitalists began investigating the possibilities of utilizing the favourable conditions presented for producing power on a scale before undreamt of.

The Niagara Falls Power Company was the pioneer in this movement, and commenced operations upon their 100,000 horse-power plant in September, 1890—that this Company has succeeded in passing the experimental stage and has become an important factor in the Commercial world, may be seen from the following list of customers now served by the Company, and which is published by permission :—

AT NIAGARA FALLS, N.Y.

	Maximum Power Used	Distance from Power House
	HORSE-POWER	MILES
The Pittsburgh Reduction Company	8,000	0.46
The Carborundum Company	5,000	0.88
Union Carbide Company	15,000	2.
Niagara Electro Chemical Company	2,000	0.75
Niagara Falls Lighting Company	1,000	0.14

AT NIAGARA FALLS, N. Y.—(Continued)

	MAXIMUM POWER USED HORSE-POWER	DISTANCE FROM POWER HOUSE MILES
International Railway Company	1,500	
The Niagara Falls Water Works Company	800	
International Paper Company	8,000	
Castner Electrolytic Alkali Company	7,000	0.85
Niagara Development Company	100	1.23
Oldbury Electro-Chemical Company	1,500	2.18
Electrical Lead Reduction Company	500	0.19
International Acheson Graphite Company	1,000	0.[illegible]8
The United Barium Company	2,000	0.66
Acetyvone Manufacturing Company	50	0.95
Roberts Chemical Company	500	1.90
Francis Hook and Eye and Fastener Company	15	0.47
Norton Emery Wheel Company	650	0.95
The Na[tural] Food Company	1,500	0.66
Ramapo Iron Works	500	1.70
By-Products Paper Company	500	0.19
Composite Board Company	200	0.34
Atmospheric Products Company	50	0.47
Niagara Research Labratories	500	0.28
AT NIAGARA FALLS, ONTARIO		
A. C. Douglass, Contractor	400	3.
M. P. Davis, Contractor	800	3.7
A. C. Jenckes, Contractor	200	3.5
The Carborundum Company	200	3.6
Niagara, St. Catharines & Toronto Railway Company	500	3.8
Lighting Company	500	3.4
AT TONAWANDA		
International Railway Company	1,500	
Tonawanda Board & Paper Compa[ny]	1,200	15.
Buffalo Bolt Company	160	14.
Philip Houck Milling Company	142	14.
F. J. Alliger Company	107	15.
Adamite Abrasive Company	50	14.5
Orient Manufacturing Company	20	14.
Felton School	22	14.
AT LOCKPORT		
Lockport Lighting Company	500	25.
International Railway Company	1,000	26.
AT OLCOTT		
International Railway Company	1,000	39.
AT BUFFALO		
Buffalo Railway Company	7,000	27.
Buffalo General Electric Company	6,000	27.6
The Charles G. Curtiss Company	125	25.5
McKinnon Dash Company	100	24.4

AT BUFFALO—(Continued)

	Maximum Power Used Horse-Power	Distance from Power House Miles
Pratt & Letchworth	233	24.5
W. W. Oliver Manufacturing Company	15	24.7
Acme Steel & Malleable Iron Works	50	24.8
New York Car Wheel Works	200	24.3
National Battery Company	90	26.3
Standard Plaster Company	100	25.5
Great Northern Elevator Company	900	29.5
Buffalo Dry Dock Company	133	30.
Electric Grain Elevator	200	30.7
Barcalo & Boll Manufacturing Company	60	30.
Schoellkopf & Company	50	30.
Iron Elevator & Transfer Company	165	30.
Great Eastern Elevator	900	30.
Sidney Shepard & Company	100	30.
J. I. Prentiss & Company	30	29.
Edward Elsworth & Company	150	30.
American Agriculture Chemical Company	125	32.
Jacob Dold Packing Company	100	32.5
Empire Bridge Company	90	33.
Buffalo Elevating Company	950	29.
John Kam Malting Company	225	24.3
American Shoe & Foundry Company	40	33.2
Buffalo Cereal Company	375	30.3
Taylor Signal Company	65	25.5
Snow Steam Pump Works	150	33.3
Wood & Brooks Company	100	24.4
U. S. Rubber Reclaiming Works	995	31.7
American Radiator Company	200	24.
Cumpson-Prentiss Coffee Company	30	29.1
Duffy Bros. & Nellis	50	33.5
Buffalo Foundry Company	240	35.1
H. O. Mills	255	29.3
Jewett Manufacturing Company	30	24.8
Buffalo Pitts Company	187	35.5
Buffalo Brake Beam Company	30	25.
Buffalo Dental Manufacturing Company	20	35.5
Keystone Manufacturing Company	25	24.8
R. L. Ginsburgh & Sons	33	34.
Buffalo Weaving & Belting Company	65	25.5
H. W. Dopp & Company	10	25.
Frontier Iron Works	15	25.
The Crosby Campany	50	33.
Lackawanna Steel Company	70	29.4
West Manufacturing Company	40	28.
Buffalo Gasoline Motor Works	20	25.
Pratt & Lambert	10	24.5
Wegner Machine Company	40	29.

	MAXIMUM POWER USED HORSE-POWER	DISTANCE FROM POWER HOUSE MILES
Spencer Kellogg Company	500	29.2
Hygenic Food Company	800	32.8
Collins Baking Company	50	33.2
George Urban Milling Company	450	34.5
Niagara Mill & Elevator Company	100	26.
D. L. & W. R. R. Shops	150	34.5
Ryder Belt & Cortage Company	65	24.7
United States Headlight Company	40	26.
George E. Laverack Building	100	28.2
Buffalo Structural Steel Company	80	26.
J. N. Adams & Company	100	28.2
Genesee Hotel	100	28.1

The Niagara Falls Hydraulic Power & Manufacturing Company

early took advantage of the changed conditions of the power market and by enlarging the dimensions of their raceway and locating their Electrical Power House in the Gorge succeeded in utilizing nearly the whole head found in the Falls, and in the upper rapids, and the following list of customers supplied by this Company testifies to the success already achieved by it in Electrical supply.

List of power consumers:—Acker Process Company, Buffalo & Niagara Falls Electric Light & Power Co., Carter-Crume Company, Cliff Paper Company, Lewiston & Youngstown Frontier Railway, National Electrolytic Company, Niagara Falls Brewing Company, Niagara Gorge Railroad, Oneida Community, Limited, Pittsburgh Reduction Company, Vermilion Chemical Company, Wm. A. Rogers, Limited. In addition to the above, power is being furnished to a large number of small consumers.

On the Canadian side, where the territorial rights necessary for the use of the waters about the Falls, under are the control of the Park Commissioners, a franchise was given in 1892, for an Electric Power development, but owing to the various causes it was not until May, 1901, that work was begun. The pioneer Canadian Company, known as the

Canadian Niagara Power Company

has its 110,000 horse-power plant well advanced towards completion, and it is expected that the first installment of power will be ready for use in January, 1905. A detailed description of this work by the officers of the Company is appended hereto.

The Ontario Power Company

secured a franchise from the Dominion Government in 1887 to tap the waters of the Welland River, about one half mile from its junction with the Niagara at Chippawa, and by means of an open headrace into the Park, and a Power House located on the Talus in the Gorge below the Falls, to generate Electric Power somewhat on the scale of the Niagara Falls Hydraulic Power & Manufacturing Company.

The Company afterwards secured an amended franchise by which the waters of the Niagara were to be taken from a point within the Park and carried, by means of underground pipes, through the Park to the location of the Power House below the Falls. This latter project is now under construction and it is proposed to develop 180,000 horse-power in this manner. A detailed description by the officers of this Company will be found appended hereto.

As the chief promoters of the two preceeding Companies were largely citizens of the United States, a number of Canadian capitalists, jealous of the honor and reputation of their country for enterprise, sought a franchise upon a site midway between the locations selected by the two companies referred to above, and the

Electrical Development Company of Ontario

commenced work upon its 125,000 horse-power development early in 1903. This project presents some novel and interesting features which will be found fully described in that Company's article.

In the three franchises granted on the Canadian side the Commissioners have reserved the right of approval of all plans and works, and require that the Park surface, where ever affected by the works in question, shall be properly restored. They also require that a yearly rental be paid by each Company, based upon the amount of Electric Power produced and sold, and have stipulated that none of the electricity generated shall be used upon Park territory, but must be disposed of outside the Park limits.

The construction of an Electric Railway was found to be necessary in order to permit visitors to economically and expeditiously view all points of the river between Chippawa and Queenston, every portion of which is full of historic interest and scenic grandeur. A franchise was, therefore, given to the Niagara Falls Park & River Railway Company, now affiliated with the International Railway Company, and the line was constructed in the season of 1892 and has been in successful operation ever since.

The Ontario Power Company of Niagara Falls.

THE grants from the Government of the Dominion of Canada, under which this Company is making its development of 180,000 horse-power, were secured in 1887. These concessions were the first, for the utilization of Niagara River power, granted in Canada, and were contemporary with the first concessions granted in the United States.

The plan of development as at first contemplated is only partially followed in the design of works now under construction, the headworks being situated at the upper end of the Park instead of at Chippawa at the mouth of the Welland River. In general, the present design consists of Headworks located in the smooth water of the upper river above the first line of rapids opposite the Dufferin Islands, three Main Conduits or flumes leading the water through the Park to a point on the cliff below the Falls, thence by Penstocks in tunnels through the cliff to the Generating Station in the gorge, with its water wheels and electric generators, and lastly the Distributing Station situated on the high bluff directly above, to which the electric cables are carried from the Generating Station in inclined tunnels. The Company still retains the right to draw additional water from the Niagara River at Chippawa and to develop power therefrom in the Park in addition to the 180,000 horse-power now under construction.

The details of the present construction are briefly outlined in the following general description:—

HEADWORKS

The Headworks consist of an intake proper, and outer forebay, screens, an inner forebay and control gates.

The intake, 618 feet long, consists of concrete piers supporting a continuous, reinforced concrete curtain wall which extends vertically downward seven feet below the normal surface of the river, to within six feet of the river bed, and upwards five feet above the normal river level, which at this point is about 555 feet above sea level. More than double the quantity of water to be utilized at the water wheels is intercepted by the up-stream face of the intake, and much is there deflected to form a cross current which will carry away ice. This is brought about by the curtain wall construction and the placing of the structure at an obtuse angle to the natural direction of the current in the river.

The outer forebay, which contains an area of eight acres, is bounded by an artificial island and the original river bank on the one side, and by a long concrete gathering wall on the other. A supply of water is provided for the restoration of the Dufferin Island channel, which is controlled by sluices on either side of the island mentioned.

Except during extremely low stages of water in the river, the outer wall of the forebay will be constantly submerged, water spilling freely over it into the river, as over a weir, carrying floating ice and debris with it. The top of the wall is at an elevation of 553 feet above sea level. A section of this wall, 100 feet in length, adjacent to the screen house, is constructed with the top depressed below the crest of the main portion. When water at the intake is at extreme low level, there is thus an additional discharge area of approximately 300 square feet cross section over the depressed section. This spillway creates a strong surface current across the front of the screens, tending to sweep out into the river all ice that may have passed the ice curtain at the intake and escaped the general spill over the wall.

The screens are in the form of a steel grillage, set on inclined guides in concrete masonry, and are removable by means of a crane. The apparatus is covered by an artistic stone building, the roof of which forms a broad promenade, commanding an exceptionally fine view of the rapids.

The inner forebay, with an area of two acres, extends from the screen house to the gate house. The landward wall and the river wall are formed partly by the rock face after excavation had been made in the river bed, and partly of concrete. On the land side, excavated material has been dumped and graded to bring the general surface of the islands in this vicinity up to the same level as the top of the concrete wall, at elevation 560. The original Dufferin Islands have been increased in area, and several entirely new islands of considerable size have been made from the excavated rock, approximately 150,000 cubic yards, taken from the bed of the river in deepening the two forebays.

ONTARIO POWER COMPANY, MAIN CONDUIT
EIGHTEEN FEET DIAMETER

SITE OF GENERATING STATION OF THE ONTARIO POWER COMPANY

The quantity of water that will be drawn into the inner forebay when the entire capacity of the plant is being generated has been calculated to be in the neighborhood of 12,000 cubic feet per second. The depth of water in the headworks under normal conditions of river gradually increases from 13 feet at the intake to 30 feet at the gate house. The velocity of flow is about three feet per second at the intake; it is swiftest, 4.7 feet per second, through the central portion of the outer forebay, and it drops to two feet at the screens, then gradually increases to 3.4 feet per second at the gate house.

The gates at the entrance to the conduits are three in number, one for each of the main conduits. They are of the Stoney pattern, of square form, full size of their respective conduit and counterbalanced to run between roller guides. A substantial and artistic building covers the gates, and an equipment of boilers and steam pipes provides against freezing.

The design of all buildings throughout the works has met the approval of the Park Commissioners, who require preservation or enchancement of the æsthetic effects that prevailed in the Park before present construction began, and it is felt that their object is fully attained.

THE MAIN CONDUITS AND PENSTOCKS

Starting from the gate house, the main conduits, three in number, follow the river bank through the park to the top of the cliff opposite Goat Island. The distance to the nearest penstock is 6,180 feet, in which length the fall in grade is 28 feet. The first of the three conduits which is now nearing completion, is 18 feet in interior diameter. When flowing at full capacity it will pass about 3,900 cubic feet of water per second.

The main conduit now constructing is built of steel plates ½ inch in thickness with double riveted joints. To secure additional stiffness, seven inch bulb tees or deck beams are riveted to the upper half of the circumference of the pipe at intervals of four feet throughout its length. The pipe is erected in a trench excavated in the Park, and before backfilling, is thoroughly cleaned with sand blast and covered with three coats of paint both inside and out. Conductors are arranged to protect the steel conduit from stray electric currents, which might otherwise cause damage by electrolysis. An open relief and spillway through a tunnel to the river is provided at the lower end to reduce fluctuations of head and pressure at increase and decrease of loads.

From the under side of the first main conduit, six penstocks, each nine feet in diameter, drop in pairs through vertical shafts and out through horizontal tunnels in the solid rock of the cliff to the power house. Each penstock supplies water for a 10,000 horse-power unit. The vertical distance from the center of the main conduit to the center of turbine is 133 feet. Two small penstocks, of 30 inches diameter, lead from the main conduit through an inclined tunnel to the power house and supply water for the two exciter turbines.

A chamber beneath the main conduit at the junction of penstocks accommodates the 108 inch penstock gate valves and operating mechanism.

GENERATING STATION AND APPARATUS

The building is 76 feet wide and 65 feet high, and for the full capacity will be about 1,000 feet in length. The roof is flat and the general style of architecture is massive and somewhat after the Egyptian order. The front wall is designed to withstand pressures that may result from ice gorging and rising in the river in front of the building. The floor level is 25 feet above the normal level of the river.

The main generators and their turbines, directly connected, are the only machines placed on the floor of the station. Each turbine unit consists of a pair of Francis turbines, mounted on a horizontal shaft, operating at 187.5 revolutions per minute, and rated at 11,400 horse-power. Before reaching the turbine, the penstock supplying it divides into two branches leading to the separate wheels that constitute one complete turbine. After passing through the wheels, the water flows through concrete draft tubes, terminating in tail races in the foundations of the generating station, which in turn discharge over a weir wall into the river. The crest of this weir wall is at elevation 349, and under full load conditions water rises on it to about elevation 353, giving as the gross head, between forebay and tail water levels, 200 feet. Of this head, 175 feet is effective on the turbines.

Six of the 20 main generators provided for by the general plan, make up the first installation. Each of these generators is rated at 7,500 kilowatts, to deliver three phase current of 25 cycles per second at 12,000 volts. They are of the rotating field type and have 16 poles each, the external diameter of the armature casing being about 21 feet. The floor space they occupy is about 26 x 20 feet each, the shorter dimension being along the shaft. The total floor space occupied by a unit, consisting of a generator and its turbine, is about 26 x 50 feet.

On a raised gallery, 11 feet above the main floor, and extending along the rear wall of the station, are located the exciter turbines, the direct connected exciting dynamos and the governors that regulate the speed of the turbines. This arrangement permits of an attendant watching the operation of the entire station, while within easy reach of important control elements of the apparatus. Contrary to general practice, however, the actual operation or management of the generating station is not conducted within its walls, but from a separate control and distributing station at a distance from the generating station. The placing of main switches, indicating instruments and similar apparatus elsewhere was necessary on account of the limited space available at the station site. The removal, however, permits of the convenient placing of this apparatus in relation to transformers and high tension switches.

Each exciter turbine and dynamo is of 500 horse-power capacity, and operates at 300 revolutions per minute, generating direct current at 250 volts. They are used for the operation of lamps, motors, oil switches, and for charging storage batteries, as well as for exciting the generator fields. One alone has sufficient capacity to excite the fields of six main generators, but two are provided for each group of six units.

Certain features of the controlling apparatus are naturally inseparable from the power house. These include 250 volt switches for the circuits from direct current dynamos to generator fields, to lighting circuits, storage batteries and the like, also switches for the circuits operating the valves in the nine foot penstocks. Time limit and overload relay switches for the protection of the main generators are also placed in the power house.

CONTROL AND DISTRIBUTING STATION

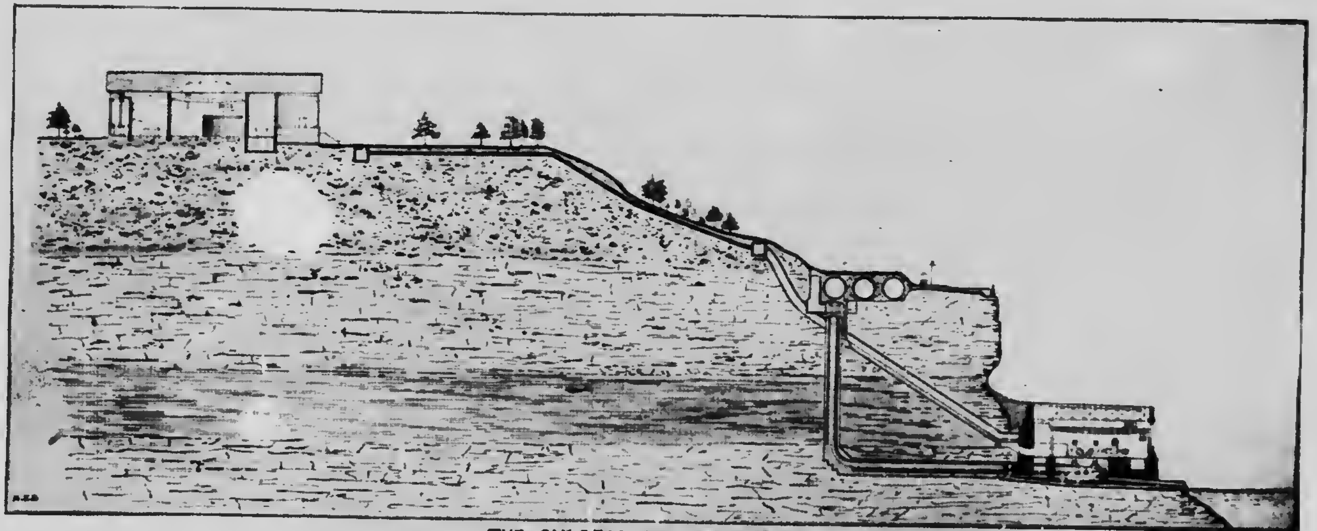
At a distance of 550 feet back from the generating station and on the bluff at an elevation of 250 feet above it, is situated the control, transforming and distributing station, as shown in the accompanying illustration. This distant control removes from the generating station the possible dangers incident to the operation of high voltage switches for generators, as well as for transformers, and also concentrates the management of both in a single operating room. On a raised gallery, indicator switches on individual pedestals afford control of speed, voltage and connections. Just back of each control pedestal there is an instrument stand which carries a full set of indicating instruments.

The control circuits pass from the generating station in insulated cables carried through inclined tunnels in the cliff, extending to a point on the hillside a little above the main conduits, thence up the bluff under ground to the distributing station. The electrical energy from the generating station is transmitted by heavy cables, insulated with paper and lead, and protected with layers of jute and steel, which follow the same route to the distributing station. They are laid in tile ducts imbedded in the sides of the tunnels.

In a separate switch room at the distributing station, the automatic oil switches for the 12,000 volt circuits from generators, are mounted in concrete cells, an isolated group for each unit. They are of the vertical plunger type and are magnetically actuated.

Transformers occupy the central place through the length of distributing station building, except in the middle, where space is given to the control gallery. Fireproof masonry walls separate low tension switch room, control gallery, the two transformer rooms and high tension switching rooms, from one another. The rating of each transformer is 2,500 kilowatts, or 3,350 horse-power, and each one weighs about 40 tons. They are set in concrete pits, in groups of three, and are water cooled. The potentials for which they are designed are 30,000 and 60,000 volts.

Three pole high tension switches of special design, to break a maximum current of 10,000 horse-power, thus necessarily involving some novel construction, connect the secondary coils of transformers to high tension bus bars. Transmission circuits will be taken off from these bus bars, although current may also be delivered to transmission circuits at generator voltage direct.



THE ONTARIO POWER COMPANY
SECTION THROUGH GENERATING AND DISTRIBUTING STATIONS.
SCALE OF FEET.

The distributing station building is of imposing appearance, as it occupies a prominent position on the bluff overlooking the Park and Horseshoe Falls. A wing to accommodate the offices of the Company extends forward in the center.

The works are being constructed by the Niagara Construction Company, Limited.

The Directors are :—

John J. Albright, Francis V. Greene, Edmund Hayes, Raymond K. Albright, Evan Hollister, Harry E. Nichols.

The Officers are :—

Francis V. Greene, President; Edmund Hayes, Vice-President; H. E. Nichols, Secretary; R. C. Board, Treasurer; Banker R. Paine, Manager.

The Engineers are :—

P. N. Nunn and L. L. Nunn, Engineers; O. B. Suhr, Engineer in Charge; V. G. Converse, Electrical Engineer; C. H. Mitchell, Mechanical Engineer; J. B. Bailey, Field Engineer.

Canadian Niagara Power Company

COFFERDAM

ONE of the most interesting features in connection with water power development in Queen Victoria Niagara Falls Park is the construction of a cofferdam in the swiftly flowing waters of the Niagara River, to allow of the forebay and other outer works being built.

The water flows past the intake of the Canadian Niagara Power Company at the rate of 11 feet per second, and building from the shore out into this current was a hazardous and difficult undertaking. The river bottom at the cofferdam site is a boulder and gravel formation about four feet from solid rock.

The cofferdam for this company consists of an inner and an outer cribwork with a puddle space between; the outer cribwork is ten feet wide, the inner, eight feet, and the puddle space, eight feet. The average depth of water is about 16 feet. The lines of cribwork are connected together below water with two inch iron turnbuckles, and above water with 12" x 12" timbers. The puddle is largely gravel, just enough clay being added to form a bonding material.

After the cofferdam was constructed, so much water leaked through the boulders between the puddle and solid rock that it was found unreasonably expensive to do the necessary pumping, so the inside of the cofferdam was covered with two layers of tongued and grooved sheathing breaking joints, and between which was placed a layer of tarred paper; all well spiked to the timbers. The river bottom at the inner face of the cofferdam was excavated, and the bottom of the sheathing fitted tightly to the rock. A small toe of concrete was placed along the bottom of the sheathing to give additional strength. A 20 horse-power electric motor, running an eight inch centrifugal pump and working about one-third time has taken care of all leakage.

The works being constructed are designed for a capacity of 110,000 horse-power. The general design is similar to that of Power House No. 2 of The Niagara Falls Power Company now in operation on the United States side of the river.

TUNNEL

The tunnel tailrace which leads the water to the lower river after it has left the turbines is 2,200 feet long and of a horseshoe form, 25 feet high and 19 feet wide, being lined with 17 inches of concrete with vitrified brick facing, except for 100 feet at river end where the tunnel drops by an ogee curve into the river. This portion is lined with two feet of granite, and a massive head-wall 60 feet long by 12 feet thick extends from 20 feet below the bottom of the tunnel to 10 feet above it, making total height of 55 feet of which 34 is below normal water level. The grade of this tunnel is seven feet per thousand which will give a speed of water, when plant is in full operation, of about 27 feet per second.

The rock through which tunnel was excavated is limestone and black shale. The former provided a good roof, but where shale was encountered timber arches resting on wall plates and plumb posts were put in to retain roof. The excavation of the tunnel was completed before the permanent lining was begun. The heading and first bench were first taken out and the remainder in two benches worked together. Nearly all was hoisted through an 8 feet by 16 feet shaft situated about midway between wheelpit and portal, the remainder being worked from portal end.

CANAL

The head canal, built entirely of massive limestone masonry, has a clear waterway 15 feet deep and 250 feet wide, and is crossed by a five span stone arch bridge which carries the tracks of the Niagara Falls Park & River Railway, a carriage way, and sidewalk. The canal widens into a forebay 600 feet wide, extending the whole length of the Power House.

ICE PROTECTION

Protection from ice is afforded by (a) an outer ice rack along river face; (b) a line of submerged arches forming outer wall of forebay room; (c) a fine ice rack extending the whole length of Power House inside the forebay room and immediately outside the penstock mouthpieces; (d) overflow weir which can be used in combination with floating booms to draw floating materials back into river again by means of a sluiceway channel.

CANADIAN NIAGARA POWER COMPANY, WHEELPIT LOOKING NORTH

WHEELPIT

The wheelpit is 165 feet deep, 18 feet wide inside of brick lining, and 570 feet long. The sides were channelled in six foot cuts. This gave smooth sides to the excavation and prevented detached portions of rock falling on the men working below. Some distance below the surface a water bearing seam was encountered, and a brick ring was built around wheelpit at this seam, all surface water led into it, and a large portion of the pumping done from this level.

Five chambers for auxiliary machinery were excavated in east side of wheelpit as the work progressed.

The wheelpit is lined with hard burned brick. The course next the rock is composed of hollow brick, and ample weepers emptying into the tail water are provided.

TURBINES

The turbines, each of a capacity of 12,500 horse-power, were designed by Messrs. Escher, Wyss & Company of Zurich, Switzerland, and are of the twin Francis vertical type, inward discharge, two draft tubes to each unit discharging into the open tailrace below. Three of these units were manufactured and are being installed by this firm, and two units on the same design are about to be installed by I. P. Morris Company, Philadelphia, Pa.

GENERATORS

One of the most distinctive features of this plant is the size of the generating units, each of which is to have a capacity of 10,000 horse-power,—the largest machines which have thus far been constructed. The plant, when completed, will contain eleven of these generators. A unit of this size was adopted for reasons of economy in hydraulic development and in electrical equipment. These 10,000 horse-power units occupy but little more space than that of 5,000 horse-power. Thus results a great reduction in length of wheelpit and power house for a given horse-power output. Furthermore the generators cost considerably less per horse-power than those of 5,000 horse-power capacity.

The generators with vertical shafts are of internal revolving field type, and are wound for three-phase current, 11,000 volts, 25 cycles at 250 revolutions per minute. This high generating voltage was selected not for long-distance transmission, but for economy in local distribution of power.

DISTRIBUTION

The cost of distributing underground at 11,000 volts, three-phase, is about one-fifth that required for a 2,200 volt, two-phase system. For long-distance transmission step-up transformers will be used to raise the voltage to 22,000, 40,000 or 60,000 volts, depending upon the distance of transmission. Three-phase was decided upon rather than two-phase for the reason that one less conductor is required, which simplifies cable connections, and because the three-phase system requires 25 per cent. less copper for transmission than one of two-phase for the same voltage. Power from this plant will be distributed by means of No. 000 B & S triple conductor, lead covered cables laid in ducts underground.

It is the intention to have cable connections so that this power house can operate, if desired, in parallel with either or both of the United States plants of the Niagara Falls Power Company. The cables will be carried across the Niagara River by way of the Upper Steel Arch Bridge, a total distance of about three and one-half miles. The 11,000 volts, three-phase, will be changed to 2,200 volts, two-phase, for paralleling, by means of step-down transformers or delivered direct to tenants on the lands of the Niagara Falls Power Company.

AUXILIARIES

The auxiliary machinery, consisting of exciter turbines, exciters, water pumps, oil pumps and oil tanks, etc., are located in the chambers built into the side of the wheelpit, 100 feet beneath the surface. This machinery will all be operated by an independent water service drawn from the canal above.

POWER HOUSE

The present Power House building, for five units, is constructed of Queenston limestone roofed with tile and has installed two 50-ton electric cranes for service in installation of machinery. It is lined inside with mottled buff brick, enamel brick, and marble.

CONDUITS

Underground conduits from Power House to Upper Arch Bridge have a capacity of 75,000 horse-power, and from Power House to a Transformer Station situated south and outside of Queen Victoria Park a capacity of 50,000 horse-power.

CANADIAN NIAGARA POWER COMPANY, POWER HOUSE AND FOREBAY

CANADIAN NIAGARA POWER COMPANY, OUTER ICE RACK AND CANAL BRIDGE

TRANSFORMER HOUSE

A Transformer House, equipped with water cooled transformers, has been constructed of a present capacity of 25,000 horse-power. It will be supplied with water for cooling purposes from pumps located in chambers of wheelpit. There is also a standpipe, 116 feet high by 30 feet in diameter, carrying one day's supply of water to be drawn upon in case of any accident to this pumping system.

This plant will be in operation this winter. Its output will be used for Canadian industries in the Province of Ontario within transmission distance of the Power House, or for United States customers, as the demand requires. A portion of this output may be sent to Buffalo by a transmission line to be built on the Canadian side of the Niagara River.

Every effort has been made in the construction of these works to build for the future. Stone, brick and cast iron have been chiefly relied on, and, where used, steel work has been designed so as to be accessible for inspection, removal and painting. The Power House and Transformer Station are practically fire-proof, the roof tiles being laid directly on the steel roof angles.

In the design, all the experience gained in the construction and operation of the plants of The Niagara Falls Power Company, has been made use of, and it is believed that the works herein described represent the best hydraulic, mechanical, and electrical knowledge available to date, and that the plant is the best of its type yet constructed.

LIST OF OFFICERS

President, W. H. Beatty; Vice-President and Treasurer, W. B. Rankine; Secretary and Solicitor, A. Munro Grier; Assistant Secretary and Assistant Treasurer, W. Paxton Little; Chief Mechanical Engineer, Dr. Coleman Sellers; Resident Engineer, Cecil B. Smith; Electrical Engineer, H. W. Buck; First Assistant Engineer, G. A. McCarthy; Assistant Mechanical Engineer, C. C. Egbert; Assistant Electrical Engineer, G. E. Brown.

Enlargement of Canadian Plant of International Railway Company

Among the great undertakings for the development of electric power in the Canadian Park one of lesser magnitude might pass almost unnoticed. The Niagara Falls Park & River Railway during the years 1892-3 built on the site of the present stone building a power house, and constructed a small headrace, wheelpit and tunnel. The hydro-electric equipment consisted of two 45" New American waterwheels on vertical shafts carried up through the centre of the steel penstocks, and geared to a line shaft. From this were driven three 200 K. W. 500 volt continuous current generators which supplied the power necessary for the operation of the electric railway from Queenston to Chippawa and two 450 K. W. 2,200 volt alternating current generators for the Canadian Niagara Power Company. In September, 1899, fire destroyed the building which was rebuilt the following spring, operation being resumed in July on same basis as formerly.

During the summer of 1903 work was begun on an increase of headrace capacity, and on an extension of the wheelpit for the reception of a new vertical shaft generating unit of 2,000 horse-power. The headrace was enlarged to be sufficient for a proposed future development of 8,000 horse-power total capacity, and this part of the work was completed last spring and 1,200 horse-power put in operation.

At present the erection of the new hydraulic machinery is being proceeded with. This consists of a 60" Francis Turbine inward discharge with single draft tube, and a vertical shaft to operate under a head of about sixty feet, and a General Electric Company 1,500 K. W. 575 volt continuous current generator. The penstock for this unit will be incased in concrete and this structure will serve as one of the abutments for the concrete arch which will support the generator. The weight of the revolving parts of this unit will be carried by the water balancing piston located near the lower end of the shaft, and by an oil thrust bearing just below the generator arch. A continuous system of oil lubrication will be supplied. The hydraulic machinery is being made by the Jenckes Machine Company of Sherbrooke, P. Q.

Consulting Engineer, Cecil B. Smith; Resident Engineer, W. G. Chace.

The Hydro-Electric Plant of the Electrical Development Co. of Ontario, Limited, and The Transmission Plant between Niagara Falls and Toronto of the Toronto and Niagara Power Co.

THE necessary rights for this undertaking were obtained from the Government by a syndicate composed of Messrs. Frederic Nicholls, Henry M. Pellatt and William Mackenzie, of Toronto, on January 29th, 1903. On the 18th February following, the Electrical Development Company of Ontario, Limited, was incorporated, by Letters Patent, under the authority of the Legislature of Ontario. This Company has a capital stock of $6,000,000. On the 2nd April in the same year, work was begun on construction.

The plant is located on the Canadian side of the Niagara River near Tempest Point about one-half mile above the Horseshoe Falls and at the foot of the rapids above the Falls. It is proposed to develop 125,000 horse-power.

The scheme of development consists of a system of Head Works for taking care of the ice and controlling the flow of water to the penstocks; a Wheelpit with a Power House or Generating Station over it; a Tail Race Tunnel; and a Transformer Station where the proper voltage for transmission to Toronto will be acquired.

Before any work could be done on sinking the Wheelpit or constructing the Head Works, a Cofferdam had to be constructed —2,200 feet long and extending about 600 feet into the river. This dam laid bare eleven acres of the river bed, which was of rock deeply eroded and covered with boulders. A maximum head of 24 feet of water was encountered, calling for a total thickness of crib-work of 40 feet. The dam was placed in position in sections 16 feet long and 24 feet wide against a current which, at times, reached 30 miles per hour. Three million ft. B. M. of hemlock timber was used in its construction and 19,000 cubic yards of stone was used to fill the cribs. The building of this Cofferdam under such conditions was a very difficult undertaking, but happily accomplished with only the loss of one life and with no serious accidents.

With the forebay unwatered, work was begun on the Head Works. A concrete Gathering Dam with granite coping, extending up stream from the lower end of the Wheelpit at an angle of thirty degrees, conducts the water to the gates increasing the available head and stilling the water. This dam is designed to act as a spill-way for its entire length, thus enabling the surface ice to escape before reaching the submerged arches mentioned later. This action is still further increased by having the top of the last 60 feet—at the down stream end—three feet lower than the rest of the dam. The heavy ice will be that brought down from the upper lakes in the early spring. It is not expected to be large in amount, as most of it passes down the river near the centre of its flow. However, ample provision is being made to handle whatever amount may possibly come. The water before reaching the penstocks will have to pass through two rows of submerged masonry arches, separated by a quiet bay equipped with a spill-way at its lower end for passing off such ice as may be in it. Between the second row of arches and the gates, lies a second bay equipped with a small spill-way at the end and with a set of metal gratings in front of each gate. This last bay comes beneath the limits of the Power House or Generating Station and will consequently be covered.

The Wheelpit, which is 416 feet long, 27 feet wide and 150 feet deep, will be lined with brick masonry. At its bottom will be placed eleven turbines of a capacity of 12,500 horse-power each. The turbines will have two runners—right and left—and will be connected with the generators on the main floor of the Power House by means of a hollow steel shafting about 115 feet in length with solid couplings. To each turbine, the water will be conducted by a penstock ten feet six inches in diameter and the tail water will be carried off through draft tubes of nine foot diameter. These draft tubes will discharge up into the invert of the Branch Tail Race Tunnels, thus securing a complete water seal regardless of the number of turbines in operation. In addition to the eleven turbines already mentioned, there will be two 125 volt exciters of 300 kilowatts capacity driven by water wheels and

ELECTRICAL DEVELOPMENT COMPANY'S WHEELPIT EXCAVATION

three exciters driven by induction motors. An oil pump for each turbine will be located in a chamber especially excavated for the purpose at the north end of the Wheelpit. These pumps will automatically furnish the oil under pressure to an adjustable floating piston carrying the wheel shaft, whenever for any reason the oil thrust bearing does not work.

The Tail Race Tunnel starts with two branches, one on either side of the wheelpit. These join at a point 165 feet beyond the end of the wheelpit, forming a section 26 feet high and 23½ feet wide of a horseshoe form. The permanent lining will consist of concrete masonry faced with eight inches of brick work. The grade, from the point of junction of the branch tunnels to the discharge point behind the Horseshoe Falls, is 5½ in 1000, and it is estimated that, with the complete plant in operation, the velocity acquired will be 26 feet per second and the discharge about 12,000 cubic feet per second. The length of the main tail race tunnel is 1,900 feet and branch side tunnels 1,260 feet. In order to begin excavation from the lower end, where the tunnel discharges under the heavy sheet of water of the Horseshoe Falls with the grade of the invert eight feet above the level of the water in the gorge, it was necessary to sink a shaft, 158 feet deep and excavate a drift—14 feet wide, eight feet high and 700 feet long—under the river. When one-half this distance was covered a cross-drift was made, forming an opening behind the Falls through which the excavated material was disposed of. This opening was a very difficult one to make, due to the immense quantity of water encountered. The site of the opening was covered with a pile of talus upon which the spray was striking. This talus led the water down into the drift—flooding it. It was necessary to make trips around behind the Falls and clear the talus away with dynamite. In spite of much difficulty, this was accomplished successfully and a timber shed or shield constructed for a length of 40 feet from the face of the cliff, almost out to the heavy curtain of water. When the main tunnel was reached, another opening was made behind the Falls. This was accomplished with less difficulty and no flooding, because at that point no talus was encountered. The excavation of the tunnel above the spring line, which lies in the shale necessitating timber lining, has progressed with unusual rapidity, the progress being about 50 feet per week.

Over the Wheelpit is located the Generating Station or Power House equipped with eleven 8,000 kilowatt generators of the vertical inside revolving field type with 12 poles, 250 revolutions per minute, and delivering a three-phase alternating current of 25 cycles at 12,000 volts. The length of the building will be 500 feet, width 104 feet and height 40 feet. Its style of architecture on the outside is of the Italian Renaissance.

The Directors of the Company are: President, Col. H. M. Pellatt; First Vice-President and General Manager, Fredric Nicholls; Second Vice-President, William Mackenzie; also Hon. Geo. A. Cox and James Ross. The other officers of the Company are: H. G. Nicholls, B. Sc., Secretary; D. H. McDougall, Treasurer. The Consulting Engineers are: F. S. Pearson, Dr. Sc., and Hugh L. Cooper; Resident Engineer, Beverly R. Value; First Assistant, Julian Thornley.

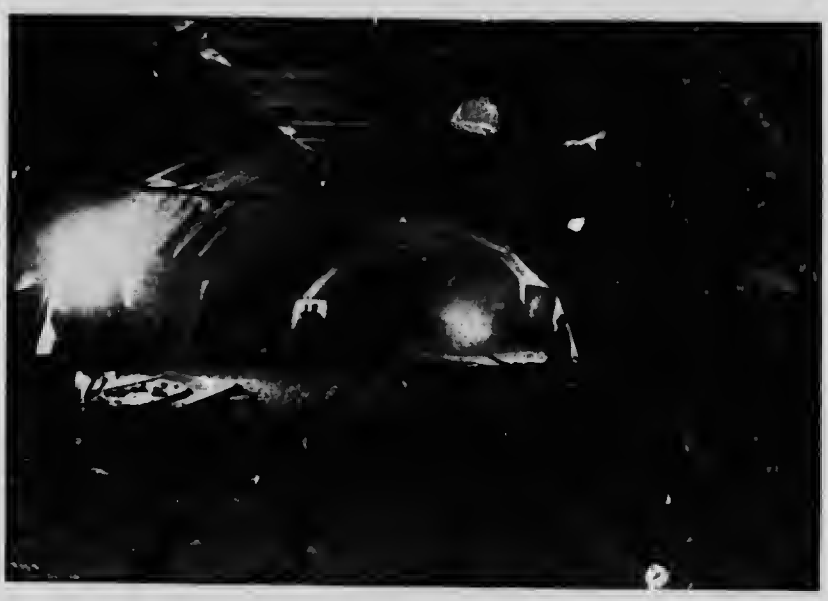
The Toronto and Niagara Power Company will receive at its Step-up Terminal Station or Transformer House, through underground conductors, the electric power generated by the Electrical Development Company of Ontario, Limited. This building—200 feet long and 65 feet wide—will be erected on the top of the Niagara embankment, about 1,500 feet from the Generating Station and sufficiently far from the Falls to be free from dangerous deposits of ice formed by the spray. Current from the Generating Station at approximately 12,000 volts will here be transformed and distributed at 40,000, 50,000 or 60,000 volts, depending upon the length of the transmission line and the quantity of the power to be transmitted. Four three-phase circuits at 60,000 volts will be used for the transmission line to Toronto. These four circuits will be carried on two lines of steel towers 46 feet high and placed about 400 feet apart.

The Step-down Transformer Station at Toronto will be similar in design to the Step-up Transformer Station. From this station will be laid conductors stored in underground conduits connecting to the sub-stations of the Toronto Electric Light Company and the Toronto Electric Railway Company.

The Directors and Officers of the Toronto and Niagara Power Company are the same as for the Electrical Development Company of Ontario, Limited. The Consulting Engineer is F. S. Pearson, Dr. Sc.; Chief Engineer of Right of Way, W. T. Jennings, M. I. C. E.; Chief Electrical Engineer, Robert C. Brown.

The Solicitor for both Companies is Hubert H. Macrae and the Bankers are the Canadian Bank of Commerce.

ELECTRICAL DEVELOPMENT COMPANY, EAST END OF MASONRY GATHERING DAM



ELECTRICAL DEVELOPMENT COMPANY'S TAIL RACE TUNNEL AT PORTAL BEHIND FALLS, EXCAVATED TO SPRING LINE

The Niagara Falls Hydraulic Power and Manufacturing Company.

IN the development of the Niagara Falls Hydraulic Power and Manufacturing Company there is to be found the oldest power project at Niagara Falls. In the year 1852 the Porter family, who were among the earliest settlers and who were much interested in the future of the place, donated the land necessary for the construction of a canal extending from the upper river to the edge of the high bank a short distance below the Falls, and negotiations were commenced with Caleb H. Woodhull and Walter Bryant for the construction of this canal.

These gentlemen organized the Niagara Falls Hydraulic Company in March, 1853, and immediately contracted for the construction of a canal 100 feet wide and ten feet deep. The turning of the first sod was made the occasion of a celebration. Work progressed nicely for sixteen months, when a lack of funds caused an enforced suspension of operations. In 1858 the work was resumed by the Niagara Falls Water Power Company, of which Stephen M. Allen was president. In September, 1860, Horace H. Day secured control of the property, and by July, 1861, had completed a canal 30 feet wide and about eight feet deep. The breaking out of the Civil War delayed operations, and for years the canal stream poured over the cliff unused. Early in the '70's Charles B. Gaskill built a grist mill on the lower end of the canal, and thus became the first user of the canal power.

In the year 1877 the canal property was purchased by Jacob F. Schoellkopf and Abram Chesbrough, who originated the present Niagara Falls Hydraulic Power & Manufacturing Company, of which Jacob F. Schoellkopf was president up to September 15th, 1899, the day of his death. From the day of the acquirement of the canal property by this company, the development has continued steadily, and what the company has accomplished has been a factor in the development of the industries of Niagara Falls. They have proceeded along the very conservative, safe and sure lines that characterize all the Niagara development. To-day the canal has a width of 100 feet for almost its full length of 4,400 feet, while its final depth will be 14 feet. At the lower end of the canal property there is a basin 850 feet long and 70 feet wide, the length of which is to be still further increased to 1000 feet. Extending from the basin to forebays located close to the edge of the high bank, are connecting canals through which the water flows from the basin to the forebays and through iron penstocks to the turbines.

It should be remembered that the early development of the Niagara Falls Hydraulic Power and Manufacturing Company was begun before engineers and manufacturers dared to design and build water wheels for use under the high head possible in connection with this plant. For this reason shafts or pits were sunk in the rock near the edge of the cliff to such depths as were considered safe for the operation of water wheels then made. These depths varied from 25 to 75 feet. The turbines were located at the bottoms of these pits, from which the water escaped through tunnels into the gorge below. The discharge from some of these tunnels is still to be seen at Niagara. Vertical shafts were installed to bring the power to the surface of the ground.

In 1881 the Niagara Falls Hydraulic Power and Manufacturing Company established its first station to supply electricity for commercial purposes. This station was known as Station No. 1, and was located in what was then Quigley's Mill, now the Cliff Paper Company's Mill. In this station there were installed three water wheels under a head of about 75 feet and with a capacity of about 1,500 horse-power. These wheels operated the paper mill, several factories and an arc light machine for street and store service. It was here that the public distribution of electricity in Niagara Falls began.

In 1895 and 1896 methods applied to the development of power had made considerable progress, and about this time the Niagara Falls Hydraulic Power and Manufacturing Company began the erection of Power House No. 2. This power house was erected at the water's edge in the gorge, and was so designed that the water could be used under the full available head of 210 feet. Not only was this made possible, but the company was also able to take advantage of the use of the horizontal shafts for turbines

POWER STATION NO. 2 AND MILLS

INTERIOR POWER STATION NO. 2

and generators, which method practically eliminates all bearing trouble, not a single shut down from any such trouble having been necessary in seven years.

In the first section of this power house there were installed four double discharge turbines built by the James Leffel & Company, of Springfield, Ohio, giving a total capacity of 6,850 horse-power. A steel penstock eight feet in diameter carries the water supply for these wheels from the forebay at the top of the cliff to the power station below.

The first section of the gorge power house having proved such a great success, the company at once added two more sections, making a station 170 feet long by 100 feet wide. The construction is of stone and steel. In this power house there are now in operation 15 turbines, the capacity of fourteen of them ranging from 1,600 to 3,500 horse-power. The combined output capacity is about 34,000 horse-power. The turbines of the two sections last built receive their supply of water through steel penstocks 11 feet in diameter. In respect of their power capacity, these penstocks are the largest in the world.

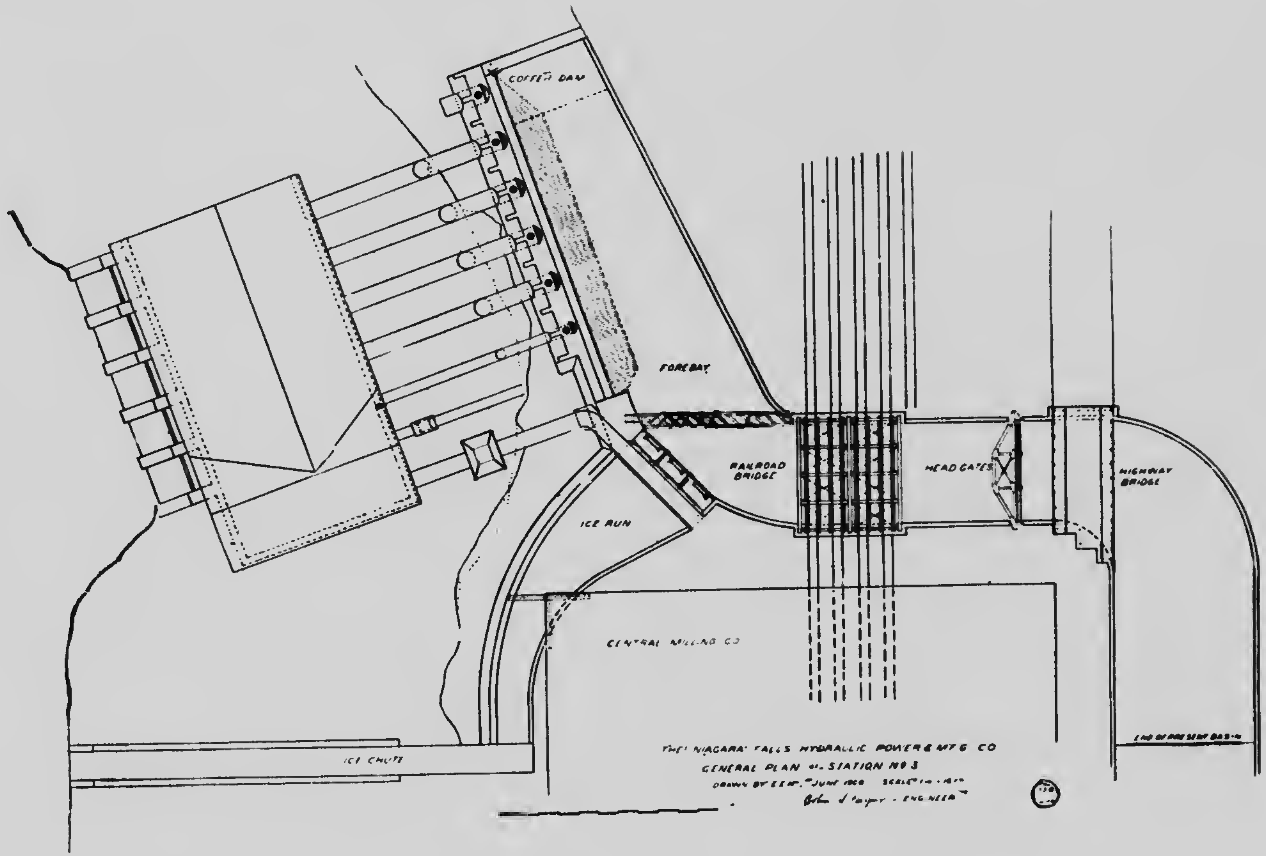
The electrical equipment of Station No. 2 consists of six 560 K.W. 300 volt, D.C. Westinghouse generators giving current to the Pittsburgh Reduction Company; two 560 K.W. 550 volt, D.C. General Electric Company generators, supplying a local commercial circuit, the Niagara Gorge R. R. Co. and the Lewiston & Youngstown R.R. Co.; one 200 K.W. 135 volt, D.C. generator used by the National Electrolytic Company; two 875 K.W. 175 volt, D. C. generators, giving current to the National Electrolytic Company; three 1000 K.W. 325 volt, D.C. General Electric Company generators, supplying current to the Acker Process Company; eight 750 K.W. 300 volt, D.C. Westinghouse generators, supplying current to the Pittsburgh Reduction Company; two 1000 K.W. 11,000 volt, A. C. Bullock Company generators, transmitting power to various concerns at a distance of about two miles from the station; one 700 K.W. 2,200 volt, A. C. Walker Company generator, supplying incandescent light throughout the city; four 1000 K. W. 300 volt, D. C. Westinghouse generators, supplying current to the Pittsburgh Reduction Company. There are also several exciters and small machines.

During the summer of 1903 work was commenced on the excavation for Station No. 3. This station is designed for 14 units of 5,000 K.W. capacity each, making a total development of about 100,000 horse-power. The water will be taken from the canal through an inlet canal to a forebay parallel to and near the edge of the high bank of the river. From this forebay the water is conducted to the wheels through steel penstocks 8 feet 6 inches in diameter. Each of the wheels will be of the horizontal single discharge type, and of a capacity sufficient to drive one of the 5,000 K.W. generators. The wheels will work under the full head of 212 feet. The generators will be 11,000 volt, 25 cycle, 3 phase machines, the rotor being mounted on an horizontal shaft. The water wheels and electric generators will be separated by a solid partition, and the wheel governing and controlling mechanism will be located in the generator room. The power will be transmitted from the station to a transformer building situated at the top of the bank, and from there transmitted as needed. Access will be had to the station by means of a passenger and light freight elevator, and all heavy material will be unloaded from the cars and lowered to the station by a traveling crane with a capacity of 50 tons.

During the seven years that Station No. 2 has been in operation, more or less difficulty has been experienced with ice, and after various experiments, a practical system for disposing of the ice has at last been evolved. Essentially it consists of a series of booms in the upper river nearly parallel to the current. These booms are so designed that the floating ice goes past them and the water in underneath. The ice that gets into the canal underneath the booms, or forms inside the booms, is disposed of by gates placed in the inlets between the canal basin and the forebays. These gates are constructed in two sections, the top section sliding down past the bottom, thus allowing a certain amount of water to flow over the top. This allows the surface water and floating ice to pass over the gates, while the wheels are supplied by the clear water below.

LIST OF OFFICERS

President, George B. Mathews; Vice-President, W. D. Olmsted; Secretary-Treasurer, Arthur Schoellkopf; Engineer, John L. Harper; Assistant Engineer, George R. Shepard; Consulting Engineer, Wallace C. Johnson.


COFFER DAM
FOREBAY
RAILROAD BRIDGE
HEAD GATES
HIGHWAY BRIDGE
ICE RUN
CENTRAL MILLING CO
ICE CHUTE
THE NIAGARA FALLS HYDRAULIC POWER & MFG CO
GENERAL PLAN OF STATION NO 3

The Niagara Falls Power Company

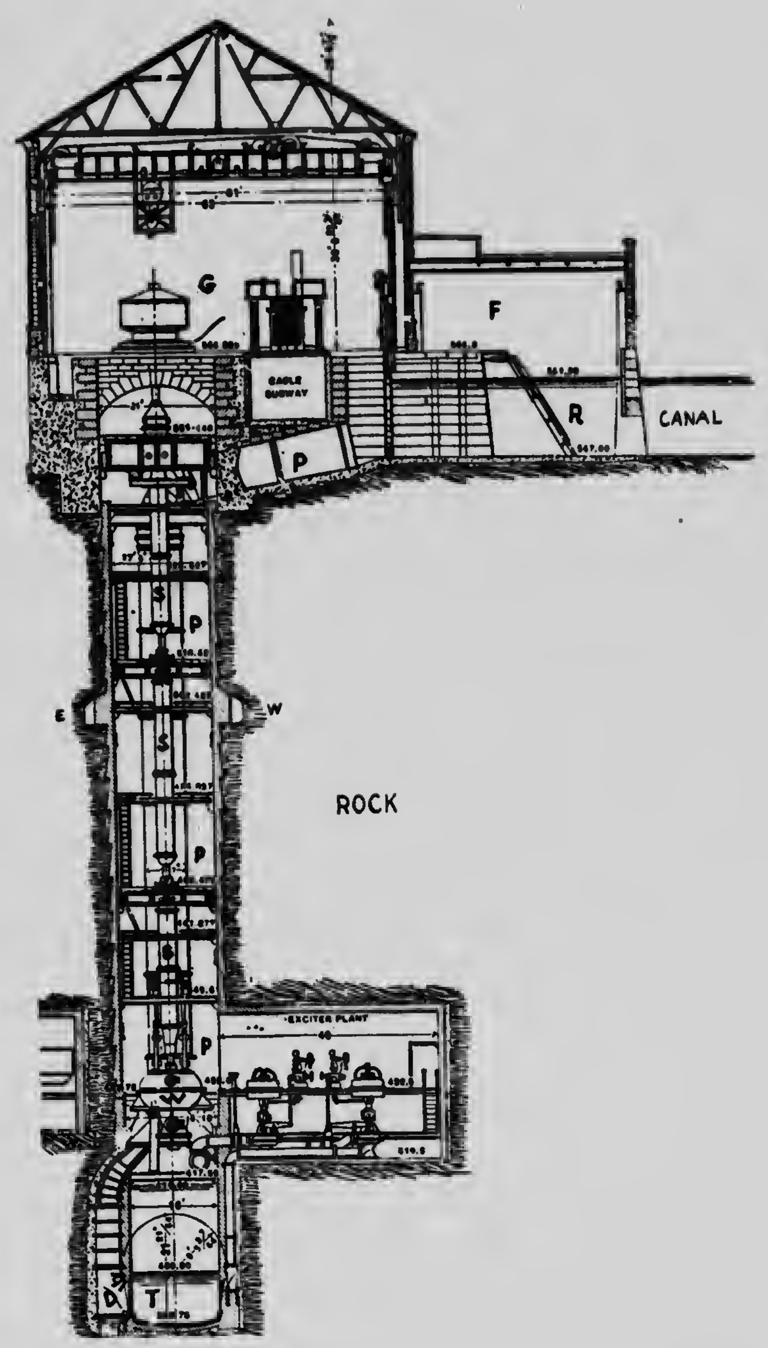
OF the large volume of water forming the Niagara River, but a very small percentage is being used to drive the turbines in two power houses constructed and operated by the Niagara Falls Power Company, upon the American side of the river.

This Company began the actual work of development October 4th, 1890, upon which date ground was broken for the tunnel. The work of construction was continued unremittingly from that date, but it was not until August 26th, 1895, that power was delivered commercially. Upon that date, the Pittsburgh Reduction Co., manufacturers of metallic aluminium, had the honor of first receiving Niagara Power in the form of electrical energy for electro-metallurgical processes. Over one year later or on November 15th, 1896, power was first delivered in the city of Buffalo. It appears therefore that five years was required to complete the initial installation, a long time seemingly, and yet in the light of subsequent events, such period of time compares very favorably with what has been accomplished since. It must be remembered that in 1890 there did not exist a parellel example to the work contemplated, many of the obstacles encountered were unexpected and could not be foreseen. The character of the excavations were, by their very nature, the most difficult to accomplish, while the magnitude of the work only added to the undertaking. Coupled with these features was to be found the special work necessary in the design and construction of equipment used in the development and in the finished apparatus, electrical, mechanical, architectural, hydraulic, etc. How thorough were the technical investigations leading up to the development, or how knowingly the designs were made and the work executed can best be understood by an inspection of the plants. The observer is at once impressed by the fact that the general scheme remains the same throughout and it is only in the details here and there that changes have been made tending to the betterment of the service or the simplification of the equipment, while at the same time from the three original generators and auxiliary apparatus, the number of dynamos has increased until they now total twenty-one.

The Niagara International Commission composed of Lord Kelvin (then Sir Wm. Thomson), Col. Theo. Turrettini, Prof. E. Mascart and Dr. Coleman Sellers with Prof. W. C. Unwin of London as Secretary, were selected for the purpose of outlining the general plan of development by the Company and they arrived at the conclusion that the best method to be applied to the conditions existing at Niagara Falls was to take the water from a short inlet canal tapping the river at a point above the upper rapids, excavate a wheelpit, place the turbines in the bottom thereof, carry the water thereto in individual penstocks and discharge the same into the river below the falls through a subterranean tail race. At the same time it was decided to place the generators on the surface and drive them by means of vertical shafts which were to be virtually a continuation of the turbine shafts. These shafts are hollow between bearings, being built up of sheet steel. The capacity of each dynamo was elected to be 5,000 horse-power at its terminals, its general features that of the external revolving field type, the armature stationary and the support of the field such as to give the finished machine the name of "umbrella type." Detail designs were left to the builders of the machinery and resident engineers of the company.

Following these outlines, an intake canal was excavated from the Niagara River eastward, making an angle of something less than 90 degrees with the up stream side. This canal is about 1,250 feet long, varying in width from 100 to 250 feet and giving an average depth of water of 16 teet. Its bed is the natural limestone of the region, the stratifications of which are practically horizontal. The sides and end of this canal are walled with heavy dressed limestone.

The discharge tunnel to carry off the water from the turbines and the waste is 6,806 feet long from the wheelpit of Power House No. 1 to the lower river. It has an extension of 675 feet to pit No. 2. The tunnel has a horse shoe shaped section 21 feet in height with a maximum width of 18 feet 10 inches. Its average



SECTION THROUGH POWER HOUSE NO. 2 AND WHEELPIT

depth below the surface is 200 feet. It is lined throughout its entire length with several layers of vitrified brick laid in cement. A recent inspection of the tunnel lining shows no erosive action whatsoever. On the contrary, the substances carried by the water in suspension have coated the lining with a sort of slime which precludes the possibility of any erosive action in the future.

Power House No. 1 has been erected upon the north side of the inlet canal. It stands over a wheelpit 424.7 feet in length, 18 feet in width and having an average depth of 178.5 feet below the Power House floor. The pit connects with the discharge tunnel making an obtuse angle with the down stream side thereof. The turbines are mounted in the pit, thirty-seven feet from the bottom, The complement of wheels consists of ten Fourneyron inverted twin turbines, the water entering between the pair and discharging at the periphery. The outside diameter of the wheels is 6 feet 3 in. operating under a head of 136 feet, without draft tubes. The wheels were designed by Messrs. Faesch & Piccard of Geneva, Switzerland, and built after their designs by the I. P. Morris Co., Philadelphia. The design of these turbines is such that through the medium of a projecting flange upon the shaft within the turbine case, the upward hydrostatic pressure of the water is just sufficient to take the weight of the moving parts from the bearings. This weight approximates 150,000 pounds per unit.

Each turbine unit is controlled in speed by automatic governors, the first three purely mechanical and the remaining seven electro-mechanical in their operation. They are very sensitive and positive in their action, maintaining a uniform speed of 250 r. p. m. under any condition of service. In this Power House two main switch-boards are installed, each board controlling five generators. The main generator and feeder panels are pneumatically operated.

There are eleven 5,000 horse-power units in Power House No. 2 as against ten in No. 1. Therefore the wheelpit situated on the south side of the inlet canal is somewhat longer, being 466 feet in length, 17.5 feet in width and having an average depth of 177.43 feet beolw the Power House floor line. Eleven Francis single turbines, each of 5,500 horse-power located 133.83 feet below the Power House floor are in service. Their outside diameter measures 5.33 feet, the average effective head 141 feet, acquired by draft tubes. This set of wheels were designed by Escher, Wyss & Co. of Zurich, Switzerland, and built by the I. P. Morris Co., of Philadelphia. The hydraulic governors of this equipment are by the same designers, but built by the Falkenau, Sinclair Machine Co., of Philadelphia. The turbine gates attached to these governors are operated through the medium of oil under high pressure. The mechanism is consequently much simpler.

Six of the eleven generators have external revolving fields, and five have internal revolving fields, the methods of support and driving similar to those used in No. 1. The entire output of this Power House is controlled by one main switch-board placed in the centre of the room. No high tension current is carried to this board, the oil break generator and feeder switches being controlled eloctro-magnetically with currents of low voltage.

The electrical energy delivered by the generators is in the form of 2,200 volt 2 phase 25 cycle alternating current. The characteristics of this current remain unchanged for delivery to some users on the lands of the Niagara Falls Power Co. For the so-called long distance load or where the amount of energy to be delivered is large the voltage is increased—stepped-up. For this purpose a Transformer House has been constructed. Herein are installed a number of banks of transformers which receive the current at 2,200 volts 2 phase and step-up to 11,000 or 22,000 volts, at the same time changing the phase relation from 2 phase to 3 phase. The transmission to Lockport, the Tonawandas and Buffalo is effected at a pressure of 22,000 volts 3 phase. Two pole lines have been erected from the Falls to Buffalo with a branch from Towawanda to Lockport. Pole line No. 1 carries two circuits of copper each wire stranded of 350,000 c.m. section, or about 7/10 inch in diameter. Pole line No. 2 carries one circuit of aluminium each wire stranded of 500,000 c.m. section or approximately 8/10 of an inch in diameter. The length of the line from the Niagara Falls Transformer House to the Buffalo terminal station is about 22.5 miles.

At this writing the maximum output of the two power houses is about 75,000 electrical horse-power delivered on the lines, 30,000 of whch is marketed in the Tonawandas, Lockport and Buffalo

INTERIOR POWER HOUSE NO. 2

and 45,000 utilized at Niagara Falls by industries located on the lands of the Niagara Falls Power Company. In the year 1903 the output of the stations aggregated a total of 348,372,512 K.W. hours or approximately 10 per cent. of the output of all the central electric light and power stations in the United States.

The lands of the Power Company comprise about 1,100 acres, adaptable to all kinds of manufacturing, favored with two miles of river frontage and trunk line transportation facilities through the medium of the Niagara Junction Railway.

The uses of the power cover almost the entire industrial field. The advent of electric power transmission and the development of electrical energy upon a large scale have been the means of bringing into existence large and important electro-chemical processes. Niagara Falls has already become the center of electro-chemical manufacture in the United States.

President, D. O. Mills; 1st Vice-President; Edward A. Wickes; Second Vice-President and Treasurer, William B. Rankine; Third Vice-President, Geo. W. Davenport; Secretary, F. L. Lovelace; Assistant Secretary and Assistant Treasurer; W. Paxton Little; Resident Engineer, A. H. Van Cleve; Electrical Engineer, H. W. Buck; Superintendent, P. P. Barton; Assistant Engineer, W. D. Robbins.

GENERAL VIEW POWER HOUSES AND TRANSFORMER STATION

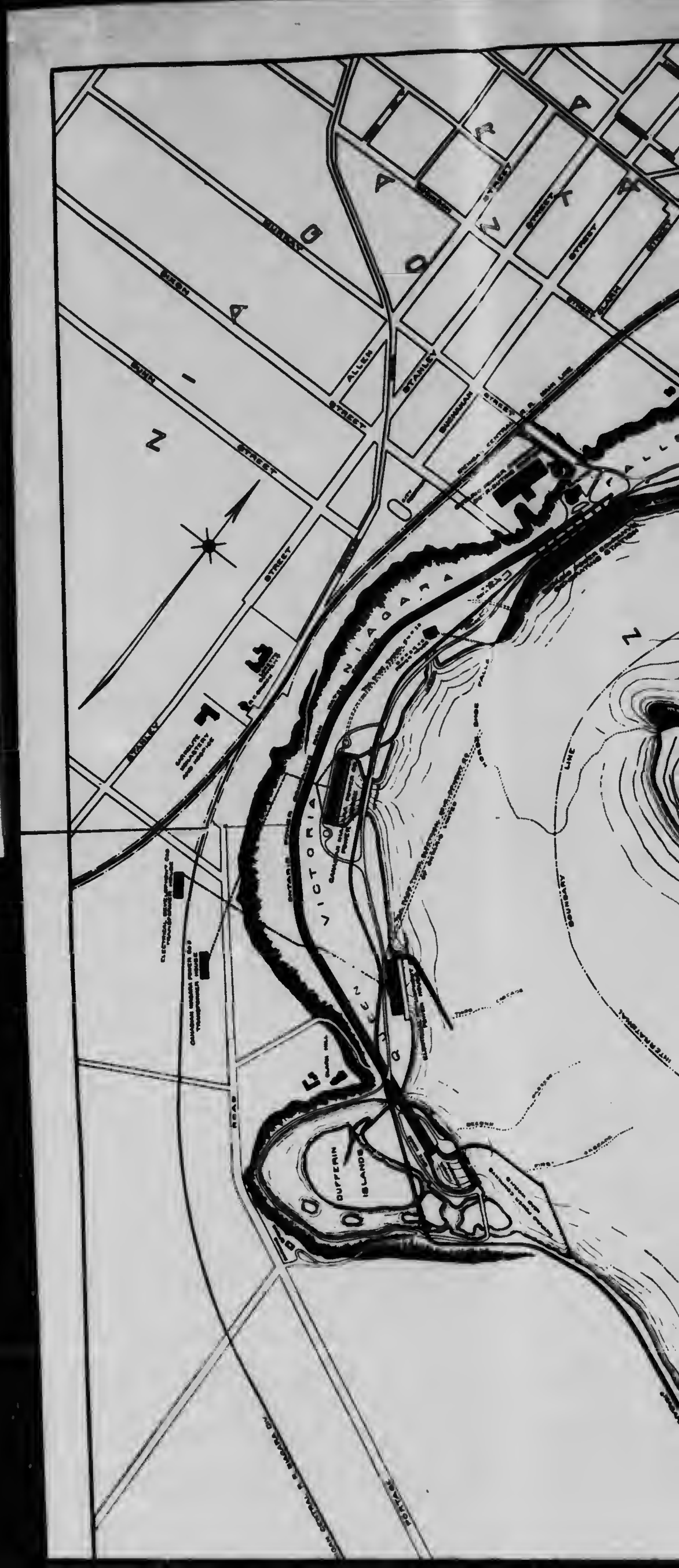
The City of Niagara Falls Canada

THE City of Niagara Falls, Canada, extends from the Whirlpool Rapids to the Horseshoe Falls and is located about seven miles from the Village of Queenston, where navigation on the lower Niagara River terminates by reason of rapids, and five miles from the Village of Chippawa where the upper river becomes unsafe for vessels.

The city owes its peculiar railway advantages to the narrow gorge of the river, it being possible to construct bridges here at less cost than at other points. The Grand Trunk and Michigan Central Railroads each have fine bridges, the former being a steel arch and the latter the cantilever construction. Nearly all the leading railways have running arrangements across these. The Wabash, Erie, New York Central, Lehigh Valley, Delaware, Lackawana & Western, West Shore, and Rome, Watertown & Ogdensburg use the arch bridge, while the Canadian Pacific, Pere Marquette, Toronto, Hamilton & Buffalo, and Buffalo & New York Central use the cantilever, thus giving railway facilities not excelled by any city in Canada. The city is further connected by trolley line with St. Catharines and the adjoining country on the Canadian side and by the upper steel arch bridge in view of the American and Horseshoe Falls, which gives access to Niagara Falls, New York, Buffalo, and the American border towns. The city is one of the chief ports of entry from United States and also does a large export business both to that and other countries. It has taken great strides toward becoming a manufacturing centre and like its sister city of the same name on the New York side of the river is destined soon to be a large and flourishing industrial city.

The municipality has a very complete system of sewerage and has expended large sums of money in perfecting its roadways and concrete walks. It owns its electric lighting and waterworks plants and has unlimited supplies of natural gas for heating and lighting. Liberal advantages are given manufacturers in the supply of power at low rates, and a number are already looking to locate here as soon as the electric power developments are completed.

George Hanan, Mayor; John H. Jackson, City Engineer.



NIAGARA
VICTORIA
DUFFERIN
ISLANDS
STANLEY
ALLEN
STREET
BOUNDARY
LINE

NIAGARA FALLS
SHOWING
ELECTRIC POWER DEVELOPMENTS
SCALE OF FEET
SEPTEMBER
NIAGARA RIVER
GOAT ISLAND
AMERICAN FALLS
NIAGARA FALLS PARK
VICTORIA PARK
CANAL
POWER HOUSE No 2
NIAGARA FALLS POWER CO
NIAGARA NEW YORK
WHIRLPOOL
CHILTON
ASHLAND
ELMWOOD
SPRUCE
CEDAR
WALNUT STREET
PINE
MAIN
NIAGARA STREET
FALLS STREET
FERRY
FOURTH
FIFTH
SIXTH
SEVENTH
EIGHTH
NINTH
TENTH
ELEVENTH
BUFFALO
FIRST
SECOND
THIRD
AVENUE
PORTAGE
ROAD
N.Y.C. & H.R.R.R. YARDS
ERIE & WABASH R.R.
INTERNATIONAL

VICTORIA
DUFFERIN
ISLANDS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NIAGARA FALLS POWER CO

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