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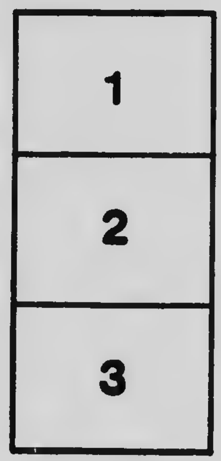
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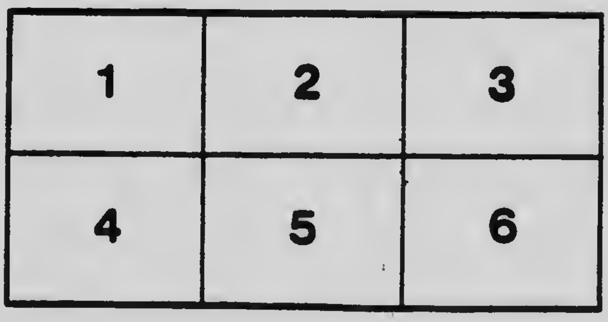
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Chippawa-Queenston Power Development

Reprint of article published in the June 20th, 1918, issue of *The Canadian Engineer*, Toronto, Ont.

Reprinted from the June 20th, 1918, issue of "The Canadian Engineer"

Chippawa-Queenston Power Development

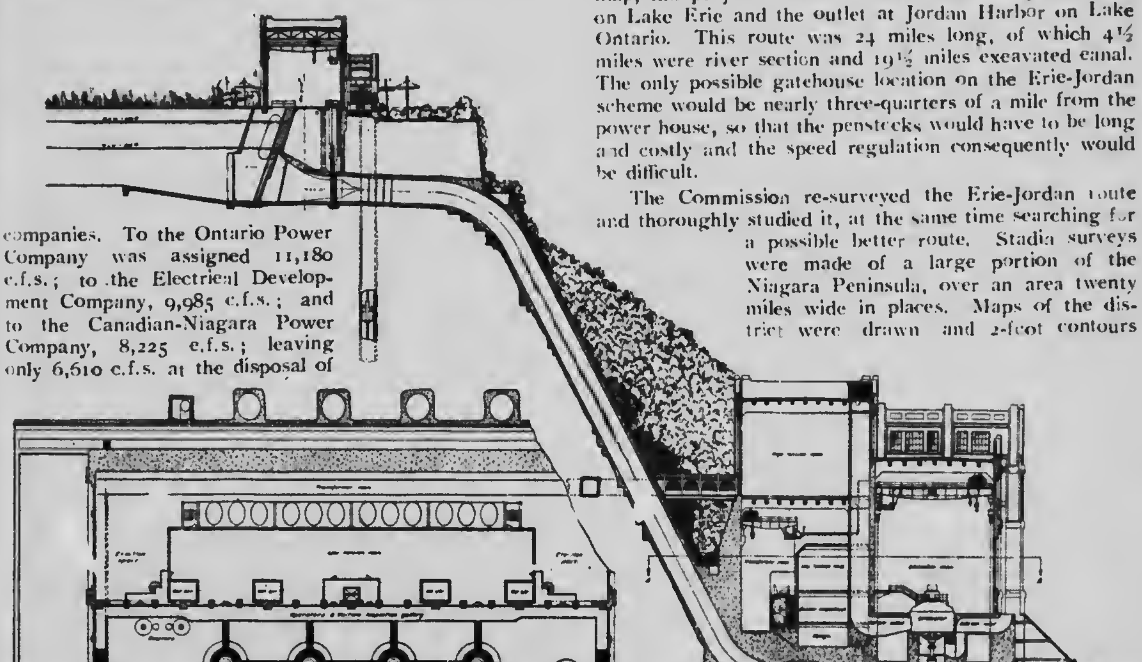
Hydro-Electric Power Commission of Ontario Will Develop 300,000 H.P. Under 305 Ft. Net Head, Using 10,000 C.F.S. from the Niagara River—Largest Hydro-Electric Power Scheme Ever Undertaken—Units Will Be of 50,000 H.P. Capacity—13,000,000 Cu. Yards of Excavation—Plant Could Be Extended to Million Horsepower

BETWEEN Lake Erie and Lake Ontario, the difference in level is 330 feet; but to date the maximum net head utilized by any Canadian hydro-electric power development on the waterway joining those lakes, is about 160 feet. On account of the shortage of h lrc· electric power in Ontario, and because of the co… inaccessibility to manufacturing centres of the · developed water powers, the Hydro-Electric P… mission of Ontario realized many years ago economic development of Niagara would be …

The treaty which was enacted by Great Britain and the United States in 1910, limits to 56,000 c.f.s. the amount of water which can be diverted for power purposes from Niagara's 220,000 c.f.s. mean flow. Of this amount, Canada is entitled to 36,000 c.f.s. By an Ontario order-in-council passed in 1915, a limit was placed on the amount of water to be used by the private companies. To the Ontario Power Company was assigned 11,180 c.f.s.; to the Electrical Development Company, 9,985 c.f.s.; and to the Canadian-Niagara Power Company, 8,225 c.f.s.; leaving only 6,610 c.f.s. at the disposal of the Commission. The Ontario Power Company has since been purchased by the Commission, however, so that the Commission now has within its control a total of 17,790 c.f.s.; and, of course, alterations in the treaty may possibly be made from time to time to meet new conditions, or the Commission may purchase one or both of the remaining two private concerns.

Two of the existing Canadian plants are said to be working under net effective heads of less than 135 feet. The Commission determined to use more of the 330-foot head between the two lakes. For the past twenty years various schemes, more or less practical, had been suggested. One of the best of these was a route that had been surveyed many years previously by the consulting engineering firm of Smith, Kerry & Chace, of Toronto. This route, called the Erie-Jordan Canal, cut across the Niagara peninsula. As shown by the accompanying map, this project located the intake near Morgan's Point on Lake Erie and the outlet at Jordan Harbor on Lake Ontario. This route was 24 miles long, of which 4½ miles were river section and 19½ miles excavated canal. The only possible gatehouse location on the Erie-Jordan scheme would be nearly three-quarters of a mile from the power house, so that the penstocks would have to be long and costly and the speed regulation consequently would be difficult.

The Commission re-surveyed the Erie-Jordan route and thoroughly studied it, at the same time searching for a possible better route. Stadia surveys were made of a large portion of the Niagara Peninsula, over an area twenty miles wide in places. Maps of the district were drawn and 2-foot contours



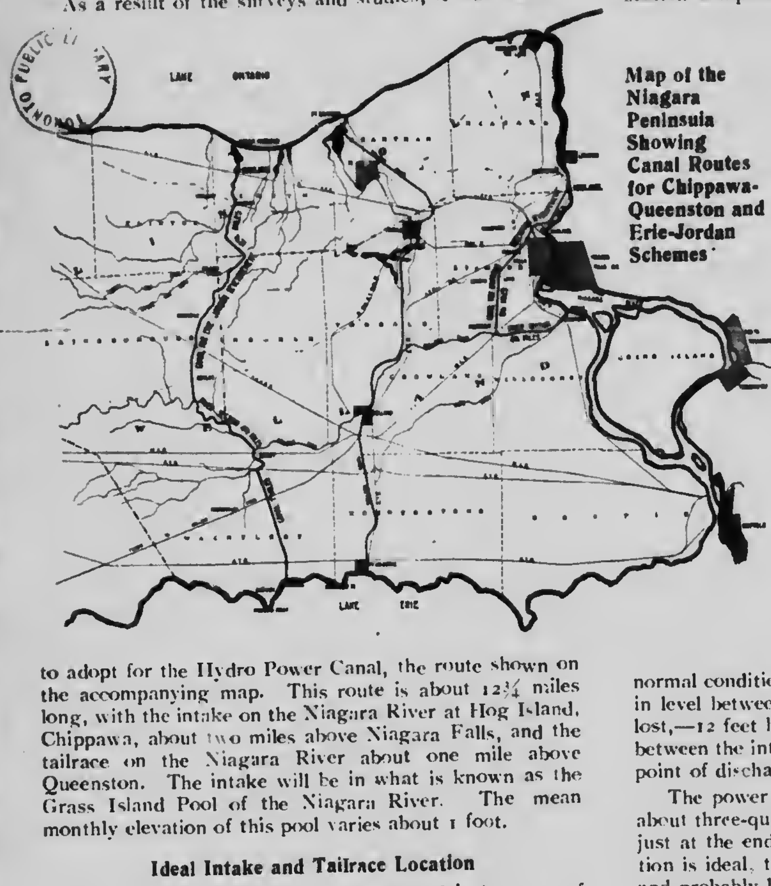
Sections Through Gate and Power Houses

plotted. Test borings were taken every 500 feet with an Ingersoll-Rand Calyx core drill, the cores still being stored for reference.

New Route Located

When the route was discovered which was tentatively decided upon, wash borings, or well-drilled borings, were made every 500 feet on the centre line of the proposed canal, to provide an accurate sub-surface profile. A large number of photographs of the district were taken, and also photographs of ice conditions at the proposed intake. The Welland River was sounded, stream measurements were made on the Welland and Niagara Rivers, and the history of the levels of the Niagara River and Lake Erie for the past sixty years was closely studied. The directions of the lines of flow at the proposed intake were noted, and there were obtained all the data necessary for the construction of hydraulic similarity models.

As a result of the surveys and studies, it was decided



Map of the Niagara Peninsula Showing Canal Routes for Chippawa-Queenston and Erie-Jordan Schemes

to adopt for the Hydro Power Canal, the route shown on the accompanying map. This route is about 12¾ miles long, with the intake on the Niagara River at Hog Island, Chippawa, about two miles above Niagara Falls, and the tailrace on the Niagara River about one mile above Queenston. The intake will be in what is known as the Grass Island Pool of the Niagara River. The mean monthly elevation of this pool varies about 1 foot.

Ideal Intake and Tailrace Location

The normal mean elevation of Lake Erie is 573; of Grass Island Pool, 561; of the Niagara River at the power house site, 245; and of Lake Ontario, 243. Probably no other river has more uniform regulation than the Niagara. The minimum flow is half the maximum, and the section is so large that over a period of fifty years the maximum difference in mean monthly levels under normal conditions, either at Chippawa or Queenston, amounts only to about 6 feet.

The ideal intake and the ideal power house location were first determined with a view to the maximum utilization of the available head, and contours and borings were then studied to decide by what route a canal could connect those two points to the best hydraulic and economic advantage. The intake was located at Hog Island partly on account of that point being just above the critical section at which the water begins to speed up for its passage over the falls. Location further up the river would have meant a larger canal; further downstream, a loss in head. Another reason quite equally important for locating the intake at Chippawa was the use which could be made of the natural channel of the Welland River—often called Chippawa Creek—which provides about 4¼ miles of the Hydro Power Canal, leaving only about 8½ miles to be excavated, although the Welland River will have to be somewhat deepened and widened. The flow of the Welland River, which is a sluggish stream with a very flat bed, will be reversed.

The Hydro Power Canal's 8½ miles of excavated section compares with 19½ miles for the Erie-Jordan scheme, and the net head is 305 feet compared with 299 feet for the Erie-Jordan.

The ice troubles that would be experienced in the Erie-Jordan scheme will also be more readily obviated. Ice would have caused immense expense in the Erie-Jordan intake, particularly during east gales, but no such trouble is anticipated at Hog Island. There will be elaborate methods of ice protection at the intake and also at the forebay, to eliminate the troubles experienced at the existing plants.

Only 11 Feet Loss of Head

The gradients adopted for the Hydro Power Canal average about 1 foot per mile, or a total of about 8 feet in the 8½ miles of excavated canal. The loss of head in the penstocks, due to friction, may amount to upwards of 2½ feet, and the loss in the Welland River from Hog Island to Montrose, where the excavated canal begins, will be about 6 inches under maximum load, so that the total loss of head will be only 11 feet, making the net effective head about 305 feet under average normal conditions. Thus, of the 330 feet normal difference in level between the two lakes, only 25 feet head will be lost,—12 feet between Lake Erie and Hog Island, 11 feet between the intake and the tailrace, and 2 feet between the point of discharge of the tail water and Lake Ontario.

The power house will be located down in the gorge, about three-quarters of a mile above the Lewiston Bridge, just at the end of the last rapids in the river. The location is ideal, the best on the Canadian side of the river and probably better than any on the American side, as it affords facilities for the extension of the power house to any degree desired, even to use the whole 40,000 c.f.s., which the U.S. War Department says is the maximum that should be diverted from the Niagara Rapids. The cliffs are nearly vertical at the power house site, which gives the ideal condition, as the gatehouse will be on the cliff just a couple of hundred feet back of the power house, with the results that the penstocks will be nearly vertical and only about 450 feet long, so that their cost is reduced to the minimum, the loss of head in the penstocks is reduced to the minimum, and the use of surge tanks is avoided. The penstocks are so short that they can be designed to withstand the stresses due to pressure surge. Valves may not be required on the penstocks; regulation will be effected by the gates at the gatehouse and by the wicket gates on the turbines.

About 30 h.p. will be obtained from each second-foot of water, compared with about 14 h.p. obtained by the existing plants. With 36,000 c.f.s., over 1,000,000 h.p. could be developed at this plant, compared with less than half that amount at the heads under which the present plants are operating.

Most of the excavated section of the canal will be in rock, but at the Whirlpool there is a stretch which is in earth; and the initial portion of the excavated section, adjacent to the Welland River, will also be in earth.

Canal Mostly in Rock

Starting at the point of diversion from the Welland River, near Montrose, as station 0, the earth section extends to station 80, a distance of 8,000 feet. Then the canal is in rock all the way to the gatehouse excepting at the Whirlpool, where it is earth from station 332 to station 351. At station 351 it is in the full rock section again, but the sub-base of rock crops up gradually far ahead of station 351, with the result that only about 1,000 feet, or from station 332 to about station 342, is entirely in earth at this part of the canal. The station at the gatehouse site is 462, a distance of 46,200 feet from the diversion at Montrose.

The stations on the Welland River section are separately numbered, beginning at Hog Island as station 36, allowing 3,600 feet for future allotment to plans for the intake works that will be constructed in the Niagara River. The diversion at Montrose is at station 222 + 40, a distance of 18,640 feet from Hog Island. The total length of the Hydro Power Canal from Hog Island to the gatehouse location is 64,840 feet, or 12.28 miles.

The gradient and the section adopted for the canal are the most economical for the amount of water which it is desired to pass through the canal. The canal is nominally designed for 10,000 c.f.s., at minimum low water. The rock is mostly very good limestone, and as all rock will be channelled, and may be lined with concrete where it is too poor to channel smoothly, the friction will not be great. Ten Sullivan channellers, each making a 20-foot cut, will be used on each side of the canal.

Earth Sections Will Be Lined

The earth sections will be lined in some manner not yet finally decided. The sides of the wetted section will be sloped 1½ to 1 and they will be "gunited" over light reinforcing, by the Cement-Gun method, or else a heavier reinforcing will be used and the walls will be poured. This detail of design and many other details of the scheme are in a state of flux and will be decided only from time to time as the work progresses. As the Commission is both the buyer and the contractor, there is no necessity for rigid decision in advance in regard to details of this sort, the Commission being able to leave them for disposal as circumstances may dictate. The entire construction programme is liable to change in any detail at any time should conditions, as the work progresses, suggest changes.

The rock section is 48 feet wide at the bottom, with perpendicular sides, the average wetted section being 35 feet deep. The velocity in the rock section will be about 6 feet per second when the plant is under maximum load. The banks of the overburden will be sloped 1½ to 1 unless local conditions in certain places require a flatter slope or other treatment.

The earth section will be 34.6 feet wide at the bottom and 162 feet at the top, the sides having a 1½ to 1 slope, the average wetted section being about 26 feet deep. The width at the mean water line will be about 84 feet.

The Commission has purchased a wide tract of land as a right-of-way, and has enough acreage to be able to build two more canals should they be required in the future. These canals would be located a few hundred feet to the west of the first canal and would be almost parallel to it. They would draw water from the Welland River just as the first canal will do. The capacity of these additional canals would, of course, depend upon the section and the gradient assumed, but could be built readily and economically to handle all of the water which both Canada and the United States are now diverting from Niagara Falls, should the people of the United States ever desire to merge their water allotment with Canada's in one big plant, for the sake of higher efficiency. The cost of all this property is being charged against the present scheme. About $1,000,000 worth of land will have been acquired when the expropriations are complete. This includes the vast disposal area at St. David's, which can accommodate about 20,000,000 cubic yards of dumped material.

The canal's designed capacity of 10,000 c.f.s. at minimum low water refers to the absolute minimum during a period of about sixty years. The records for the Niagara River had been kept for fourteen years, and the records for Lake Erie had been kept for about sixty years, and from the Lake Erie levels the Niagara River levels were estimated for the period prior to the fourteen years for which direct records were kept for the Niagara River. This minimum low water has occurred only about once in fourteen years; the average monthly minimum is much higher; so, in assuming the absolute minimum, the

CHIPPAWA-QUEENSTON SCHEME IN TABLOID

Horse-Power Developed	**300,000**
Capacity of Units	**50,000 H.P.**
Number of Units	**6**
Diameter of Main Penstocks	**13 ft. 6 ins.**
Gross Head	**316 ft.**
Net Effective Head	**305 ft.**
Water Required	**10,000 c.f.s.**
Length of Canal	**12¾ Miles**
River Section	**4¼ Miles**
Excavated Canal	**8½ Miles**
Gradient in [illegible] Canal, per mile	**1 ft.**
Width of Rock Section	**48 ft.**
Width of Earth Section	**162 ft.**
Earth Excavation	**11,000,000 Cu. Yds.**
Rock Excavation	**4,000,000 Cu. Yds.**
Deepest Cut	**145 ft.**
Surveys Started	**1914**
Construction Commenced	**1917**
Completion of Work	**1921**
Estimated Cost, about	**$25,000,000**

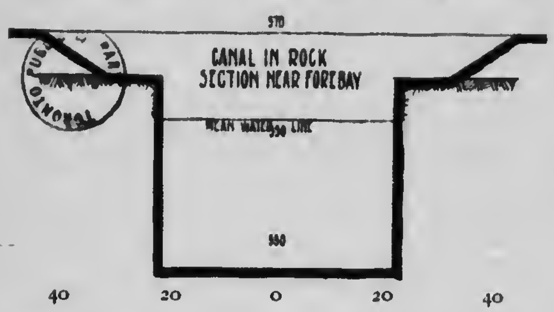
Commission allowed a factor of safety which will pr vide against possible future contingencies.

The scheme as now laid out, using 10,000 c.f.s., will have a capacity of 300,000 h.p., and the canal, forebay, gatehouse substructure and power house substructure are designed for that capacity. The power house and gatehouse superstructures will be designed initially for 200,000 horse-power.

50,000 E.H.P. Units

There will be control works at the head of the excavated canal near Montrose, but from there the canal will be unobstructed until the forebay location is reached, which is at Smeaton's Ravine. At station 438 + 33, 2,367 feet from the gatehouse, the canal widens into the forebay, the forebay gradually increasing in width to 300 feet, which will be the approximate overall dimensions of the gatehouse. The last 1,000 feet of the fo. ebay will be 300 feet wid. The initial development contemplates four steel penstocks each about 13 feet 6 inches diameter, 450 feet long, and one exciter penstock, about 5 feet diameter.

There will be four units, each 50,000 h.p. capacity. Two more penstocks will be installed when it is desired to



bring the capacity of the plant up to 300,000 h.p. Both the gatehouse and the power house are designed so that they may be extended whenever conditions warrant and practically to any extent desired.

Single Runner Turbines, 187½ R.P.M.

The turbines will be of the single runner type, probably with cast steel scroll cases. The specifications call for 187½ r.p.m., which is the maximum safe speed giving satisfactory hydraulic characteristics. The specifications for the turbines have been prepared by the Commission and prices will be secured in the near future. Although these turbines will have the greatest capacity of any water turbines yet designed, they will not be so large in overall dimensions as some others that have been built which operate at lower heads. The Keokuk and the Cedars Rapids turbines, for instance, are bigger than the Commission's turbines will be, but the latter will be more powerful on account of the higher head. Steam turbines have been built of equally large capacity; in fact, the Westinghouse Company is now said to be constructing for the Chicago Edison Company a 75,000-h.p. steam turbine, with generator direct connected; but the units at the Commission's power plant will be the biggest capacity hydro-electric units ever installed.

The Commission has desig for a 100,000-h.p. turbine installation and when th is increased from 200,000 to 300,000 h.p. it m done by installing just one 100,000-h.p. unit instea two 50,000-h.p. units. It was decided to install the aller units for the initial development on account of the proportion of the plant which would be tied up should one of only two b g un have to be shut down for any reason.

The power will be taken off the generators at 12,0 volts and will be stepped up, probably to 100,000 vol for long-distance transmission. Elaborate arrangemen will be made not only for leading cool air to t generato but, what is more unusual, for taking t heated ai of the power house. Large ducts will le cold air to below the rotors, and after the air has go through the generators, it will be carried away in du There is also a scheme for removing the runners from t turbines without dismantling the turbines and generato which will weigh about 1,000 tons, the moving p weighing about 500 tons. Each draft tube will b arranged that the runner can be dropped into the dr tube, loaded onto a car, pulled through a tunnel and l f through a shaft by a crane, so that repairs can be effec without dismantling the unit.

The power house will be served by two 300-ton elect cranes. Over the power house will be a large suit executive offices.

Maximum Cut at Lundy's Lane

Chief Engineer Gaby says that the plant will be tu ing over in the spring of 1921. Meanwhile temporary tensions are being made at the Ontario Power Compan plant to provide needed power. A large amount of struction plant is necessary in order to complete the mendous amount of excavation within the time requir While the wetted section of the canal is mostly in ro there is a considerable amount of overburden to stripped. The maximum cut is at Lund''s Lane, wh the ground elevation is 664 and " vation o bottom of the canal is 519, ma'.ing a .ut of 145 feet, which about 70 feet is overburden. The average cut o the four miles of the canal adjacent to the Welland Ri is about 80 feet, of which about half is overburden, w the average cut of the four miles adjacent to the fore is abou 50 feet, mostly rock.

In the concrete-lined sections the soil is a sandy and very firm, but some of the overburden is quicksa The excavation will preceed from the forebay toward Welland River, so that the quicksand will be given ev opportunity to drain through the canal itself. It is pected that pumping will have to be resorted to at tin and occasional slides may be expected, but no undue d culty is anticipated.

The borings show a considerable number of pock of water in the sub-base. As all of these are un pressure, it is thought that a number of springs will f into the canal and that these will slightly augment flow of water in the canal. During excavation th springs will be allowed to drain down the centre line the canal, the excavation proceeding upgrade.

Two Huge Bucyrus Shovels

The surveys for the work were begun in 1914 and tinued for nearly two years. During the year 1917 construction plant brought onto the job and sembled, and durin first part of this year the ca were nearly comp...ed. At the present time the rock that is being taken out is at the f repay and the earth that is being moved on the excavated section i the Whirlpool, but a start will be made soon on exca tion at other points. Eight hundred men are now work.

The main equipment for the earth and rock exca tion consists of two very large electrically driven, rev ing, Bucyrus shovels, fitted with an 8-cubic-yard buc for excavation in dirt, and of capacity to handle a 5-cubic-yard bucket in rock. The boom on No. 1 shovel is 90 feet long, and the dipper stick 58 feet. The boom on No. 2 shovel is 80 feet long and the dipper stick 54 feet. Either shovel can load dump-cars which stand on a track the level of which is 62 feet above the level of the tracks on which the shovel stands. The shovel rests on two tracks (four rails) and is mounted on 16 wheels. The tracks are 30 feet centre to centre. The nominal horse-power of each of the two shovels is [illegible]15 h.p. upon a half-hour intermittent rating. Each shovel weighs over 400 tons, contains 75 tons of ballast, and has a capacity of 3,000 cubic yards a day when handling earth. At the present time No. 1 shovel is working at the Whirlpool against a face 100 feet high. It is said to be the largest electrically driven shovel in the world, working against the highest face excavated on work of this character.

There are also five other electrically driven shovels at work, having dipper capacities ranging from 4½ to 7⅛ cubic yards.

Power Construction Equipment

At the Welland River section of the canal, a Lidgerwood cable excavator is at work, fitted with a 3-cubic-yard Andreson-Evans clam. The cableway has an 80-foot head tower and a 60-foot tail tower, and has a span of 800 feet. The excavated material is being disposed of along the north bank of the river. The width of the Welland River at the water line averages about 300 feet.

The Commission has purchased one hundred and fifty 20-yard Western air dump cars, each of 80,000 pounds capacity, six 40-ton steam locomotives and twelve 50-ton electric locomotives. The steam locomotives are switchers purchased from the Pennsylvania Railroad. The electric locomotives were built by the National Steel Car Company, Limited, of Hamilton, Ont., six of them being constructed with General Electric equipment and six with Westinghouse equipment. Two pile-drivers are at work on the river section. There are three 40-ton and two 15-ton Bay City locomotive cranes for general utility work. Drag-line excavators may be purchased at a later date to clean the sloped banks of the overburden which cannot be reached or smoothed down so advantageously by the shovels, or the locomotive cranes may be rigged up for the purpose.

It is estimated in round figures that 9,000,000 cubic yards of earth and 4,000,000 cubic yards of rock must be removed from the excavated section; and from the river section, 2,000,000 cubic yards of material, mostly earth.

Disposal Area at St. David's

At the present time the material which is being excavated from the Whirlpool section is being used to fill the old Whirlpool gulley, but the main dump will be at St. David's. A double track railway line has been built for the full length of the canal from Montrose to the forebay, and a branch extends to the St. David's dump, two miles away.

There will be various other branches of the railroad constructed from time to time as needed. A railway will probably be built from the power house to connect with the Michigan Central at Queenston to bring in the machinery and to take out the material excavated from the power house substructure.

The dump cars drop the material alongside the track and two Jordan spreaders are used to shove it back over the embankment.

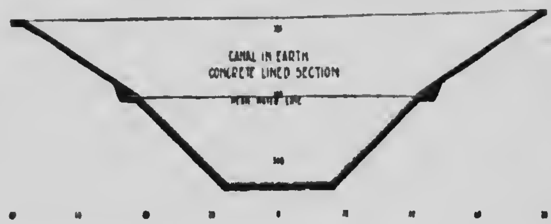
The railroad lines are all electrified, the trolley wires being offset on one side of the track, and carried in clamps devised by the Commission's line construction department. These clamps and the hangers which suspend them from the poles, are all made up of standard material, and are so arranged that the temporary use of the material does not injure it. A number of timber trestles are set alongside the temporary tracks and carry the trolley wire for those tracks. These trestles are mounted on four wheels and can be [illegible] right on to the track and pulled away readily by a steam locomotive when the track is to be moved.

The Commission has its own telephone, water and electric light systems, and has private, direct telephone communication from the Whirlpool to the head office on University Avenue, Toronto.

Splendidly Equipped Sub-Station

No. 1 sub-station is located at the Whirlpool. The power comes into the station from the Ontario Power Company's plant at 12,000 volts and is stepped down to 4,000 volts by three Canadian General Electric Transformers, each of 1,500 k.v.a. capacity. The power is distributed up and down the canal at 4,000 volts. Westinghouse and Maloney transformers step some of the power down from 4,000 to 440 volts for use by the shovels. Three rotary converters, each of 500 kw. capacity, convert some of the power to 600 volts d.c. The station is equipped with most modern conveniences in the way of switches and other apparatus, the [illegible] equipment costing about $110,000.

At this sub-station there are [illegible] erected, ready for operation, four Sullivan belt-driven air compressors, each



of [illegible],000 cubic feet per minute capacity against [illegible]5 pounds pressure. They are belt-driven from Canadian General Electric 550-volt motors, 180 amperes, 750 r.p.m. As the work progress[illegible] [illegible]ght or ten more compressors will be installed at t[illegible] [illegible]ation. All the rock drills, channellers and forge[illegible], a[illegible] much of the other equipment, will be driven by compressed air. The air is piped up and down the canal for three miles in each direction, the mains leading from the sub-station being 10 inches in diameter, reducing to 8 inches and 6 inches. Another sub-station will be built near Montrose and more compressors will likely be installed there.

In the Whirlpool yards is located a large repair shop containing drills, shapers, planers, lathes, forges, trip-hammers and wood-working machines. The Commission has built about eighty buildings, including bunk-houses, freight-house, offices, machine shop, store-houses, sub-station, etc., also a number of buildings are used which were on various parcels of purchased property.

Buildings are Being Gunited

Most of the buildings are of frame construction, but are being gunited on the outside over tar paper and wire mesh, using 1 to 3 mix of cement and sand. Sharp concrete sand is being used and the gunite applied by cement-guns. The sub-station, machine shop and all of the more important buildings have already been fireproofed in this manner, and it is the intention to gunite most of the other buildings. The bunk-houses are comfortably arranged upon the cottage plan. Each house has its own garden plot, which the men take care of during the evenings.

The crushing plant is located on the forebay. At the present time there have been erected three gyratory crushers, two No. 7's and one No. 7½, but in the Montrose yards are now the parts for a great 84-inch Traylor jaw crusher which will be erected this summer, and which will have a capacity of 2,000 cubic yards of crushed stone per day. Whether much of the rock will be dumped at St. David's or whether it will all be crushed for sale to the general public, is a matter of policy that will be determined by the Commission.

Building Four Concrete Bridges

The rock will all be drilled with Ingersoll-Rand and Sullivan rock drills and blasted with dynamite. C.X.L. brand, 40 per cent. and 60 per cent. has been used to date. The rock will be loaded on to the dump cars by electric shovels. At the present time the rock excavation at the forebay is on a very small scale, the stone being quarried merely to provide aggregate for concrete work and to supply ballast for the railways. The rock is loaded into skips which are picked up by a locomotive crane and which dump into a bin. A belt conveyer carries the stone from the bin to the crushers, and there is another conveyer from the crushers to the cars.

The concrete work for which the rock is now being used is in connection with a number of bridges which must be built by the Commission. There are four railway bridges to be constructed over the canal, one for the Niagara, St. Catharines and Toronto Railway (electric), one for the Wabash Railroad, one for the Michigan Central Railroad and one for the Grand Trunk and Michigan Central Railroads.

These will be reinforced concrete arch bridges, 36 feet to 38 feet in width, 100 feet clear span. There will also have to be constructed a number of highway and foot bridges to carry the various roads across the canal. In the concrete work to date, both Canada and St. Mary's cement have been used.

Hydraulic Similarity Models

Under the direction of Professor R. W. Angus, of the University of Toronto, several hydraulic similarity models are being prepared at Dufferin Islands, near the Ontario Power Company's intake in the Niagara River. These models are based on designs prepared by the Commission and are for the purpose of studying the conditions at the intake. The design of the intake works will be based upon the results of these studies. The models are being made to a 1/20th scale.

Personnel

Hon. Sir Adam Beck is chairman of the Hydro-Electric Power Commission of Ontario, the other commissioners being Hon. I. B. Lucas and W. K. McNaught, C.M.G. W. W. Pope is secretary, and Frederick A. Gaby, under whose direction the entire work was planned and is being constructed, is chief engineer.

The design and construction of the project are under the direction of the Hydraulic Department of the Commission, as were also the studies and surveys for the scheme. Henry G. Acres is hydraulic engineer; Thomas H. Hogg, assistant hydraulic engineer; and Max V. Sauer, the department's designing engineer. E. T. Brandon is electrical engineer.

There is a large staff of engineers and construction superintendents and foremen at Niagara Falls under the direction of J. B. Goodwin as works engineer and of George Angell as general superintendent. A. C. D. Blanchard is field engineer; F. W. Clark, assistant field engineer; R. T. Gent, plant engineer; William Smith, office engineer; W. S. Orr, resident engineer on Division No. 1 (Welland River section); and George Lowry, resident engineer on Division No. 3 (station 235 to station 438 + 33, where the forebay begins). No construction work has been done yet on Division No. 2 (from the Welland River to station 235). To date, Mr. Orr has been acting as resident engineer on any work done on Division No. 4 (power house, gatehouse and forebay).

F. W. Scriven is division superintendent on Division No. 3, and C. Anderson acting superintendent on Division No. 1. Nos. 2 and 4 division superintendents have not yet been appointed. Harold L. Bucke is superintendent of railway construction; E. M. McGivern, mechanical superintendent; F. F. Cooper, chief clerk in charge of the accounting, cost-keeping and time-keeping systems.