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DEPARTMENT OF THE INTERIOR—CANADA

Hon. W. J. ROCHE, Minister, W. W. CORY, Deputy Minister

DOMINION WATER POWER BRANCH

J. B. CHALLIES, C.E., Superintendent

WATER RESOURCES PAPER No. 17

CANADIAN HYDRAULIC POWER DEVELOPMENT AND ELECTRIC POWER IN CANADIAN INDUSTRY

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Parts 12 and 13, Annual Report, Superintendent of Water Power, 1914-15

OTTAWA
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BY

CHAS. H. MITCHELL, C.E., M. Can. Soc. C.E., M. Am. Soc. C.E.,
Consulting Engineer to Branch.

Prepared at the request of the Superintendent of Water Power for presentation at the International Engineering Congress, San Francisco, September, 1915.

PARTS 12 AND 13, ANNUAL REPORT, SUPERINTENDENT OF WATER POWER, 1914-15.

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Part I.

CANADIAN HYDRAULIC POWER DEVELOPMENT.

BY CHARLES H. MITCHELL, C.E.

M. Inst. C.E., M. Can. Soc. C.E., M. Am. Soc. C.E., Consulting Engineer to Dominion Water Power Branch, Department of the Interior, Canada.

In the presentation of this paper, it is intended to especially deal with the progress in hydraulic power utilization in the Dominion of Canada; to discuss some of the features involved in the design, construction, and operation of hydraulic plants which have found special application, and to incidentally describe a number of typical Canadian power developments.

The Dominion of Canada, lying entirely northward of the United States and stretching from the Atlantic to the Pacific ocean, embraces a variety of climates and a wide range of topographical features which include possibly all favourable and unfavourable characteristics in so far as development of hydraulic power is concerned. The water-powers of the Dominion are almost limitless, and while a great majority are very remote from consuming centres, it is inconceivable, notwithstanding any radical changes in the art of power transmission, that the water-powers would ever be completely commercially developed. The cities of Canada are fortunate in being, without exception, within the zone of economic electrical power supply from hydraulic sources.

Engineers, manufacturers and financiers of the world have appreciably marked influence directly upon the conducting of engineering undertakings in Canada on account of the economic relations of the Dominion with Great Britain, the United States and the continental countries. The bulk of the financing of large works is undertaken in England. While complete mechanical equipment of very high grade made entirely in the Dominion, is obtainable, and the customs tariff levies a duty on imports from all countries, it must be appreciated that the manufacturers of Great Britain, France, Germany, Switzerland, Italy, Sweden, and the United States, are available in Canada on a competitive basis. This is true of practically all machinery and materials, so that in practice it transpires that an equipment may be assembled from many different sources, requiring on the part of the engineer the harmonizing of the designs of these individual parts of varied origin.

While the first half of the last twenty years initiated the radical advances in the whole field of hydraulic engineering, the last decade has been notable for the increase in capacities and efficiencies and for the refinements in design of the various components of the power developments.

It cannot be said yet that hydraulic engineering is approaching a condition possible of complete standardization. Every development shows a combination of features requiring an individual arrangement and design, and it is apparent that within the last few years notable strides have been made with the development of dams, conduits, turbines, regulating devices, and so forth.

Rather than deal exhaustively on one subject or too briefly on all, the general considerations of many of the features and problems of contemporary hydraulic engineering will be undertaken in what follows. It is to be noted that reference is made to the subjects of storage of water for power purposes, and to the ice problems; the former is now engaging the Dominion Government and the governments of several provinces

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aiming at the improvement of rivers for power and navigation purposes; the problem of the freezing of water has always been a serious one, but it is now almost universally successfully dealt with.

WATER STORAGE.

Storage of water for power purposes by no means presents a new problem, but the application to the immense power projects now existing or under way demands a systematic conservation of water quite beyond the requirements of the past, and introduces many new phases into the question.

The seasonal changes in river flow are very pronounced, as the winter discharge is, in general, retarded by freezing, and in the late summer the combined effect of low precipitation, excessive evaporation, and depletion of natural storage again creates low water, the lesser flow of the two periods definitely determining the economic value of the water-power. The enormous flood flows following the winter seasons are available for but a very short period, but if properly conserved and further augmented by the storage of the surplus of the subsequent rains, the minimum flow can be materially increased and the value of benefited power developments correspondingly raised.

The condition is general in Canada that hydro-electric developments have approached or exceeded the unregulated capacities of their respective rivers, and while very few extensive storage systems are as yet constructed, the activity of industrial expansion now demands that the power developments must anticipate the very near future and fully provide for the securing of maximum available outputs and that every advantage be taken for complete conservation and storage. It is remarkable that practically all Canadian rivers are naturally provided with excellent storage possibilities.

Pondage, differentiated from storage as being the day-to-day storage of water immediately available at the turbines, is an essential in Canadian water-powers as providing an insurance against ice, which, as later described, is a factor commanding the full respect of the engineer. The river flow, due to the controlled discharge from remote storage reservoirs, may not correspond to the variation in power demand during the day, thus further necessitating pondage as an important component to the economic regulation.

The investigation of storage and pondage requirements must fairly establish the load factors of the power supply imposed on the system, the load distribution over the twenty-four hours and, further, the seasonal variation of load as dictated by the nature of the market. The study of the unexploited fields demands an approximation of loads whose character may be assumed by comparison with other existing loads, and it is essential that the inherent load factors applicable to the respective types of loads be fully recognized.

It must be appreciated that effective storage requires relatively large areas of land for flooding purposes, and such lands by growth of population and by the establishment of permanent improvements, increase in value at a rapid rate; at the present time, however, it transpires that the majority of the Canadian storage schemes now under way involve remote forested Crown lands readily adaptable for storage purposes. The multitude of interests involved in extensive storage developments make the accomplishment of storage in most cases quite beyond the capabilities of the power developing companies, and requires concerted action in the obtaining of the necessary rights. In Canada the respective Government, Dominion or Provincial, which has jurisdiction over water-powers, acts as the intermediary, and this has been a very substantial factor in the notable success of the power situation throughout the country.

The Government of the Dominion of Canada has full control of all navigable and floatable streams and, in addition, through the Dominion Water Power Branch of the Department of the Interior, controls all water-power developments and possibilities in the provinces of Manitoba, Saskatchewan, Alberta, and the Northwest territories and the Yukon, and follows a policy of encouraging legitimate enterprise for the development of power resources.[1]

In the province of Ontario the Department of Lands, Forests and Mines, in conjunction with the Hydro-Electric Commission of Ontario, controls the water-powers on other than navigable streams. The Hydro-Electric Commission is virtually a government commission acting in trust for the various municipalities which have combined for the securing of cheap power; the influence of the Hydro-Electric Commission tends to the development and distribution of power under public ownership. The extent of the operations of this commission is very great and calls for consideration quite beyond the scope of this paper.[2]

In the province of Quebec the Department of Lands and Forests controls the power in provincial waters, and through the Quebec Streams Commission has now under way an immense storage project on the St. Maurice river. Water-powers of the province of New Brunswick are administered by the Provincial Government, but in Nova Scotia a great portion of the land with the included water-powers has passed from the control of the Government, the remaining sites, however, continue under full provincial control. The province of Prince Edward Island is without powers of any magnitude.

It must suffice to briefly describe several Canadian storage developments now under way or contemplated.

In Nova Scotia, about 16 miles from Halifax, a small yet interesting scheme is being developed on the Northeast and Indian rivers which flow into St. Margaret bay on the Atlantic coast. The water available in each of these distinct watersheds is fully conserved by storage dams, and the water from the Northeast river is carried over the intervening height of land to the No. 1 or upper power-house (see plan on page 8), in which the water under each of the two heads serves a generating unit, the discharge being into Indian lake, at the foot of which the No. 2 or lower power-house is situated with tailrace at tide-water level. By conservation the low summer flow is doubled, thus making such a development a good commercial possibility.

On the Saguenay river, in Quebec, the outlet of lake St. John, which has an area of 350 square miles, there are excellent natural features permitting of an enormous development, the organization of which is now well under way, contemplating an output of 1,200,000 horse-power with an initial installation of 300,000 horse-power, the immense capacity being justified by the very low cost of power in large generating units of 50,000 horse-power each, for the manufacture of nitrogenous products for export.

The Quebec Streams Commission is constructing the necessary works for the storage system on the St. Maurice river which supplies the Shawenegan and Laurentide (Grand'Mère) plants.[3] This system raises the minimum flow of 6,000 cubic feet per second to 15,000 cubic feet per second, the effective drainage area being 16,200 square miles and the reservoir dam at La Loutre impounding 160,000,000,000 cubic feet. This work is undertaken by the commission for the benefit of the present power producers, increasing the power available at the now developed sites by 122,000 horse-power at Shawenegan falls and 63,000 at Grand'Mère, and as an improvement on six undeveloped sites on the St. Maurice, which will thus aggregate 182,000 horse-power capacity; appropriate rentals will be charged the individual users, and the costs assumed by the commission defrayed.

Surveys have just been completed in connection with the storage possibilities on the Winnipeg river, on which two very important power plants have already been developed. The Winnipeg Electric Railway has a plant on the Pinawa channel making use of the

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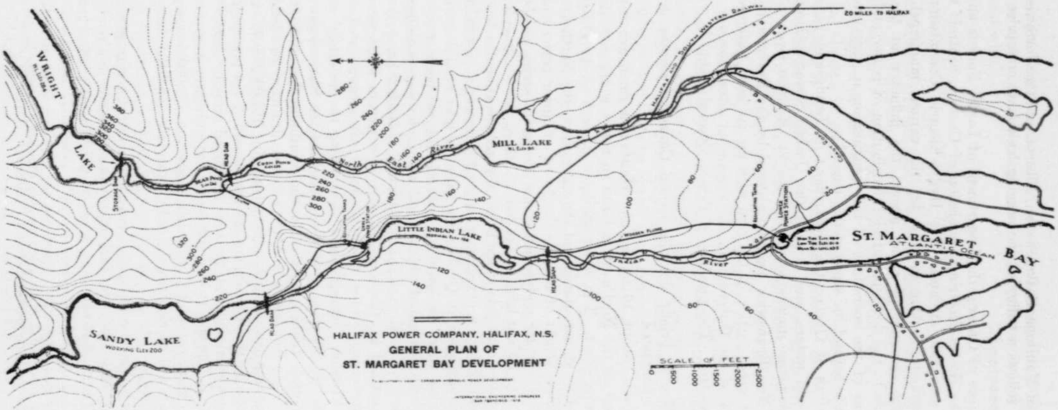
[1] See reports of Dominion Water Power Branch, Department of the Interior, Canada.

[2] See Part II of this report, "Electric Power in Canadian Industry."

[3] See "Second Report, the Quebec Streams Commission, 1913."



HALIFAX POWER COMPANY, HALIFAX, N.S.
GENERAL PLAN OF
ST. MARGARET BAY DEVELOPMENT

Du Bonnet falls;[1] at this plant 26,500 horse-power has been developed. The city of Winnipeg Hydro-electric plant[2] (see illustration below) at Point du Bois, about 77 miles northeast of Winnipeg, has an installation of eight units aggregating 51,500 horse-power output, the ultimate plant being designed to have an output of 76,000 horse-power. The Point du Bois site has a pondage of about 7 square miles above the dam. The surveys show that the minimum flow on this river may be increased from 12,000 second-feet to 20,000 second-feet by storage to be readily obtained in the head-waters in the Lake of the Woods and the Rainy river and English river watersheds, there being a combined area of 47,000 square miles drained.[3]

The Bow river in Alberta rises in the Rocky mountains and is subjected to climatic conditions, notably severe in river flow, the sources being mountain streams, glaciers, and snowfields. The excellent facilities for power development on the Bow at several locations adjacent to the power market of Calgary and the immediate requirement for regulated flow in the case of the Calgary Power Company at Horse Shoe falls, where the minimum flow of 550 cubic feet per second was not sufficient for the market demands,

Plan of Layout of City of Winnipeg Plant, Point du Bois, Winnipeg River, Elevations given to City Datum. Zero of City Datum = 769·1. Water Power Survey Datum.

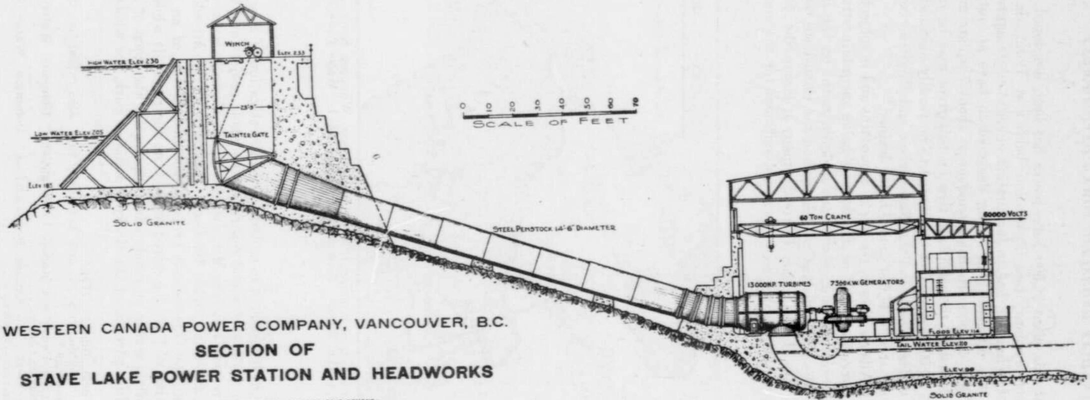
induced the Dominion Government to undertake the investigation of Bow River storage possibilities, resulting in a survey and report[4] on the whole project and the immediate construction of the reservoir at lake Minnewanka on the Cascade river, a tributary of the Bow, near Banff, and lying within the Rocky Mountains park. An added feature of this reservoir is that the Government proposes the installation of an hydro-electric generating plant which will use the stored water from the reservoir while in transit to the Bow river, and thus secure an ample power service for the town of Banff and the immediate surrounding portions of the Rocky Mountains park, the whole of which has

[1] See *Electrical World*, June 23, 1906.

[2] See *Engineering*, London, July 26, and August 2, 1912, also "Canadian Society of Civil Engineers, 1911, Proceedings."

[3] See "Winnipeg River Power and Storage Investigations," Dominion Water Power Branch, Department of the Interior, Ottawa.

[4] See "Bow River Power and Storage Investigations," Dominion Water Power Branch, Department of the Interior, Ottawa.



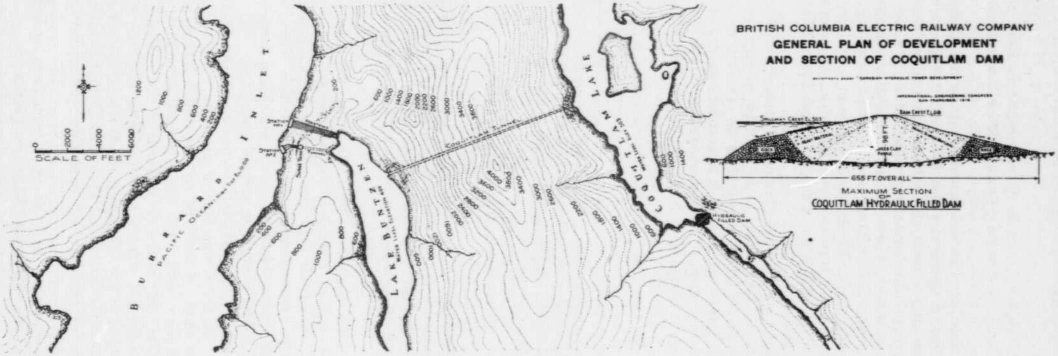
WESTERN CANADA POWER COMPANY, VANCOUVER, B.C.

SECTION OF

STAVE LAKE POWER STATION AND HEADWORKS

To accompany paper "CANADIAN HYDRAULIC POWER DEVELOPMENT"

INTERNATIONAL ENGINEERING CONGRESS
SAN FRANCISCO 1915


BRITISH COLUMBIA ELECTRIC RAILWAY COMPANY
GENERAL PLAN OF DEVELOPMENT
AND SECTION OF COQUITLAM DAM
INTERNATIONAL ENGINEERING CONGRESS
SAN FRANCISCO, 1915
655 FT. OVER ALL
MAXIMUM SECTION OF
COQUITLAM HYDRAULIC FILLED DAM
ROCK
HYDRAULIC FILLED DAM
BURRARD INLET
PACIFIC OCEAN
LAKE BUNTZEN
COQUITLAM LAKE
COQUITLAM TUNNEL
SCALE OF FEET
0
2000
4000
6000

an area of 1,800 square miles, and to a great extent includes all the storage areas required for the Bow River storage system, which will aggregate over 10,500,000,000 cubic feet.

At the present time investigation is under way by the Dominion Water Power Branch in the creation of storage for the Athabaska river, which has its source in northern Alberta some miles north of Calgary. This river flows towards the Arctic ocean, and, while having its headwaters extending far above Lesser Slave lake into the Rocky mountains, the winter conditions are such that the minimum winter flow is approximately 2,000 second-feet at Athabaska, as compared with the minimum summer flow of over 20,000 cubic feet. The power possibilities on this river are enormous if the flow can be economically regulated and the adjacent markets of Edmonton and the Peace River country—the latter, Canada's "Last Great West"—comprise an exceedingly attractive goal.

At the Stave Lake plant of the Western Canada Power Company, situated 36 miles east of Vancouver, B.C., there is an available storage immediately above the power site on Stave lake capable of impounding the complete run-off from the glaciers and snowfields above; this storage reservoir has a total capacity of 14,000,000,000 cubic feet, which will serve the ultimate two power sites at this point. The output of the upper plant is at present designed to be 52,000 horse-power, with 26,000 horse-power already installed.[1] (See illustration on page 10.)

The Coquitlam-Buntzen plants of the British Columbia Electric Railway Company, situated on tide water at Burrard inlet, have an interesting system of storage, utilizing two adjacent watersheds. The general scheme of development is shown on page 11, and is later described herein. The lake Coquitlam storage in which the water of the Coquitlam watershed is collected, has a capacity of 7,623,000,000 cubic feet. The rainfall is notably excessive, averaging 156 inches per annum over the last ten years.

PROGRESS IN HYDRAULIC ENGINEERING.

Progress in engineering construction and practice can possibly best be described and illustrated by reference to local applications, and it will readily become apparent that Canadian plants have provided a field for, and have demanded, the development of the foremost and most radical advancements in constructional features and equipment.

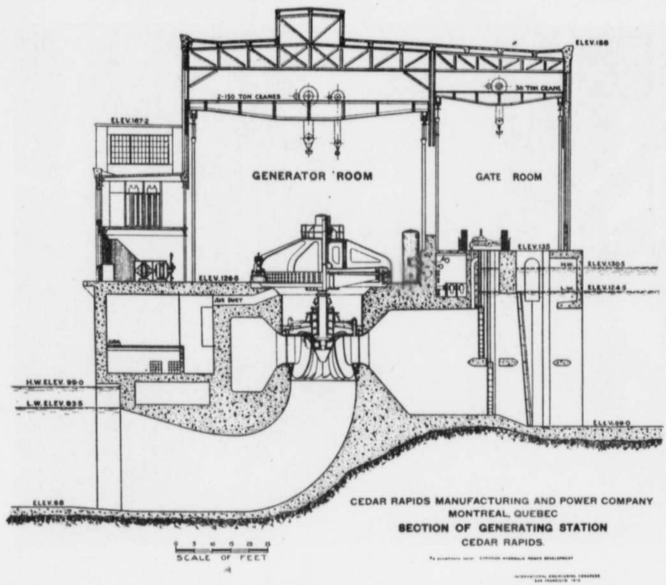
Turbines.—The notable advance in turbine design has been the attaining of high specific speeds and the making possible of the development of low heads by turbines of large capacities of comparatively high speeds and of a much improved efficiency. The economic utilization of low heads generally resolves itself into a vertical shaft installation, and many persistent objections to the established form of such a construction have demanded radical changes in turbine design.

The single runner vertical shaft turbine has a very important position in Canadian developments. In the Cedar Rapids plant on the St. Lawrence river, near Montreal, the largest wheels of this type are now installed, there being twelve units of 10,800 horse-power under a head of 30 feet at a speed of 55·6 revolutions per minute. (See page 13.) At the Grand'Mère development of the Laurentide Company on the St. Maurice river in Quebec, similar units are being installed of 20,000 horse-power capacity under a head of 76 feet at a speed of 120 revolutions per minute. The Cedar Rapids units are much the larger and have a much higher specific speed than the Laurentide units. A few years ago such capacities were beyond the comprehension of the hydraulic engineer.

The commercial efficiencies to be obtained from these modern high specific turbines are remarkably high, approaching 93 per cent and more.

[1] See *Electrical World*, New York, 1912, p. 489.

The advantage gained over the multiplication of runners formerly required on one shaft to develop under low head a capacity economically suitable for a hydro-electric installation, are many. The simplicity of a single-gate mechanism; the elimination of submerged gate gears and the torsional effects of the transmitting gate shafts; the small vertical dimensions required conforming more rationally to the available distance between head- and tail-waters; the single-draft tube which may be placed more advantageously; the accessibility of mechanisms for inspection, repair and dismantling; low comparative cost of turbine, of concrete settings and water passages, and of handling, and the possibilities of concrete-formed water passages with smooth curved surfaces and small head loss are all points whose value may be readily appre-

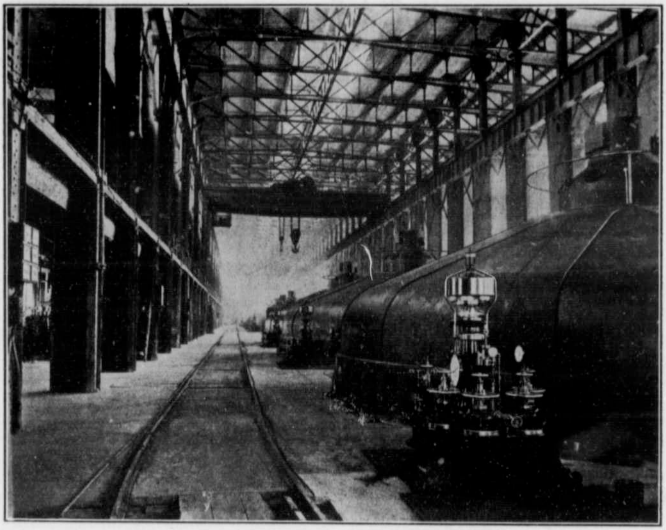


ciated. The disadvantages of the high efficiency being confined to a small load range and the necessity of supporting bearings have small weight in the selection of this type of turbine. The three-quarter load efficiency compares favourably with the maximum efficiency of the lower specific speed turbines. The development of supporting bearings of the Kingsbury, roller and ball types has kept pace with capacity requirements. The section and interior view of the Cedar Rapids generating station shown above and on page 14 will illustrate the general design.[1]

Exciter arrangement.—Within the last few years designers have reverted to the arrangement of direct connection of exciter generators to the power unit turbines. While this practice was for long disapproved of, the electrical voltage regulator as

[1] See *General Electric Review*, June, 1914, p. 533.

now developed has proved its ability to counteract the combined effects of a varying exciter and generator speed when these are direct connected, and within reasonable limits of speed variation, the voltage curve of a power generator may be maintained commercially constant, regardless of load and variation of speed of the turbines. The advantage in generating station and general works design by elimination of duplicated turbine-driven exciter sets is obvious, but it must be remembered that while power units may be self-excited by direct connected exciters, in a station of any magnitude the auxiliary equipment of the plant will demand a source of power available, preferably of direct current, independently of the main power generators. The application of direct connected exciters in a large installation is well demonstrated in the installations of the Toronto Power Company's generating station (see illustrations on



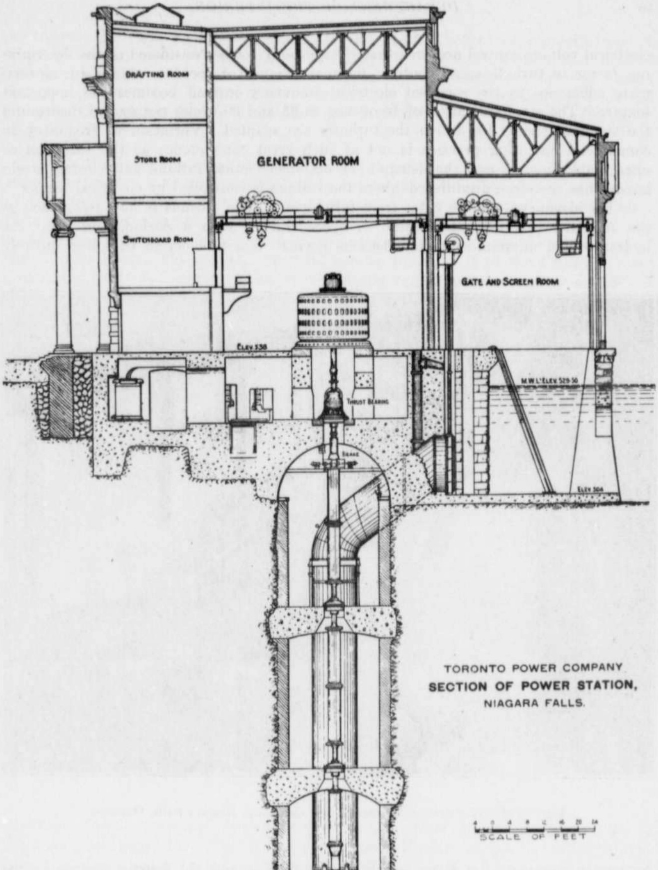
Interior of Power Station, Cedar Rapids, St. Lawrence River.

pages 15 and 16), where the generators ten in number, aggregating 100,000 horse-power, have all been equipped with direct connected exciters; this plant is situated at Niagara Falls, Ont., and transmits power to Toronto, approximately 80 miles distant.

Excitation systems now approach the elaborate and possibly are the most finely adjusted and most fully automatic devices of power plant equipment. The supply of exciting power in the station of 100,000 horse-power calls for generating units of large dimensions, which in themselves compare with the entire capacities of many well-known power plants.[1]

Turbine Speed Control.—Speed control of turbines has in general been required to meet the demand for constant voltage maintenance. The present methods of

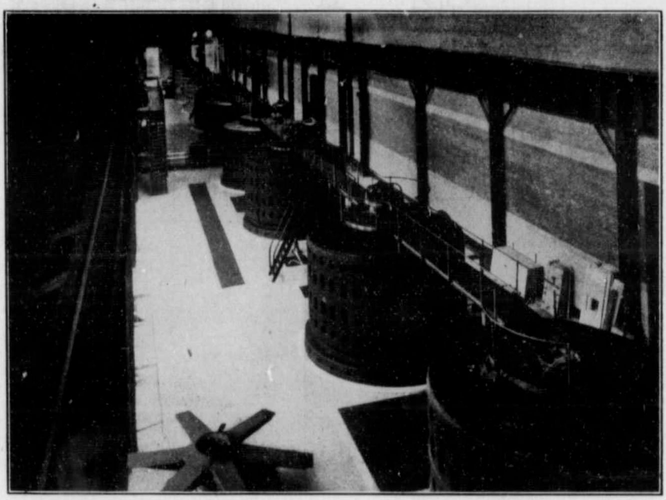
[1] See Excitation and Voltage Control, *Electrical Journal,* November, 1914, p. 612.



TORONTO POWER COMPANY
SECTION OF POWER STATION,
NIAGARA FALLS.

electrical voltage control are such that voltage need not be considered as the determining factor in turbine speed control; the maintenance of speed to obtain an approximate adherence to the specified electrical frequency instead becomes the important feature. The standardization of frequency to 25 and 60 cycles per second determines the standard speeds for which the turbines are adapted. Variation of frequency in commercial operating practice is not of such great consequence as the variation of unregulated voltage and the demand for extremely quick turbine gate-closing mechanisms has therefore diminished where the voltage is controlled by electrical means.

The closing of turbine gates from fully open in two seconds is now recognized as the standard practice. Regulation of speed during such a period, and until the hydraulic and mechanical factors become normal, is a problem to be solved entirely

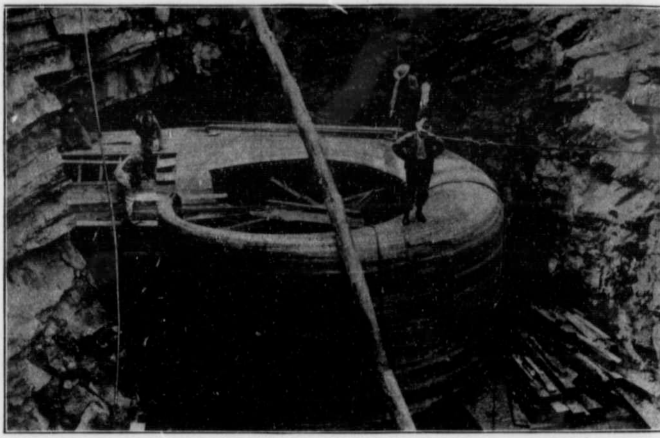


Interior of Power Station, Toronto Power Company, Niagara Falls, Ontario.

by proper designing for water supply to the turbine and the inertia storage in the moving parts. The fly wheel, whether separate or incorporated into the electrical generator, is an essential element of the regulation.

Water Passages.—The obtaining of high efficiency and good inherent regulation of turbines requires the greatest refinement in the construction of water passages throughout the whole system. The magnitude of the modern turbine demands large water passages which readily permit of their formation in concrete; the easy curves and smooth surfacing thus possible to obtain has been one of the greatest factors in the attaining of the high efficiencies. As an interesting example of the possibilities of such types of concreted structures, reference may be made to the Calgary Power Company's Kananaskis Falls plant on the Bow river in the Rocky mountain foot-hills in Alberta; the form shown in position (see illustration below) is approximately 24 feet in diameter, made in one complete structure in a convenient place and hoisted into final position. The form is for one of the 6,000 horse-power turbines, which operate under a 70-foot head at 164 revolutions per minute. Attention must also be drawn to the concrete-formed distributor and draft tube in the Cedar Rapids plant. (See illustration on page 13.)

Surge Tanks.[1]—The development of the surge tank for penstock, and flume regulation has reached a most advanced stage in two recent installations. The first is that of the Ontario Hydro-Electric Power Commission's development at Eugenia falls, Ontario, where the surge tanks are installed on the 4-foot penstocks leading to the power-house, these tanks being placed on their respective pipes near the upper level of the 542-foot head. The second, and most notable example, is at the Ontario Power Company's plant at Niagara Falls, in which the surge tank terminates an 18-foot



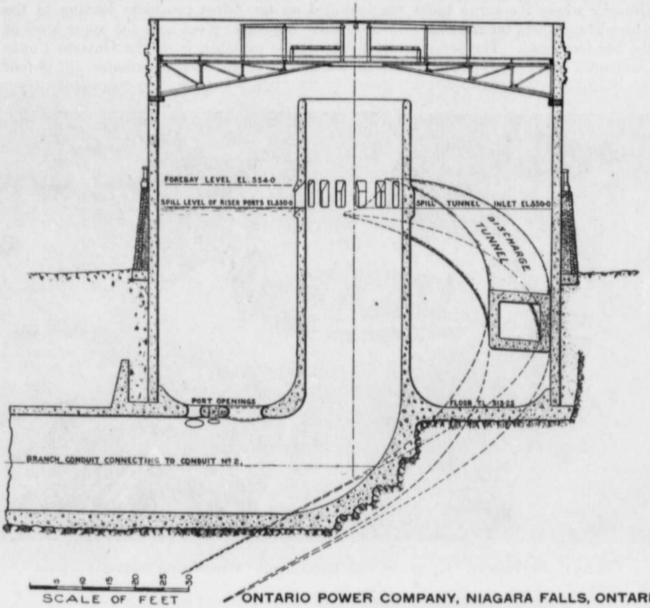
Calgary Power Company. Kananaskis Falls Development. Formwork for Scroll-case in place.

concrete conduit described herein and shown on page 19. The surge tank is illustrated on page 18. The pressure of water during surges is differentiated from the stored water by being carried up in the conduit riser or stand pipe and allowed to overflow through ports, or over the top of the riser if the surge is of sufficient magnitude, into the body of the enclosing surge tank; the stored water as demanded is drawn into the conduit only through the small ports in the tank which connects with the conduits. Surplus water and overflow water in the tank is discharged to the river by means of a tunnel whose upper length, in the form of a helix conforming to the circular tank wall, the spillway crest of the tunnel mouth being on a level with the riser port discharge level and 4 feet below head-water level at the intake fore-

[1] See "Proceedings, American Society of Mechanical Engineers, 1908"; "Proceedings, American Society of Civil Engineers, December, 1914."

bay. The regulating action in practice has been excellent, and promises to be a great aid in the practical development of many projected undertakings involving very long pipelines.

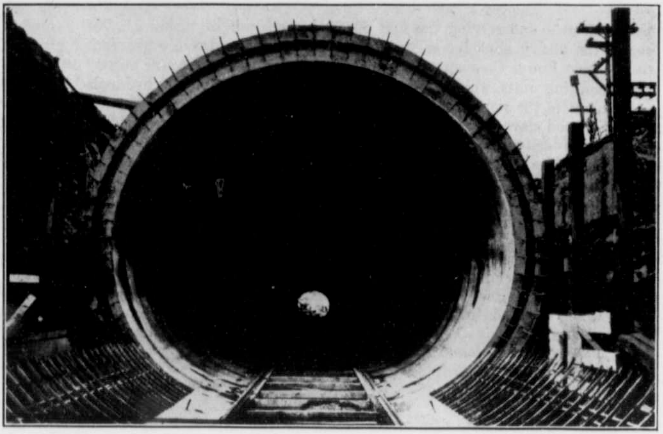
Water Conduits.—Several interesting examples of water conduits have been constructed during the last few years. The foremost by virtue of its magnitude and its theory of design is that of the Ontario Power Company at Niagara Falls, as illustrated on page 19. This conduit has an equivalent diameter of 18 feet, but it is of a distorted shape, having a horizontal diameter of 19¼ feet and a vertical dimension of



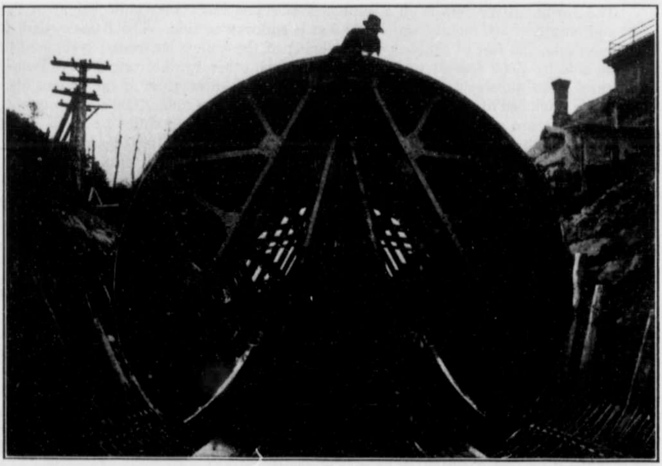
ONTARIO POWER COMPANY, NIAGARA FALLS, ONTARIO
SECTION OF SURGE TANK, No. 2 CONDUIT.

16½ feet, adhering to the natural shape assumed by an elastic tube under its self-contained water and equivalent hydraulic head.[1] The conduit is of reinforced concrete, the bottom being formed first, as shown in the foreground of illustration on page 19, and the upper portion being formed by the collapsible movable forms carried on trucks, shown on page 19; the outside forms are bolted to the inner form through iron sleeves which are left in the finished structure and eventually plugged. The inner face was given a permanent hard smooth surface by trowelling to minimize frictional losses. The conduit is 6,500 feet in length and has a rated capacity of 90,000 horse-power at maximum velocity. This conduit is the second installed for this development, No. 1

[1]See "The Hydrostatic Chord," Proceedings, American Society of Mechanical Engineers, May, 1910; "Stresses in Circular Pipes," *The Canadian Engineer*, November 13, 1913.



Section of 18-ft. Concrete Conduit, Ontario Power Company, Niagara.



Collapsible Steel Form for Conduit, Ontario Power Company, Niagara Falls.

being of steel and serving the first 80,000 horse-power of turbines[1]; No. 2 conduit serves the 90,000 horse-power turbines since installed. In this generating plant of the Ontario Power Company there is 160,000 electrical horse-power output from fourteen operating units, which makes the plant the largest individual hydro-electric generating plant in the world.

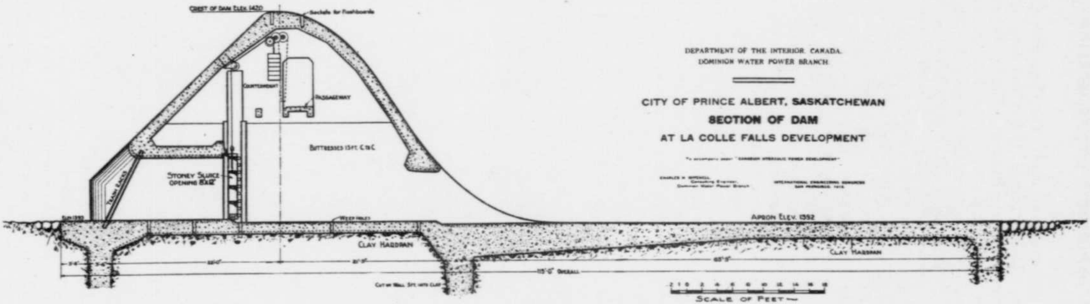
The wood stave pipe as now built for water conduits must be considered a successful type of construction. The half round open sections made of British Columbia fir are quite widely used in Canadian developments and are relied on to give long service if properly constructed. The ease with which the wooden conduit materials, including prepared staves, banding irons, etc., may be transported and erected; the peculiar adaptability to the forming of curves as construction proceeds, and the freedom from penstock ice troubles when operating justify its use in a great many installations. The general experience has been that the rotting of the wood is not a serious factor, and if the conduit is full of water under a pressure sufficient to cause saturation of the staves, rotting is entirely absent. A most interesting development recently completed which has made extensive use of wood stave pipe of various dimensions and type is that of the Canadian Colleries on Vancouver island, British Columbia.[2] The many novel devices for the conducting of water in this hydro-electric installation are well worthy of considerable study as representing, possibly, the most advanced practice in the use of wooden conduits.

Dams.—The concrete dam of the hollow buttress type is in almost universal use where any magnitude is involved. The most notable installations in Canada are possibly those of the Vancouver Island Power Company at Jordan river on Vancouver island; the Canadian Pacific Railway Company's irrigation dam on the Bow river at Bassano, near Calgary, and the power dam at Cole falls on the North Saskatchewan river, built for the city of Prince Albert, Saskatchewan. (See illustration on page 21.)

The Jordan River dam is on a solid rock base and has a maximum height of 125 feet and length of 800 feet, of which 300 feet is spillway section. The Bassano dam is of three parts, 720 feet of spillway section being of the hollow buttressed type, flanked on one side by 7,000 feet of earth dam and on the other by the concrete headworks structure. The spillway portion is built upon a 14-foot substratum of impervious clay lying on a thick bed of quicksand which comes to the surface some 3,000 feet upstream; the buttresses are carried above the dam to form twenty-four sluice openings fitted with Stoney gates which are of sufficient capacity to discharge 100,000 cubic feet per second maximum flood water. The Prince Albert dam is also built on a clay stratum with sand underlay; the most notable feature of this dam is the length of spill apron used, which is required for the maximum discharge of 180,000 cubic feet of water per second during flood period, the whole crest being used as a spillway and, in addition, this spill capacity is augmented by eleven Stoney sluices discharging through the dam. The section shown on page 21 illustrates the general arrangement of the Prince Albert dam; the dam is 550 feet long extending between a concrete navigation lock and the hydraulic canal intake; the standard height is 29 feet above river bed and the sectional width, including the apron, is 119 feet.

The best Canadian example of the hydraulic fill dam is at lake Coquitlam for the British Columbia Electric Railway Company, supplying the city of Vancouver and its vicinity in British Columbia. This latter dam is shown in section on page 11 and its relation to the rest of this interesting plant may be judged from the general plan of the whole development. The scheme of construction of the Coquitlam follows the now well-established principles, the material of a suitably graded nature being sluiced into its final position from the adjacent banks, and the sluicing flumes directed so that the discharge deposits the heavier materials towards the slopes of the dam and the compacted sand, rock dust and clay thus being carried towards the centre by the

[1] See "The Development of the Ontario Power Company," P. N. Nunn, A.I.E.E. Proceedings, June, 1905 and subsequent descriptions published by the O. P. Co.
[2] See *Engineering News*, October 23, 1913.


CREST OF DAM ELEV. 1420
COUNTERWEIGHT
PASSAGEWAY
BUTTRESSES 15 FT. C to C
STONEY SLUICE OPENING 15x12'
TRASH RACKS
WEEP HOLES
CLAY HARDPAN
CUT OFF WALL 5 FT. INTO CLAY
115'0" OVERALL
APRON ELEV. 1392
SCALE OF FEET
DEPARTMENT OF THE INTERIOR, CANADA.
DOMINION WATER POWER BRANCH.
CITY OF PRINCE ALBERT, SASKATCHEWAN
SECTION OF DAM
AT LA COLLE FALLS DEVELOPMENT

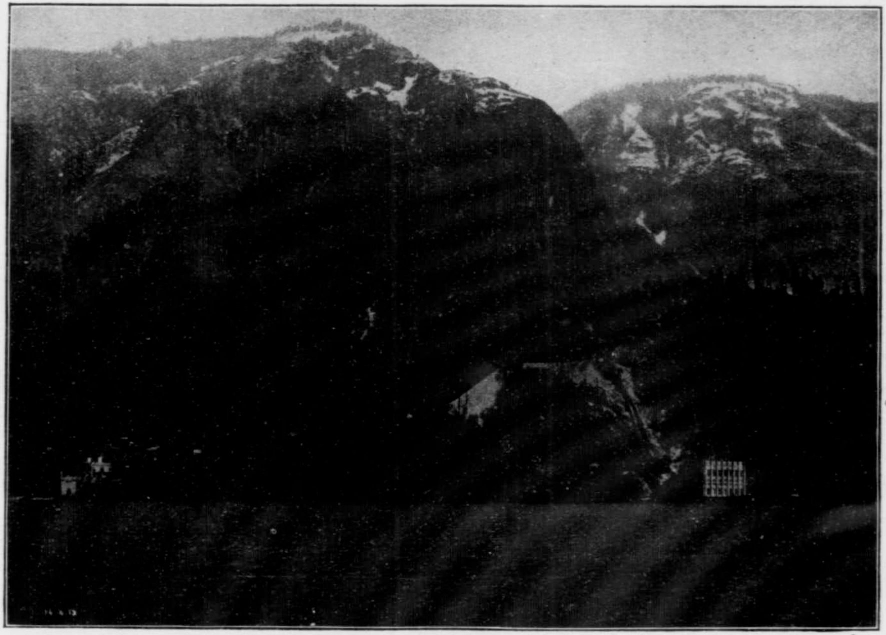
sluicing water to form the impervious core. The Coquitlam dam impounds the water in Coquitlam lake from which a tunnel, 12,650 feet long through the intervening granite mountain, discharges into lake Buntzen. The initial power development, which is of 43,000 horse-power capacity, has its intake on Buntzen lake with penstocks leading down to the No. 1 power-house. (See illustrations on pages 11 and 23). For No. 2 power-house a concrete-lined tunnel leads from an intake on lake Buntzen to a surge tank constructed in the tunnel portal from whence three penstocks are led down the cliff to the power-house, making a head of 400 feet; the turbines in No. 2 plant as also are those in No. 1 plant, are of the Pelton-Doble impulse type, each of the three units being of 14,000 horse-power capacity under a head of 400 feet. The total installed capacity of the two power-houses is 85,000 horse-power.

Relief valves.—A very necessary adjunct to the long water conduit is the relief valve for discharge of surplus water under the high pressure encountered on the closing of turbine gates and on the consequent surges. The characteristics of operation of relief valves vary over a wide range from spilling water continually to more or less ineffective opening after the building up of a very high excess pressure. The types which act synchronously with the closing of the gates, anticipating the pressure rise by the relative speed of gate closing, have reached a comparative perfection. The continuous spilling of water under normal operation is in general to be termed bad practice, and the high pressure type may sometimes suffer harm before the relief occurs. A bursting plate inserted on the penstock which by destruction under abnormal pressure permits the escape of water until the whole system is shut down and the repair men become active, has its uses in remote cases; the reason for its limited application is obvious.

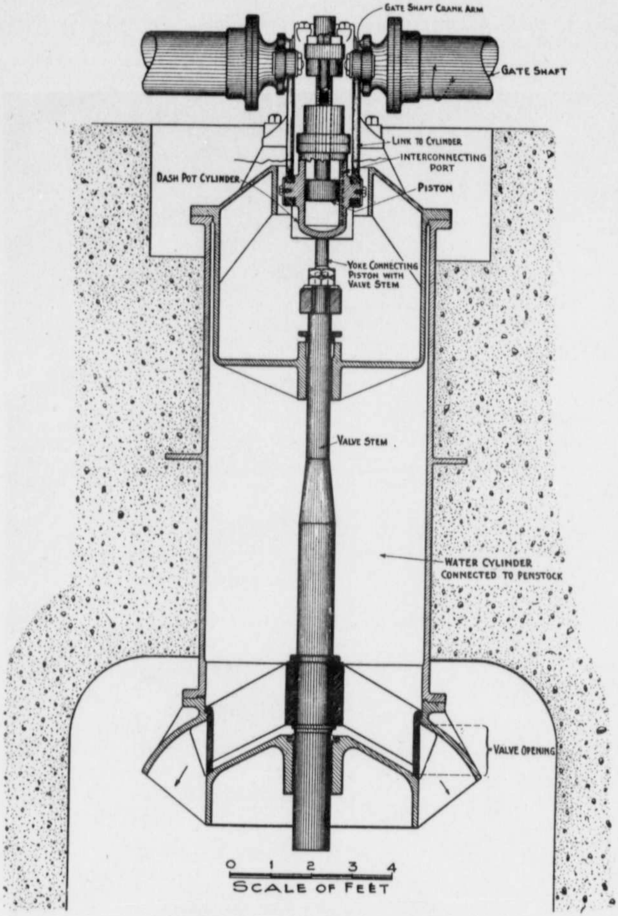
Reference to reproduction on page 24[1] will illustrate the relief valve equipment employed on the 20,000 horse-power turbines at the generating plant of the Shawenegan Water and Power Company, which, to a great extent, is the result of this company's experience with relief valves throughout the earlier portion of the development. This plant has now installed an aggregate of 147,000 horse-power in No. 1 and No. 2 power houses,[2] the latter having 100,000 horse-power capacity in five units; in addition, the company sells water to customers for utilization in adjacent privately-owned plants for the development of 43,000 horse-power. Penstocks approximately 600 feet long and 14 feet in diameter, with a normal velocity of 8·5 feet per second under 145-foot head supply each of the five 20,000 horse-power turbines; each penstock divides into two feeders, one for each of the wheel cases of the respective turbines, and the relief valve is set in the crotch between the feeders and is arranged to discharge from the feeders into th draft tube. The mechanism of the relief valve may be readily understood from the drawing. The operating shaft is connected to the relief valve dash-pot by levers and lings and the dash-pot piston to the relief valve spindle by yokes and trunnions. The dash-pot is oil filled and the ends of the dash-pot are inter-connected by two by-passes cored in the casting one by-pass containing a needle valve and the other a spring check valve operating in only one direction. When the turbine gates are closing the dash-pot moves up, being operated by the gate shaft lever, and should the speed of this movement be such that the oil underneath the dash-pot piston will by-pass through the needle valve to the other side of the piston without building up sufficient pressure to overcome the weight of the relief valve then the relief valve remains closed, while if the movement occurs at such a sufficient rate that pressure is built up to overcome the weight of the relief valve, the valve is opened and tends to close again by return flow of the oil through the check valve. Adjustment is made by manipulation of the needle valve.

In the impulse water-wheel installation at Coquitlam, previously described herein, relief valves operated by the governor are installed. The impelling nozzles are of the needle type; the relief needle nozzle is similar to the power nozzle and is connected to

[1] By courtesy of The I. P. Morris Company, Philadelphia.
[2] See *Electrical World*, May 4, 1912.



Hydro-Electric Plants, Lake Buntzen.—Power House No. 1 on the left of the picture. Power House No. 2 on the right.



SHAWINIGAN WATER AND POWER COMPANY

SECTION OF RELIEF VALVE,

NO. 2 STATION.

To accompany paper "CANADIAN HYDRAULIC POWER DEVELOPMENT"

INTERNATIONAL ENGINEERING CONGRESS
SAN FRANCISCO, 1915.

the governor gear so that the relief valve tends to open through the intermediary of an oil pressure dash-pot when the impelling nozzle closes.[1]

Protection against flooding.—Several aggravated cases of power-house flooding due to failure of hydraulic equipment or excessive rise of tail-water, with consequent shutting down of plant and the destruction of electrical apparatus, have had a marked effect on design of stations. Isolation of hydraulic machinery has been obtained in the Shawenegan No. 2 station by a wall separating hydraulic and electric bays, the wall being carried to a sufficient height to accommodate the maximum unimpeded flow through one of the 14-foot penstocks if accidentally discharged into the station, the water finding a vent through the doors and windows, etc. In some stations all exposed doors and windows are fitted up with stop-log seats, a barricade being built up on occasion to protect against outside flood in case of abnormal water conditions. In many instances power-houses can only be economically placed in positions which at very infrequent intervals may be subjected to flood conditions, and while available sources of information in regard to maximum water levels, historically speaking, indicate the safety of the situation, the introduction of a new element in the river courses in the form of power works may greatly affect the normal characteristics of river behaviour. Precautions against the remote possibilities of excessive flood are so easily taken that it is advisable to make all possible provision.

Log Runs and Fish Ladders.—Log runs and fish ladders are peculiar to a great many Canadian developments. Most of the northern rivers are the arteries which tap the timber limits and conveniences for logging are necessitated by the obstructions created by power works. Lumbering is one of Canada's principal industries, and from pioneer days has been controlled and protected by very efficient legislation.

A log run is approached on the upper level by an ample forebay which narrows down to an intake approximating to a V-shaped trough into which the logs can be floated and carried down by a water stream until discharged into the tail-race. Interesting diversions from the usual practice of timber-constructed log runs are that of the High Falls dam on the Lièvre river in the province of Quebec,[2] in which a reinforced concrete V section trough is used (see illustration on page 26[3]), and also that of the contemplated Grand falls development in New Brunswick, which is now under way to supply the city of St. John; in this latter plant, due to adverse topographical features, a tunnel is planned to lead from the forebay to the lower river, and will be utilized to carry logs only, the necessary water being admitted at the upper portal of the tunnel. The season during which the logs are moving is usually the spring flood period, when a surplus of water is available for manipulation of logs in transit.

Fish ladders and fish-ways are demanded at the discretion of the Minister of Fisheries in Canada, to be installed in connection with power works which otherwise obstruct the fish channels. Such fish ladders generally take the form of a series of pools built of wooden boxes, the lift on each being about 10 inches and the partition bulkhead between the compartments having a 1-foot square opening through which, in addition to the spill over the tops of the bulkheads, the water passes from the upper level to the lower.

The foregoing subjects, which have appeared to the writer as comprising the outstanding features of Canadian hydraulic power developments from the hydraulic engineers' standpoint, have in their discussion permitted the description of several of the Canadian plants of greater or less magnitude. Canada is well known as having limitless water-powers, and practically all of those which lie within economic range of markets or are so situated as to be favourable for creation of industry, have been developed in some manner, and at present it is estimated that over 1,700,000 horse-power

[1] See *General Electric Review*, p. 549, June, 1914.
[2] See *Canadian Engineer*, January 7, 1915.
[3] By courtesy of John B. McRae, Ottawa, Consulting Engineer.

Concrete Log Chute, High Falls, Quebec.

is developed as hydraulic power, the greater portion of which is converted into electrical energy. In the near future several of the schemes of enormous size now contemplated, and with power units of capacity far in excess of any now developed, will doubtless be realized, and in less than a decade even more notable progression may be recorded than that herein described.

ICE CONDITIONS.

As stated, ice conditions have been a serious factor against the continuous operation of hydraulic plants.

The ice problem is one which has engaged the hydraulic engineer through the whole history of development of Canadian water-power plants. The low temperatures of winter are responsible for the diminution of run-off, the reduction of river areas and the entire freezing-up of small streams. The retention of the greater portion of the winter's precipitation leads to spring flood flows of magnitude many times greater than the normal discharge, while the breaking up of surface ice in spring readily becomes a menace to be guarded against in protecting constructed works. The augmenting of small winter water supply is an economic problem, and the controlling of floating ice and flood water is a problem of recurring operation. The great difficulties, however, in the handling of water under winter conditions are due to the slight changes in the temperature of the water when varying but a small fraction of a degree about the freezing point. It must be realized that the temperature of the water even in the most severe weather does not appreciably vary from the freezing point; indeed it is only by the most delicate thermometers that the variation can be detected, but within a small range of temperature the most distracting troubles may arise.

There are three kinds of ice which are generally recognized: First, surface ice or sheet ice, which forms on still or comparatively still water; second, anchor ice which forms and grows on the beds of rivers which are not protected with surface ice; and third, frazil ice which forms in the agitated water of rapids, falls, and high-velocity channels, and accumulates in great masses in adjacent undisturbed water.

Surface ice may or may not be harmful. The chief trouble is experienced by the total freezing up of small streams and the diminution of the cross-sectional area of the rivers. The ice floes and broken sections when loosed in spring are frequently troublesome through the forming of jams in the water channels thus cutting off water supply or raising the tail water to an extent sometimes disastrous. Further, it must be realized that surface ice in an open stream converts the waterway to a closed channel, and by the friction imposed by the surface covering transfers the cross-sectional area of maximum velocity to a greater or less depth according to conditions. The velocity factors in stream gauging under such circumstances must, of course, be correspondingly changed.

Anchor ice most often causes trouble by its rising in masses from the river bottom, even rising and carrying stones and boulders of considerable size which have been embedded in the mass. While anchor ice is first formed by the radiation of heat on a cold clear night, this will probably be accompanied by the forming of frazil, the anchor ice becoming the nucleus for the accummulation, such active masses are to be included among the operators' greatest trials.

Frazil ice is the most troublesome, but it is only to be expected where the air temperatures are hovering slightly below the freezing point, and this is a condition to be met at the beginning and end of the winter season or during a changeable period, and after a short experience with it its vagaries may be readily anticipated and the necessary precautions taken. The ice crystals formed by exposure to the cold atmosphere grow rapidly and adhere to one another to form lumps and spongy masses attaching to every cold body it encounters; racks or screens, penstocks, turbines, and all essential parts of water-power equipment are readily affected by enormous accumulations cap-

[1] See *Canadian Engineer*, January 7, 1915.

able of completely closing down the plant. The great majority of power plants have suffered; the modern plant, however, has become more immune from the effects now that a full understanding of the problem is possible.

In selecting the site for power works on a river one must bear in mind the chances of ice troubles. Naturally it is preferable to have large still water pondage immediately above the water intakes; such a provision assures surface ice which will obviate the formation of frazil and anchor ice adjacent to the power works. Unruffled water in the river supply for several miles above the pondage may be expected to reasonably free the lower waters of frazil; this condition is usually readily obtained, as in the damming of the river adjacent rapids or falls are drowned out and the consequent head taken advantage of. The tail-race and lower river must be viewed from the standpoint of ice discharge, and the river course eased sufficiently to preclude any possibility of ice jams. Floating ice may be discharged from the forebay by booms arranged to deflect the ice to ice overflows and runways which may carry it to the tail-race. Ice which may be carried under the boom or screen house curtain so as to accumulate in front of the intake racks has generally to be poled out to the main ice overflow or to a separate runway adjacent to the screens.

It has been found by experience that the source of trouble from frazil ice is its great adhering power to cold bodies in the water. Iron screen racks are much affected when in the presence of frazil; their temperature is but a fraction of a degree below the freezing point. The precautions are obvious. The submerging of iron racks below the surface will ensure their being at the same temperature as the water, and they will not act as conductors of the cold from the air; the top screen section which may extend above the water level may be of wood, which will act as a comparative insulator to the transfer of cold. Iron racks rising above the waterline may be fitted with a housing containing heat supplied by electricity or steam, so that the iron will conduct a small amount of heat throughout its length; the wider application of this is the screen house which is sheltered completely from outside air, and may or may not be heated.

Iron penstocks, and turbine cases, have been known to be completely blocked by frazil ice due to the colder temperature of the iron. The housing-in of all water-carrying equipment is essential where frazil is encountered. The covering of surge tanks to protect against excessive freezing where the surface water is undisturbed for a sufficient period, such as may occur with a continued steady load, is essential.

The problem of housing of penstocks has evolved several practical and economic methods, when burying them is not possible nor desirable. The commonest and possibly the cheapest arrangement is by means of a continuous wooden sheeting having two vertical sides and a sloping or peaked roof, all on a simple wooden framing. A better arrangement and undoubtedly a more desirable method is by the application of metal lath or wire netting on metal or wooden framing plastered over by cement gun or by hand; the same scheme of covering may be used on surge tanks; these, however, are generally of such magnitude that it is preferable to include them in the architectural featuring along with the power-plant buildings.

The necessary exposure of gates, sluices, stop-log guides, and seats, racks, etc., has required in several cases the installation of steam heating plants, supplying permanently placed steam piping for maintaining freely working equipment, and in the notable case of the Shawenegan plant heated air is blown on the protruding racks, and on the incoming water in the screen house.

PART II

ELECTRIC POWER IN CANADIAN INDUSTRY

Part II.

ELECTRIC POWER IN CANADIAN INDUSTRY.

By Charles H. Mitchell, *C.E., M. Inst. C.E., M. Can. Soc. C.E., M. Am. Soc. C.E., Consulting Engineer to Dominion Water Power Branch, Department of the Interior, Canada.*

Electricity maintains its commercial supremacy as a source of energy to the general public as a convenience; to the manufacturer requiring a source of power, on account of its adaptability to his respective needs and by its economy in application; in the field of traction, by its operative simplicity, cleanliness, and comparative silence and suitability to frequent short haul; to the electrometallurgist and electrochemist, by permitting of concentration of energy, simplification of processes and equipment, for its uniformity and control of results, and from its application in the production of materials unavailable from any other source. In communication and therapeutics, its field is absolute. Dominating all these elements of industrial power supremacy, cheapness of electrical energy is paramount.

In the study, from the Canadian standpoint, of the use of electric power and its generation and supply it is necessary to analyse the make-up of the typical power load such as may be found to comprise the greater portion of the aggregate loads throughout the Dominion.

In general, a mixed power load consists of domestic, industrial, or power load, municipal service, commercial lighting, and street lighting. The domestic load has by energetic campaigning by the power-distributing companies been constructed into one involving no mean figures; the former incandescent lighting load generally to be found in meagre quantities, even ten or fifteen years ago, has been greatly amplified, so that the unequipped and unlighted residences, anywhere throughout the Dominion within reach of electrical sources, has become the exception; the day load of the many household electrical accessories and conveniences has appreciably added to the consumed power, tending to flatten out the peaked curve of this load and extend the service hours of the distribution system and transformers over a longer remunerative period and, further, to get fuller advantage of power purchased on a peak-load basis. The non-load night hours are now engaging the attention of the central station with the hopes of commercially establishing electric heating accumulators for charging during such hours. As yet it is the experience that lighting and domestic loads create a peak in early evening, unapproached by any other loads on domestic service transformers.

While the domestic service loads cannot be termed industrial loads, the subject this paper is more properly confined to, examples of loads, to be quoted herein, are appreciably composed of domestic loads and in most cases the present power service originated many years ago from the immediate prospect of this market alone, and to-day it is usually the personal aspect and home convenience of electrical power that carries the great weight in the establishment of a publicly owned system or the granting of service franchises. Directly and indirectly, domestic electrical power service bears a most important relationship with electricity in industry.

For municipal uses such as pumping and street lighting, electricity is universal. Off-peak hour pumping into water reservoirs has proven an economical system when operated as a component of a mixed power load. The enormous strides in application and design of street lighting units, and the great efficiency to be obtained, has placed electrical street lighting far beyond the reach of any other illuminating source.

Electric power in industry has a wide and practically limitless field. As a motive power available in any capacity, conveniently and economically applicable to every class of service, it out-ranks all its competitors, from the rolling mill steam engine reversing its ponderous thousands of horse-power to the infinitesimal foot power of a sewing machine. In the heating and welding of materials, as a part of the process of manufacture, electricity, by its control, speed, and concentration or distribution, enjoys a peculiar field, distinct from either coal or gas.

Electric railways have not reached beyond the industrial, urban, interurban and terminal use. The electrification of trunk lines, which awaits the supply of economic electric power at frequent intervals along the route and the overcoming of the many necessary minor changes in trunk-line operation, besides the enormous capital outlay required, comprise a combination of requirements not considered economically attractive as yet.

Electro-metallurgy and *electro-chemistry* have been responsible for the handling of materials not workable by any other means, have made available new materials and have greatly cheapened the production of many important materials of wide use. Aluminium, calcium carbide, chromium, cyanamid, silicon, etc., are products only from electrical processes. Alkalies, hypochlorite, phosphorus, magnesium, sodium nitrates, etc., are produced at the lowest cost electrically.

Telephony and telegraphy, radio-telephony and radio-telegraphy, in radiography and therapeutics, while possibly providing the greatest conveniences and aids afforded to mankind, are not of such power-consuming magnitude as to require further mention.

The source of electric power for commercial purposes is motive power produced by steam, oil, gas, or water. In Canada it is notable that, without exception, all cities are now supplied by, or are within the economic distribution zone of hydro-electric sources; and, further, commercial conditions are such that power from these sources is available to the consumer at very attractive rates, and it is apparent that the future of power-consuming industries has its foundation in the bountiful and widespread water-power resources of the country.

The Dominion of Canada has an area of 3,729,700 square miles stretching from the Atlantic to the Pacific and from the northern boundary of the United States to the Arctic ocean.

The Northwest Territories, the vast northern portion of Quebec, and the greater part of the Yukon cannot be considered, within our generation, to be factors in the industrial field. The possibilities in these districts from the standpoint of natural resources are not, as yet, with the incomplete investigations made up to the present, capable of appreciation; water-power is plentiful, but so remote from any present market that the capacities of the thousands of known water-powers are not included in statistics; within a limited area, the Yukon is an exception. In the provinces of Nova Scotia, New Brunswick, Prince Edward Island, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia, power is available in great abundance.

Nova Scotia water-powers are, in general, of small dimensions as a result of the limited drainage areas and the low available heads on the various rivers due to the general topography of the country. New Brunswick has many rivers of magnitude, but with gradual drop and small facilities for storage. Prince Edward Island is very limited in water-powers, there being no site capable of development of over 100 horse-power. Quebec and Ontario and the eastern and northern portions of south Manitoba have enormous possibilities in power production, while the western part of Manitoba, southern Saskatchewan, and southeastern Alberta are quite limited in capacities, being the prairie wheat-growing "West" of Canada. The Rocky mountains and eastern foot-hills in Alberta provide a notable source of power, and the province of British Columbia, comprising the western slope of the Rocky mountains to the Pacific ocean, is capable of enormous water-power development.

Within the provinces of the Dominion of Canada, and excluding the Northwest territories, practically all of the Yukon, and the northern and eastern portion of

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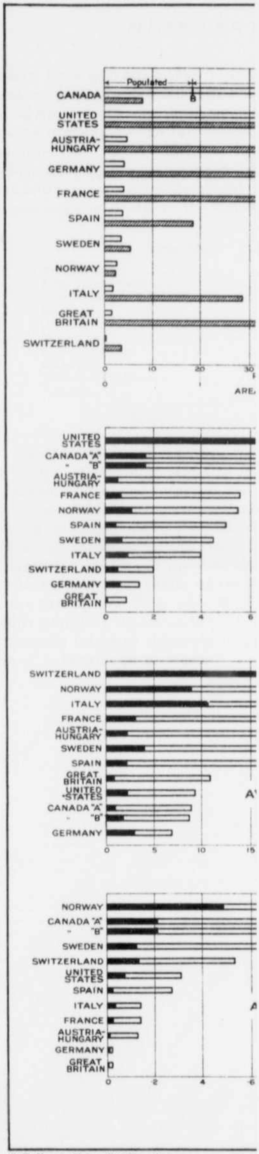


B. E. Norrish, M.Sc., Chief Draughtsman.
N. T. Allan, Draughtsman.

DEPARTMENT OF THE INTERIOR, CANADA.
DOMINION WATER POWER BRANCH.

GRAPHICAL COMPARISON OF

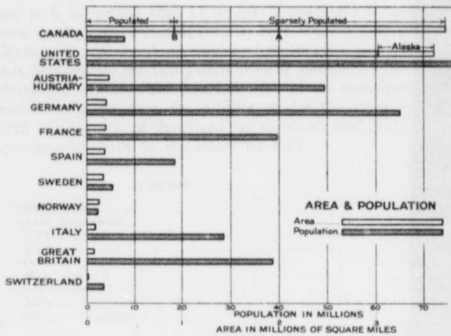
AREA, POPULATION, AVAILABLE AND DEVELOPED WATER-POWER IN CANADA, THE UNITED STATES AND CERTAIN EUROPEAN COUNTRIES.

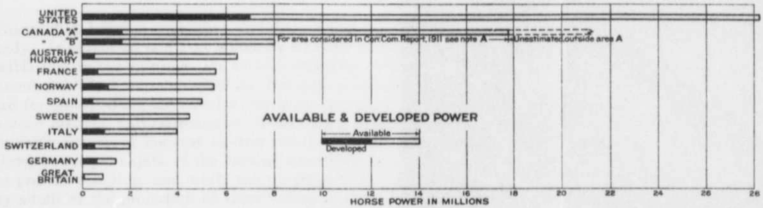
GENERAL NOTE:

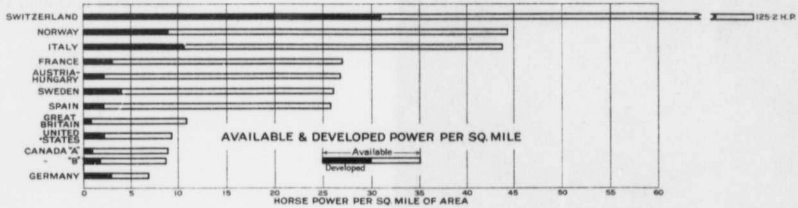
EUROPE. Data concerning available and developed power in Europe taken from Mr. Surveyer's recent paper, read before the Canadian Society of Civil Engineers, revised, where possible, from figures in U.S. Consular Reports, current technical periodicals, etc.

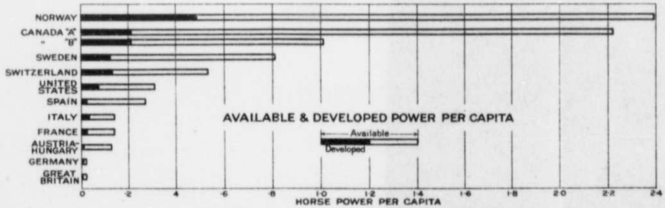
UNITED STATES. Data from Evidence before Senate Committee on Water Power Bill, December, 1914.

CANADA. Available power from Conservation Commission Report, 1911. "A" refers to the area considered in Conservation Commission Report, the remainder of the Dominion being so remote that no specific data is available. "B" refers to the populated area only.









MARCH, 1915.

B. E. Norrish, M.Sc., Chief Draughtsman.
N. T. Allan, Draughtsman.

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Quebec, it is estimated that 17,764,000 horse-power is available, this amount being inclusive, in the case of Niagara Falls, Fort Frances, and the St. Marys river at Sault Ste. Marie, of only the development permitted by international treaties, and further does not contemplate the full possibilities of storage for the improvement of capacities. The developed powers which are inclusive of all water-powers, whether for electrical production, pulp grinders, for milling or for the great many other uses, aggregate 1,712,193 horse-power as developed by turbines, and this amount is distributed over the provinces as shown in the following table:—

Province.	Horse-power Developed.
Nova Scotia	21,412
New Brunswick	13,390
Prince Edward Island	500
Quebec	520,000
Ontario	789,466
Manitoba	56,730
Saskatchewan	45
Alberta	33,305
British Columbia	265,345
Yukon	12,000
Total	1,712,193

The relation between population and water-power developed makes a very interesting study. It cannot be said that a definite relation exists or should exist, although it is possible that in the future as the rapidly changing commercial conditions assume a permanent stability from established markets and universal demand, a constant may be deduced for the equation, the variables being environment, government policy, inherent commercial instinct, natural resources of materials, accessibility of market and, above all, available sources of low-cost electric power.

Horse-power per capita of the various manufacturing countries may be compared on the present standing, and while the contemporary industrial conditions may not readily admit of the projection of these values to the next few years to come, in the commercial future of the world it must be recognized that cheap power will be the keynote of industrial advancement.

Country.	Area Square Miles.	Population (Latest available figures.)	Horse-power available (1915 estimate.)	Horse-power developed, (1915 estimate).	Per cent utilized.	Horse-power per square mile of Area		Horse-power per Capita.	
						Available	Developed.	Available	Develop'd
United States	3,026,600[1]	92,019,900[2]	28,100,000	7,000,000	24·9	9·3	2·31	0·31	0·076
Canada A	2,000,000	8,033,500	17,820,000	1,712,193	9·6	8·91	0·86	2·22	0·21
Populated B	927,800	8,000,000	8,094,000	1,700,000	21·0	8·74	1·83	1·01	0·21
Austria-Hungary	241,330	49,418,600	6,460,000	566,000	8·8	26·8	2·34	0·13	0·011
France	207,100	39,601,500	5,587,000	650,000	11·6	27·0	3·14	0·14	0·016
Norway	124,130	2,302,700	5,500,000	1,120,000	20·4	44·3	9·02	2·39	0·487
Spain	194,700	18,618,100	5,000,000	440,000	8·8	25·7	2·27	0·27	0·024
Sweden	172,900	5,521,900	4,500,000	704,500	15·6	26·0	4·08	0·81	0·127
Italy	91,280	28,601,600	4,000,000	976,300	24·4	43·8	10·7	0·14	0·034
Switzerland	15,976	3,742,000	2,000,000	511,000	25·5	125·2	32·0	0·53	0·137
Germany	208,800	64,903,400	1,425,000	618,100	43·4	6·8	2·96	0·02	0·010
Great Britain	88,120	38,802,500	963,000	80,000	8·3	10·9	0·91	0·02	0·002

Canada "A" 2,000,000 square miles taken as the area treated in the Conservation Commission's estimate of available water-power, and the area which we may expect to see fairly thickly settled during the next few decades, 3,729,700 square miles=area of whole Dominion.

[1] Excluding Alaska (area about half million square miles).

[2] 1911 Census + 12 per cent.

The comparison of the above figures is shewn diagramatically facing page 32.

As statements from official sources, or as computed from all accessible sources of information, the amounts of water-power available and developed and the horse-power per capita have been compiled and are here presented for the various industrial countries of Europe and America.

No uniform method of obtaining the figures of horse-power available has been employed, information as to the extent of possible storage in the respective cases not being available and, further, these amounts may be the aggregate of individual estimates as in the case of Canada,[1] or estimates of district totals as in the case of United States,[2] both of the latter cases, moreover, do not include maximum economic storage, and include only such power plants as may reasonably be included within the range of market in the near future.

Notwithstanding such possible discrepancies in the compilation of available power, the developed power has permitted of close totalling and thus, with population,[3] gives reliable figures for the horse-power per capita.

While the United States leads in available capacity and in power developed, and Norway leads in power developed per capita, available power in Canada is enormous and the developed power now ranks second in amount developed and in amount per capita. The distribution of available power in Canada adjacent to the natural resources and to the transportation routes ensures the continuation of rapid development, there existing every indication that the rate set between 1911 and 1914 of an increase from 1,016,521 horse-power developed to 1,712,193 horse-power developed will be readily maintained.

Twenty years ago the position of the various manufacturing countries, in the scale of industrial production, undoubtedly bore a direct relation to the consumption of coal, and power was a major factor in industry. In the present day, where so many factors are in a transition stage, it cannot be said that either coal consumption alone or water-power developed alone is indicative of commercial standing, although the aggregate power equivalent may do so. All such studies of power economics, however, will disclose that low-cost power is the underlying element of the industrial world.

Fortunate as is Canada in water-power distribution, the added advantage of a great share in the world's mineral resources with, moreover, the proximity of power to the mines, will by their inter-dependence provide a great stimulus to the development of both. Coal, iron, copper, nickel, gold, silver, cobalt, lead, asbestos, mica and corundum are the principal minerals, and the output value of these, aggregating $186,802,-406 in 1910, is one of the chief elements in the commerce of the Dominion.

The appreciation of low cost of power is relative only: relative in the first place to our ideas of absolute cost of commercial power as produced, possibly, by the steam engine; and secondly, low cost, relatively, when cost of power as a major factor in production is lower than the critical power cost at which manufacture becomes commercially feasible. We are apt to think of low cost of power as something tangible and absolute. Under certain conditions, steam power at $100 per horse-power per year is low-cost power, and under certain conditions power at $6 per horse-power per year is high-cost power; $6 power may show a loss in an extensive electrochemical plant, while $5 power may show an attractive profit.

In general, low-cost power is considered by the majority to be synonomous with hydro-electric power. The constituents of power cost may be readily analysed. In a hydro-electric generating plant, charges against capital—the aggregate of interest, sinking fund to retire bonds, depreciation fund, taxes and insurance, etc., go to make up the greatest portion of the total cost; water charges, if any; operation, maintenance, and supplies are, in general, the minor items. In the steam plant the cost of fuel alone will generally greatly exceed capital charges, while capital cost of a steam plant may

[1] "Water Powers of Canada," Commission of Conservation, Ottawa, 1911.
[2] "Forest Service, Department of Agriculture, United States.
[3] Population compiled from Encyclopædia Britannica, 11th edition.

readily compare with the capital cost of an hydraulic generating plant. In the steam plant the greater the capital cost properly expended the greater the over-all efficiency, and thus the increase in the minor factor of capital charge may provide a more than proportionate decrease in the major item of fuel. In the hydraulic plant, efficiencies are practically standardized and fixed; capital charges, however, greatly vary from many causes within the wide limits of a low-cost plant with a head of several hundred feet, with small headworks and a small number of large capacity generating units, to the high-cost plant with low head, with extensive construction and a multitude of small units.

Quality of power is an element in the cost of an hydro-electric plant. In the supply of industrial power, continuity of service and more or less adherence to a definite standard of electrical characteristics of the supply are the essentials of quality. Absolute continuity is impractical, and the safeguards required in securing even an approximation of continuity in generating plants and transmission and distribution systems are usually so costly as to prohibit cheap power. The electrical characteristics of voltage and frequency, as representing the factors of greatest appeal to the consumer, are dependent on design and operation, and their maintenance is readily to be obtained.

In the electro-chemical and electro-metallurgical field the lowest-cost power only can be entertained, and such is available only from the largest of plants; power at from $6 to $10 per horse-power per year must be the aim to secure such a market.

While abundance of water-powers exist in Canada to-day, only the most cautious governmental administration policies can provide for the anticipated requirements of the future. The majority of water-powers within market range will undoubtedly be developed, and the future is one of vital importance.

It has been fortunate that, in Canada, the water-power rights have mostly remained in the control of the Dominion or Provincial Governments. The Dominion Government controls navigable streams and their water-powers throughout the Dominion, and the water-powers of the provinces of Manitoba, Saskatchewan, and Alberta, the Yukon and the Northwest territories. Quebec, and New Brunswick have granted powers heretofore on broad leases, while Nova Scotia has many of its water-powers privately owned outright from eighteenth-century Government land grants; these provinces are now planning much more efficient control. In the province of Ontario the administration has become of such exceptional nature that it is worthy of a very complete study, as being possibly the greatest of municipal power undertakings.

The Dominion Government administration policy affords every reasonable protection to the public as to rentals, periodic revisions, control of rates, limited grants, etc., and at the same time fosters legitimate private enterprise to return reasonable profits. Regulations are in force affording all possible assistance to the development of water-powers which have every reasonable assurance of economic utilization and, further, before the authorization to proceed with development is given, complete investigations are undertaken to prove the economic features of design, capacities, and costs, and eventually supervision is carried out during construction. Proper government supervision and control of the construction and maintenance of all developments is the only safe method of intelligently initiating construction and maintaining an adequate system of river improvement for power purposes.

The Hydro-Electric Commission of Ontario has created a world-wide interest in an experiment of publicly owned power. The history and results of the undertaking deserve fullest consideration in dealing with electric power in Canadian industry.

For some years previous to 1906, several of the energetic and leading citizens of central southwestern Ontario had endeavoured to secure a working basis for a comprehensive scheme of supplying power to the various municipalities, the city of Toronto comprising the largest interests in the matter. In 1906 the Provincial Government created a commission empowered to investigate power conditions every-where in the province, and a further commission was established after the rendering of the preliminary reports on the situation which resulted in by-laws on the question of power supply being voted upon by the interested municipalities, and an agreement was entered into by the cities and towns of Toronto, Hamilton, London, Brantford, Guelph, Stratford, St. Thomas, Woodstock, Ingersoll, Berlin, Galt, Toronto Junction, Hespeler, St. Mary's, Preston, Paris, Waterloo, New Hamburg, and Weston with the Hydro-Electric Power Commission of Ontario for a supply of electric power to be transmitted from Niagara Falls. The commission is empowered by Act of Parliament to make expenditures for the carrying out of the necessary work, and these expenditures are repayable to the commission by the municipal corporations which have entered into contracts. The price per horse-power per year that each municipality has to pay for the respective block of power is the cost to the commission and, in addition: (*a*) interest at the rate of 4 per cent upon the moneys expended by the commission on capital account in the construction or purchase of works; (*b*) an annual sum sufficient to form in thirty years a sinking fund for the retirement of the securities issued by the province under the Act for the payment of the cost of the works; and (*c*) line loss and the cost of operating, maintaining, repairing, renewing, and insuring the works. The amounts payable are annually adjusted and apportioned.

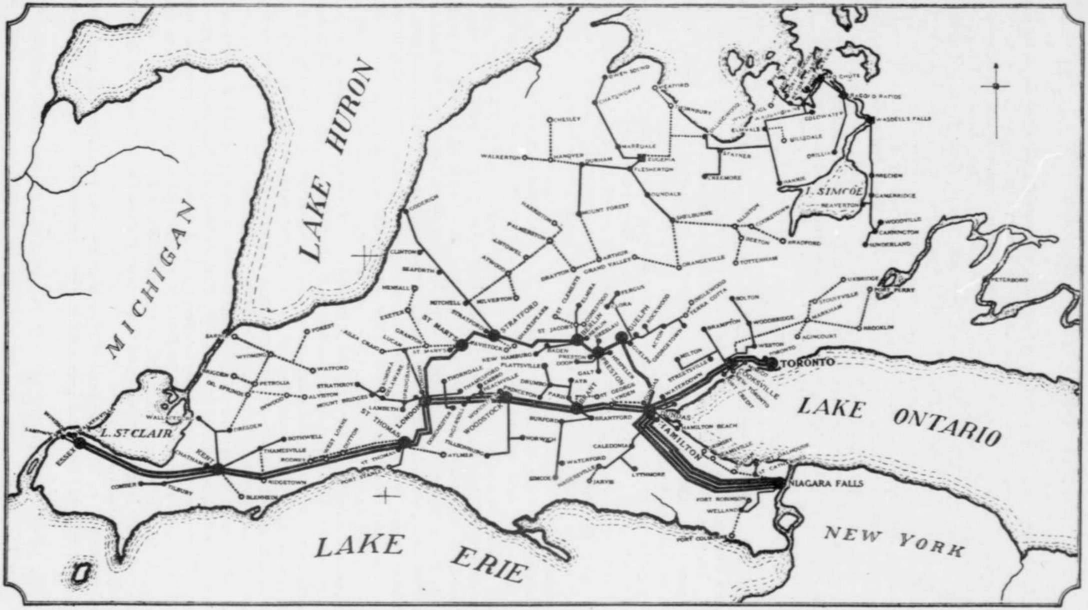
Tenders are called for the supply of electrical power from the producing companies at Niagara Falls, Ont., and in March, 1908, the commission entered into a contract with the Ontario Power Company for amounts up to 100,000 horse-power. Power was obtained from this source at the price of $9.40 per horse-power per anuum for amounts up to 25,000 horse-power, and when the power demand exceeded 25,000 horse-power the prices became $9 per horse-power per annum. This price is for 12,000-volt 3-phase, 25-cycle power delivered in the commission's transformer station in Niagara Falls.

In addition to the district served in the Niagara system, the commission buys power from the Kaministikuia Power Company of Fort William, Ont., and sells to the city of Port Arthur; from the Ottawa and Hull Light and Power Company, selling to the city of Ottawa; from the Auburn Power Company, selling to the city of Peterborough; and from the York and Ontario Power Company for selling to the group of towns in the St. Lawrence system. Further, the commission purchased the generating and distributing system of the Simcoe Railway and Power Company at Big Chute on the Severn river, and made considerable extensions to the distribution system, this plant being arranged to tie in with a generating plant being built by the commission at Eugenia falls, where a 542-foot head is to be obtained, and which is to supply power on June 1, 1915. A generating station and distribution system has just been completed at Wasdell's falls on the Severn river at the outlet of lake Couchiching to supply power to the Wasdell's falls system. The commission is at present engaged on the preliminaries to construction of radial electric railroads in the vicinity of Toronto, and has undertaken the engineering and construction of the electrification works of the London and Port Stanley railway.

A reference to the map on page 38 will well show the extent of the distribution area served by the commission, excluding the Port Arthur, Ottawa, and St. Lawrence systems. The transmission lines to-day aggregate 395·7 miles of double-circuit 110,000-volt line; 37 miles of single-circuit 110,000-volt line, 722 miles of single- and double-circuit pole lines of voltages from 13,200 up to 46,000; and 77 miles of low-voltage circuits. All the 110,000-volt lines and the greater portion of the others are included in the Niagara system.

On December 31, 1914, the number of customers served by the system was 96,744. on February 28, 1915, the power purchased by the commission was over 100,000 horse-power.

Three features are outstanding: first, the power is intended to be available for every class of consumer, rural or urban; second, the equipment and general design



Ontario Hydro-Electric Commission's Systems, Southwestern Ontario.

is selected for most permanent and effective service; third, the power is supplied to the municipalities at cost.

Being assisted by complete effective legislation from both provincial and municipal standpoints, these operations of the Hydro-Electric Power Commission are the broadest examples of municipal ownership. The field entered by the commission, wherever established municipal plants did not previously exist, was quite fully covered by private companies.

The adverse criticism which a publicly owned electrical power system must expect when entering an established commercial market was based, at the inception of the commission's plans, on the monopolistic tendency, on the possible effects of the introduction of provincial party politics, and on the experimental nature of the scheme. The entire success as a commercial system, as an engineering work, and as a popular undertaking has entirely vindicated the situation.

The sale of power at cost eliminates much competition. This cannot be said to be creating a monopoly, as several of the established companies were able to reduce their rates to a corresponding amount and, with the decidedly less remunerative rates have been able, by a much increased activity in the handling of business, to maintain a sound financial existence. The popular idea of the effect of a monopoly is that the public pays more and gets less in return, a condition certainly not comparable with the commission's enterprise.

The selection of the personnel of the commission has been a very judicious one, quite beyond criticism from the [illegible]y standpoint, and to these men, of whom Sir Adam Beck, K.B., has been the chairman from the beginning, must belong much of the credit for the present position.

The experimental features of the engineering and commercial problems involved, particularly, long distances, it being 233 miles from Niagara Falls to Windsor; the fact that 110,000-volt transmission at the time designs were commenced was in its earliest stages; that power was to be available to the municipalities at 25 cycles for use in established markets using 60 cycles and 133 cycles; the necessary duplication in many cases of distribution systems; published power prices were based on estimates only, of cost of construction and distribution; large blocks of power with corresponding prices were apportioned to the respective municipalities considerably in excess of their needs at the time and, in reality, in most cases in excess of the power consumption from all sources of steam, water, gas, and oil; an appreciably leavening factor was to be introduced into the industrial rivalry of the various communities; the consideration of an aggregate load of 100,000 horse-power, as was anticipated, and which was to be an element in the ultimate success, was beyond the comprehension of the great majority; and possibly, lastly, no apparent provision was made for the development period in acquiring the load contracted for.

The analysis of the foregoing is quite beyond the capabilities of this paper. In 1908 the municipalities entering into the agreement subscribed for 29,335 horse-power; distribution of power was commenced in 1910; in 1915 the power will be in excess of 100,000 horse-power in the Niagara system alone. These figures may broadly suffice in place of a complete analysis, as each of the problems enumerated was eventually met by a successful solution. The rate of this growth in the Niagara system from 1910 to 1914 is shown graphically on page 40.

The municipalities originally included in the power agreements numbered fifteen; on February 28, 1915, this number had increased to eighty-two, and the growth in the number of consumers is well shown in the following table:—

—	Approximate number of consumers (to December 31, 1914.)		
	1912	1913	1914
Light	33,568	63,157	93,179
Power	1,399	2,532	3,565
Total	34,967	65,689	96,744

The total cost of the Niagara system of the commission to October 31, 1914, is as follows:—

Transmission Lines—		
Right of way	$ 574,806.67	
Steel tower lines	2,095,050.23	
Telephone	129,706.69	
Relay system lines	54,537.32	
Conduit systems, Ontario Power Co., to Niagara station	66,844.67	
		$ 2,920,945.58
Windsor Extension (Operating, 1915.)—		
Right of way	195,060.87	
Steel tower and telephone lines	835,734.97	
		$ 1,030,795.84

Duplication of Transmission Lines, Niagara to Dundas (Operating, 1915)—		
Right of way	$ 47,264.25	
Steel tower and telephone lines	258,305.92	
		$ 305,570.17
Wood pole Line in operation	$ 1,047,924.46	
Wood Pole Lines in course of construction	191,572.20	
		$ 1,239,496.66
Welland and St. Catherines District lines		8,239.20
Rural Line construction		159,382.23
Transformer Stations—		
Stations in operation	$ 1,905,352.25	
Stations and extensions in course of construction	342,080.83	
		$ 2,247,433.08
Distribution stations in operation	$ 86,674.65	
Distribution stations in course of construction	5,138.18	
		$ 91,812.83
Total		$ 8,003,675.59

The aggregate of the annual cost of operation, capital charges, up-keep, etc., of the municipal systems is as follows for the years 1912, 1913, and 1914:—

——	Dec. 31, 1912	Dec. 31, 1913	Dec. 31, 1914
Number of municipalities included in report	28	45	69
Operating and maintenance expenses	$ 1,086,135.00	$ 1,511,048.00	$ 2,012,754.07
Debenture charges and interest	291,033.00	479,995.00	661,949.23
Total annual expense	1,377,168.00	1,991,043.00	2,674,703.30
Total revenue	1,617,674.00	2,611,918.00	3,433,936.16
Gross surplus for year	240,506.00	620,875.00	759,232.86
Depreciation charge	179,847.00	230,480.00	357,883.31
Net balance, profits in excess of depreciation	60,659.00	390,395.00	401,349.55
Total plant value	6,349,711.00	9,196,483.00	12,901,125.43
Net debenture debt and overdraft	5,882,156.00	10,468,351.78	12,702,689.81
Accumulated gross receipts invested in plant extension	....	861,381.00	1,601,167.42
Accumulated depreciation reserve	....	410,327.00	850,618.07
Net surplus from operation	....	451,054.00	750,549.35

The assets of the sixty-nine municipalities in the system to December 31, 1914, were:—

Lands and buildings	$ 791,732.20
Sub-station equipment	1,476,087.84
Distribution system, overhead	3,422,763.93
" " underground	807,153.53
Line transformers	787,613.52
Meters	1,172,475.11
Street lighting equipment, regular	1,071,255.37
" " ornamental	270,386.55
Miscellaneous equipment and construction equipment	2,062,035.90
Steam or hydraulic plant	420,108.33
Old plant	478,881.56
Other miscellaneous assets	140,631.56
	$ 12,901,125.40

Table No. 1 shows municipal power rates for the year 1914, and covers cost to municipality per horse-power per year, power rates, domestic and commercial lighting, and street lighting.

The rates at which the commission sells to the municipality consider the distance from the Niagara or other generating source, cost of 110,000-volt and 13,000-volt local

TABLE No. 1—Municipal Rates, 1914.

Municipality.	Cost of power to municipality per h.p. per year.	Lighting Rates. Domestic Per 100 sq. ft.	Lighting Rates. Domestic Per kw-hr.	Lighting Rates. Commercial 1st 30 hr. per kw-hr.	Lighting Rates. Commercial All add'l per kw-hr.	Lighting Rates. Prompt payment discount.	Power Rates. Per h.p. per month.	Power Rates. 1st 50 hr. per month per kw-hr.	Power Rates. 2nd 50 hr. per month per kw-hr.	Power Rates. All add'l per kw-hr.	Power Rates. Prompt payment discount.	Street lighting.
	$ c.	c.	c.	c.	c.	%	$ c.	c.	c.	c.	%	$ c.
Acton	36 00	4	5	10	5	10	1 00	4·3	2·9	0·4	10	15.00 per 100-w. incan.
Ancaster	Served by Dundas	4	5	10	5	10	1 00	3	2	0·25	10	14.00 "
Baden	32 00	4	4·5	9	4·5	10	1 00	2·8	2·5	0·3	10	12.00 "
Barrie	33 70	4	4·5	9	4·5	10	1 00	3·6	2·4	0·3	10	12.00 "
Beachville	31 00	4	5	10	5	10	1 00	3	2	0·25	10	10.00 "
Beaverton	Note A.	3	4	8	4	10	1 00	3·6	2·4	0·3	10	13.00 "
Berlin	21 50	4	3·5	7	3·5	25	1 00	2·1	1·4	0·2	10	9.00 "
Brampton	25 00	4	3	6	3	20	1 00	2·8	1·8	0·2	10	8.00 "
Brantford	19 50	4	3	6c. 1st30 hr. 3c. next 70 hr.	0·15	10	1 00	1·9	1·3	0·15	10	8.00 " 40.00 Magnetic arc.
Bullock's Corn. and Greensville.	Served by Dundas.	4	4	8	4	10	1 00	2·8	1·8	0·25	10	12·00 100-w. incan
Caledonia	24 00	4	4	8	4	10	1 00	3·7	2·5	0·3	10	12.00 100-w. incan.
Cannington	Note A.	3	4	8	4	10	1 00	3·6	2·4	0·3	10	13.00 "
Chesterville	44 43	4	5	10	5	10	1 00	4·2	2·8	0·3	10	13.00 "
Clinton	41 00	4	5	10	5	10	1 00	4·9	3·3	0·4	10	12.50 40-c.p. incan.
Coldwater	28 00	4	4	8	4	10	1 00	3·2	2·1	0·3	10	12.00 100-w. incan.
Collingwood	33 97	4	4·5	9	4·5	10	1 00	3·6	2·4	0·3	10	12.00 "
Creemore	54 00	4	7	14	7	10	1 00	6·4	4·3	0·5	10	12.50 "
Dundas	15 00	4	3	6c. 1st25 hr. 3c. next 75 hr.	0·15	10	1 00	1·6	1·1	0·15	15	9.00 "
Elmira	38 00	4	5	10	5	10	1 00	4·7	3·1	0·4	10	12.00 "
Elmvale	31 00	4	4·5	9	4·5	10	1 00	3·6	2·4	0·3	10	12.00 "
Flora	33 97	4	4·5	9	4·5	10	1 00	3·9	2·6	0·3	10	12.50 "
Fergus	33 97	4	4·5	9	4·5	10	1 00	3·9	2·6	0·3	10	12·50 "
Galt	21 50	3	2·5	6	2·5	10	1 00	1·9	1·3	0·15	25	8.50 "

Georgetown.......	36 00	4	5	10	5	10	1 00	4	2·7	0·3	10	12.50 "
Glen Williams....	Served by Georget'n	4	6	12	6	10	1 00	4·3	2·9	0·4	10	14·00 "
Goderich.........	37 00	4	4·5	9	4·5	10	1 00	4·8	3·2	0·4	10	15.00 80-c.p. incan. 55.00 3-lt. standard 40.00 1 " 25.00 1 "
Guelph...........	21 00	4	4	8	4	25	1 00	2	1·5	0·2	25	9.00 100-w. incan.
Hagersville.......	33 21	4	4·5	9	4·5	10	1 00	3·9	2·6	0·3	10	12.00 "
Hamilton.........	15 00	4	3	6c. 1st25 hr. 3c. next 75 hr.	0·2	20	1 00	2·1	1·4	0·2	25 & 10	8.00 " 13.75 250-w. " 50.00 500-w. nitrogen-filled on stand.
Hespeler..........	23 00	4	4·5	9	4·5	10	1 00	3	2	0·25	10	12.00 100-w. incan.
Ingersoll..........	25 50	4	4	8	4	10	1 00	2·8	1·8	0·2	10	12.00 80-w. " 12.50 100-w. "
London...........	23 00	4	3	6c. 1st30 hr. 3c. next 70 hr.	0·6	25	1 00	2·5	1·7	0·2	10	11.00 75-w. " 12.85 100-w. "
Midland..........	19 45	4	3	6	3	10	1 00	1·7	1·1	0·15	10	13.50 " " 35.00 500-w. arc.
Milton............	28 00	4	4	8	4	10	1 00	3	2	0·25	10	9.00 100-w. incan.
Mimico...........	30 00	4	4	8	4	10	1 00	3·3	2·2	0·3	10	11.00 "
Mitchell..........	37 00	4	4	8	4	10	1 00	4·2	2·8	0·3	10	12.00 "
New Hamburg....	32 00	4	4	8	4	10	1 00	3·8	2·5	0·3	10	9.00 "
New Toronto.....	28 00	4	4	8	4	10	1 00	3	2	0·25	10	12.00 "
Norwich..........	32 00	4	4	8	4	15	1 00	3	2	0·25	10	12.00 " 9.00 60-w. incan. 10.00 100-w. "
Ottawa...........	15 00	4	2·5	6	2·5	20	1 00	1·8	1·2	0·15	20	45.00 Arc.
Paris.............	21 00	4	3·5	7	3·5	10	1 00	2·5	1·7	0·2	10	11.00 100-c.p. incan.
Penetang..........	26 50	4	3	6	3	10	1 00	1·7	1·1	0·15	10	12.00 100-w. "
Peterborough.....	18 00	3	2·5	6	2·5	10	1 00	1·3	0·8	0·1	10 & 10	12.00 16&32-c.p.incan. 50.00 500-w. arc. 50.50 magnetic arc.
Petersburg and St. Agatha......	Served by Baden.	4	6	12	6	10	1 00	5·1	3·4	0·4	10	
Port Arthur.......	22 25	4	2·5	6	2·5	10	1 00	2	1·3	0·15	10	5.00 60-w. incan. 8.30 100-w. "
Port Credit.......	28 00	4	4	8	4	10	1 00	3	2	0·25	10	11.00 "
Port Dalhousie...	21 50	4	3	6	3	10	1 00	2·1	1·4	0·2	10	
Port Robinson....	Served by Welland	4	3	6	3	10	1 00	1·8	1·2	0·15	10	
Port Stanley......	42 70	4	4·5	9	4·5	10	1 00	5	3	0·4	10	16.00 "
Prescott..........	34 05	4	4	8	4	10	1 00	2·8	1·8	0·2	10	
Preston...........	21 00	4	4	8	4	20	1 00	2·3	1·6	0·2	20	11.00 60-w. incan. 12.00 100-w. "
Rockwood........	38 00	4	5·5	11	5·5	10	1 00	4·7	3·1	0·4	10	13.00 " "
Seaforth..........	40 00	4	4	8	4	10	1 00	4·3	2·9	0·4	10	15.00 " " 12.00 75-w. "

TABLE No. 1—Municipal Rates, 1914—*Concluded.*

Municipality.	Cost of power to municipality per h.p. per year.	Lighting Rates.					Power Rates.					Street Lighting.
		Domestic		Commercial		Prompt payment discount.	Per h.p. per month.	1st 50 hr. per month per kw-hr.	2nd 50 hr. per month per kw-hr.	All add'l per kw-hr.	Prompt payment discount.	
		Per 100 sq. ft.	Per kw-hr.	1st 30 hr. per kw-hr.	All add'l per kw-hr.							
	$ c.	c.	c.	c.	c.	%	$ c.	c.	c.	c.	%	$ c.
Sebringville	Served by Stratford.	4	5	10	5	10	1 00	5·4	5·6	0·4	10	
St. Catharines	14 00	4	3	6c. 1st30 hr. 3c. next 70 hr.	0·6	25	1 00	1·8	1·2	0·15	25	8.00 100-w. incan.
St. Mary's	29 50	4	5	10	5	10	1 00	3·6	2·4	0·3	10	13.00 100-w. incan. 25.00 250-w. nitrogen. 65.00 Arc.
St. Thomas	28 00	4	2·5	6	2·5	20	1 00	2·5	1·7	0·2	10	10.00 75-w. incan. 53.00 Arc.
Stayner	43 57	4	4·5	9	4·5	10	1 00	4·2	2·8	0·3	10	12.00 100-w. incan. 9.00 60-w. "
Stratford	30 00	4	4	8	4	20	1 00	3·6	2·4	0·3	10	
Sunderland	Note A.	3	6	12	6	10	1 00	4·5	3·0	0·4	10	
Thamesford	45 00	4	6	12	6	10	1 00	5·6	3·8	0·5	10	14.00 100-w. "
Thorndale	45 00	4	6	12	6	10	1 00	5·6	3·8	0·5	10	14.00 "
Tillsonburg	32 00	4	4	8	4	10	1 00	3·8	2·5	0·3	10	11.00 "
Toronto	15 00	4	3	8	3	10 to 20	1.35 1st 10 h.p 1.00 all add'l.	1·5	1	0·5	10to 20	9.00 "
Walkerville	38 00	3	4	8c. 1st30 hr. 4c. next 70 hr.	0·8	10	1 00	3	2·4	0·3	10	10.50 60-w. incan.
Waterdown	26 00	4	5	10	5	10	1 00	3·5	2·4	0·3	10	10.00 100-w. "
Waterloo	22 50	4	4	8	4	25	1 00	2·5	1·7	0·2	25	8.75 100-w. mul. or 75 w. series incan. 10.00 100-w. ser. incan. 10.50 150-w. mult. " 25.00 3-lt. standard 1-100-w. & 2-60-w.

Welland.......	14 00	4	3	6	3	25	1 00	1·8	1·2	0·15	25	40.00 5 lt. standard 1-100-w. & 2-60-w. incan. 18.00 250-w. incan. 9.00 100-w. "
West Hamilton...	Served by Dundas.	4	4	8	4	10	1 00	2·8	1·8	0·2	10	14.00 "
Weston..........	30 00	4	3	6	3	10	1 00	3	2	0·2	10	12.00 " 40.00 5-lt. st., 4-100-w. incan.
Winchester........	43 77	4	4	8	4	10	1 00	3·1	2·0	0·25	10	15.00 100-w. incan.
Windsor..........	38 00	3	4	8c. 1st30 hr. 4c. next 70 hr.	0·8	10	1 00	3·6	2·4	0·3	10	
Woodbridge.......	33 83	4	4·5	9	4·5	10	1 00	3·9	2·6	0·3	10	
Woodstock........	23 00	4	3	6	3	20	1 00	2	1·5	0·2	10	25.00 250-w. incan. 10.00 60 or 100-w. incan.
Woodville.........	Note A.	3	6	12	6	10	1 00	4·5	3·0	0·3	10	

NOTE A.—Service commenced during October, 1914.

systems of supply and the amount and load factor of power consumed. The commission recommends the rates to be applied by the municipality for the consumers, and the municipalities, in general, adopt them. The rates for sale are now on a uniform basis and involve a service charge which, in case of power, consists of a flat rate of $1, a special rate of approximately twelve times the standard rate for the first fifty hours of service each month, and of approximately eight times the standard rate for the second fifty hours of service each month, the balance being at a standard rate per kilowatt hour. Domestic lighting rates bear a service charge of 3 or 4 cents per 100 square feet of floor area per month and a standard rate of from 2·5 to 7 cents per kilowatt hour. Commercial lighting rates in general have a service charge involving the first thirty hours per month and a standard rate for all additional time. Discounts for prompt payment apply throughout. The average rate paid for domestic service is calculated to be 3·7 cents per kilowatt hour. Street lighting rates are, in general, flat rates applied to the particular type of street lighting units used by each respective municipality.

Power is bought from the Ontario Power Company on a 20-minute peak basis, and taken by the municipalities in a similar manner. The oversale of power by the commission, resulting from the time distribution of the respective superimposed pay peaks is quite an appreciable amount, and is in excess of the line and transformer losses, etc., which has justified the commission in excluding loss costs from power rates; the flattening of the load curve, however, over the 24-hour period is gradually reducing the oversale.

As examples of the nature of daily load curves, typical summer and winter loads are shown on page 47. The individual loads are typical commercial, domestic, and municipal loads, and do not include any electrochemical or electrometallurgical loads. The municipal nature of practically all the loads concerned has shown the possibilities of flattening the 24-hour load curve. Pumping to reservoirs is undertaken on off-peak hours, and is responsible to a great extent for the magnitude of night loads as shown, and again the pumping equipment usually includes synchronous motors which, when necessarily operating as day loads, have a power factor corrective value favourably comparative with their energy consumption. The load factor on the Niagara system is said to average about 80 per cent.

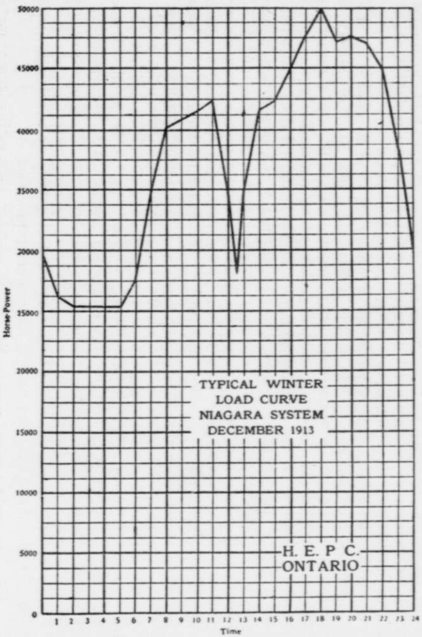
The Ontario Power Company at Niagara Falls, the source of power for the Niagara system, has an installed capacity of 160,000 horse-power in fourteen generator units and, in addition to the Hydro-Electric Commission of Ontario, has a very large market established in New York state, through the Niagara, Lockport, and Ontario Power Company, and a considerable market in Ontario adjacent to the generating plant.[1]

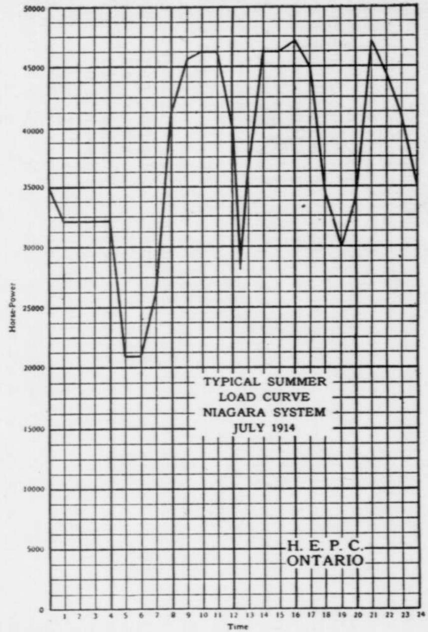
The Big Chute generating station owned by the Hydro-Electric Commission, and which serves the Severn system, is shown on plan, page 49.

Previous to the use of the commission's power, the industrial market for steam generating central electric stations was limited, as the rate for power from the water-power companies bore a recognizable relation to cost of power from isolated steam-power plants of corresponding capacities. The municipalities served by the commission represent the major portion of the industrial centres of the province, and amongst these considerable rivalry has existed as to their industrial growth.

The practice of granting of municipal bonuses of fixed taxation or water rates, debentures or bond guarantees, free sites, money grants, etc., greatly in vogue several years ago, is gradually disappearing and, aside from these inducements, the individuality of the community was chiefly based upon transportation facilities, labour economics, and cost of power. The elimination of cost of power as a selective factor by the application of comparatively similar rates over a wide area, and the discouragement of bonusing, has led to a more fruitful and substantial competition among the

[1] See publications issued by the Ontario Power Company.





Typical Winter and Summer Daily Load Curves.

municipalities, the active improvement of all public services directly influencing the conditions of transportation and labour.

The powers of the commission are very wide, and extend far beyond the distribution of power. Rates throughout the province may be investigated and controlled on application of any municipality; existing systems and undeveloped sites may be bought or expropriated; systems, in part or complete, may be designed, financed and constructed; rivers may be improved for storage purposes, and so forth. These are particularly mentioned as they have been included in the actual work of the commission to date. Further, by its administration conjointly with the Provincial Department of Lands, Forests, and Mines of all water-power matters under provincial jurisdiction, that is, excluding only such affairs as arise under the Dominion Government's rights on navigable streams, the interests of the municipalities are fully guarded.

The existing competitors, in such portions of the province as are not directly served by the commission's systems, either by influence of the commission or by respect for its powers, sells at quite comparable rates.

As examples of two conditions of development quite different in aspect to the Hydro-Electric Commission, but which also are well worth study, reference is made herein to the Shawenegan system in the province of Quebec, and to the developed and undeveloped sites on the Winnipeg river in the province of Manitoba. Special attention must be directed to the curves of the Hydro-Electric Commission, to the curves of the Shawenegan system, and to the loads in the city of Winnipeg, as denoting the rapid growth in power consumption. It is to be found that throughout the whole of Canada the loads of the power systems have increased rapidly. The consideration of such rates of increase as being applicable to the future creates a most striking condition, and the development to meet such demands can only be supplied by the most careful utilization of water-power sources.

The Shawenegan Water and Power Company at Shawenegan Falls, Quebec, has an interesting system for study as to industrial use of electric power. This plant is noted for several reasons: first, its magnitude; second, its extent of distribution; third, its creation of an industrial centre from the power standpoint alone; and fourth, its supplying of power for several electrochemical plants.

Shawenegan Falls is situated on the St. Maurice river about 20 miles north of the St. Lawrence river and about 80 miles east of Montreal. The St. Maurice river, on completion of the storage works now under construction,[1] will have a capacity of 204,000 horse-power at the minimum-flow period, which practically corresponds to the present capacity of the installed machinery at Shawenegan Falls. The water is used in the two electric generating stations of the company and, in addition, water is sold to the Northern Aluminium Company for use in their turbines, and to the Belgo-Canadian Pulp and Paper Company. The Northern Aluminium Company uses water to generate 33,000 horse-power for use in their reduction furnaces, the direct-current generators being installed connected to the hydraulic turbines, the water rates being on the basis of direct current output. In the Belgo-Canadian Pulp and Paper Company, 14,000 horse-power is delivered by turbines on the pulp grinders. In addition, the Canadian Carbide Company at Shawenegan Falls utilizes 12,000 horse-power, and a cotton factory, 550 horse-power, so that, besides a miscellaneous local load, industries have been created consuming nearly 60,000 horse-power at a site where but a few years ago no community existed and transportation was entirely absent.

The map on page 50 shows the large field which this company serves with its 675 miles of high-voltage lines and 105,000 horse-power transmitted.

The Shawenegan power plants are two in number, aggregating approximately 150,000 horse-power capacity. No. 2 plant[2] contains five units, each of 20,000 horse-power capacity. The hydraulic bay and electrical bay of No. 2 generating station are shown on page 51.

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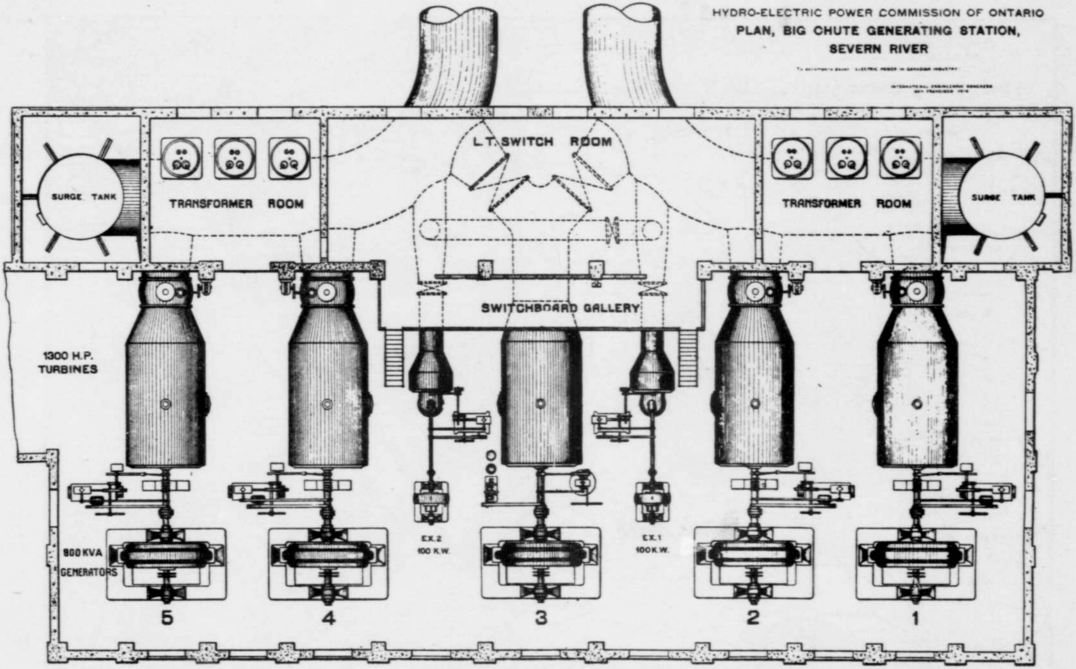
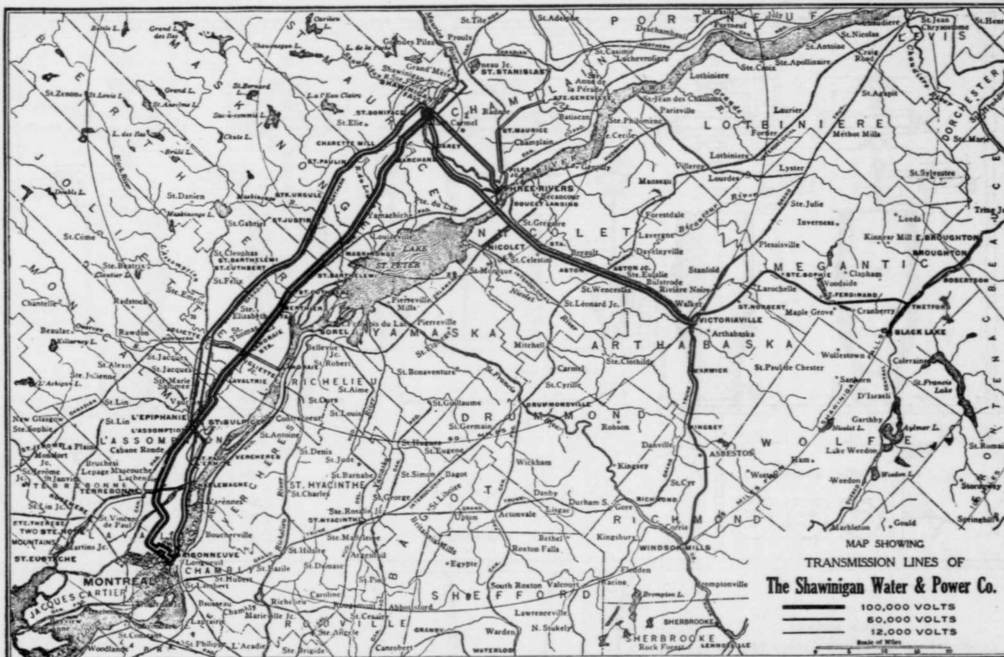
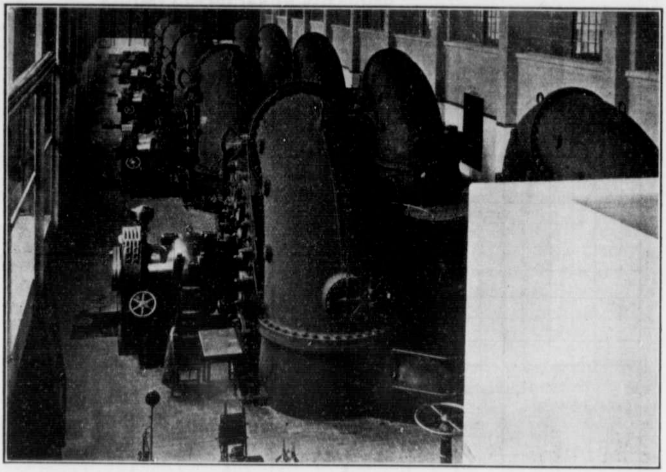
[1] See Part 1 of this report. "Canadian Hydraulic Power Development."
[2] See *Electrical World*, vol. 59, p. 958.

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

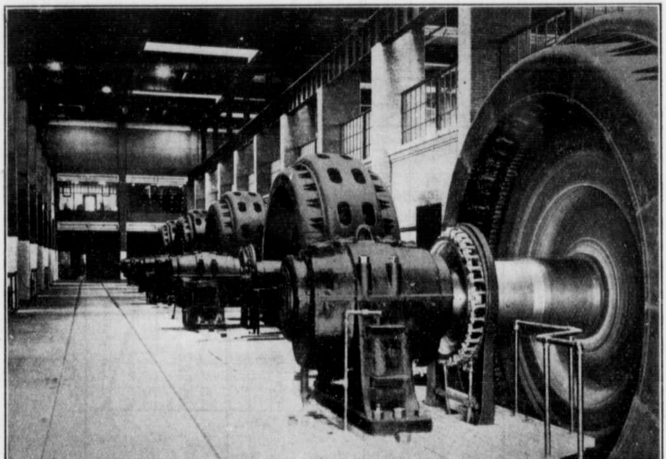
PLAN, BIG CHUTE GENERATING STATION, SEVERN RIVER



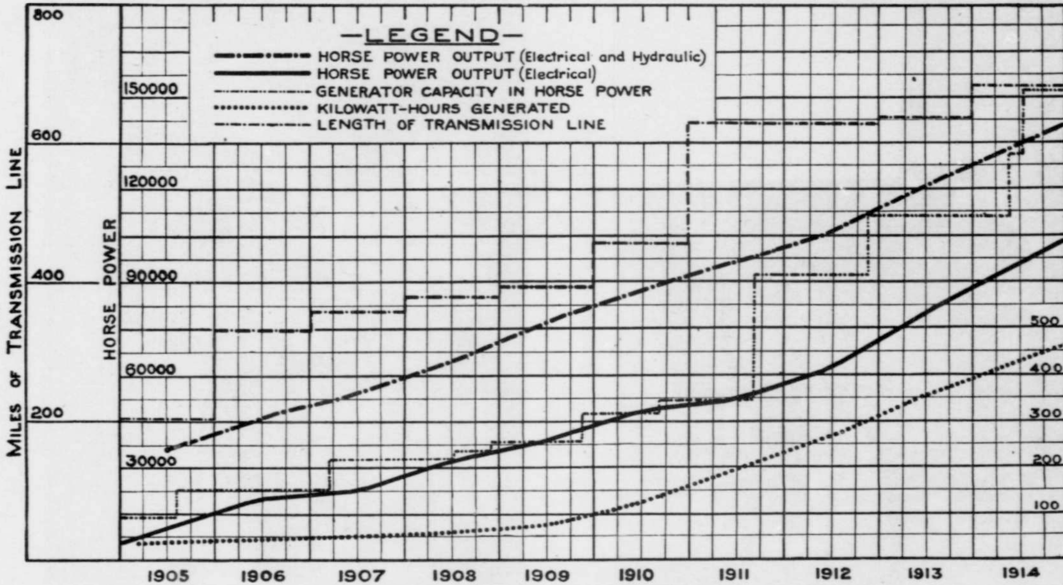

MAP SHOWING
TRANSMISSION LINES OF
The Shawinigan Water & Power Co.
100,000 VOLTS
50,000 VOLTS
12,000 VOLTS
MONTREAL
THREE RIVERS
SHAWINIGAN FALLS
VICTORIAVILLE
LAKE ST. PETER
SHERBROOKE



Hydraulic Units, No. 2 Power Station, Shawinigan Falls, Quebec.



Electrical Units, No. 2 Power Station, Shawinigan Falls, Quebec.



Growth of Load and System, Shawinigan Water and Power Company, Shawinigan Falls, Quebec.

The greatest load of the power transmittted is at the city of Montreal, which is served with four transmission circuits direct from Shawenegan Falls, this being but one source of the horse-power consumed in that city. A market for 6,000 horse-power has been built up at the city of Three Rivers on the St. Lawrence river, a location which affords excellent facilities for transcontinental railway service, and lake and ocean transportation. The asbestos district in southern Quebec consumes several thousand horse-power, and the many municipalities in the various districts are also supplied.

The growth of power load and equipment of the Shawenegan Company affords an excellent example of the industrial growth of the country. Diagram on page 52 shows the comparative values of generating capacity, length of transmission lines, horsepower output, and kilowatt hours generated. Optimism as to the future of the industrial situation is indicated by the excess of generator capacity over the present load.

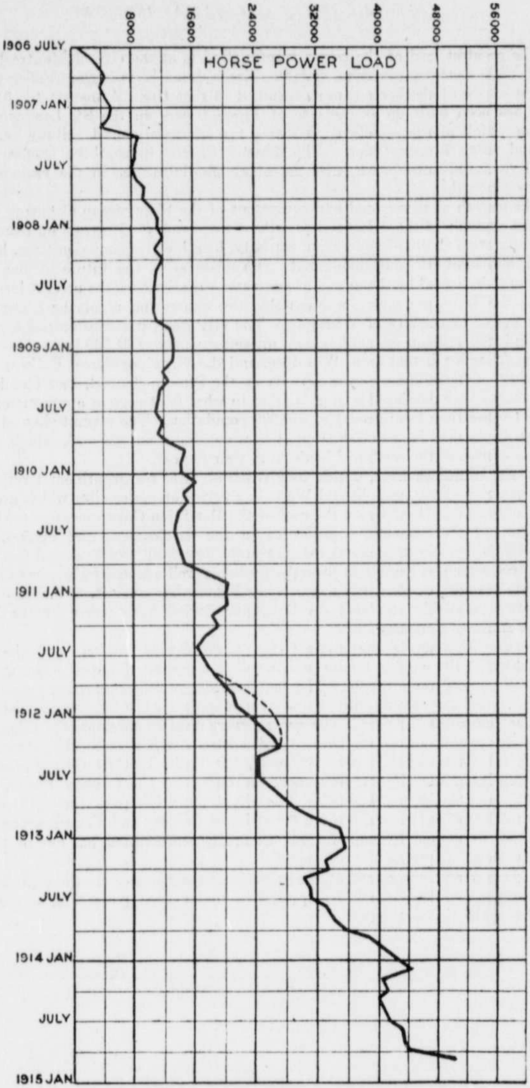
On the Winnipeg river, in Manitoba, two generating plants have been built to deliver power to the city of Winnipeg. The city itself has constructed a generating plant and transmission system having a present capacity of 51,500 horse-power at Point du Bois, 77 miles distant from Winnipeg, and the Winnipeg Street Railway Company has a plant of 28,000 horse-power capacity on the Pinawa channel, near Lac du Bonnet. These plants have developed a large market in what is at present a non-manufacturing city (for other than local needs) of 210,000 population. The magnitude and character of these loads may be realized from the curve shown on page 54, which shows the curve of growth of the combined loads from year to year.

On the Winnipeg river, within easy reach of three transcontinental railways, and at the gateway of the agricultural West, is a series of power sites which are now the subject of considerable study on the part of the Dominion Government as to the storage facilities and the economic possibilities in the development and market. Storage regulation is feasible to increase the minimum flow from 12,000 second-feet to 20,000 second-feet, which will result in several sites being well adapted for power purposes, the aggregate capacity of electrical power being 262,000 horse-power, in addition to 76,800 horse-power available at Point du Bois, and 28,200 horse-power at the Winnipeg Electric Railway Company's site.

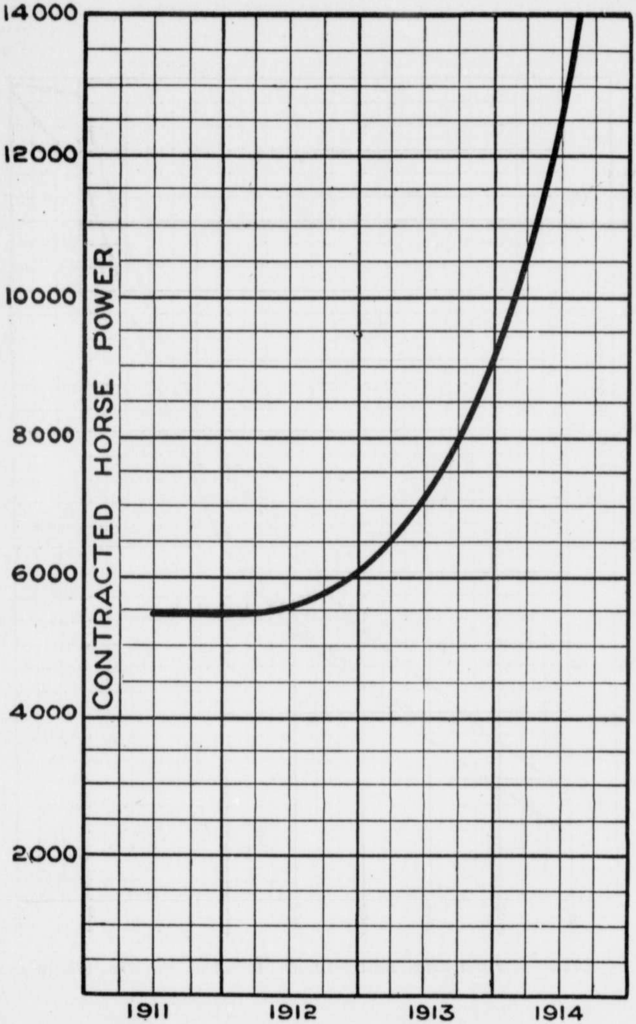
Western Canada is the granary for a world-wide market, and the artificial replenishing of the notably fertile prairie soil is a problem for the future, to be solved only by abundant water supply. The communities, rapidly increasing in number and population, and the manufacturing now commencing for the local market will demand enormous quantities of power. The water-powers must be developed for this purpose.

As companion curves to those included herein which show the growths in the loads of the Shawenegan Power Company, the Hydro-Electric Commission and the plants supplying the city of Winnipeg, the curves of the Calgary Power Company (page 55), and the British Columbia Electric Railway Company (page 56) are shown herewith. The latter companies serve the cities of Calgary and Vancouver respectively, the British Columbia Electric Railway Company representing but one of the hydro-electric systems supplying Vancouver.

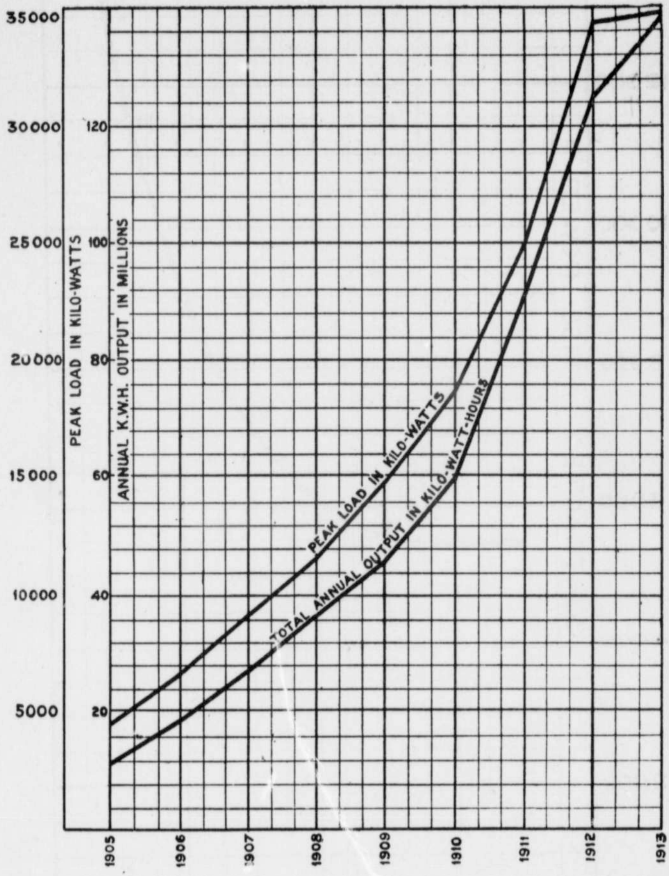
In these curves, the record of the principal cities across a continent, it is remarkable that the growth of each has proceeded under such paralleling circumstances; truly this is the electrical age.



Growth of Power Loads in the City of Winnipeg.



Growth of Power Loads, Calgary Power Company, Calgary, Alberta.



Growth of Power Loads, British Columbia Elec. Rwy. Co., Vancouver, B. C.

CLASSIFIED LIST OF REPORTS.

The Reports published by the Dominion Water Power Branch with the exception of the Annual Reports, have been called Water Resources Papers, and have been numbered 1, 2, etc.

Annual Reports previous to 1913 are included with the Annual Report of the Department of the Interior, and can be secured from the Secretary of the Department.

Annual Report for 1912-13, published 1914. Out of print.

Annual Report for 1913-14, published 1915.

Annual Report for 1914-15, published 1916.

Annual Report for 1915-16. In Press.

WATER RESOURCES PAPER No. 1.—Report of the Railway Belt Hydrometric Survey for 1911-12, by P. A. Carson, B.A., D.L.S., Chief Engineer. Published 1914.

WATER RESOURCES PAPER No. 2.—Report on Bow River Power and Storage Investigations (Bow river west of Calgary,) by M. C. Hendry, A.M. Can. Soc. C.E., Chief Engineer in charge of surveys. Published 1914.

WATER RESOURCES PAPER No. 3.—Report on Power and Storage Investigations, Winnipeg river, by J. T. Johnston, A.M. Can. Soc. C.E., Chief Hydraulic Engineer, Dominion Water Power Branch. Published 1915.

WATER RESOURCES PAPER No. 4.—Report of the Manitoba Hydrometric Survey to end of year 1914, by M. C. Hendry, A.M. Can. Soc. C.E., Chief Engineer. Published 1916,

WATER RESOURCES PAPER No. 5.—Preliminary Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., M. Can. Soc. C.E., Chief Engineer in charge of Reclamation Survey. Published 1914. Out of print.

WATER RESOURCES PAPER No. 6.—Report on cost of various sources of power for pumping in connection with the South Saskatchewan Water Supply Diversion Project, by H. E. M. Kensit, M.I.E.E. and M. Am. Inst. E. E., M. Can Soc. C.E. Published 1914. Out of print.

WATER RESOURCES PAPER No. 7.—Report on the Manitoba Water Powers, by D. L. McLean, S. S. Scovil, and J. T. Johnston, compiled for the Manitoba Public Utilities Commission. Published 1914.

WATER RESOURCES PAPER No. 8.—Report of the British Columbia Hydrometric Survey for 1913, by R. G. Swan, A. M. Can. Soc. C. E., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 9.—Report on Red River Navigation Surveys, by S. S. Scovil, B.Sc., Assistant Chief Engineer of Manitoba Hydrometric Survey. In course of preparation.

WATER RESOURCES PAPER No. 10.—General Guide for Compilation of Water Power Reports of Dominion Water Power Branch, prepared by J. T. Johnston, A. M. Can. Soc. C. E., Chief Hydraulic Engineer. Published 1915. Limited edition.

WATER RESOURCES PAPER No. 11.—Final Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S. M. Can. Soc. C.E., Chief Engineer in charge of Reclamation Survey. Published 1915.

WATER RESOURCES PAPER No. 12.—Report on Small Water Powers in Western Canada, and discussion of sources of power for the Farm, by A. M. Beale, A. M. Can. Soc. C.E., Published 1915.

WATER RESOURCES PAPER No. 13.—Report on the Coquitlam-Buntzen Hydro-Electric Development, by G. R. G. Conway, M. Inst. C.E., M. Can. Soc. C.E., Chief Engineer of the British Columbia Electric Railway Company, Limited. Published 1915.

WATER RESOURCES PAPER No. 14.—Report of the British Columbia Hydrometric Survey for 1914 by R. G. Swan, A. M. Can. Soc. C.E., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 15.—Report on the Water Powers of Alberta and Saskatchewan by C. H. Attwood. O.L.S., A. M. Can. Soc. C.E., Chief Engineer Alberta and Saskatchewan Power Surveys. In course of preparation.

WATER RESOURCES PAPER No. 16.—Water Powers of Canada. A series of five pamphlets in one volume covering the water power situation in Canada prepared for distribution at the Panama-Pacific Exposition, San Francisco, 1915, by G. R. G. Conway, Consulting Engineer, Toronto, Percival H. Mitchell, E.E., Consulting Engineer, Toronto, H. G. Acres Hydraulic Engineer Hydro-Electric Power Commission Ontario, F. T. Kaelin, Asst. Chief Engineer Shawenegan Power Co., Montreal, Quebec, K. H. Smith, Engineer, Nova Scotia Water Power Commission, Halifax, N.S. Published 1916.

WATER RESOURCES PAPER No. 17.—Canadian Hydraulic Power Development and Electric Power in Canadian Industry, by Charles H. Mitchell, C.E., Consulting Engineer to Dominion Water Power Branch. Published 1916.

WATER RESOURCES PAPER No. 18.—Report of the British Columbia Hydrometric Survey for 1915 by R. G. Swan, A. M. Can. Soc. C.E., Chief Engineer. In Press.

WATER RESOURCES PAPER No. 19.—Report of the Manitoba Hydrometric Survey for 1915 by M. C. Hendry, A. M. Can. Soc. C.E., Chief Engineer. In Press.

WATER RESOURCES PAPER No 20.—Report on the Interests dependent on Winnipeg River Power, with special reference to the Capital Invested and the Labour Employed, by H E. M. Kensit, M.I E E., M. Am. Inst. E E., M. Can Soc. C.E. In press.

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