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The Canadian Engineer

A weekly paper for engineers and engineering-contractors

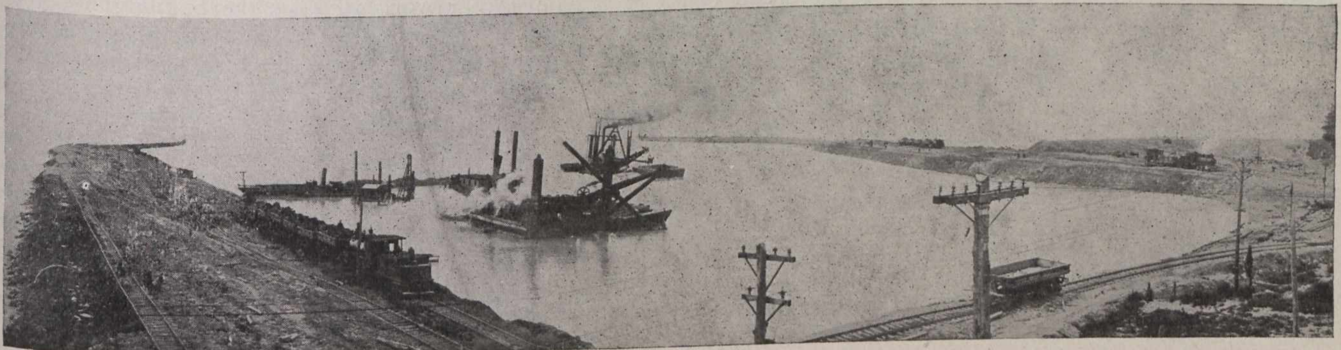

Fig. 1.—The Harbor Under Construction at Port Weller.

WELLAND SHIP CANAL CONSTRUCTION

NOTES ON THE SEASON'S ACTIVITIES IN THE CONSTRUCTION OF CANADA'S $50,000,000 WATERWAY BETWEEN LAKES ERIE AND ONTARIO, UNDER THE DIRECTION OF THE DEPARTMENT OF RAILWAYS AND CANALS, OTTAWA.

THE present season has been one of remarkable activity along the line of the proposed New Welland Ship Canal. The northern portion of the route has been converted into a scene of constructional development embodying works whose proportions and involved methods of construction are on a scale with which few of our Canadian enterprises are comparable, and certainly far beyond anything of a similar nature ever attempted in this country.

For general information respecting the new route, and essential features of design, the reader is referred to an article which appeared in *The Canadian Engineer* for August 21st, 1913. Briefly, it is to replace the present Welland Canal whose length of 26¾ miles from Port Colborne on Lake Erie to Port Dalhousie on Lake Ontario, provides, through 25 locks, the only existing means of water transportation in this section of the Great Lakes' route. The old canal, with locks 45 feet in width, afforded some 14 ft. of water over the sills. The new canal will be 25 miles in length, from lake to lake, overcoming a difference of level of 325½ feet. There will be seven locks, each of 42½ ft. lift, 80 ft. width, and of sufficient length to accommodate a vessel 800 ft. long. The present construction is to provide a depth of 25 ft. over the sills; this to be ultimately deepened to 30 ft., according to the design.

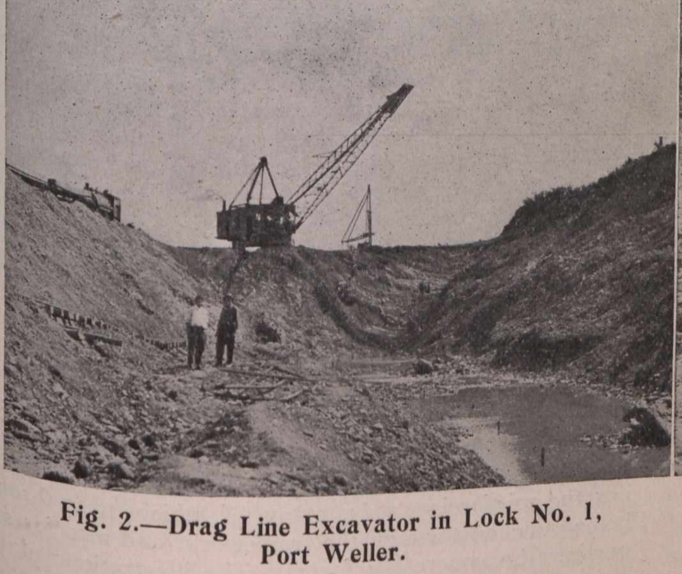

Fig. 2.—Drag Line Excavator in Lock No. 1, Port Weller.

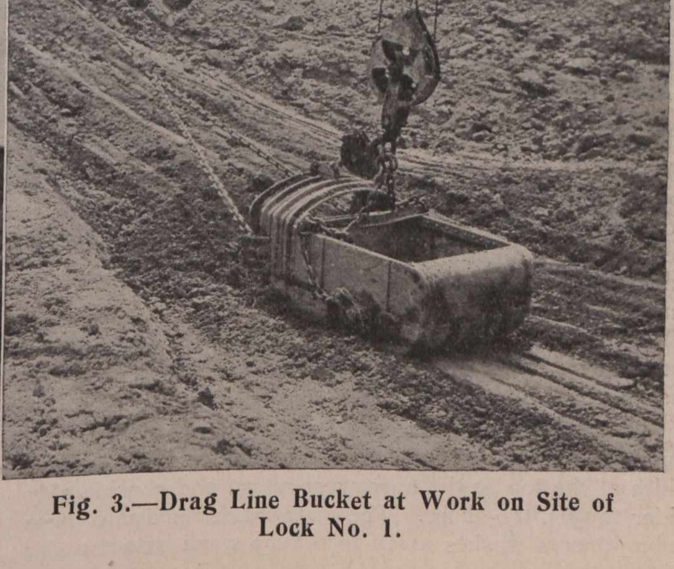

Fig. 3.—Drag Line Bucket at Work on Site of Lock No. 1.

The work has been divided into nine general sections and up to the present contracts have been let for Sections 1, 2, 3, 5, and a portion of Section 4, called 4A.

Section 1.—The contract for Section 1 was let on August 1st, 1913, to The Dominion Dredging Company, Limited, Ottawa, at about $3,500,000. It extends from deep water about 1½ miles from the Lake Ontario shore line to Sta. 150, about 1½ miles inland. The contract includes the construction of Lock 1, the lower end of which is about 2,500 ft. from the shore line. There is a lock wall about 800 ft. in length and an entrance wall also 800 ft. long. The inland part of this section entails a large amount of dry excavation. The contract also includes sub-structures for two bridges. One of these will be situated over the head of Lock 1 and will be for the electric line to Niagara, of the Niagara, St. Catharines and Toronto Railway. This will comprise a bascule lift bridge over the Canal proper with 95 ft. clear span, and a reinforced concrete approach of six spans over the regulation weir on the east side. The two outer spans will be 41½ ft. and the four central spans 40 ft. in length. The contract calls for the complete construction of this approach.

The other bridge, No. 2, will also be a bascule lift highway bridge, but of 200 ft. span. It will be situated about a mile south of bridge No. 1, and will lie between the second and third concessions of the Township of Grantham.

A considerable part of The Dominion Dredging Co.'s contract consists of the construction of a harbor at Port Weller. This harbor is to be formed by two earth dykes about 500 ft. in width and extending, as stated, 1½ miles from shore line. These dykes each carry a temporary trestle used in their formation. This trestle carries the tracks of a railway to be described later. Here all the surplus material from Sections 1 and 2 and the lower end of Section 3 is being dumped. At present the trestle on the west side extends over half way out and that on the east side is almost as far advanced.

It is expected that the side embankments of the harbor will eventually be three or four hundred feet in width at the top at the narrowest point, and considerably wider toward the shore. The material dumped into these embankments washes away to a very small extent under normal conditions, and even during storms no great quantity has so far been taken out. When the earth filling is completed rock will be brought from Section 3 to roughly rip-rap the outer slopes.

The work in the lake includes dredging a 25-foot channel from deep water to the shore line, the material being cemented gravel and hard-pan overlying shale rock. Some of the latter will also be removed.

The harbor work includes the building of 55 cribs, each weighing about 2,000 tons, to be placed at the entrance piers and at the east docking and gate yard slip, near the shore line. Each is 110 ft. in length, 38 ft. wide and 34 ft. deep and contains 18 compartments, each 12 x 18 ft. The exterior walls are 18 in. wide at the bottom, tapering to 12 in. at the top. The base and top widths of the interior walls are 14 and 10 in. respectively. There is an offset at the bottom of each compartment providing a seating for a movable timber bottom. When the cribs are floated to position they are sunk by the removal, by chain operation, of these bottoms. When sunk they will be filled with earth. One of the cribs has already been constructed and floated out into the lake and temporarily rests on bottom pending the dredging of a deeper channel and the preparation of the site. The bottoms of the compartments of the crib are, as stated, removable, and will be used over and over in the construction and placing of the different cribs. When sunk, the top of the cribs will reach water level. They will extend for a distance of 700 feet on either side of the harbor entrance. Upon such cribs also will be placed the concrete superstructure forming the lines of docking at the shore end of the harbor.

The entrance wall to Lock No. 1 involves some interesting construction. The steel frame work, 41½ ft. in height, and a large part of the steel reinforcing has already been placed and considerable concreting has been done. The entrance wall extends from near the lake to the foot of the lock and is of reinforced concrete, buttress type. In the use of the structural steel frames, one in each counterfort, a departure from ordinary design has been made. These frames are for the purpose of supporting the reinforcing rods, many of which pass through holes punched through the framework, and also for supporting the concreting forms. The illustrations of this

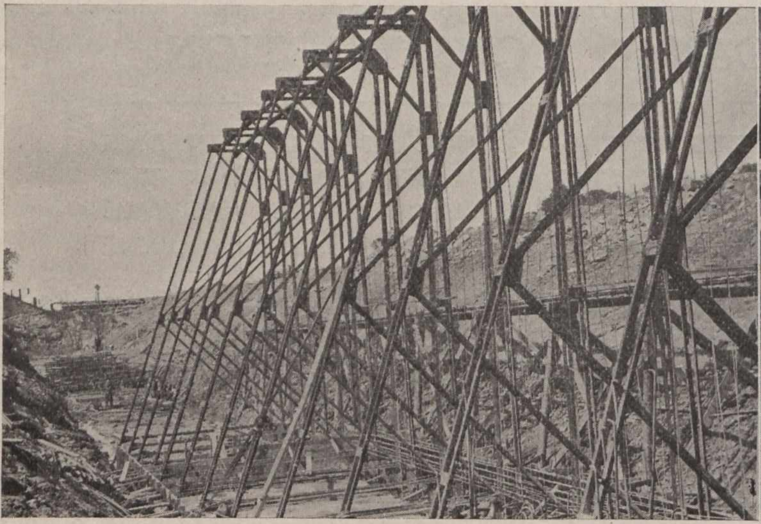

Fig. 4.—End Section of Steel Frame for West Entrance Wall at Port Weller, Before Placing Reinforcing Steel.

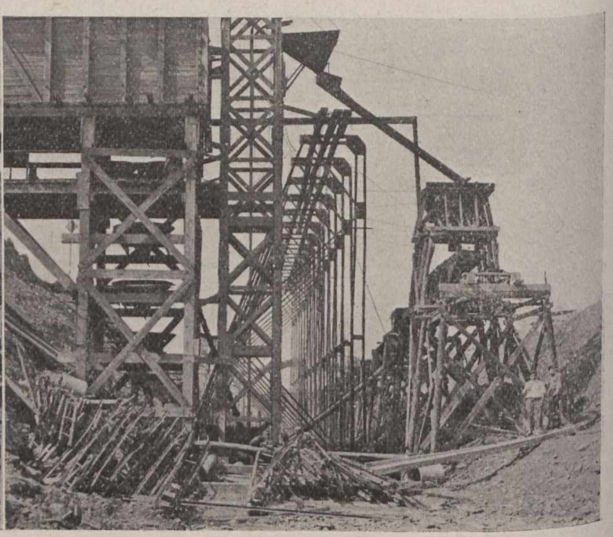

Fig. 5.—Part of the Concreting Plant at the South End of the Retaining Wall.

wall show some interesting reinforcing work. The wall has a rock foundation. The reinforced concrete crib docking, mentioned above, will extend from its outer extremity into the harbor.

At work in the harbor is a sounding scow about 40 feet square, and provided with 4 large spuds or anchors. This scow was built for the general purposes of the survey staff in connection with the harbor work, but principally for ascertaining the elevation of the surface of the rock beneath the overlying material. As it was liable to be caught out in rough weather before the piers were extended as far as they are into the lake, and as sometimes a perfectly steady platform is required, the scow is arranged with a heavy engine on each spud, by means of which the scow is enabled to hoist itself completely out of the water and above the reach of wave action, which will thus have only the four spuds to strike against. When it is required to move the machine the scow is lowered into the water and the spuds lifted up clear of the bottom by the same machinery.

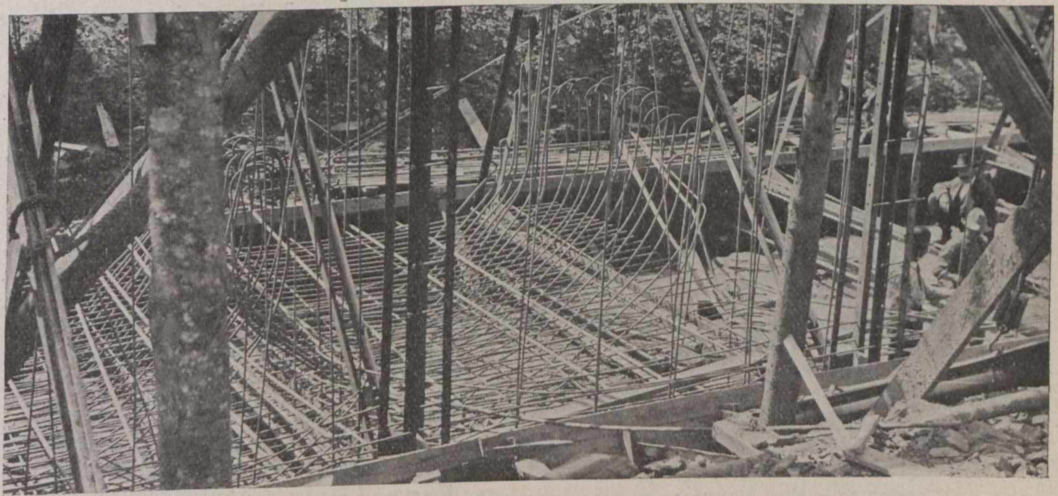

Fig. 6.—Reinforcing Steel at the Base of One of the Counterforts—West Side Entrance Wall, Port Weller.

A reinforced concrete scow, built in 1910, is also engaged on the work.

Up to the end of September the work done on Section 1 of the Canal included about 300,000 cubic yards of dredging from the harbor and about 1,000,000 cubic yards of dry excavation from the lock division. This material has all been used in the embankment construction.

Fig. 7.—Grader and Mule Outfit Working on a Watertight Embankment, Section 2.

Section 2.—This was let by contract on December 31st, 1913, to Baldry, Yerburgh & Hutchinson, an English firm with an office in St. Catharines. It extends from Sta. 150 to Sta. 380, approximately 4⅓ miles, and includes the construction of Locks 2 and 3, with necessary entrance walls, regulating and supply weirs. Substructures for three bridges will be required in addition to road diversions, etc. Bridge No. 3 will be an 80-ft. bascule bridge to be used for highway purposes and will be situated over the head of Lock 2. The contract requires the construction of a reinforced concrete approach of six spans, each 40 ft. in length and 21½ ft. wide.

Bridge No. 4, to be also of bascule lift type, will have a 200-ft. span with earth approaches. It will be over the Queenston Road and about midway between Locks 2 and 3. The location of bridge No. 5 is on the St. David's-Merritton Road, near the boundary line of Sections 2 and 3 of the canal. It will also be a bascule lift bridge with a span of 200 ft.

In Section 2 there will be a crossing of the present and new canals. The water in both is to be at the same level thereby affording vessels an alternative passage to or from Lake Ontario by way of Port Dalhousie. This will probably be taken advantage of largely by smaller craft.

During the season the embankments for a pondage of 200 acres required for Lock No. 2 have been in progress, east of the canal bank. About half a mile of it is completed. Six elevating graders have been employed on the work. A dam is also being built to the east of Lock 3, to form an equalizing basin. Lock 1 will also have a pond. These basins are necessary in order to prevent fluctuations in the levels when a lock is filled or emptied, as the filling of a lock would lower the water in a 70-acre pond one foot. It is therefore advisable to have these ponds as much over 70 acres as possible.

At the site of Lock No. 2, the excavation for a heavy breast wall is in progress. A cavity about 175 ft. long and 25 ft. wide has been made and enclosed in sheet piling 45 ft. in length, driven to refusal and supported by wooden bracing. Excavation will be carried to a depth of 60 ft. to solid rock, whereupon the pit will be filled with concrete, thus forming the breast wall for Lock No. 2.

Fig. 8.—Rock-cut on G.T.R. Relocation, 3rd Curve. Thorold (Section 3).

This method of construction was adopted in order to conserve the ground above the breast wall in its natural state, as, had the lock pit been excavated in the usual manner, it would have been open for a couple of years, during which time a slope probably flatter than 1 to 1 would have formed above the breast wall, as well as along the sides of the pit. The present method will leave the material above the breast wall intact.

The contractors had completed on September 30th, 1914, a total of 1,500,000 cubic yards of dry excavation in Section 2. All this material, with the exception of that required for grading the construction railway, has been transported to the harbor site and used in the construction of the dykes. The section involves the excavation of about 6,000,000 cu. yds. of earth. This part of the work has proceeded very rapidly by means of heavy steam shovels, drag-line excavators and several mule outfits operated in connection with grading machines. The embankments are being built by mule teams hauling wagons from the grading machines to the different banks, where it is placed in layers and compacted after being watered.

Section 3.—The contract for Section 3 was let on October 4th, 1913, to O'Brien & Doheny, Montreal, and Quinlan & Robertson, Toronto, in combination, the price being approximately $9,500,000. It extends from Sta. 380 to Sta. 490 and includes the twin Locks Nos. 4, 5 and 6 in flight, single Lock No. 7, and guard gates. A part of the contract is the diversion of the Welland Division (to Port Colborne) of the Grand Trunk Railway. At present this line extends along the right-of-way of the canal. The relocation is along the west side for a distance of about 3 miles, and extending into Section 4.

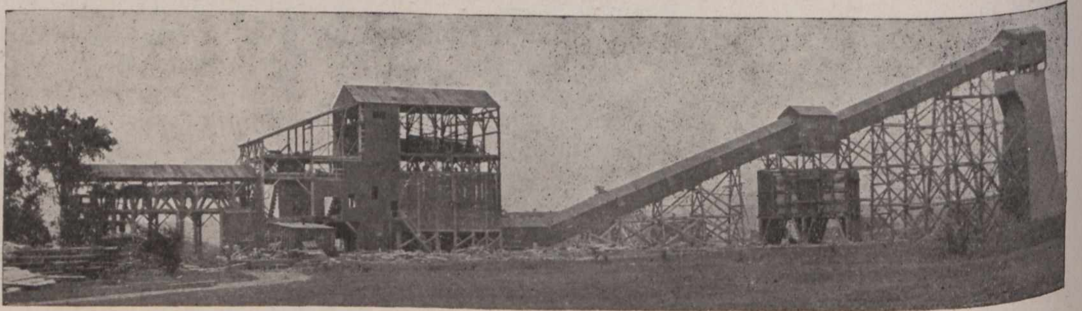

Fig. 9.—Department's Main Crushing Plant, Section 3.

The part of this work included in Section 3 is practically completed. Some particularly heavy rock excavation and earth cutting were encountered, as the railway here climbs the Niagara escarpment. The location of the line at this point was a difficult matter on this account. Over 500,000 cu. yds. of material have been removed from this cutting within a length of 1½ miles.

There is also a diversion of the main double-track line of the G.T.R. to Niagara Falls. This line crosses the right-of-way at the foot of Lock 4. The diversion has required the erection of a bridge of 4 truss spans, already supplied and erected by the Hamilton Bridge Works Company. This diversion is only temporary, and the bridge will be removed when the canal is nearing completion, whereupon it will be available for use elsewhere. The pier for the ultimate structure is to form a part of the centre wall of twin Lock No. 4. The final bridge will consist of a bascule lift span on either side of this pier. This diversion allows free passage for the excavated material from the lock pits to the stone crushing plant, and to Port Weller. In order that the diversion might be finally disposed of and cause no further trouble to the Grand Trunk Railway or to the contractor, the centre pier upon which one end of the steel spans rest has been sunk through earth and rock, a depth of 90 ft., to the level of the foundations of the locks, and, as stated, it will be eventually incorporated in the centre wall of the locks. The side piers have been sunk to about two-thirds of this depth, to the surface of the rock below. This will allow the contractors to excavate the lock pit completely and the lock walls to be built without interfering with the bridge. It will be noted that instead of building double-track spans, two single-track spans have been constructed, the idea being that they will be more easily disposed of, upon the completion of the work, than a double-track structure.

In addition to the above, which in reality calls for two bridges, the contract includes the substructures for four others. One of these is bridge No. 7 on the St. David's-Thorold Road in Thorold. It consists of a reinforced concrete bridge 99 ft. in length, and a double bascule bridge over the canal. The contract requires the complete construction of the former and the foundations for the latter. The Hamilton Bridge Works Company has recently finished the erection of a steel bridge for the Welland division of the Grand Trunk Railway. This consists of two deck plate girder spans and one through girder span. It is located close to the guard gates above Lock No. 7.

A highway bridge, No. 8, over the railway cutting at Peter Street, Thorold, will consist of a bascule lift bridge, 80-ft. span, over the canal, and a reinforced concrete bridge of 3 spans, each 36½ ft. c. to c. of piers, over the G.T.R. right-of-way. It has a 16-ft. roadway and 6-ft. sidewalk.

Bridge No. 9, for the Niagara, St. Catharines and Toronto Railway, will be a swing span of 222 ft. 11 in., with a reinforced concrete skew approach, the centre spans of which are 46 ft. 9 in. c. to c., while the end spans next and farthest from the canal bridge are 11 ft. 7 in. and 28 ft. 6 in. in length respectively.

These bridge structures and diversions are really incidental to the general scope of the contract, and have been mentioned first as the work they involve is encountered at an early stage. There are about 3,500,000 cu. yds. of earth, 2,500,000 cu. yds. of rock and 1,500,000 cu. yds. of concrete masonry on this section. The 3 twin locks in flight are to be built, the lower end of twin Locks No. 4 being located under the Grand Trunk Railway main line, where the 4 large steel spans noted above carry the diverted railway. These three locks will lift a vessel 139½ feet to a regulating basin which will be formed by a large dam now in course of construction, on the east side at the head of Lock No. 6. Above this pond will be built single Lock No. 7, the head of the lock being located at Peter Street in Thorold, where a swing bridge crosses the present canal at the head of Lock 24.

The dam at the head of Lock No. 6 is an interesting and important part of the section. It is of earthen construction, having a concrete core wall extending from the rock surface to an elevation about 30 ft. below the top of the dam. The latter will be 75 ft. in height at its highest point, and the core wall is built in a trench in the clay overlying the rock, varying in depth from 5 to 30 feet. The good earth from the excavation has been dumped on either side of the dam site, and is now being re-handled into the work. The seat of the dam was carefully prepared by removing all loam and other loose material and by benching all sloping surfaces. A toe trench was then excavated along the full length of the dam for a few feet in depth into the solid material, and the dam has been built up in layers of approximately 8 to 12 in., each layer being carefully spread, watered and compacted by rolling. This process will be continued to the top. A heavy stone talus consisting of rock from the excavation will then be placed on the downstream side of the dam to add weight and to prevent sliding, and earth will be dumped on the upstream side after the water has been let in, to reduce the depth of water in the pond to about 10 or 12 feet.

The construction of this core wall and watertight embankment will provide a pondage covering 84 acres, for Lock No. 6. The core wall, which has been completed, is irregular in alignment. For a distance of approximately 500 ft. it projects from the canal wall at an angle of 45°. Then its direction changes through an angle of 49°, and for a distance of about 675 ft. it extends outward from the canal and at nearly right angles to it. The centre line of the dam extends from the terminus of the core wall at this point at an angle of nearly 30° for a distance of about 400 ft. where a backward sweep of about 67° occurs. This new line is followed for the remaining portion of the embankment, approximately 650 ft. The thickness of the core wall varies from 5 to 10 ft., depending on the depth, tapering at the top with a batter of 1 to 6 to a uniform width of 3 ft. At any vertical cross-section the thickness is uniform from the taper to the base of the wall.

Two drag-line excavators are re-handling the material that has been dumped along the side of the proposed dam from the stripping of the site of the flight locks, and from railway cuttings in the vicinity. The watertight embankment has been completed to a depth of about 6 ft.

It should be stated that the location of these flight locks, as well as the diversion of the Welland division of the G.T.R., is in the heart of the town of Thorold and

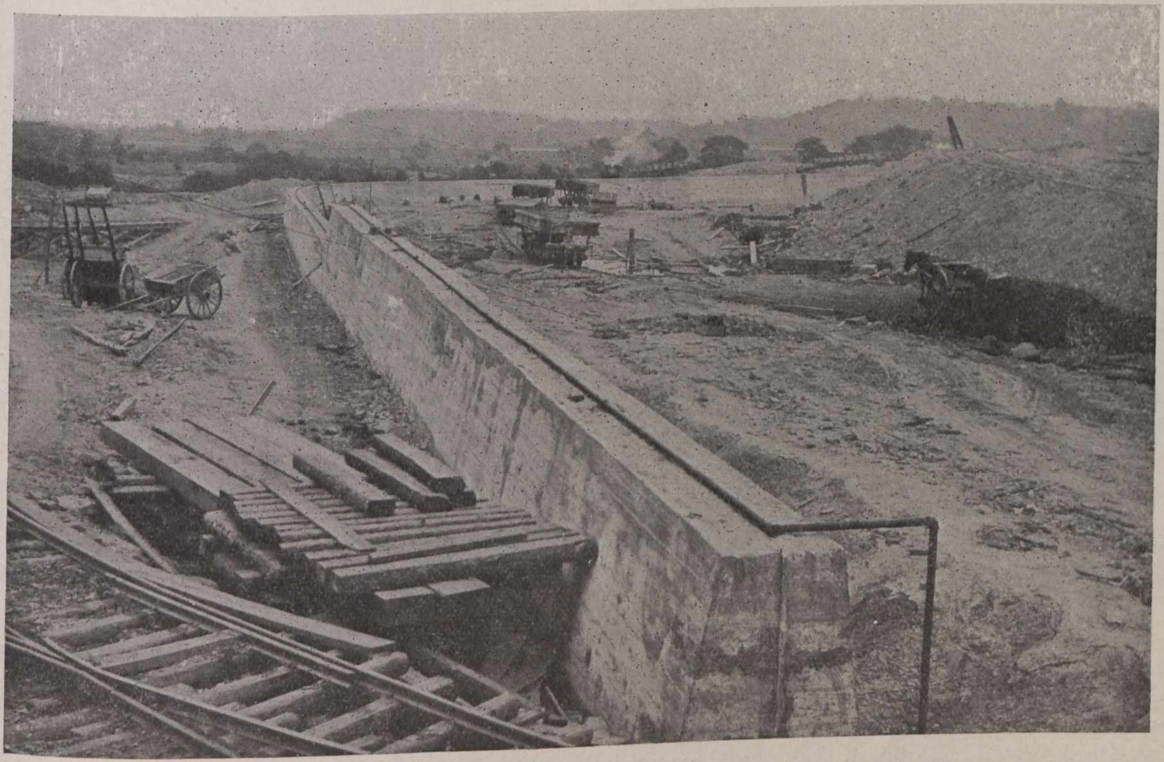

Fig. 10.—Core Wall of Dam at Head of Lock No. 6, Section 3.

that these undertakings have involved the removal of a number of houses. The stripping has been done and at present Keystone and Cyclone drills, operated by electricity, are working on the site of Lock 5, drilling blast holes from 30 to 40 feet in depth into the rock.

The contractors for this section of the canal are required to provide crushed rock for the concrete work, not only for this section but for Sections 1 and 2. This has necessitated the installation of a large rock-crushing plant which is located east of Merritton and north of the G.T.R. line. The capacity of this plant is such as to provide 2,000 cu. yds. of crushed rock per day for each of Sections 1 and 2, besides the amount required for Section 3. The arrangement is described more fully later, in connection with the construction railway.

Fig. 11.—Reinforcing Work for the Supply Weir. Section 4 A.

Section 5.—The contract for this section was let to the Canadian Dredging Co., Midland, Ont., on December 22, 1913, the price being approximately $1,950,000. The section is about 2½ miles in length, from Sta. 636 to Sta. 774. It consists of widening the present canal between Allanburg and Port Robinson and dredging the channel to the proper depth of 25 ft. The widening is being effected by removing the west bank of the present canal. The contract calls also for the foundation work for one bascule lift bridge over the canal at Main Street, Port Robinson. It will have a span of 200 ft.

Up to September 30, 1914, the contractors had handled about 700,000 cu. yds. of excavation. Five steam shovels have been steadily employed on the work all summer. The material is being disposed of on dumping grounds provided on the west side between the present and old canals, opposite Section 4. Provision is made there for dumping the entire excavation from Section 5, which will aggregate about 5,000,000 cu. yds., practicallv all earth.

Section 4 A.—The contract for this division of the work was awarded on May 6, 1914, to Maguire & Cameron, St. Catharines, Ont., at about $80,000. It consists chiefly of the construction of a supply weir near the boundary of Sections 3 and 4 to furnish water to the old canal through an existing channel connecting with the present canal. Two culverts for drainage purposes under the dumping grounds mentioned above are also necessary and included in the contract.

Construction Railway.—As mentioned elsewhere, a double-track standard gauge construction railway has been built on the west side of the canal. As noted above, the contractor for Section 3 supplies the crushed stone required for the three sections, there being plenty of rock on Section 3, but none on Sections 1 and 2. A short distance from the crushing plant, track scales are being constructed which will weigh a train of cars 150 feet in length. These scales will weigh all the crushed stone leaving the plant for Sections 1 and 2. When the contractors for these sections require it, they will send their cars to this source of supply and the cars will be loaded by the contractor for Section 3. It is expected that the big plant will be in full operation within a few weeks.

The railway extends from these scales to Lake Ontario, a distance of about six miles. It is carried over the present canal, about a mile north of the crushing plant, by means of a double-track steel swing bridge, recently completed. It was built, and is maintained by the Department of Railways and Canals, under whose direction a superintendent, dispatchers and switchmen control all the operations on the road. The contractors for Sections 1, 2 and 3 are entitled to the free use of this road for the purpose of moving crushed stone from the crushing plant to their respective works, and for the purpose of removing excavated material from their respective works to the service ground fills in Lake Ontario. A complete interlocking plant and block signal system is being installed. The ballasting of the line was done by the contractors for Section 2.

Near the shore line the railway branches and each harbor embankment has its own tracks, supported by temporary wooden pile trestles that are being built out into the lake in advance of the dumps. In order to give the piles of these trestles a firm bearing and more stability than would ordinarily be the case, under-water embankments are being built in advance of the trestles. These are formed by dumping the scows of excavated material from the dredges on the line of the trestles till the scows will no longer float over it, and through this dump the piles are driven.

Up to September 30th approximately 2,500,000 cu. yds. of excavation had been transported to the harbor embankment since the completion of the railway to this point.

Sub-contracts.—The Dominion Dredging Company have sublet several portions of their work in connection with Section 1. The locks, retaining walls and other concrete work has been let to Lane Bros., while the J. H. Tromanhauser Co., Toronto, has the construction of the 55 cribs for the entrance piers and gate yard slip. On Section 2 Baldry, Yerburgh & Hutchinson have sublet portions of the excavation work to Yale & Reagan, Chicago, Ill; Hill-Leonard Engineering and Construction Company, Toronto, and to Stein & Reade, Merritton, Ont. The construction of embankments has been sublet to Michael Conroy, Chicago, who has about 50 mule teams on the work. Jos. Battle, Thorold, Ont., has already finished a small concreting sub-contract; Ernest Bennett, St. Catharines, will construct a number of culverts, while Jos. Riley, St. Catharines, has the contract for sodding the finished slopes of the canal in Section 2. As the work proceeds on the several sections the slopes are being sodded. This will tend to prevent washing out and thereby materially reduce the cost of maintenance of the canal, besides adding to the appearance of the canal banks.

No contracts have been sub-let on Section 3. On Section 4 A, the 2 culverts will be built under sub-contract, while on Section 5, J. H. Corbett & Company, of Moncton, N.B., has the dry excavation work.

Synopsis.—The general dimensions of the canal are as follows:—

Length, lake to lake	25 miles
Bottom width	200 feet
Width at water line	310 feet
Depth of canal	25 feet
Depth on lock sills	30 feet
Number of lift locks	7
Usable length of locks	200 feet
Usable width	80 feet
Height of lock walls above sills	81.5 feet
Lift of each lock	46.5 feet

All the work is being executed under the direction of J. L. Weller, C.E., Mem. Can. Soc. C.E., chief engineer of the canal for the Department of Railways and Canals, Ottawa.

STEAM TURBINE POWER PLANT AT KAMLOOPS.

THE city of Kamloops, B.C., has recently completed a municipal power plant which, while it is smaller than some other Canadian municipal plants, differs in some respects from the ordinary steam turbine plant because of a combination of conditions which controlled the design.

The following description of the plant, written for the "Municipal Journal" by H. W. Beecher, M.E., will be found of interest:—

The city, which is located at the junction of the North Thompson and South Thompson rivers, and is on the Canadian Pacific Railway, has been growing rapidly and promises to continue to do so, and this has required provision for water supply and street lighting plants of much greater capacity than were originally constructed. The water supply is drawn from Thompson river and pumped to reservoirs on neighboring hills. Several years ago it seemed to city officials that this offered an excellent opportunity for combining pumping and electric power plants, the former being used to fill in the times between peak loads and thus keep the load more uniform. H. K. Dutcher, of Vancouver, was employed to report upon the proposition, and located a power site on the Barriere river about forty miles north of Kamloops, where an ultimate development of 16,000 h.p. was possible. The municipality voted $475,000 for the project and proceeded to carry it out. The present plans call for only 2,200 h.p. installation, but provision is made for the ultimate development of the entire power available.

The plant on the Barriere river now nearing completion will consist of two 1,100 h.p. Victor-Francis turbines made by the Platt Iron Works Company, of Dayton, Ohio, and supplied through Charles C. Moore & Co., engineers, of Seattle; and two Westinghouse water wheel type generators direct connected to the turbines. The turbines will operate at 720 r.p.m., will be of the single-runner scroll-case Francis type and will be provided with outside gate mechanism and direct-acting Lombard governor.

To provide for accidents to the power plant, and especially on account of the long transmission line, it was considered necessary to install an auxiliary steam plant in the city. As the demand for increased power was immediate, and the steam plant could be constructed more quickly than the hydraulic works, it was decided to build the steam plant as quickly as possible so that it could be used while waiting for the completion of the hydro-electric system. The engineers prepared plans for a combination steam plant, sub-station and pumping plant, and this has recently been completed and is the most interesting feature of the municipal installation.

On account of the shifting bed of the Thompson river, it was considered advisable to construct the main power house some distance from the river, where suitable foundations could be secured, and place an auxiliary pump house at the river's edge. The plan provided also for the future construction of filters to receive the discharge from the auxiliary pumps, from which the effluent could flow by gravity to the pump well of the main pumps.

The auxiliary pump house contains two vertical centrifugal pumps operated by vertical motors placed above the highest known water level. Water is brought to the pumps through long intake pipes which terminate in a screened inlet located in the middle of the river. The inlet pipes terminate at the pump house in gate valves, hand-operated. After leaving these pipes the water passes through a double system of screens into the suction chamber. The pumps are operated from the main switchboard, one by a standard hand-operated starter and the other by an automatic patent starting device controlled by a float switch which maintains at a given level the water in the suction chamber. By proper regulation of the inlet valves this automatic pump is kept in practically uniform service. The pump house is of concrete heavily reinforced throughout.

Power House and Plant.—The main building is of reinforced concrete, 90 x 75 feet ground plan, divided into boiler room, turbine room and high-tension sub-station. In the basement at the extreme west end is located a reservoir from which the pumps take their suction, and here also are located the condenser and condenser auxiliaries. The basement under the turbine room is on the same level as the boiler room floor. The suction well is connected to the auxiliary pumps on the river's bank by about 600 feet of 6-inch mains. The roof over the boiler room is supported by trusses and that over the turbine room and switchboard by deep web I-beams. The horn gap structure for the high-tension lines allows them to come in through roof cones, well within the confines of the plant.

The boiler room contains four Babcock & Wilcox water tube boilers of 250 h.p. each. Each boiler contains ten sections of ten 4-inch by 18-foot tubes, mounted under one 54-inch steam and water drum. They are designed to operate at 160 lbs. pressure. The pumps were manufactured in the Renfrew, Scotland, factory of the Babcock & Wilcox Company, and are arranged so that superheaters can be added later if conditions warrant. Shaking grates for hand firing are used, but the plant can readily be converted to an oil-burning plant. Coal is brought direct from the mines in bottom-dump cars and dumped from an overhead spur into the coal bunkers just outside the building. From the bunkers it runs by gravity onto the firing floor through chutes in the rear wall of the boiler room, from which point it is fed by hand into the furnaces. Ashes are raked into the boot or hopper of a motor-driven conveyor elevator of the endless chain type, which discharges them on the ground about 40 feet east of the boiler room. The chimney is 89 inches in diameter and 180 feet high above the boiler room floor. It is heavily reinforced with ⅝-inch steel rods and is of the tapering or coniform type. The boiler feed pumps are of the Smith-Vaile outside end packed plunger type, 6 x 4 x 6 inches, manufactured by the Platt Iron Works. They receive water from a Stilwell open type heater. This type of heater is advantageous because it permits the settling out in the filter beds in the bottom of the heater of sediment contained in the river water which is used for boiler purposes. In the heater the water drips over a large tray surface and then passes into the settling chamber and filter.

The boiler branches leading from the four boilers are each provided with automatic steam stop and check valves at the boiler nozzles and a double wedge gate valve at the header. The header is carried on the boiler room side of the partition between that and the turbine room, branches to the turbine being carried through openings left in the concrete wall. Gate valves are placed on each turbine branch. An auxiliary header is installed within the turbine room, from which branches are carried down to the air pumps and circulating pumps.

The generating equipment consists of two Curtis turbo-generators of 600 kw. capacity built by the General Electric Company. They are wound for 2,200 volts three-phase 60-cycle and operate at 3,600 r.p.m. The governor mechanism operates six inlet valves, giving very close speed regulation. Each unit has an electric speed-changing device and over-speed safety trip. The speed of the turbo-generator is thus controlled by the switchboard operator, materially facilitating the paralleling of the machines at the time of bringing the machine onto the line. A 20-kw. G.E. motor generator exciter running at 1,200 r.p.m. is provided, and for breakdown service and for starting a 15-kw. Curtis steam turbo-generator exciter.

The turbines exhaust through corrugated copper expansion joints into cylindrical surface Wheeler condensers equipped with steam turbine-driven circulating pumps and Edwards suction valveless air pump. Each condenser contains 1,440 square feet of cooling surface of ¾-inch brass tubes, secured in brass sheets by ferrules and packed joints. The air pumps are single cylinder, single acting, 7-inch steam cylinder and 16-inch air cylinder with 10-inch stroke. The suction valveless feature makes it possible to use the one pump for handling both air and condensate and maintain a high vacuum. The condensed steam and non-condensible vapors flow continuously by gravity from the condenser to the base of the pump and are removed by a conical piston, which projects the water without shock at high velocity through ports in the sides of the working barrel. The condensing equipment is arranged to produce between 28 and 28½ inches of vacuum and was furnished by the Wheeler Condenser and Engineering Company.

Waterworks Equipment.—The waterworks pumping plant consists of two Platt 2-stage centrifugal pumps of the horizontal split casing type, fitted with bronze runners and arranged for motor drive. Their efficiency is 72 per cent. They are driven by two 200 h.p., 1,760 r.p.m. induction motors manufactured by the Canadian General Electric Company. A third pump, manufactured by the Platt Iron Works, is steam-driven, of the 2-stage type, operated by a 200 h.p., 2,200 r.p.m. Kerr economy type condensing turbine, exhausting into a Wheeler waterworks type condenser with Edwards air pump. The condenser has 1-inch tubes and is placed in the suction of the pump so that no circulating pump is necessary. Each of these three pumps has a capacity sufficient to supply the city consumption if operated twenty-four hours a day, but all three can be operated at once, the large reserve capacity being considered advisable to insure adequate fire protection in the business section. Each pump has a capacity of 1,200 Imperial gallons per minute against a head of 350 feet.

The steam turbine-driven pump is found to be very economical, owing to its being operated condensing, the greatest efficiency being obtained with 28 inches vacuum.

Water from these pumps is discharged into a reservoir about a mile away and about 320 feet above the pumps. The main between pump and reservoir serves also as distribution main.

The discharge from the pumps is measured by a Simplex venturi meter located just outside the building wall, the recording and integrating apparatus being placed in the corner of the turbine room.

There is an elaborate switchboard of natural slate containing 22 panels. All high-voltage connections on switchboard leads which would prove dangerous to the operators are on a structure placed some distance to the rear of the switchboard and operating by remote control. There is no apparatus on the panels at a potential above 110 volts. The switchboard consists essentially of a station lighting panel box, three generator panels (one blank as yet), 2 station power panels and 2 incoming high-tension line panels, the balance being feed panels. At the extreme end of the board are located the constant current panels for controlling the constant current tubs on the series arc lighting system of the town. The voltage on the system is kept constant by a Tirrell automatic voltage regulator. The high-voltage apparatus for the proposed high-tension lines from the hydro-electric plant are behind and above the switchboard, partitioned off from the rest of the equipment. It consists essentially of oil switches, aluminum lightning arrester and static transformer, which reduces the voltage from 44,000 to 2,200. Under the transformer are provided suitable oil tanks and water piping to cool the oil in the transformer.

A 10-ton hand-operated traveling crane which runs over the entire turbine and pump room is provided for handling heavy machinery parts. A transfer car permits the transformers to be wheeled out under the crane to facilitate handling their cores for inspection or repair.

This plant, during the short time which it has been operated, has shown a material saving of fuel as compared to the old plant which it supplants. A still greater saving is anticipated when the new hydro-electric plant comes into service and the steam station is held as an auxiliary only.

HUMIDITY OF COAL MINE AIR.

The fact that dry bituminous coal dust will explode under certain conditions has been proved both by the experience of the past and by laboratory tests and is now generally admitted by all coal men.

That coal dust may be rendered inert by the proper application of moisture has been shown both by laboratory tests and by the absence of explosions at mines in which moisture is present in the proper proportion to the quantity of dust produced. The result of an investigation in Illinois, of the humidity of mine air, carried out by the United States Bureau of Mines, leads to the belief that steam may be applied to the intake air in such a way as to offer the most economical and efficient method of dampening coal dust.

The Panama Canal was closed to traffic five days, October 15-20, by a landslide in Culebra Cut. Fifteen ships were detained one or more days each, and will have claims on the government for demurrage.

DESIGNING SMALL WATERWORKS SYSTEMS.*

By William S. Johnson.

IN Massachusetts there are 215 water supply systems, and of these, 152 were installed before the population of the towns they supply was 5,000, and 111, or more than half, are now still supplying towns of less than 5,000. In fact, the opportunity seldom comes to design a complete system of works for a large community, the larger systems being extensions of the system designed for the small town. As there are only four towns in Massachusetts having a population of more than 3,000, which remain unsupplied with water, it is likely that, in that State at least, the problems arising in small systems will be more numerous than the problems connected with the larger systems, although, perhaps, not so interesting to any but those immediately affected.

It has been my lot to put in a number of small waterworks plants, and it has surprised me to see how easily 10 per cent. of the cost of construction may be saved by a thorough study of the problem. I have also found that many problems over which I have worked have been solved by others, who have kept the results to themselves, not because of unwillingness to part with the information, but because the matter seemed too small to be of general interest. It is with a view of encouraging the discussion of the problems connected with small waterworks installations, as well as to give a few of the results of my own experience that this paper is presented.

Provision for Future Requirements. — The works should be designed for a long time in the future, but the design should provide for as little immediate construction as is possible except where the cost of extensions or increased capacity will be much more than the cost of doing the work in the beginning.

To build works for a long time in the future assumes a power of prophecy which most of us do not possess. It is impossible to foretell the future growth of the whole or any part of the community. The advancements in the art of water supply engineering are so rapid that portions of the plant are likely to become obsolete before they are worn out. The requirements of the public which uses the water are changing very rapidly. For these reasons it is desirable to build only for the immediate future, and to plan for additional works to be constructed as they become necessary.

Fire Protection Requirements.—The capacity of the distributing system is determined, in the case of the small town, by the fire-protection requirements solely. One good, effective fire stream will use water at as great a rate as the ordinary town of 5,000 inhabitants will require for domestic purposes during the hours of maximum draft.

The quantity of water which will be drawn from the sources of supply depends upon the population to be supplied, the character of the residences supplied, the care taken to prevent leaks and other wastes, and the use of water for manufacturing or mechanical purposes. It is exceedingly difficult to evaluate these factors, since it is impossible accurately to forecast the industrial development or retrogression of the average small community. The population to be served depends primarily upon the growth of the community's industries. A future per capita domestic consumption of from 75 to 100 gallons per day for ordinary small towns does not seem unlikely, and in the case of towns having large estates and a large area of well-kept lawns the consumption may be much larger.

Metcalf, Kuichling and Hawley, in a paper before the American Waterworks Association, state that "the cost of the portion of the waterworks plant involved by fire protection probably constitutes from 60 to 80 per cent. of the entire cost of the physical property in the case of communities having less than 5,000 population." This is undoubtedly true except in those places where it is necessary in order to secure water of sufficient purity for domestic purposes, to go to a large expense in obtaining it or in its purification.

In a small town it is usually necessary to depend entirely on hydrant streams without the use of steamers, and it is essential, therefore, that the works, either by themselves or assisted by some outside source, should furnish both the requisite quantity of water and the proper pressure with which to fight the greatest conflagration which is likely to occur, and to do this under the most unfavorable conditions in regard to domestic consumption and quantity of water in reservoir or standpipe.

Fire Streams.—The standard fire stream is now considered to be that thrown by a 1⅛-inch smooth nozzle, discharging 250 gallons per minute, and it is generally considered by the insurance engineer that a hose stream which does not throw 200 gallons per minute is not a good stream. There are many cases, however, where smaller streams throwing from 150 to 175 gallons per minute would furnish reasonable protection, and this is all that a town would be justified in providing in some districts. In the outlying sections of small towns any fire which gets sufficient headway in the ordinary building so that it cannot be controlled with two streams of 150 to 175 gallons each is not likely to leave much of value if it is extinguished by using six streams. In such cases the value of the water is chiefly in saving adjacent buildings, and for this purpose even small streams are of great value. For streets in a district where the houses are small and occupy comparatively large lots with no prospect of any considerable increase in density of population, and where extensions of the mains are not likely, a hydrant which will furnish 300 gallons per minute under a suitable head to any building in the territory supposed to be covered by this hydrant will be good fire protection. More is desirable, but the advantages are not sufficiently great to warrant the expense of larger mains to secure it. In a district where the houses are nearer together, but where there are no business blocks, apartment houses or other large buildings, it should be possible to get 500 or 600 gallons per minute at any point. Where there are business blocks and other large buildings and where the buildings are very close together, as they frequently are in the centre of a small village, it should be possible to get 1,000 gallons per minute. Where there are factories or other special fire risks a much larger quantity may be necessary. and a special study should be made of each case.

Pressure and Hydrant Spacing.—The pressure required at the hydrants while the hydrants are being used should be great enough to force the water through the greatest length of hose which will be used and throw it to a sufficient height to cover any building. The hydrant spacing and the pressure should, therefore, bear some relation to each other. Table I., from E. B. French, gives the limit of a good, efficient fire stream with different lengths of good, rubber-lined cotton hose, with a constant pressure of 60 lbs. at the hydrant, with moderate wind. Table I. also gives the corresponding amount of water which would be discharged.

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* Read at a meeting of the New England Waterworks Association.

Table I.—Height and Volume of One $1\frac{1}{8}$-Inch Stream Flowing from a Smooth-Bore Nozzle.

Length of hose, ft.	Limit of height, ft.	Discharge, gals. per min.
100	67	250
200	59	222
300	52	206
400	44	188
500	40	178
700	33	158
1,000	25	140

Table I. shows the importance of having hydrants near the buildings to be protected. Unless the hydrants are near enough to furnish water at the fire under a good pressure, the expense of large pipes and a high reservoir is largely wasted. The cost of a two-way hydrant in place is about $40, and in the ordinary distribution system about eight hydrants are required per mile of street main to keep the hydrants within 250 feet of every building in the territory covered; so that the expense of hydrants is very small compared with the expense incurred in other parts of the system to obtain efficient fire protection. In general, hydrants should not be more than 500 feet apart in the outlying sections. In the more closely built-up sections they should be so spaced as to make it possible to get the number of streams which are considered necessary at any particular point with the use of not more than 300 feet of hose for each stream. This figure may be modified, however, if the pressure is unusually high, and should be if the pressure is unusually low.

The minimum pressure desirable for good fire protection with hydrants spaced as suggested is about 50 pounds per square inch at the hydrants when they are in use. This pressure will give, with 300 feet of best quality hose and a $1\frac{1}{4}$-inch nozzle, a stream of 185 gallons per minute, which can be thrown to a height of 44 feet. With 200 feet of hose the quantity thrown would be about 200 gallons per minute, and the height would be increased to 50 feet. There are cases where in the higher sections of the town these pressures are almost impossible, and in such places the hydrants should be so located as to require as little hose as possible. In the case of thickly built-up villages, the pressure should be 60 pounds per square inch at the hydrant when the water is being drawn at the maximum rate. This pressure will give a stream of more than 200 gallons per minute with 300 feet of hose, and with 200 feet of hose will throw 222 gallons per minute to a height of about 60 feet.

Size of Mains.—The size of the mains depends entirely on the requirements determined on to give fire-fighting facilities and on the head available. When these are known the system can readily be designed. Generally, however, the head which can be secured is not fixed, but can be made whatever is desired by going to additional expense, and the determination of the most economical arrangement of height of reservoir, size of pipes and spacing of hydrants is a matter for careful study. The rule adopted in many places to put in no street main less than 6 inches in diameter in most cases works out properly, but there is no excuse for it as an arbitrary rule. A short street will many times be better served with a 4-inch pipe than other streets in the same system with 6-inch mains, and the money saved by using the smaller pipe could well be expended in strengthening those parts of the system which are weaker. The standard should be the quantity of water the pipe will deliver and the head under which it delivers this amount. If a 4-inch pipe will do this satisfactorily, there is no good reason why it should not be used.

The loss of head due to friction in a 6-inch pipe which has been in the ground for some time, when water is being drawn at the rate of 300 gallons per minute, is about 10 feet per 1,000 feet of length, and this figure, together with the required pressure at the hydrant of 50 pounds per square inch, should, in general, determine the allowable length of 6-inch pipe as a dead end.

The maximum desirable pressure is a matter on which there is much disagreement, but the limit is constantly being extended. If it should prove to be more economical to have a system where the pressure runs up to 150 pounds, there would seem to be no good reason why this should not be done in a new system of waterworks, and it would be likely to prove much more satisfactory than to maintain two levels. In 86 small towns in Massachusetts the average static pressure in the central portion of the town is 79 pounds per square inch. Nine of these towns have pressures of less than 50 pounds; 33 have pressures of from 50 to 75 pounds; 21 from 75 to 100 pounds, and in 13 the pressure is more than 100 pounds.

Pumping Engines.—The development of the oil and gasoline engine has done much to make waterworks systems for small places financially possible. When the only available pumping machinery was the steam pump, the cost of installation of pumps and boilers, the cost of the pumping station to house them, and the cost of maintaining the plant made waterworks practically out of the question unless a gravity supply could be secured. With the new form of engine, however the conditions are quite different. The cost of the machinery has been greatly reduced, the cost of the station is much less, and the cost of operating is reduced to a minimum on account of the fact that with oil or gasoline there is no consumption of fuel except while work is being done, while with a steam plant a large proportion of the coal is used in banking the fires and getting up steam. Electricity is also becoming an important factor in connection with small pumping plants, although the cost of current is so great (in New England) that there are few places where oil or gasoline are not more economical except for auxiliary plants used only occasionally.

Pumps should usually be designed for the greatest economy in doing the work which they are called upon to do regularly in supplying the domestic needs of the town without regard to their use for fire protection purposes. It is seldom feasible in the small system to have pumps of sufficient capacity to be of very great value in case of fire, and dependence for fire protection should be placed on water stored in a reservoir or large standpipe or tank, or on some connection with factory pumps through which a large supply of water can be quickly secured. With increased size of pumps it is necessary to have a larger force main, a larger suction pipe, more wells, if the supply is taken from driven wells; in fact, a considerable portion of the plant must be increased in size and made more expensive in order to operate large pumps. Large pumps are somewhat more efficient than small ones, and if an attendant remains at the station while the pumps are in operation there is a saving in the shorter hours required with the large pump. With the oil engine, however, or with electricity, constant attendance is unnecessary, especially in the case of the smaller plants.

Pumping machinery should always be provided in duplicate, and works, although designed to run most economically when one unit is in operation, can be operated, if necessary, at double capacity with a somewhat reduced efficiency. A plant designed for a community which will use from 100,000 to 150,000 gallons per day, should generally have a capacity of about 250 gallons per minute for each unit. This would mean the operation of one of the pumps for from six to ten hours each day. Such a plant would give two large fire streams in case of fire by starting both of the pumps. Many pumping plants are undoubtedly of too large capacity for economy, and the tendency in recent years has been to make them smaller, especially when the power used is some form of internal combustion engine.

Distributing Reservoir.—The design of the distributing reservoir is affected chiefly by the topography, the requirements for fire protection and by facilities for pumping. In a much less degree it is affected by the consumption of water. The effect of the topography upon the design is generally to change the reservoir from what is desirable to what is practicable. In a comparatively flat community it is practically impossible to store as much water at so great an elevation as is desirable, and in such cases the distributing reservoir must be cut down and other portions of the system must be designed to do the work which should properly be done by the distributing reservoir.

When the topography is such that it is feasible to build a reservoir of any desired size and any height, the design is dependent almost entirely upon the requirements for fire protection. Generally, it is found that the desirable static pressure from the reservoir at the point where there is likely to be the greatest demand for water is from 80 to 100 pounds, depending to a large extent upon the distance from the reservoir to the centre of distribution. The reservoir should be, if practicable, large enough to hold at the required elevation, in addition to the domestic supply for 24 hours, a sufficient quantity of water with which to fight any fire which is likely to occur. A fire in the built-up portion of a village may take about 1,000 gallons per minute, or 60,000 gallons per hour. In general, the time during which this quantity will be required will not be more than from two to four hours. Applying this rule to the ordinary town with no large fire risks, the capacity of the reservoir to standpipe should be from 300,000 to 400,000 gallons.

Pipe Thickness.—The part of the design in which theory plays the smallest part, and in which even experience is likely to count for little, is in the determination of the thickness and weight of cast-iron mains. The static pressure which pipes have to withstand and the breaking strength of the cast-iron are the only elements in determining the proper thickness of the pipes which are even approximately known, and determining the thickness from these elements alone would give pipes of about the thickness of cardboard.

The formula used by the New England Waterworks Association is:—

$$t = \frac{pr}{1/5\ (16{,}500)} + \frac{p'r}{1/5\ (16{,}500)} + 0.25$$

where t is the thickness of the shell in inches; r, is the radius of the pipe; p, the static pressure in pounds per square inch; p', an assumed water hammer in pounds per square inch; 16,500 is the breaking strength of cast-iron; and 5 is a factor of safety.

The chief uncertainties in the determination of the proper thickness of pipes are the water hammer, the effect of corrosion, the possibility of breakages in handling, the strains due to imperfect foundations or unequal settlement, and the eccentricity of castings and other imperfections in the pipe. There is no reason why the water hammer in a small system should not be kept below the figures ordinarily used in the formula. There are few, if any, authentic cases where corrosion of a cast-iron pipe has caused its failure. In fact, if a pipe has been in the ground long enough to corrode, it seldom fails from any cause. The strains due to imperfect foundation and settlement, in the case of small pipes, can be neglected if proper precautions are taken during construction. The difficulties due to imperfections in the casting and to the handling of thin pipes are the most serious, and to overcome these is the duty of the founders. That they will be overcome, if the engineers insist on light pipes, there is no doubt, for already much has been done along these lines; the cost per ton may be somewhat increased if lighter pipes are used, but this increased cost will be nothing like the saving accomplished by the use of the lighter pipe.

In my own practice I have put in many miles of Class C pipe where the pressures run up to 115 pounds per square inch and have never known of a failure which would have been prevented by using thicker pipe. The breakage in the handling may be or may not have been greater. In any case, it was not excessive. For the ordinary conditions in a small town I would never use a heavier pipe than the Class C, and lighter pipe may safely be used in many cases.

Depth of Cover for Pipe Lines.—The depth to which street mains should be laid has been investigated by a special committee of the New England Waterworks Association (see report presented at November, 1909, meeting), and the experience of the cold winter of 1911-12 has given valuable experience to those who have had charge of waterworks. The depth determined on affects the cost of the works materially, especially if rock is encountered, and if it is safe to reduce the depth it certainly should be done.

Theoretically, street mains might be laid at different depths in different soils, being a foot nearer the surface in clay than in gravel, but in the average New England town there are so many soils that it is not wise to make any distinction. The only discrimination which it would appear safe to make is in the case of places where the ground water always stands near the surface; here the pipes may be laid in shallow trenches. The freezing of the pipes is such a serious matter that it would seem to be unwise to take any chances in an attempt to save money on trench excavation. The best practice seems to be, for a climate like that of Massachusetts, to have the centre of the pipe from 4.75 to 5 feet beneath the surface.

OPPORTUNITIES FOR EXPORT OF RAILWAY MATERIAL.

German exports of rails to South Africa last year were valued at $300,000, and that of rolling stock at $120,000, according to a report of the Department of Trade and Commerce. Canada should make progress in both these items in the future. Under the item of locomotives, Germany's trade for 1913 was only $22,000. In addition to the railway material imported under the general heading, there were also imported in 1913 for the Union Government: rails, $1,315,000; sleepers, $897,000; locomotives, $570,000; rolling stock, $1,742,000, and under the item, all other, $329,000. The only line which Germany shipped was under all other, and her total was only $15,000. This year a number of locomotives and cars were ordered in Germany and under normal conditions she would have figured both this year and next in the Union Government's imports.

TRANSMISSION LINE CHARACTERISTICS.

By E. Maerker, A.Sc.
Designing Structural Engineer, Toronto.

(Continued from October 15th issue.)

An article on transmission line characteristics by the same author appeared in the issue of October 15th, dealing with 250,000 C.M. copper wire and 400,000 C.M. aluminum wire, both for 600-ft. spans. In transmission line work the standard span (of, say 600 feet) cannot always be adhered to, due to river crossings, railways, highways, etc. For this reason a chart comprising various spans would be of great value. Furthermore, since Charts I. and II., in previous issue, give a complete picture of the behavior of the wire under different loadings and for different temperatures, a chart with no ice and no wind acting on the wire, would be more useful for stringing purposes, including, of course, the usual range of temperature.

Chart III. has been drawn up for this purpose for a 250,000 C.M. copper wire, ranging from a 200-ft. span to a 1,000-ft. span, with no ice and no wind acting on the wire. It is to be understood that all these spans pull up to 5,900 lbs. at 0° F. with ½ inch of ice and 8 lbs. per square foot of wind pressure on the wire, as explained in previous article. In Charts I. and II. the points of intersection were solved graphically by assuming values for S_1, the sag, and computing the corresponding values for P_1, the tension. In Charts III. and IV. all points of intersection will have to be solved algebraically and then plotted.

Following equations of previous article are employed:

Modified equation (2) $L_1 - L_0 = L_0 \alpha t + \dfrac{P_1 - P_0}{aE} L_0$

Equation (4) $P_1 = \dfrac{w_1 l^2}{8 S_1}$

Solving for P_1 in the former equation, we have:

$$P_1 = \frac{L_1}{L_0} aE - [aE(1 + \alpha t) - P_0]$$

and substituting for L_1 and L_0 its equal $l + \dfrac{8S_1^2}{3l}$ and $l + \dfrac{8S_0^2}{3l}$ respectively, we obtain:

$$P_1 = \frac{3l^2 + 8S_1^2}{3l^2 + 8S_0^2} aE - [aE(1 + \alpha t) - P_0]$$

$$= \frac{3l^2 aE}{3l^2 + 8S_0^2} + \frac{8S_1^2 aE}{3l^2 + 8S_0^2} - [aE(1 + \alpha t) - P_0]$$

but $S_0^2 = \dfrac{w_0^2 l^4}{64 P_0^2}$ and substituting this in above:

$$P_1 = \frac{3l^2 aE}{3l^2 + \dfrac{w_0^2 l^4}{8P_0^2}} + \frac{8S_1^2 aE}{3l^2 + \dfrac{w_0^2 l^4}{8P_0^2}} - [aE(1 + \alpha t) - P_0]$$

Rearranging and simplifying terms:

$$P_1 = \frac{aE}{\dfrac{l^2}{8}\left(3 + \dfrac{w_0^2 l^2}{8P_0^2}\right)} S_1^2 + \frac{aE}{\dfrac{1}{3}\left(3 + \dfrac{w_0^2 l^2}{8P_0^2}\right)} - [aE(1 + \alpha t) - P_0]$$

Eliminating P_1 by using equation (4):

$$\frac{w_1 l^2}{8S_1} = \frac{aE}{\dfrac{l^2}{8}\left(3 + \dfrac{w_0^2 l^2}{8P_0^2}\right)} S_1^2 + \frac{aE}{\dfrac{1}{3}\left(3 + \dfrac{w_0^2 l^2}{8P_0^2}\right)} - [aE(1 + \alpha t) - P_0] \quad - \quad (6)$$

Equation (6) is a reduced cubical equation of the form

$$x^3 + px + q = 0$$

S_1 being the unknown quantity. All other quantities are constants for a definite span and temperature.

Table VII. has been compiled to solve equation (6).

$aE = .19635 \times 16{,}000{,}000 = 3{,}141{,}600$; $\alpha = .0000096$
$w_1 = .762$
$w_0 = 1.788$
$w_0^2 = 3.1969$
$P_0 = 5{,}900$
$P_0^2 = 34{,}810{,}000$

With these values substituted in equation 6, we are now able to solve for the sag, S_1. This is easily accomplished by trial with two sets of slide rules, as follows:

Let it be desired to find the sag for a 400-ft. span at 90 degrees F. With values substituted from Table VII., equation 6 will reduce to $\dfrac{15{,}240}{S_1} = 52.3\,S_1^2 + 3{,}139{,}678 - 3{,}138{,}415$, and finally $\dfrac{15{,}240}{S_1} = 52.3\,S_1^2 + 1{,}263$.

With the left-hand side of the equation operated by the setting of one slide rule and the term $52.3\,S_1^2$ operated by the setting of the other, the value for S_1 will soon be found by successive trials. In this case we have, assuming $S_1 = 5.43$ ft., $\dfrac{15{,}240}{5.43} = 52.3 \times 5.43^2 + 1{,}263$ or $2{,}810 = 1{,}545 + 1{,}263 = 2{,}808$, which gives the sag sufficiently accurate.

Table VIII. has been figured accordingly and the values for P_1 computed from equation 4 $P_1 = \dfrac{w_1 l^2}{8 S_1}$.

Chart III. has been drawn up with the tension as the horizontal axis and the sag as the vertical axis. Any values for spans between those shown, can be interpolated with sufficient accuracy.

Chart III. is indispensable for the purpose of stringing wire at any temperature. It brings out a very important factor which, to the author's knowledge, has been disregarded in the construction of many transmission lines.

Coupling a 600-ft. span with a 200-ft. span, it is seen that at 120 degrees F. the tension for the 600-ft. span is 2,465 lbs., and for the 200-ft. span 2,350 lbs., a difference of 115 lbs. in favor of the longer span. At -30 degrees, the 600-ft. span has a tension of 4,110 lbs. and the 200-ft. span a tension of 6,400 lbs., a difference of 2,290 lbs. in favor of the shorter span. These 2,290 lbs. represent a dead pull along the line and too great a stress on the insulator and the supporting structure, especially if this particular tower should happen to be at an angle, in which case the insulator would have to bear the stress due to the angle in addition to the stress of 2,290 lbs., as mentioned above.

It will be noticed here that, although a maximum tension of 5,900 lbs. is specified at 0° F., with ice and wind, the tension for a 200-ft. and 300-ft. span at -30°

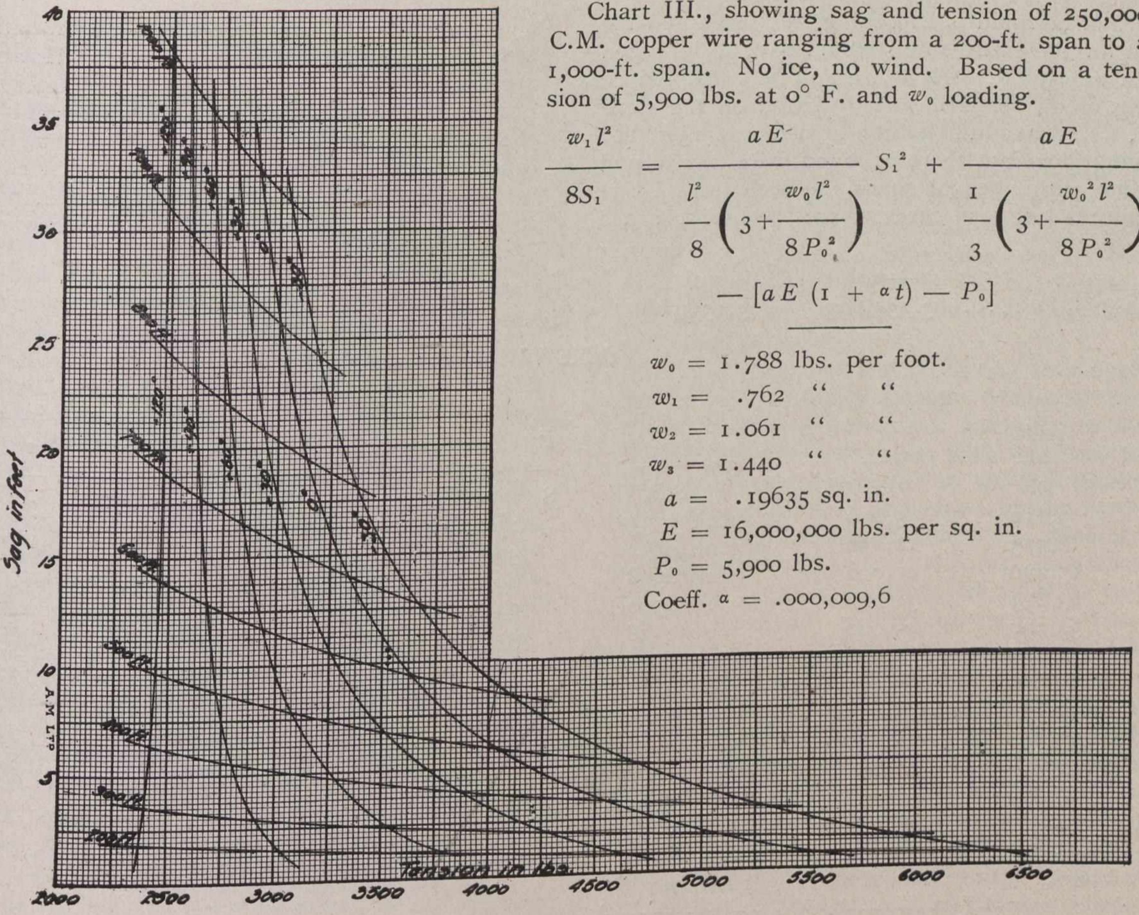

Chart III., showing sag and tension of 250,000 C.M. copper wire ranging from a 200-ft. span to a 1,000-ft. span. No ice, no wind. Based on a tension of 5,900 lbs. at 0° F. and w_0 loading.

$$\frac{w_1 l^2}{8S_1} = \frac{aE}{\frac{l^2}{8}\left(3+\frac{w_0 l^2}{8P_0^2}\right)} S_1^2 + \frac{aE}{\frac{1}{3}\left(3+\frac{w_0^2 l^2}{8P_0^2}\right)}$$

$$-[aE(1+\alpha t)-P_0]$$

$w_0 = 1.788$ lbs. per foot.

$w_1 = .762$ " "

$w_2 = 1.061$ " "

$w_3 = 1.440$ " "

$a = .19635$ sq. in.

$E = 16,000,000$ lbs. per sq. in.

$P_0 = 5,900$ lbs.

Coeff. $\alpha = .000,009,6$

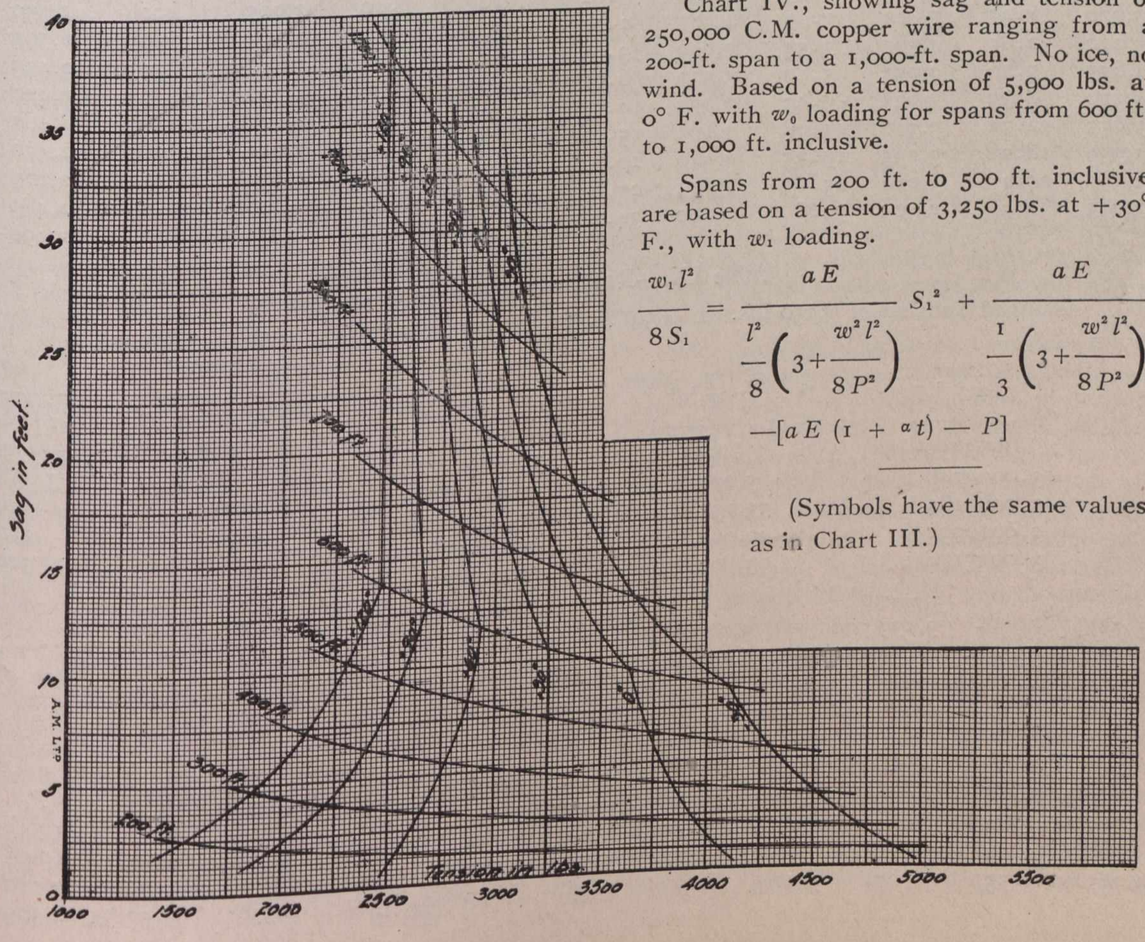

Chart IV., showing sag and tension of 250,000 C.M. copper wire ranging from a 200-ft. span to a 1,000-ft. span. No ice, no wind. Based on a tension of 5,900 lbs. at 0° F. with w_0 loading for spans from 600 ft. to 1,000 ft. inclusive.

Spans from 200 ft. to 500 ft. inclusive are based on a tension of 3,250 lbs. at +30° F., with w_1 loading.

$$\frac{w_1 l^2}{8S_1} = \frac{aE}{\frac{l^2}{8}\left(3+\frac{w^2 l^2}{8P^2}\right)} S_1^2 + \frac{aE}{\frac{1}{3}\left(3+\frac{w^2 l^2}{8P^2}\right)}$$

$$-[aE(1+\alpha t)-P]$$

(Symbols have the same values as in Chart III.)

with no ice and no wind is exceeding this value and the computation for these two spans would have to be based on 5,900 lbs. at −30° F. with no ice and no wind. Since the stringing of all spans is usually based on the same assumption, *i.e.*, maximum tension at a low temperature under maximum loading, there is bound to be a dead pull along the line with unequal spans, as seen from Chart III. The author has seen cases where the line turned a slight angle and a standard tower was found sufficiently strong to resist this additional sidepull. However, a short span was used on one side of the tower, toward the angle, presumably to counteract the sidepull. This, of course, made matters worse and added to the pull on the insulator and tower, instead of relieving the stress.

The influence of the temperature in the tension is much greater for short spans than for long spans. It is

	−30°	0°	+30°	+60°	+90°	+120°
$aE(1+\alpha t) - P_0$	3,134,795	3,135,700	3,136,605	3,137,510	3,138,415	3,139,320

Table VII.

Span.	$\frac{w_1 l^2}{8}$	$\frac{l^2}{8}$	$3+\frac{w_0^2 l^2}{8P_0^2}$	$\frac{l^2}{8}(3+\frac{w_0^2 l^2}{8P_0^2})$	$\frac{1}{3}(3+\frac{w_0^2 l^2}{8P_0^2})$	$\frac{aE}{\frac{l^2}{8}(3+\frac{w_0^2 l^2}{8P_0^2})}$	$\frac{aE}{\frac{1}{3}(3+\frac{w_0^2 l^2}{8P_0^2})}$
200	3,810	5,000	3.0004592	15,002	1.000153	209.4	3,141,119
300	8,573	11,250	3.0010332	33,762	1.000344	93.1	3,140,518
400	15,240	20,000	3.0018368	60,037	1.000612	52.3	3,139,678
500	23,813	31,250	3.0028700	93,840	1.000957	33.5	3,138,597
600	34,290	45,000	3.0041328	135,186	1.001378	23.24	3,137,278
700	46,673	61,250	3.0056252	184,095	1.001875	17.07	3,135,720
800	60,960	80,000	3.0073472	240,588	1.002449	13.05	3,133,928
900	77,153	101,250	3.0092988	304,692	1.003100	10.31	3,131,927
1000	95,250	125,250	3.0114800	376,435	1.003827	8.35	3,129,624

Table VIII.

$$\frac{w_1 l^2}{8S_1} = \frac{aE}{\frac{l^2}{8}(3+\frac{w_0^2 l^2}{8P_0^2})} S_1^2 + \frac{aE}{\frac{1}{3}(3+\frac{w_0^2 l^2}{8P_0^2})} - [aE(1+\alpha t) - P_0]$$

	−30°		0°		+30°		+60°		+90°		+120°	
	P_1	S_1	P_1	S_1	P_1	S_1	P_1	S_1	P_1	S_1	P_1	S_1
200	6,400	.59	5,520	.69	4,650	.82	3,810	1.00	3,025	1.26	2,350	1.62
300	5,910	1.45	5,075	1.69	4,287	2.00	3,550	2.42	2,905	2.95	2,395	3.58
400	5,310	2.87	4,565	3.34	3,880	3.93	3,280	4.64	2,810	5.43	2,425	6.28
500	4,675	5.10	4,055	5.89	3,520	6.77	3,080	7.74	2,730	8.74	2,440	9.76
600	4,110	8.35	3,635	9.43	3,255	10.53	2,940	11.68	2,695	12.82	2,465	13.92
700	3,675	12.72	3,340	13.98	3,065	15.22	2,835	16.45	2,645	17.68	2,470	18.90
800	3,350	18.2	3,135	19.45	2,940	20.75	2,790	21.85	2,610	23.35	2,475	24.65
900	3,190	24.2	3,010	25.65	2,855	27.05	2,715	28.45	2,600	29.7	2,485	31.0
1000	3,045	31.3	2,905	32.8	2,790	34.1	2,685	35.5	2,585	36.9	2,490	38.2

Table IX.—Rectification of Curves.

Assumed Tension of 3,250 lbs. at + 30° F. for Spans from 200 ft. to 500 ft., Inclusive.

	$3+\frac{w_1^2 l^2}{8\times 3250^2}$	$\frac{l^2}{8}(3+\frac{w_1^2 l^2}{8\times 3250^2})$	$\frac{1}{3}(3+\frac{w_1^2 l^2}{8\times 3250^2})$	$\frac{aE}{\frac{l^2}{8}(3+\frac{w_1^2 l^2}{8\times 3250^2})}$	$\frac{aE}{\frac{1}{3}(3+\frac{w_1^2 l^2}{8\times 3250^2})}$
200	3.0002748	15,001	1.0000916	209.4	3,141,312
300	3.0006184	33,757	1.0002061	93.1	3,140,953
400	3.0010992	60,002	1.0003664	52.3	3,140,449
500	3.0017178	93,804	1.0005726	33.5	3,139,802

	−30°	0°	+30°	+60°	+90°	+120°
$aE(1+\alpha t)$ - - -	3,139,790	3,140,695	3,141,600	3,142,505	3,143,410	3,144,315
$aE(1+\alpha t) - 3250$	3,136,540	3,137,445	3,138,350	3,139,255	3,140,160	3,141,065

Table X.

	−30°		0°		+30°		+60°		+90°		+120°	
	P_1	S_1	P_1	S_1	P_1	S_1	P_1	S_1	P_1	S_1	P_1	S_1
200	4,880	.78	4,050	.94	3,250	1.17	2,540	1.50	1,955	1.95	1,545	2.47
300	4,715	1.82	3,950	2.17	3,250	2.64	2,655	3.23	2,200	3.90	1,855	4.62
400	4,500	3.39	3,830	3.98	3,250	4.70	2,770	5.50	2,400	6.35	2,110	7.22
500	4,285	5.55	3,725	6.40	3,250	7.33	2,870	8.30	2,550	9.33	2,305	10.32

not always sufficient to base all computations on a maximum loading at 0 degrees F., but investigate the tension at the lowest temperature with a w_3 loading, especially for short spans. (See Charts I. and II. in previous article.) Since unequal spans cannot be avoided in transmission line work, the absolute pull along the line can be lessened materially. This is accomplished by reducing the tension for the shorter spans, *i.e.*, by altering the assumed basis of maximum loading at 0 degrees F. The ideal condition would be to have a +45 degrees temperature curve run vertically and the intersection points for all spans equidistant from this line (Chart III.). This would distribute the stress equally. From Chart III. we notice that at +30 degrees and a 600-ft. span, the tension is, say 3,250 lbs. By producing this +30 degree temperature curve vertically down and rectifying all curves below this point accordingly, we are able to distribute the stress more equally. The new basis to work from now is 3,250 lbs. at +30 degrees F. with no ice and no wind for spans ranging from 200 ft. to 500 ft. inclusively. The values for this new basis of w_1 loading (no ice and no wind) and 3,250 lbs. tension at +30 degrees F. will have to be substituted in equation 6.

w_1 is to be substituted for w_0, and 3,250 lbs. for P_0, and the temperature is to be based on +30° instead of 0° as before.

Table IX. shows these corrections and substituted in equation 6, we again solve for values of S_1 and P_1.

Table X. gives these new values for the sag and the tension, and plotted, we obtain the rectified curves for spans from 200 ft. to 500 ft., as shown on Chart IV.

It will be noticed that the tension for the 200-ft. span has been reduced to 4,880 lbs. at −30 degrees F.

If we attempt to couple this span with a 600-ft. span, we have a difference of 4,880 — 4,110 = 770 lbs. at —30° F. in favor of the short span and at 120° F., a difference of 2,465 — 1,545 = 920 lbs. in favor of the longest span, against a former difference of 2,290 lbs.

By proper substitutions we can figure what tension these spans would reach at 0° F. and maximum loading, and also at —30° F. and w_3 loading. The latter being the critical value. By substituting for this critical value in equation 6, we find a maximum tension of 5,520 lbs. for a 200-ft. span, which is less than the allowable tension of 5,900 lbs. In conclusion, it might be said that Chart IV. gives all necessary information to the engineer in the field for stringing wire according to the best engineering practice.

CEMENT AND PLASTER OF PARIS.

In 1912, Australia imported 2,603,792 cwt. (of 112 lbs.) of cement (Portland) to the value of £261,680. Of the quantity stated, Germany was the country of origin of 1,393,456 cwt., valued at £144,564, while Belgium contributed 269,760 cwt., valued at £25,879. Favorable freight rates and the quality of brands established on the market for many years were contributing factors to this trade. Australian manufacturers of cement have notified an increased output, but when present stocks of imported cement are exhausted there should be a market available for Canadian manufacturers, established near shipping port, to exploit.

In 1912, the imports of plaster of Paris, approximately, were 251,051 cwt., valued at £39,104, of which Germany contributed 116,659, valued at £17,184. This item is of particular interest to the manufacturers of plaster of Paris in Nova Scotia and New Brunswick, one brand of which is becoming favorably recognized in Australia. The plaster must be dead white to meet the requirements of the trade and any pink shade in the material will condemn it.—Canadian Trade and Commerce Report.

STANDARDS WITH REFERENCE TO SEWAGE TREATMENT.

By R. O. Wynne-Roberts,
Consulting Engineer, Regina.

In the latest issue of the Public Health Journal there appears the paper on the above subject, which Mr. T. Aird Murray read at the Public Health Convention held in Regina in September, 1913. His paper was relegated to the tail end of the convention, and it was with regret that many found the time too limited for a full discussion.

Mr. Murray started by stating that engineers, when called upon to design sewage treatment work, will naturally "ask the Provincial authority to state what it expects and will insist upon with reference to the degree of purification and manner of sewage treatment." This would be an excellent procedure, but he further on states that it is "impossible to adopt any general standard of required degree of purity, and that each case under consideration requires separate adjustment with reference to local conditions and requirements." This places the engineer in an anomalous position, for he is left in doubt as to what may be required.

It should, however, be possible to give the engineer some indication as to what will be demanded to satisfy the provincial authorities as regards design, capacity and degrees of purification under certain specific conditions. Such requirements cannot, of course, be rigid or stereotyped, but should possess sufficient elasticity.

Mr. Murray next referred to the standards suggested by the Royal Commission on Sewage Disposal in their fifth report. These standards were revised in the eighth report and bear little resemblance to those quoted.

The revised standards are, that the effluent should not contain more than 3 parts of suspended matter per 100,000 parts, and with the suspended matter should not take up more than 2 parts of oxygen per 100,000 at 65° F. in 5 days. If the dilution is very low, then it is proposed to make the standard more stringent. If the dilution is from 150 to 300 volumes, the dissolved oxygen test may be omitted and 6 parts of suspended matter per 100,000 permitted. If the dilution is from 300 to 500 volumes, the suspended matter may be 15 parts per 100,000, and when the dilution is over 500 volumes crude sewage may be discharged into the stream after the coarser particles have been removed by detritus tanks and screens.

Mr. Murray appears to consider the British standards as inapplicable to Canadian conditions. It may be that they are less stringent than is desirable here, but that is only a question of degree of purification. These standards, however, afford the basis for others more or less stringent, and have been favorably considered by American authorities, for expert chemists, bacteriologists, sanitarians and engineers recognize that the purity of the effluent must be based upon the dissolved oxygen tests, the character of the bacteria, and the quantity and nature of the sediment contained in such effluent.

To ensure as uniform a quality of effluent as possible, it is necessary to conduct regular tests, and this entails the employment of chemists and bacteriologists as well as engineers, which would mean a heavy charge in the case of the smaller towns and cities. Even the employment of chemists and bacteriologists to conduct daily investigations will not obviate the discharge of unsatisfactory effluents, because sewage disposal plants are subject to disturbances, such as failure of pumping machinery, surcharging due to storms, fluctuation in flow of sewage, and to the frailty of human agencies in the management of such works.

The following extract from the report of the Royal Commission on Sewage Disposal was quoted by Mr. Murray: "That any authority taking water from such rivers for the purpose of water supply must be held to be aware of the risks to which the water is exposed, and that it should be regarded as part of the duty of that authority, systematically and thoroughly, to purify the water before distributing it to their customers." Bearing in mind the contingencies inherent to works of this kind, operated under such fluctuating and variable conditions, and by agencies which are inevitably more or less inconstant, the above advice is as reasonable in Canada as anywhere else. The risks are too great to allow of any town consuming water which is liable to contamination. The discovery of contamination is often subsequent to an outbreak of disease, and to depend on effectual purification of sewage effluent before its discharge into a stream is a risky procedure. Sewage treatment is one which varies hourly and daily. It is affected by climatic and meteorological influences, and by manufactural wastes. Its final oxidation by effectual dilution is affected by the fluctuating river flows, by varying velocities of the recipient stream, by the nature of the stream beds and surroundings, by seasons, and by the means adopted for dispersion and diffusion of the effluent.

Dr. Dunbar, when dealing with the pathogenicity of effluents, remarked that "in the case of rivers which serve as sources of water supply, attempts should be made to restrict the infection to a minimum." Whilst this advice is good, it introduces an interesting point, namely, the possibility of pathogenic germs surviving in sewage-polluted waters. Dr. Houston, the Director of Water Examination to the Metropolitan Water Board of London, England, has for many years been conducting a series of researches in this connection. His report may be consulted by anyone interested in this matter. It is the Ninth Research Report, published in April, 1913.

It is not necessary to enter into the details, but it may be stated that 28 samples of crude sewage-polluted waters—one set of which was purposely infected with typhoid bacilli and the other set was not inoculated—were examined according to the most approved method recognized by specialists. The average number of excremental bacteria, as judged by the bile-salt-agar test, was 1,155,040 per c.c. of sewage. Five thousand four hundred and eighty-five colonies recovered from each set of samples were studied, but not one of the colonies from the non-infected samples gave the characteristics of typhoid bacillus, but in the case of the infected samples, out of an average of 205 typhoid bacilli added per 0.01 c.c. of sewage, an average of 20 were afterwards isolated. "The positive result with one set and a negative result with the other justifies the conclusion that whatever number of typhoid bacilli were added to one set of samples, that number could not have been present in the other." Dr. Houston also states that the Thames water in its present condition does not, on the average, contain one single typhoid bacillus per 24 c.c. of water. Over 50 per cent. of the raw water samples contain B. Coli in 0.1 c.c., and less than 25 per cent. of the filtered water samples had B. Coli in 100 c.c.; so, generally speaking, he "concludes, on the basis of the test, that the purification process improves the water at least 1,000 times," and that it requires some imagination to conjecture the possibility of an ordinary consumer of London water imbibing an infective dose of typhoid malarial from this source, always assuming the absence of any accidental infection of the water between the works and the tap."

Like Worcester, Hereford, Shrewsbury and other towns in England, drawing water from contaminated streams, London depends on its supply of water from the Rivers Thames and Lea, both of which are observably contaminated with more or less sewage from a large number of towns, yet the typhoid fever death rate is only 3.3 per 100,000. The water is, of course, carefully stored and filtered before being distributed to the consumers.

The typhoid bacillus is rarely found in sewage, but, assuming a stray one does survive, Dr. Houston submits that it is difficult to believe that "the ingestion of a solitary typhoid bacillus would be likely to produce typhoid fever, even in a highly susceptible individual."

The above named authority, when discussing the incidence of typhoid fever in North America, which is usually attributed to the consumption of impure water, suggests that it may be due to accidental pollution by typhoid "carriers," of whom it is estimated there are about 3 or 4 per 1,000 inhabitants. Dr. Houston submits that the discharge of one person is potentially more dangerous than that of a community. As an instance of this the writer may refer to an epidemic of dysentery which occurred about eight years ago at Simon's Town, South Africa. When it was investigated it was discovered that a Kaffir suffering under that ailment had been employed on the watershed near the head works, and that on the next day there was a heavy rainfall, which evidently washed the filth into the water mains with the above result.

The writer may at a future date further discuss the incidence of typhoid fever from the engineer's point of view, but the foregoing will suffice to indicate that the problem of sewage treatment is one, the principal function of which is to safeguard the health of the public, as far as it is possible. But it is unwise to depend on such treatment to assure a pure water supply, even though thorough sterilization of the effluent is effected. In some parts it is difficult to secure an outfall which will not affect the water supply of a neighboring district. On the other hand, certain towns have contaminated streams or lakes as the most available source of water supply. The duty which devolves on the city authorities is to attain the highest possible efficiency in the treatment of sewage and in the purification of water. There nevertheless remains a duty on the provincial authorities to formulate a standard, and whilst some governmental officials consider it impossible to establish regulations as to the degrees of purification of sewage necessary under different conditions, it is becoming recognized that certain standards, subject to modifications to meet different requirements, can be formulated.

The Royal Commission on Sewage Disposal has published its proposed standards, which have already been quoted in the foregoing.

The authorities in Lancashire, Derbyshire and Yorkshire have their standards. Prof. Phelps submitted in connection with New York sewage disposal that the recipient waters should contain 70 per cent. of possible saturation of dissolved oxygen. Mr. Soper, chairman of the New York Sewerage Commission, considers that a definite standard of cleanness should be established as a guide for future operation. Dr. Winslow expressed an opinion that arbitrary standards are not feasible or desirable, but it is feasible to formulate standards as guiding principles, to be intelligently interpreted in the light of available knowledge in individual cases. He submits that the dissolved oxygen content of recipient waters should not be less than 50 per cent saturation. There should be no effervescence, marked discoloration, decided turbidity, oily, sleek, floating, solid sewage material deposits of sludge or other conditions offensive to sight or smell.

With regard to the purification of polluted water, the International Joint Commission re Pollution of Lakes report that the number of B. Coli per 100 c.c. should be expressed as annual average, that the safe limit of loading water purification plants is exceeded when the annual number of B. Coli in the water delivered to the plant is higher than about 500 per 100 c.c., or when in 0.1 c.c. samples of water B. Coli is found over 50 per cent. of the time.

ELECTROLYTIC TREATMENT OF SEWAGE.

THE purification of sewage by electrolytic treatment has received considerable investigation during the past season by the Borough of Queens, New York City. A plant was installed at the Elmhurst disposal plant on March 26, 1914, for the purpose of observing the effect of the electrolytic and electro-chemical method devised and patented by Mr. C. E. Landreth, of Philadelphia. The process is being introduced by the Electro-Chemico Corporation of New York. It includes screening, passage through an electrolytic machine with addition of lime, and sedimentation for about half an hour. The sludge is dried by filter press. Both the tank effluent and the water extracted from the sludge are stated to be clear, almost devoid of bacteria, and non-putrescible. A report has recently been issued upon the operation and results obtained. From this report, written by Elmer W. Firth, C.E., Ph.D., Engineer of Maintenance, the following information is presented:

The sewage reaching this plant is very variable in composition. Cesspool wastes are permitted to be emptied from tank wagons into a sewer manhole adjacent to the receiving well. The capacity of these wagons varies from 400 to 1,040 gallons and on some days nearly a hundred loads of this strong sewage are added to the normal flow. This contribution will run from 10,000 to 60,000 or more gallons per day in a normal sewage flow of about 800,000 gallons. On the other hand, storm water and ground water render this sewage at times very dilute. The contribution of this cesspool waste has greatly increased the difficulty of treatment by the old methods.

History of Electrolytic Treatment of Sewage and Water.—It should be noted at the start that the present investigations were undertaken with full knowledge of the history of electrolytic appliances as they have heretofore been employed for sewage and water purification; their limitations and failures, the employment of correct principles and on the other hand the unscientific and ridiculous attachments which have from time to time been tried and then discarded as useless. All this, as recorded in the literature on the subject, has been sufficiently discouraging to serve as a warning against blinding enthusiasm for new methods. A brief review of previous efforts in this line will be helpful in comparing the process under consideration with its forerunners.

Electrolytic phenomena have been employed in two ways: First, by the immersion of electrodes in the sewage or water to be treated, and second, by the production of hypochlorites from salt solutions, to be subsequently added to the liquid under treatment.

William Webster, of England, appears to have been the first to utilize the principle of electrolysis in the purification of sewage about 1889, when it was tested on a small scale at Crossness and at other places. His patented process consisted in passing sewage through flumes in which iron or aluminum electrodes were immersed, and he called attention to the oxidizing and precipitating effect and suggested also the production of hypochlorite, which idea was developed three or four years later by Hermite, of France, and Woolfe, of America, in the manufacture of hypochlorite from common salt solution, or from sea water. These two similar ideas could not successfully compete with the cheaper production of hypochlorites on a larger scale and often as bi-products, and their processes appeared to have no advantage beyond the action of the disinfectant. The Woolfe "Electrozone" was used at Brewster, New York, and for a while at Danbury, Conn. The Hermite process was used at Ipswich, England, where the liquid hypochlorite was run into the main sewer. This was abandoned in 1905, after about ten years' operation, because the results obtained were not commensurate with the cost.

It is now recognized that where disinfection alone is desired, the expense is much reduced by applying the reagent as a finishing process after much of the organic matter has been removed from the sewage by sedimentation or filtration. It will, therefore, be perceived that these two processes showed no advance over the Webster process toward the complete purification of sewage.

Under the Harris patents, which were similar to the Webster process, experiments were made on Passaic River water about 1893, and the system was tested again at Louisville, Ky., by Mr. George W. Fuller, in 1896, and his report, "The Purification of the Ohio River Water at Louisville," refers to it as a complete failure. Harris had introduced magnets and a "sparking drum" for passing high-tension electric currents through the liquid, and notwithstanding Mr. Fuller's conclusion that they were absolutely useless, these features were again employed at Santa Monica, Cal., in 1908, but were finally abandoned, resulting in a return to the simple principles utilized by Webster. Alternate iron and aluminum electrodes were used at Santa Monica, spaced about ⅝ in. centre to centre, until it was found that the plates lasted only about three weeks. Later the electrodes used were all iron and they were bound on top with strips of copper in an attempt to lengthen the life of the plates, and it was claimed that the production of copper sulphate helped in the treatment. The Harris patents were later taken up by The Electro-Sanitation Company of Los Angles, which company secured new patents stripped of all useless devices that had been discarded after trial, and in this form the system was again installed at Oklahoma City in 1911.

Experiments were recently made at Toronto on electrolytic apparatus fashioned on the lines of the Oklahoma plant, and the degree of purification effected, according to the published analyses, is not calculated to engender confidence in the process.

All the processes thus far mentioned have relied on the consumption of the iron electrodes by the action of acid ions liberated from any electrolytes normally present in the water or sewage. These acid ions attacking the iron plates produce a certain amount of ferric hydrate, which serves as a coagulant, but in the presence of carbonic acid much of this is dissolved and passes on in solution as ferrous carbonate. Other soluble ferrous salts, such as iron chloride and iron sulphate formed by the attacking ions, constitute additional drains on the metallic iron. This accounts for the failure of the processes mentioned to effect a removal of the suspended matters in the sewage proportionate with the great amount of iron wasted.

It was concluded from the Louisville experiments that atmospheric oxygen served to oxidize the ferrous to ferric salts, thus airing the formation of coagulants, but that atomic oxygen, produced electrolytically, tended to oxidize the iron plates, thus constituting a serious disadvantage in the waste of electric power and metallic iron, and further, that atomic or nascent oxygen did not result in the destruction of bacteria or organic matter. This was all doubtless true of the processes then under observation.

Electro-Chemical Process.—These deficiencies have all been fully met in the process employed at the Elmhurst plant by what will now appear a very simple conception, namely, the introduction of lime with the sewage or water under treatment. The lime solution is added in sufficient quantity to neutralize the free and half-combined acid present and render the liquid slightly alkaline to phenolphthalein. The lime solution serves three purposes: 1st—It prevents the waste of iron electrodes by neutralizing the attacking acid ions; 2nd—The calcium hydroxide, being readily ionized, liberates nascent oxygen from the hydroxyl, while the positive calcium at the cathode reunites with water to form calcium hydroxide again; 3rd—A bulky hydrated calcium carbonate is produced which with any ferric hydrate formed furnishes a remarkable coagulant which settles out in a few minutes, carrying with it most of the suspended matter.

The notable effect of the nascent oxygen in the destruction of organic matter and bacteria is evident from the analyses made.

The first bacteriological tests made on samples taken from the electrolytic machine and from the small sedimentation tank in unsterilized bottles and placed an hour later in the laboratory, showed amazing results in that only one plate out of twelve made with gelatine and agar developed two or three colonies, the rest remaining sterile. Fermentation tubes also showed no gas production in 48 hours, while gas was formed from sewage samples in full quantity in 24 hours and the sewage plates were overgrown with colonies. These results inspired a more careful and systematic study of the effects produced under the conditions adopted for operation.

It has been suggested by some of the engineers and scientists who have inspected this plant that lime alone would have a sterilizing effect, but Dr. Samuel Rideal has observed that "caustic lime used even to the extent of 60 to 70 grains per Imperial gallon (860 to 1,000 parts per million) of sewage is inefficient in sterilization," so that the bacteriacidal effect must be due to the ionization of the calcium hydroxide.

The suggestion has also been made that lime itself has sufficient coagulating effect, without the use of electrolysis, but observations made at the Columbus, Ohio, experimental station showed that 5.87 grains of lime and 5 grains of copperas, with 8 hours retention in tanks, removed only 52% of the suspended matter, and 11% of the dissolved volatile matter, and that the dissolved mineral matter was increased 3% and the bacteria 18%. The statement was also made that 8 hours was insufficient to effect complete coagulation with this amount of coagulant, or to allow for the sedimentation of the precipitant formed in this time. The lime in the Columbus experiments was then increased to 20 grains per gallon and a satisfactory clarification was obtained, but it is stated that a sedimentation period of at least 24 hours following the application was required to prevent the escape of hydrated coagulant from from the precipitation tank. According to a recent report by Sir M. Fitzmaurice, Chief Engineer of the London County Council, lime is held to be of little benefit as applied to London sewage.

In the face of this evidence a single observation of the wonderful coagulation and rapid sedimentation produced immediately with the use of lime in the Elmhurst electrolytic installation will convince the most skeptical of the unique advantage secured by electrolyzing this coagulating agent. The effect is to be ascribed to the hastening of chemical reactions under electric current.

No doubt the colloidal matters which may be assumed to be held in suspension by mutual repulsion of the microscopic particles, due to electric charges of similar polarity, owe their coagulation and precipitation, to a large extent, to neutralization of these charges by means of the current.

The conservation of the metallic iron of the electrodes is shown by the absence of color in sample of the effluent and by the small increase in the iron content, as shown by analysis. Inspection of the electrodes from time to time when the machine has been opened for the observation of visitors, showed no apparent corrosion, oxidation, or fouling, after 2½ months' use. The edges of the plates are still as sharp as when they were cut.

Other difficulties recorded both in the report on the Louisville experiments and in the application of electrolysis elsewhere, are: 1st—Polarization, and 2nd—The waste of iron electrodes even when the current is turned off, with the formation of deposits on the plates, which increase the power consumed in starting the process after a rest. The first of these difficulties is here overcome by the use of rotating elements in the form of paddles continuously operated between the electrodes. These serve several purposes, namely the prevention of polarization, the breaking up of solids in suspension, the cleaning of the plates, the mixing of the reagents produced electrolytically, and the bringing of all portions of the sewage into contact with the electrodes. It is hardly necessary to elaborate these suggestions, as the mechanical advantages will be apparent. It may, however, be well to explain that polarization is due to the tendency of ions to part with their electric charges more or less reluctantly, the positive ions attracted to the negative pole, for example, tend in some degree to remain positive and thus repel the following positive ions, which would otherwise be attracted. These are swept away by the revolving paddles. The breaking up of solids is important in view of the fact that sterilizing agents require some time to penetrate large masses or gelatinous membranes. The only other point which it seems necessary to note is that certain strata in the sewage flow tend to pass between the electrodes without coming in contact with them where the paddles are not used.

The second difficulty mentioned above, namely the waste of iron when the current is turned off, arises from reverse currents set up in the machine, which in the Elmhurst apparatus are taken care of by simply short-circuiting the iron electrodes with a zinc plate. The zinc being positive to iron attracts the current, thus saving the iron from decomposition and preventing the increased resistance observed in starting the electric current through the older devices.

Ten carbon electrodes which are placed in the Elmhurst machine at the point of entrance of the sewage, being electro-chemically passive, serve to utilize the common salt or other electrolytes normally present in the sewage, for the production of hypochlorite with its sterilizing effect. It will be noted that the lime solution used is introduced at a point above the carbon and just below the iron electrodes, for the reason that the electric current passes by way of the electrolyte which predominates, or which is more easily ionized, and the presence of the lime in the passive carbon electrodes would result in the dissociation of calcium hydroxide, rather than the sodium chloride, and no sodium hypochlorite would be liberated.

Description of Electro-Chemical Apparatus.—In the old process the sewage on entering the receiving well at the Elmhurst plant passes through a perforated metal screen with ⅝ in. circular openings, and is pumped to the level of the sedimentation tanks, from which it flows by gravity to sand filter beds. There are four of these old sedimentation tanks used in series, each holding about 65,000 gallons, and enclosed under the roof of the building.

In preparing for the tests on the new electrolytic process, the apparatus was placed on a temporary platform built over one end of the first tank in the old series above mentioned. This platform has a floor area of 18 x 24 ft., which provides sufficient room for a 2-in. centrifugal pump and motor, the electrolytic machine, lime solution tank, effluent sedimentation tank, platform scale and laboratory table. The pump was required only for the purpose of lifting the sewage treated to the higher level above the flow of the old tanks. A ⅜-in. perforated screen is used on the suction line of this pump. The electrolytic machine used is erected vertically, the sewage flowing through the bottom to top, the electrodes being entirely enclosed. It stands 7 ft. 3 in. high from the floor to its outlet pipe flange and is 24 in. x 18 in. in cross-section. The cypress frame enclosing the electrodes is 4 ft. 10 in. high, sets on a cast iron base, which holds also the motor-generator set, is capped with the outlet casting which is bolted through to the base by outside bolts at the four corners. The electrodes are set horizontally one above the other. At the bottom of the electrolytic machine one bank of 10 carbon plates, or electrodes, are placed and connected in series, and above this are four banks, each consisting of 12 iron electrodes. The alternate iron electrodes are connected in groups of three and these groups are then connected in series. The one bank of carbon plates is parallel with the whole set of iron electrodes, so that 9/10 of the current is taken by the carbon and 1/10 by the iron electrodes. The iron plates are connected so as to be automatically short-circuited to a zinc plate in the top when the operating current is shut off. A volt meter and an ammeter are attached to the front of the machine. The motor of the generator set furnishing direct current for the electrodes also rotates two ¾-in. vertical square steel shafts connected by gearing to the motor shaft. These vertical shafts carry paddles which operate between the electrodes continuously. The shafts are made in sections just long enough to pass through a single bank of electrodes and the sections are keyed together in the spaces between each bank. This arrangement supplies two paddles in each space between the electrodes and they are rotated in opposite directions, one slightly in advance of the other, with high mechanical efficiency since the water pressure generated by one aids in driving the other. The paddles are made of material which is non-absorbent, non-conducting and very durable. In this machine they are 9 in. long, ¼ in. thick and 2¼ in wide at the centre, tapering to 1⅛ in. at each end, while the shaft opening at the centre is a ¾ in. square.

The iron electrodes are made of a certain grade of low carbon steel and are 10 in. x 16 in. x 3/16 in. thick and spaced ⅜ in. apart. An opening is left at one end of the lower plate in each bank for the entrance of the sewage or water, which then is divided by the plates into thin films as it passes on to the next bank of electrodes. A space of 3 inches between each bank or section of electrodes facilitates the connection of the paddle shaft sections as they are inserted with each tank of plates when the machine is erected.

Lime Tank.—The lime solution tank used is 3 ft. x 5 ft. and 3 ft. deep, holding about 336 gallons. Lime solution is introduced into the electrolytic machine just above the carbon electrodes and mixes with the sewage as it passes from the carbon to the iron plates. In this instance a small plunger pump electrically driven was used to inject the lime, as there was not sufficient head room to secure a gravity flow into the machine. From the electrolytic machine the sewage flows through a weir box to provide means of measuring the quantity treated. This box is 23 in. x 37 in. x 17 in. deep, with a 3-in. pipe outlet into the sedimentation tank.

Sedimentation Tank.—A small sedimentation tank is provided to take the flow from the electrolytic machine. Its outside dimensions are 11.5 ft. x 7 ft. x 5 ft. and was built as a two-story tank with a false bottom sloping from a line 2 ft. below the top on one side, down to the front bottom edge, but as septic action plays no part in this process, the effluent is permitted to pass through the sedimentation slot and emerge from the 6-in. space between the side of the upper compartment and the outside wall of the tank. This space is usually provided for the escape of septic gases in biological processes when it would be filled with decomposing sewage. Notwithstanding the unsuitableness of the design, this tank has served as well as any, inasmuch as any form of tank properly baffled and with convenient means for removing the sludge, is all that is needed. Its effective capacity is only 1,550 gallons, which, at the rate of 25,000 gallons per day, gives a theoretical retention period of ½ hour. However, tests have shown that the clarified effluent leaves this tank in from 10 minutes to 1 hour. This was conveniently tested by the introduction of phenolphthalein, which holds its pink color in the slightly alkaline effluent throughout the flow through the tank. The strongest traces of color usually emerge in about ½ hour.

The time of flow through the electrolytic machine when 25,000 gallons per day were being treated, averaged about 2 minutes, though the first traces of color showed in 1 minute and all color of the indicator used had disappeared in 3 or 4 minutes.

The weir box was calibrated by means of a scale fastened to the inside. The flow was measured by weighing the effluent on a platform scale, and a curve was plotted to indicate the number of gallons treated per day for each reading on the scale in the weir box.

The quantity of sewage treated was generally held at 25,000 gallons per day to suit the capacity of the lime tank and the small sedimentation tank and also to maintain uniform character in the effluent, which, after settling in the small tank, was run into the large plant tank below, and there retained for observation.

Amount of Lime Required.—The amount of lime used will vary in each case with the normal free and half-combined carbonic acid contained in the sewage. The softer the water of the public supply, the less the amount of lime required for purification. The lime used at Elmhurst averages about 1,200 lbs. per 1,000,000 gal.

As shown by the analyses, the hardness of the Elmhurst water supply is 102 p.p.m., total hardness, and the lime necessary to overcome this is 496 lbs. per 1,000,000 gal. of sewage. Analysis of the effluent shows that the hardness is reduced 50%.

In treating the sewage of the Borough of Manhattan only 180 lbs. of lime per 1,000,000 gal. would be required to overcome hardness, since the total hardness of Croton water is only 40 p.p.m. This would indicate that only 941 lbs. of lime would have to be used per 1,000,000 gal. in the electro-chemical treatment of sewage in Manhattan.

Power Used.—The electric power supplied to this plant is alternating current, 2-phase, 220 volts, 60 cycle. The current used for electrolysis on a flow of 25,000 of sewage daily is 18 to 20 amperes, with a pressure of 7½ volts, or a power consumption of 135 to 150 watts, which is about 1/5 h.p. The carbon electrodes take about 9/10 of the current, the balance going to the iron electrodes; hence out of 20 amperes 18 go to the carbon and the remaining 2 amperes are seriesed 8 times on the iron plates, giving an efficiency of 16 amperes on the iron. Estimating the power required per million gallons from the above figures, and remembering that with the increase of plate area in larger machines, the voltage required to put through a given amperage is proportionately reduced, about 6 kw. should be sufficient to effect the high degree of purification obtained in these tests.

Where an electrolytic machine designed to treat 1,000,000 gallons is installed, and a similar reserve unit is added, the utilization of both machines simultaneously for the million-gallon flow should cut the voltage required in half, since the plate area is doubled and the amperage remains the same. This would also halve the cost of power, which is the product of the voltage by the amperage.

Improved Electro-Chemical Machine for Sewage Treatment.—The electrolytic machine tested here was designed primarily for water purification. An improved type for sewage purification is now being built. It is designed to be installed horizontally, with the electrodes in a vertical plane and set longitudinally to secure the advantage of having the grit drop to a bottom trough. This also minimizes wear on the electrodes due to the grinding of grit by the rotating paddles, which in the new arrangement will, of course, turn in a vertical plane. In the vertical machine tested at Elmhurst this wear, however, has been hardly appreciable, notwithstanding the surface of the electrodes underneath the paddles are more subjected to it. The large machines are about 20 ft. long and 3 ft. square. As is usual with most mechanical and electrical devices, higher efficiency may reasonably be expected with increasing size.

Effects produced.—The effluent from the electrolytic machine shows immediate coagulation and when taken in a glass and held to the light the flocculent precipitate is seen to increase rapidly in bulk and starts to settle immediately. The liquid between the coagulated particles at once appears clear. Grease is rapidly saponified by the lime under the hastening action of the electric current and precipitates out as lime soap. This effect can be illustrated by the simple experiment of adding lime to a soap solution and holding two carbon electrodes in it for a moment.

Grease is one of the most disturbing elements in the purification of sewage by biological processes, on account of its tendency to clog bacterial filters and dosing devices, and the difficulty with which it is decomposed and mineralized by bacteria. Electrolytic treatment is well suited to handle sewage of this character.

Nitrogenous organic matter in the sewage becomes highly oxidized in this process, and this, together with the dissolved oxygen produced, yields an effluent of very high stability and as it leaves the small sedimentation tank after about ½ hour's retention, it is clear, colorless and without odor. The removal of bacteria is close to 100%. Disease-producing germs and allied species, outside of the body, are destroyed more readily than the ordinary bacteria of decomposition and hence if a few bacteria survive electrolytic treatment, they will not be pathogenic germs. This is borne out by observations on cultures made to identify this class of bacteria.

Storage of the Effluent for Observation.—From the small settling tank the clear effluent was run into the large concrete sedimentation tank, over which the electrolytic apparatus was erected. This tank has a capacity of about 67,000 gallons and is one of the four regular sedimentation tanks built with the Elmhurst plant. Chemical and bacterial observations made from time to time on the liquid stored in this tank showed some very interesting results. The bacterial content remained very low and the fixation of nitrogen, as shown by the increase in the nitrites and nitrates on standing, is remarkable, notwithstanding the fact that the tank is open to contamination from the air and by birds which nested in the rafters of the roof. This tank was kept full for 66 days. When emptied, a light deposit, about ¼ inch thick, was found at the bottom. This was light colored and inoffensive and was composed largely of calcium carbonate. The clear appearance of the water in this tank made interesting contrast to the dark septic sewage in the adjacent tank, with its deposited sludge continually forced to the surface in large masses by the rising gases of decomposition.

Sludge.—The flocculent precipitate in the machine effluent after sedimentation in the small tank was drawn from the bottom of this tank through 2-inch outlet pipes and forced into a filter press under about 25 pounds pressure by means of a small water-feed pump. At this pressure about 20 pounds of liquid sludge, containing about 95% moisture, could be dehydrated per hour, per square foot of filter area, based on the operation of a large press. The percentage of moisture remaining was from 55 to 60%. The filtrate from the sludge is quite odorless, colorless and has sufficient available oxygen to remain nonputrescible. The sludge has no odor, except possibly a very slight suggestion of ammonia.

The extraction of this readily settling sludge from the electrolytic machine effluent, by a process other than sedimentation in tanks, is now being considered, but on account of the short period of sedimentation required the elimination of a small tank area would be important only under exceptional conditions.

Cost.—Without including pumpage, the necessity of which would have to be determined at each point of treatment, according to topography, the cost of electricity for electrolysis at the rate of six kilowatts per million gallons at a cost of 3c. per kilowatt hour is 6 x 24 x .03 = $4.32

Lime 941 lbs. x .003 = $2.83

$7.15

Disastrous fires at the docks along the Seattle waterfront have led to an ordinance providing that all docks constructed hereafter shall be provided with fire walls spaced not further apart than 500 ft. on centres and fire stops not more than 100 ft. apart. These provisions are not required in structures fully equipped with automatic sprinklers.

Editorial

THE WORDING OF SPECIFICATIONS.

One of the most frequent causes of trouble between owners, engineers and contractors is the inability of some engineers to express their requirements clearly, concisely and in plain, unequivocal English, so that all concerned may read and know what their specifications mean and call for. Most of this trouble can be ascribed to the practice of copying specification provisions from some other person's work or from some ancient specifications with no regard or consideration as to whether the class of materials is the present market classification or whether even obtainable except at an exorbitant price. Such specifications usually contain ambiguous phrases which have been rightly named "club" or "big stick" clauses, unfair to all parties, and which create the impression that the engineer himself does not know what he wants, and that he expects to cover up his deficiency by other common phrases such as "the decision of the architect as to the true construction and meaning of the drawings and specifications shall be final"; "that all work and materials must be to the entire satisfaction of the engineer"; "that all materials must be of the best quality"; "that all work must be done in the best manner as the engineer shall direct," etc. Nor do these expressions always accomplish the expected result. Some examples that well illustrate this were enumerated by Wm. L. Bowman, C.E., LL.B., in a paper entitled "The Engineer and the Law," read before the Harvard Engineering Society, of New York. One instance he cites was where a contract for a heating plant provided for a "complete and perfect job, even though every item required to make it such is not specially noted in the drawings or these specifications"; also that the contractor "shall furnish all labor, tools, and appliances necessary to complete his work according to these specifications, and shall perform his work in a true workmanlike manner in every particular, and thus provide the building with a durable and mechanically perfect system"; it was held that the contractor was not required to improve upon the plans in order to make a mechanically perfect system.

Another example given by Mr. Bowman was where a contract required the construction of a cellar according to specifications, it was held that an additional requirement that "the whole to be perfectly watertight and guaranteed" only bound the contractor so far as his own work was concerned, and that he was not held to guarantee that the plans would produce a watertight job. In another instance, where a tin roof of the "best quality" was called for, the trial justice in charging the jury held that such a requirement was satisfied when the roof as finished "was equal to the standard contemplated by the contract." In another contract a reservoir was required to be built according to definite plans and specifications, and the contract further provided that "the work contemplated . . . is the construction of a watertight reservoir," and it was held that that did not impose upon the contractors the responsibility of making the reservoir watertight, because consideration of the entire terms of the contract showed that they had no discretion as to the method or means of doing the work.

These numerous examples are given because of the tendency on the part of some architects and engineers to reject work under such circumstances, involving all concerned in expensive and needless litigation, and opening themselves to severe and sometimes well-merited criticism.

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CO-OPERATION BETWEEN SCIENCE AND BUSINESS.

Professor Ed. D. Jones, in his new book on business administration, makes some interesting allusions to the fruitful co-operation of men of widely differing talents, in business. He shows clearly how industry and science agree in making extensive use of that simple form of co-operation, commonly known as division of labor, by which men of unlike genius are united in the same enterprise for the accomplishment of different functions. He turns first to pure science of modern times and displays a striking instance, in the life history of two noted men, of the benefits of individual co-operation. Tycho Brahe, the leading astronomer of the latter half of the sixteenth century, was a nobleman of proud spirit and, by reason of a certain dramatic talent which attracted attention, able to secure from his royal patrons large grants for astronomical apparatus. He was an expert instrument maker, and an accurate observer. His life was spent largely in compiling tables of observations of planetary movements. Kepler, who came under his patronage, and who worked with him for many years, was a poor observer, suffering from defective eyesight. He was awkward in his movements and possessed little mechanical ability. He was, however, a good mathematician, and he possessed the rare ability to become enthusiastic over statistical calculations. The five laws of planetary motion which Kepler discovered, and the Rudolphine tables which he completed, are monuments to a splendid and devoted co-operation between two geniuses of entirely different endowments.

As for applied science, the writer reverts to the more familiar case of Isaac Watt and Matthew Boulton. Watt has described himself in the following words: "I am not enterprising. I would rather face a loaded cannon than settle an account or make a bargain; in short, I find myself out of my sphere when I have anything to do with mankind." Boulton was a man of affairs, full of energy and common sense, and possessed of property. He is remembered because he was able to perceive and respect the talent of a man entirely different from himself, and because he tenderly encouraged and courageously defended that genius through manifold attacks and disappointments, to the lasting benefit of the world.

Professor Jones treats the subject in a manner that permits of but brief mention here. One observation of his will bear frequent repetition, however. It is this: "There are even enough men of wealth ready to enter into an arm's-length alliance with science and education, by means of a cold bequest. But there is a waiting opportunity for men of affairs to go into living, daily partnership with the arts and sciences, by entering into close personal relationships with men who need help of a natural administrator to make their contribution to progress. A good many captains of industry might weave their names firmly into the fabric of history, as did Boulton, by aiding some delicate flower of genius with energetic counsel and a wise corrective influence.

PERMEABILITY OF GRAVEL CONCRETE.

THE following is a summary of tests that have been under way at the Engineering Experiment Station, University of Wisconsin. They were recently described in a paper read by Prof. M. O. Withey, before the Western Society of Engineers.

1. None of the concretes tested were absolutely watertight if we consider continuous flow into the specimen as proof of permeability, but the majority of the mixes (varying from 1 : 1 to 1 : 3 : 6) were so impervious that no visible evidence of flow appeared. For most purposes such mixes can be considered watertight.

2. The visibility of dampness on the bottom of the specimens increased with the humidity of the air and the non-homogeneity of the concrete. The minimum rate of flow for which leakage was indicated was 0.00011 gal. per sq. ft. per hr.

3. In tests of nearly all of the properly made mixes of 1 :7 proportions, or richer, the rate of flow for a 50-hr. period was less than 0.0001 gal. per sq. ft. per hr. under a pressure of 40 lb. per sq. in.

4. Through increasing the fineness of the cement a reduction in the rate of flow and a considerable increase in the strength of a 1 : 9 mix were secured.

5. By grading the sand and gravel in accordance with Fuller's curve it was possible to obtain practically watertight concrete of 1 : 9 proportions under pressures less than 40 lb. per sq. in. To secure such results, however, requires great care and careful supervision in mixing, in determining the proper consistency, in placing, and in curing the concrete.

6. In the proportioning of such materials as these, volumetric analysis coupled with a determination of the density and air voids yields very valuable information concerning the best proportions of sand and gravel for a given proportion of cement. If proportions must be selected arbitrarily a 1 : 1½ : 3 mix, by volume, is very impervious.

7. The use of the proper amount of water necessary to produce a medium or mushy consistency is one of the most important conditions in securing impervious concrete, especially when lean mixtures are used. Dry mixtures cannot be sufficiently compacted in the molds and are more difficult to cure properly than the mushy mixtures. Although the use of a wet consistency does not materially affect the imperviousness of very rich mixes, such as 1 : 1½ : 3, it greatly increases the flow through a lean mix.

8. For lean mixes made from damp sand it seems advisable to mix longer than is now common practice. These tests would indicate that for a mixer running at 30 r.p.m., a period of one and one-half to two minutes is required to secure thorough mixing of a 1 : 9 concrete. For a rich 1 : 1½ : 3 mix a one-minute period appears to be sufficient. The method of mixing in which water is first admitted to the mixer is to be condemned. A preliminary period of dry mixing lasting from 15 to 30 sec. seems desirable.

9. No stage or process in the making of impervious concrete is of more importance than curing. The results of these tests clearly demonstrate that premature drying destroys the imperviousness of 1 : 9 mixes, seriously impairs that of the 1 : 2 : 4 mixes and somewhat diminishes that of the 1 : 1½ : 3 mixes. For thin sections, not over six or eight inches thick, the curing conditions should be such that a lean concrete will be kept damp for a period of one month and a rich concrete for at least two weeks. Even after a month of proper curing, complete desiccation of a lean mix composed of these materials produces an increase in permeability, but the effect on a rich mix is not marked.

10. In these tests the imperviousness of the concrete increased rapidly with the age of the specimens for the first month; thereafter the change was not marked.

11. From the tests thus far made it seems probable that the permeability of lean concrete in a direction normal to the pouring is greater than in the direction of pouring.

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USE OF CONCRETE IN WATERWORKS CONSTRUCTION.*

THE author does not pretend to advance any new theories, but rather endeavors to present in convenient form the general principles involved in the use of concrete in such structures as may be employed in connection with waterworks. There is no recognized standard test or specifications now in use for concrete. There has not as yet been developed a set of standard tests or specifications, the use of which will in cases guarantee entirely satisfactory finished work. That the cement and aggregate stand the laboratory tests is no guarantee that the workmanship will give the best of results.

Neither sharpness nor excessive cleanliness in the sand is worth seeking after if it involves much expense. Tests have shown conclusively that sand with rounded grains makes quite as strong a mortar, other things being equal, as does sand with angular grains. Comparative sand tests of cement-sand mortar should be based on compressive strength values instead of tensile strength values. The strength of all sand mortars is affected by the amount of water used over that required for normal consistencies. The more water used the greater will be the loss in strength at early periods. A fine sand takes much more water to produce a certain consistency of mortar when mixed with cement than does a coarse sand. A fine sand makes a weaker mortar than a coarse, because of the lower density. The only substitute for natural sand for concrete that need be considered is pulverized stone, either dust and fine screenings produce in crushing rock or an artificial sand made by reducing suitable rocks to powder. The danger of using stone dust is failure to secure the proper balance of large size grains. The coarseness as well as the fineness of a good concrete sand is limited. The best sands will show not more thon 40 per cent. retained on a No. 10 sieve, and not more than 5 per cent. passing a No. 80 sieve.

Upon large or important structures it pays from an economic standpoint to make very careful studies of the materials of the aggregates and their relative proportions. W. B. Fuller has shown that by changing the ordinary mixture of watertight concrete, which is about 1 :2½ :4½, and which requires 1.37 barrels of cement per cubic yard of concrete, by carefully grading the materials by methods of mechanical analyses he was able to obtain watertight work with a mixture of about 1 :3 :7, thus using 1.01 barrels of cement per cubic yard of concrete. This saving of 0.36 barrel is equivalent, with Portland cement at $1.60 a barrel, to 58 cents per cubic yard of concrete.

A better and more uniform concrete can be made with a good machine mixer than by hand. A plastic con-

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* Abstract of a paper by Edgar B. Kay before American Water Works Association.

crete of jelly-like consistency always produces stronger concrete than a wet mix and is preferred where conditions will admit of its use. It is absolutely necessary, however, in reinforced concrete to employ a consistency sufficiently wet to flow around the steel and into the corners of the forms and in rubble concrete, to flow around the large stones.

Concrete should never be placed in running water.

It is almost impossible to satisfactorily plaster a face of hardened concrete.

A wall of concrete may be rendered watertight in various ways:

1. By accurately grading and proportioning the aggregates and the cement. The proportions employed to resist the percolation of water usually range from 1:1:2 to 1:2½:4½, the most common mixture being 1:2:4 or 1:2½:4½. With accurate grading by scientific methods, watertight work may be obtained. For maximum watertightness, a mortar or concrete may require a slightly larger proportion of fine grains in the sand than for maximum density or strength. In general it may be stated that in monolithic construction a wet mixture, a rich concrete and an aggregate proportioned to secure great density will in the majority of cases give the desired results. It is impossible to specify definite thicknesses of concrete to prevent percolation under different heads of water, because of variations in proportions and methods of laying.

2. By special treatment of the surface of the concrete. Various methods have been employed, such as plastering the surface of concrete with rich Portland cement mortar in proportions 1:1 or 1:1½. Watertightness may also be secured by the use of a granolithic finish; by troweling the surface so as to produce a hard finish. Layers of waterproof paper or felt cemented with asphalt or bitumen or tar are extensively used, and sometimes asphalt alone. A mixture of alum and lye has also been used.

3. A waterproof concrete can be prepared by the application of fluates. The operation, however, requires a great deal of time and labor. By the application of an 8 per cent. solution of potash soap, instead of water, in mixing, the concrete can be rendered waterproof, so as to fulfil all requirements as to permeability of water.

The first method suggested is unquestionably the best to secure permanent watertightness, and the writer is not in favor of using waterproofing ingredients or of making surface applications except in cases where such may be required by reason of imperfections in the original concrete.

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NEW BUILDING FOR THE HYDRO-ELECTRIC POWER COMMISSION.

A new office building, to cost approximately $200,000 is to be erected by the Hydro-Electric Power Commission of Ontario on a newly-purchased site on University Avenue. The building will be 6 stories in height, with white stone frontage and will be constructed of brick. Its floor dimensions are to be 63 x 83 ft. The whole of the building will be used by the Commission. Contracts for the exterior work were let last week to Messrs. Witchall and Sons, Toronto.

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Agents of the Grand Trunk Pacific are taking measures to get Belgian settlers for the territory opened by the company's lines in western Canada. It is expected that the European war will result in a rush of settlers to Canada. Belgian farmers are very thrifty people. It is hoped to settle a large tract in the Stuart River district.

Coast to Coast

St. Andrews, N.B.—Plans for the rebuilding of the C.P.R. Algonquin Hotel, burned last April, have been prepared by Barrott, Blackader and Webster, architects, Montreal. A reinforced concrete structure is contemplated.

Sault Ste. Marie, Ont.—The third lock of the St. Mary's Falls canal was formally opened to traffic last week. It is 1250 ft. long, 80 ft. wide and 23 ft. deep. Its construction began in 1908, and has cost $6,250,000. It is rated the longest lock of its kind in the world.

St. Vital, Man.—The Manitoba Engineering and Construction Company, of Winnipeg, were awarded, last September, the contract for the construction of a 12-inch cast-iron water main to extend from the pump-house at this point to a reservoir in the National Transcontinental Railway yard at Transcona. This is being proceeded with, and is giving employment to quite a number of laborers. The estimated cost of the line is $87,000.

Brandon, Man.—Last week Mr. J. G. G. Sullivan, chief engineer of western lines for the C.P.R., made the announcement that 350 miles of double-tracking had been completed during the season between Brandon and the Pacific coast. Prior to this year the road had been double-tracked from this point to Fort William, which makes a distance of 909 miles completed to date. The entire distance between Fort William and Vancouver is 1908 miles. It is expected that the line of the C.P.R. between Swift Current and Bassano will be completed in a few days

Montreal, Que.—As announced in another department of this journal, the Grand Trunk Pacific Railway is going ahead with the construction of terminals in British Columbia. Contracts to the value of $300,000 at the four divisional points, viz., Prince George, Smithers, Pacific, and Endako, have recently been let. They include the construction of roundhouses, machine shops, and other railway facilities, and will require the services of large numbers of mechanics and laborers during the winter months. It is to be noted that large oil storage buildings are included, indicating that the company may have under consideration the use of oil-burning locomotives on its fast transcontinental service.

Montreal, Que.—No sooner had the contractors placed the roof on a large extension to the Ross Rifle factory than work was commenced on a second extension, which will double the size of the present factory, and more than double its capacity. The output of the enlarged factory will be at least 500 rifles per day. The contractors for the new structure, the C. E. Deakin Co., of Montreal, have been urged to rush the work, and the concrete foundations are already being placed. The building, which will be of brick construction, is to be handed over on December 1st, ready for the installation of machinery. It is also understood that the Quebec Railway, Light and Power Company has signed up a contract with the Ross factory for a large block of additional power. The machinery and equipment for the extensions are on the way from England.

St. John, N.B.—Several large steel bridges are now under construction in this Province. The spandral arch bridge at St. John, which bridges the Reversing Falls, and which will be utilized for street car and general traffic, is well advanced, and the remaining work will be completed in time for use next spring. The new steel bridge, which the provincial government is constructing at Grand Falls, is almost completed, and in a few days the finishing touches will have been made to the magnificent new bridge which crosses the Miramichi river at Newcastle. In addition to these splendid structures two large steel bridges for the use of the Valley Railway are in contemplation. The C.P.R. also has under consideration the building of a new cantilever bridge, of a somewhat different type from that now used by the railway, at the Falls, St. John.

PERSONAL.

J. J. McNIVEN, B.Sc., of Vancouver, has been appointed assistant inspector of gas and electricity in that city.

JOHN T. MATTHEWS, of St. John, N.B., has been appointed inspector of boilers and machinery and of hulls and steamboat equipment at Edmonton, Alta.

R. A. ROSS, consulting engineer, Montreal, has been retained by the city of Peterborough, Ontario, as its representative in the settlement of the taking-over of the plant of the Peterborough Light and Power Company by the city.

T. R. DEACON, C.E., whose second term as Mayor of the city of Winnipeg is drawing to a close, has announced that he will not seek re-election to the office. Mayor Deacon's work in connection with the Greater Winnipeg Water District has been of such a nature as will for all time associate his name with the supply of good water to the city of Winnipeg. It was to further the scheme that he permitted himself to be chosen as head of the civic administrative board, and the present extensive construction work on the 95-mile aqueduct bespeaks the fruits of his great service to the city.

H. S. VAN SCOYOC, A.M. Am. Soc. C.E., has been appointed chief engineer of the Toronto-Hamilton highway, on which work is to start at once. Mr. Van Scoyoc has been inspecting engineer of the Canada Cement Co., Limited, at Montreal, for the past few years, and is thoroughly familiar with the construction of concrete roads. The Toronto-Hamilton Highway Commissioners chose Mr. Van Scoyoc in order to make the Canada Cement Co. more definitely responsible for the success of the road than the company would be if the engineer in charge were not practically one of its own men.

OBITUARY.

The death has been announced of Mr. E. R. BABINGTON, a well-known architect of Toronto. The deceased started his profession in 1874, and, after twenty-three years of active professional work, he became an instructor in the Toronto Technical School, which position he held until forced by ill-health to resign.

INSPECTION OF NEW WELLAND SHIP CANAL.

As intimated in last issue, a tour of inspection was made over the sections of the new Welland ship canal now under construction, by members of the Toronto branch of the Canadian Society of Civil Engineers, and of the University of Toronto Engineering Society, on Saturday, October 31st. Several hundred took advantage of the opportunity afforded them by Mr. J. L. Weller, chief engineer of the Canal, to examine closely the enormous equipment and methods, somewhat unusual to Canadian construction, that were to be seen on Sections 1, 2 and 3.

The party was divided into groups, each looked after by several members of the engineering staff of the Canal. Beginning at Thorold, the various features of the work, outlined in the leading article of this issue, were examined, every development of interest between that town and the harbor at Port Weller receiving the attention of the closely interested engineers. Luncheon was served at one of the construction camps; electric cars, drawn by one of the locomotives, conveyed the party along the department's construction railway. At the close of the day a dinner was held in St. Catharines, the party returning to Toronto by special train.

EDMONTON BRANCH, CANADIAN SOCIETY OF CIVIL ENGINEERS.

The Edmonton Branch of the Canadian Society of Civil Engineers held their regular meeting on Oct. 22nd. An informal dinner was served to about forty-five guests. Following the dinner, the gathering was addressed by A. M. Calderon, F.R.A.I.C., and J. L. Cote, M.P.P., on the Military Engineers' Corps, which is now established in the city. Several military engineers who were present also gave short addresses on various aspects of military engineering. The members of the Branch, who strongly favored the movement regarding the formation of a local corps of military engineers, unanimously passed the following resolution: "Whereas there are a large number of qualified engineers having headquarters at Edmonton who are desirous of putting their scientific training and practical experience at the service of the Empire; be it resolved that the Secretary of the Branch be instructed to communicate with the District Officer commanding this military district, urging upon the Militia Department the desirability of authorizing an engineering unit in Edmonton."

The chair was occupied during the evening by Professor Edwards, of the University of Alberta. Mr. L. B. Elliot is the secretary of the Branch.

COMING MEETINGS.

AMERICAN HIGHWAYS ASSOCIATION.—**Fourth American Road Congress to be held in Atlanta, Ga., November 9th to 13th, 1914. I. S. Pennybacker, Executive Secretary, and Chas. P. Light, Business Manager, Colorado Building, Washington, D.C.**

WASHINGTON STATE GOOD ROADS ASSOCIATION.—**Convention to be held at Spokane, Wash., November 18th, 19th, and 20th. Secretary, M. D. Lechey, Alaska Building, Seattle, Wash.**

ANNUAL MEETING, AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—**The annual meeting of the American Society of Mechanical Engineers will be held in New York, December 1st to 4th, 1914. Secretary, Calvin W. Rice, 29 West 39th Street, New York.**

AMERICAN ROAD BUILDERS' ASSOCIATION.—**Eleventh Annual Convention; fifth American Good Roads Congress, and 6th Annual Exhibition of Machinery and Materials. International Amphitheatre, Chicago, Ill., December 14th to 18th, 1914. Secretary, E. L. Powers, 150 Nassau Street, New York, N.Y.**

EIGHTH CHICAGO CEMENT SHOW.—**To be held in the Coliseum, Chicago, Ill., from February 10th to 17th, 1915. Cement Products Exhibition Co., J. P. Beck, General Manager, 208 La Salle Street, Chicago.**

AMERICAN WATERWORKS ASSOCIATION.—**The 35th annual convention, to be held in Cincinnati, Ohio, May 10th to 14th, 1915. Secretary, J. M. Diven, 47 State Street, Troy, N.Y.**

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.—**Annual meeting to be held at the Iowa State College, Ames, Iowa, June 22nd to 25th, 1915. Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.**