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SUBSTRUCTURE OF THE QUEBEC BRIDGE.

COMPLETE RÉSUMÉ OF THE CONSTRUCTION OF THE PIERS AND ABUTMENTS—SOME INTERESTING CAISSON SINKING FOR THE SOUTH MAIN PIER—PLANT OPERATION.

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NOTE:—The construction of the new Quebec Bridge is a most illustrative piece of engineering, and has been closely followed, since its beginning, in the columns of THE CANADIAN ENGINEER. *The substructure, now complete with the exception of a few finishing details mentioned in the first paragraph below, is a vital part of the world renowned undertaking, and engineers of all countries have been interested in its progress. In the following article Mr. Borden has reviewed for us its entire construction. For greater detail respecting the piers and abutments the reader is referred to previous issues of* THE CANADIAN ENGINEER *as follows: July 14, and Oct. 6, 1910; June 13, 1911; Oct. 31, 1912; Feb. 13, 1913, and April 9, 1914. These deal with their design and constructional progress. Other articles appearing in various issues refer similarly to the superstructure.*
—EDITOR.

THE contract for the construction of the piers for the Quebec Bridge was awarded to Messrs. M. P. and J. T. Davis, of Quebec, in February, 1910. This work has been continued constantly since that date, and is now practically completed with the exception of pointing and cleaning the masonry and dressing the bridge seats.

This contract, as finally completed, is divided into the following units: North abutment (alterations), 404.5 cu. yds.; north intermediate pier, 1,665.6 cu. yds.; north anchor pier, 17,736.0 cu. yds.; north main pier, 31,870.4 cu. yds.; south main pier, 38,279.4 cu. yds.; south anchor pier, 16,073.0 cu. yds.; south abutment (alterations), 61.1 cu. yds. Total, 106,090 cu. yds.

At the start, a careful study was made by the board appointed by the government, to determine whether it was possible to use the old masonry. After a thorough investigation it was found that, owing to the increased weight of the steelwork, all the old masonry, with the exception of the abutments, would have to be taken down and new piers constructed. It was, therefore, decided to move the whole bridge to the south about 65 ft., retaining the original longitudinal centre line. This brought the north main pier further into the water and the south main pier the same distance towards shore, the same centre to centre length of span of 1,800 ft. being retained. It was impossible to place the south main pier nearer the river on account of the wreckage which lies in the water at that point.

Before the contract was awarded, a series of borings were made at and about the location of the two main and anchor piers. Nineteen borings in all were taken, each boring penetrating at least 15 ft. into solid rock in order to make sure that it was bed rock rather than a boulder that had been struck. These borings showed that bed rock would be encountered approximately at El. 0.0 on the location of both north and south main piers, which elevation was about 101 ft. below extreme high water and 70 and 85 ft. below the bed of the river on the north and south sides respectively. The formation of the bed of the river on the two sides, however, was found to be totally different. On the north side heavy boulder formation was encountered for the entire depth, the boulders being closely packed together with coarse sand and gravel. On the south side the borings showed sand formation for the entire depth with only a sprinkling of boulders at various points. The bed rock was a hard sand-stone, called "Sillery grit," overlaid with a red and gray shale. On the south side 2 ft. of hardpan overlaid this shale.

The caisson for the north main pier was started first and was constructed at Sillery, about 3 miles down the river. This caisson was 180 ft. long and 55 ft. wide. It was constructed of 12 x 12-in. southern pine with a cutting edge of the same material 30 in. square. This cutting edge was shod with a 6 x 12-in. oak timber instead of the steel shoe, as usually used. It was claimed in this case that if any distortion of the caisson took place the steel shoe would tend to prevent the caisson from readily re-adjusting itself—as would be the case with a wooden shoe—and that the wooden shoe gave sufficient service during the process of sinking. The caisson had a working chamber 8 ft. high in the clear, divided by longitudinal and transverse bulkheads into 18 compartments. It was built in the winter under a construction shed, thus enabling the men to work without interruption from the weather. The caisson was built over launchways with a 10% grade which led out into deep water. The walls of the caisson were built up about 40 ft. before it was launched. When ready for launching, the caisson was lowered down to its inclined position on the launchways by means of heavy jacks. When everything was ready an impetus was given by jacks placed at the rear horizontally, and launching was effected without mishap.

It was towed to the bridge June 14, 1910, and placed in position over the site which had been previously dredged to an average depth of about 20 ft. in order to push ahead the work of sinking as fast as possible.

The work of filling it with concrete was started immediately and some 2,000 yds. of concrete had been deposited before the caisson began to touch bottom as its corners. The caisson was leaking to a certain extent, but could be readily kept dry by means of two pumps. At this time, however, an accident happened to the boiler equipment and before it could be repaired the caisson had been filled with water to such an extent that it grounded on an uneven bottom. The result was that the caisson was seriously strained and the seams opened up to such an extent that it was found impossible to keep air in the working chamber. It was decided to remove the concrete from the caisson and tow it to St. Joseph de Levis and have permanent repairs made there during the coming winter.

In view of this accident a re-consideration of the masonry design was made by the board, with the result that it was decided, in consequence of the difficult sinking on the north side, to use two caissons for the north main pier and to use the reconstructed larger caisson for the south side, where the sinking operations would be much simpler and the material to be penetrated would be, as shown by the borings, composed mostly of sand. This entailed the abandonment of the enlargement of the south main pier and meant the sinking of a caisson south of the old pier and entirely distinct from it. It was, therefore, decided to sink this new large caisson, or caisson No. 1 as it has been designated, 65 ft. nearer the shore, or south of the existing main pier, and to sink the caissons for the north main pier the same distance towards the river, or south of the existing north main pier, thus making the span 1,800 ft.—the same as that of the original bridge. This change in the plans allowed the board to keep the centre line of the bridge coincident with that of the old structure which was a very important item, as it would avoid the large expense of changing the location of the railroads approaching both ends of the bridge.

It was found that caisson No. 1 could be satisfactorily repaired in dry-dock, and on May 28, 1911, it was floated out and towed up the river about nine miles to the site on the south side which, being exposed at low water, had been carefully levelled off. At extreme high water there is about 15 ft. of water over this prepared bed. As the caisson from its construction had a pretty deep draught, a false bottom was constructed with a view to decreasing this draught before floating into position. The result was that the caisson floated with a draught of 11 ft. and was placed in its exact position for sinking without serious difficulty.

The openings in the various shafts were then left unobstructed in order that the rise and fall of the tide would not lift the caisson from its permanent bed. This caisson was left in this position throughout the season of 1910, the work of the contractor being directed towards the sinking of the caissons on the north side of the river.

Caissons Nos. 2 and 3, for the north main pier, were constructed at Sillery on the same location as caisson No. 1, the same details of construction being followed throughout. Each of these caissons were 85 ft. long by 60 ft. wide. No. 2 was started June 15, and No. 3 on June 29th, 1911. Both these caissons reached their permanent location at El. 20.0 about October 20th, 1911.

The average rate of progress of sinking the westerly caisson (No. 2) was 0.37 ft. per day, and that of the easterly caisson (No. 3) 0.47 ft. per day. It was the original intention to sink these caissons to rock, but as the work progressed the sinking became more difficult, and finally, when the caissons had reached El. 20.0, it was considered that the foundations at this point were quite satisfactory for many times the load that the piers would be called upon to carry.

Bearing tests were made at this point to determine the supporting value of the foundation. A cube of granite 2 ft. square was placed on an average section of the bottom and over this was placed a lever composed of 2 I-beams supported on pin bearings. The short end of the I-beams was supported against the roof of the caisson. A hydraulic jack was placed to exercise a definite load at the end of the longer lever arm. A load of 59 tons per sq. ft. showed a settlement of only 1/8 in., practically no settlement at all being noticed at 20 to 30 tons. As the average working load at the foot of this pier was only 8 tons per sq. ft., it was considered that the board would not be justified in carrying the foundations to a lower level.

In the operation of sinking these caissons, the contractor met with considerable difficulty owing to large bounders fouling the cutting edge, and in several places this cutting edge was forced inward from 6 to 10 in., and, as it was feared that if the sinking was continued in the same manner this cutting edge would be further distorted and sinking operations endangered, the method of sinking was then changed so as to avoid any such contingency.

Timber blocking was placed beneath the bulkheads and at the centre of the chambers. A trench was then excavated all around and below the cutting edge and for several inches outside the exterior surface of the caisson. This trench was excavated to a depth of about 2 ft., after which it was filled with blue clay in bags and when all was ready the blocking was under-scoured with water jets and the caisson lowered on a cushion of clay. The clay tended to act as a lubricant and also prevented considerable air leakage, and as all boulders were removed from beneath the cutting edge before the caisson was lowered, all further damage to the cutting edge was prevented, and it was found that the sinking was carried on even more rapidly.

After the caisson had reached its final location the working chamber was filled with concrete composed of one part of cement, two parts of sand, and four parts of small crushed stone. This concrete was made much drier than the concrete used in the main caisson, it being found that concrete deposited under compressed air gave better results when very dry than in a more or less liquid state.

Concrete was deposited in terraces, the men working towards the centre from the sides and ends. Great care was taken to ram the concrete thoroughly round the roof timbers so that a bearing would be assured under the roof of the working chamber. After the working chamber was filled as carefully as possible by hand the shafts were filled with concrete. As a still further precaution, a rich grout was forced in through 4-in. blow pipes by compressed air under a pressure of 100 pounds per sq. in. One hundred and fifty-four bags of cement were used in grouting caisson No. 2, and 274 for caisson No. 3.

Caissons Nos. 2 and 3 were sunk with 10 ft. space between the two ends, thus making the overall length of the two caissons 180 ft., the same as No. 1. After they had been filled with concrete, the space between them was dredged by a clam-shell bucket to a depth of 25 ft. below high water, the boulders and hard sand being excavated with considerable difficulty. Shutters 40 ft. high, made of 12 x 12-in. timbers, were placed vertically against the outside walls of the adjacent caissons so as to close each end of the space between the caissons and overlap about 12 in. on their sides. The bottoms of the caissons were banked up on the outside with clay dumped in the river and covered with heavy rip-rap. The shutters were securely bolted to the caisson walls down to low-water level, and thus formed coffer dam walls enclosing this space between the caissons. This space was then filled with concrete deposited under water up to an elevation of 7 ft. below low-water mark. After the concrete was deposited the water was pumped out and the space between the caissons was then bridged by six old steel girders, 6 ft. deep, resting in pockets left in the concrete in the adjacent ends of the caisson, the wooden walls of the caisson having been cut away to allow this to be done. Afterwards the concrete was deposited in a continuous mass in and between both coffer dams and caisson, thus forming a monolith upon which the masonry shaft of the pier could be carried. The masonry of the pier was then built up inside of the crib work, which was kept in place until the mason work had extended above high water.

The sinking of the large caisson for the south main pier was started July 28, 1912, and was completed October 24, 1912, or at the rate of 0.75 ft. per day during the entire period. The material encountered at this point was, as indicated by the borings, chiefly sand, and required that the pier be carried down to rock, which was reached at El. 0.0, 101 ft. below high water, and 86 ft. below the bed of the river. The difficulty experienced on the north side in keeping the cutting edge intact, and also on account of the fact that the caisson had previously been overstrained, and the fear that it might yet be weak, led the contractors to take unusual precautions to prevent the possibility of any accident happening to the caisson during the sinking operations. For this reason, special appliances were devised for relieving the cutting edge from carrying all the load, and by the use of sand-jacks the total weight of the caisson was distributed over the entire bottom area. The manner of using these sand-jacks was one of the most interesting features connected with the sinking of this caisson, and possibly merits especial description.

The jacks themselves were of very simple construction. The cylinders of the sand jacks had an internal diameter of 31 in., and were 36 in. long, constructed of ¼-in. steel plate with 4-in. lap joint; two angles 1½ x 1½ x ¼-in. reinforced the cylinder at top and bottom. The piston was a block of yellow pine 2½ ft. square and 5 ft. long. Four feet at one end was round with a diameter of 29 in., thereby allowing 1 in. play in the cylinder. The lower end of the piston was reinforced by a 2½ x ⅜-in. welded iron band. During operation the piston was attached rigidly to the roof of the working chamber by long screw bolts, and remained there permanently during the entire period of sinking.

In preparing for a drop, the first step was to excavate a hole under the piston. The cylinder was filled about ⅔ full of sand, placed in position under the piston, and blocked up hard against it by means of timbers. While this was being done the caisson was supported on timber blocking under the bulkheads and other points. At the bottom of the sand-jack was a 2-in. iron pipe extending entirely across the cylinder, the centre of which was split and opened up to allow the sand to escape. This type had no bottom to the cylinder, the timbers acting as a support for the sand. Another type used had a steel bottom and two 3-in. holes with sliding cover at each side at the foot of the cylinder. The operation in both cases was the same.

When everything was ready for a drop, the timber blocking supporting the caisson was undermined by a water jet and the full load taken by the sand jacks. A man was stationed at every jack, and at a given signal, afforded by the flashing of electric lights, each man turned a hydraulic jet with 60 lbs. pressure into the hole at the bottom of the cylinder, thus washing the sand out. The sand was caught in canvas bags of uniform size. When the canvas bag was full the lights flashed again and the water jet was turned off. Another bag was then obtained, and at the signal the jet was again turned on and the bags filled. Each cylinder contained in the neighborhood of 16 bags of sand. This operation was continued until the required settlement was obtained. By adopting the signal system and emptying the sand into bags, it was possible to guarantee that the whole caisson was being sunk at a uniform rate, and that there was no reasonable possibility of any part of the caisson being strained by being sunk more rapidly than another portion. As a rule, a drop of from 1½ to 2 ft. could be effected at each operation, the recurrence of the operations depending entirely on the nature of the material to be removed. When the drop had been finished the blocking was again placed under the bulkheads to take the load of the caisson, and the holes under the sand-jacks deepened in order that the operation might be repeated. The greater part of the material excavated in this caisson, being sand, was forced out through blow pipes.

Practically no problems were encountered in the construction of the north and south anchor piers and the north intermediate pier. Both anchor piers were constructed on a location south of the existing anchor piers. For the north anchor pier a coffer dam had to be constructed around the foundations since the foot of the pier was below high-water mark. The south anchor pier was well above high-water mark, so that all excavation was in the dry.

The anchorage girders were embedded in concrete and the first length of anchorage eyebars set in place, two shafts being left in each anchor pier for connecting up the anchor eyebars of the main anchorage. It is the intention ultimately to embed the bottom section of eyebars in concrete, but this will be deferred until they receive the full dead load stress.

The concrete used in the caisson and backing of the piers was 1:2½:5 by volume, except the concrete in the working chamber, which was 1:2½:4. The cement was required to pass a tensile test for neat cement of 450 and 540 lbs., for 7 and 28 days respectively; and for 1 part of cement and 3 parts of sand, 140 and 220 lbs. respectively. For the main piers entirely new quarry cut stone was used. For the anchor and intermediate pier the specification allowed the use of stone from the old masonry. The greater portion of the old stone demolished from the old masonry was consequently used in the construction of these piers. The abutments were not radically changed, it being only necessary to raise the ballast walls and make minor alterations to suit the new design.

The masonry in the pier shafts consists of grey granite rock faced ashlar, laid with alternate headers and stretchers and backed with concrete, in which were embedded displacer stones usually about 1 cu. yd. in size. Headers were required to have a length of at least 2½ times their build, with a minimum length of 7 ft. Bed joints were ½ in. throughout and vertical joints ⅜ in. for 12 in. back from the face and not exceeding 4 in. wide at any point.

All stones in rounded ends of main piers were clamped together and connected vertically by dowels. The upper 18 ft. of these piers were built with cut granite backing. About 40% of the stones in these backing courses were made to project up through the course above, in this way giving a very strong vertical bond. The bridge seats proper are built 2 ft. higher than the surrounding upper coping course, and are 4 ft. deep, extending to the bottom of this coping, thus providing heavy stones under the main bearings.

The anchor piers are in plan about 136 ft. long by 29 ft. wide at the bottom, with a batter of 1 in 24, and reduced in section for 41 ft. at the centre to a vertical wall 18 ft. thick, thus forming pilasters at the ends, through which the anchor wells are built.

Owing to the importance of the work, the contractor spared no effort or expense to provide a plant up-to-date in every respect.

On the north side a large wooden trestle was built around the four sides of the caissons, all supported on piles and cribs. As the current here reaches 7 miles per hour and there is an average tide of 16 ft. and a maximum of 20 ft. it was necessary to have this trestle very strongly built. Platforms extended to the shore from the up- and down-stream ends of the pier carrying standard gauge double tracks which formed loops around the caisson and connected with the concrete plant 600 ft. inshore and located at the foot of the cliff.

The power plant, dining-room for "sand-hogs," and two-story bunk house were also located at the water's edge—just upstream from the pier. All supplies and material required were received by rail or team at the top of the cliff, some 160 ft. above high-water level and were delivered by gravity to the concrete plant and service tracks at the foot. A service elevator was operated by cable and hoisting engine at the top of the cliff which was an angle of about 45° at this point connected the tracks at the top with those at the bottom. A stairway provided means for the men to reach the upper and lower levels. The board of engineers' office was located at the top of the cliff.

At the foot of the cliff were situated the mechanical plants which furnished the power for the various operations. To supply compressed air, five Ingersoll-Sargeant compressors were employed. Four had a capacity of 1,250 cu. ft. and one 2,500 cu. ft. per min. These compressors discharged into a 12-in. main from which 7-in. branches led into the two caissons. Each branch was fitted with a gate valve so that the air could be cut out of either caisson at will. The main pipe was carried in a sluice of running water about 400 ft. long, which kept the temperature of the air down to about 75° F. As a consequence, the temperature of the working chamber rarely exceeded 90° F., although the service shaft, on account of the heat generated by the setting of the concrete around it, generally exceeded 100° F. For this same reason the temperature of the working chamber reached as high as 110° F. when being finally filled with concrete.

The compressors were at first supplied with power from six 100-h.p. horizontal boilers. As the work proceeded it was found that the demand on the compressors was greater than was anticipated. As a consequence, an extra 100-h.p. boiler was installed, together with one 500-h.p., one 75-h.p. and one 250-h.p. boilers, making a battery of 10 boilers, aggregating 1,075 h.p. These boilers were all coupled up, and in addition to the compressor plant, supplied power to the power-house, rock crusher and concrete mixing plant. There were also one 100-h.p. vertical and two 50-h.p. horizontal boilers on the platform near the caissons, and were used to furnish power to six 15-ton stiff-leg derricks which were used for handling stone, concrete, etc., during the sinking operations. They also furnished power to one 8-in. high-pressure pump used for washing material in the working chamber and to two 4-in. pumps which supplied water to the high-level tank on the top of the hill, thus furnishing the water supply for the whole plant.

The plant was supplied with electric light from its own power set situated near the boiler-house. It was equipped with a 30-kw. C.G.E. generator, capable of operating 16 arc lights and 100 incandescent lights (16 c.p.). There was also a blacksmith and machine shop in connection, so that all minor repairs to plant and equipment could be made on the job.

The concrete mixing plant was placed just at the foot of the cliff. Half-way up the slope was the rock crushing plant. The rock used for the concrete was obtained from an adjoining cut and was brought to the brow of the hill in cars which dumped into a chute leading to the crusher plant. The stone was fed into 2 gyratory crushers which were capable of dealing with about 500 cu. yd. in 12 hours. After passing through the crushers the stone was led over an inclined screen of 2-in. mesh, and thence into a storage hopper bin of about 200 yds. capacity. These chutes led from this to the concrete mixing platform below, the mouth of each chute being directly over a mixer. From this platform the sand, stone, cement and water, were fed in the proper proportions to the mixers underneath the platform, which in turn dumped into self-discharging buckets on trucks, which were hauled to the caissons by horses. Three Ransome mixers were used on the work, two having a capacity of 2/3 cu. yd. and the other 1 1/3 cu. yds. Owing to the conditions under which the work was carried on the mixers never had a chance to work to their full capacity; their best day's work being 450 cu. yds. for the 24 hours.

The sand used in the concrete was conveyed to the concrete mixing platform in the same manner as the stone, i.e., by means of a chute from the upper level, where it was unloaded from hopper bottom cars. The chute was 8 ft. wide by 6 ft. high and was kept practically full all the time, the sand being taken from the lower end as required. The coal for the boilers was also delivered from the upper level through a chute, which emptied into 2-yard side-dump cars at the boiler-house level. By means of a track these cars delivered the coal to each boiler-house as required. On the top of the coal chute was a double line of rails with balanced trucks, which conveyed the cement from cars at the upper level to the storage shed at the level of the concrete mixing platform. The cars could, therefore, be unloaded as they arrived and the cement placed where required for use with the minimum amount of handling.

For the convenience of the "sand hogs," who were compelled to work on shifts through the whole 24 hours, the contractor erected both sleeping and dining quarters for a large number of his men. On the lower level a bunk-house had been provided to accommodate about 100 men, and a dining room that would seat as many more. On the upper level was a similar house with bunks for about 60 men and dining quarters of about the same capacity. On the dock the contractor erected a number of buildings, which included an office and bath accommodation for the inspectors, a hospital with a doctor in continual attendance, where first aid might be administered in case of serious accidents, or regular treatment in case of minor troubles. There was also provided a coffee-house, kept at a high temperature, where the "sand hogs" could change their clothes and receive hot coffee at the end of their shift in the working chamber. In addition to the above were the usual stores, offices, etc., for the contractor's own use. In connection with the hospital arrangements there was also provided a steel hospital tank connected with the compressed air system, to which men suffering from the "bends" could be immediately transferred and treated.

For serving each caisson four 30-in. shafts for material and two 30-in. ladder shafts were employed. For ejecting the sand and smaller stones four 4-in. blow pipes were used. The larger boulders were broken up and hoisted through the material shaft in buckets having a capacity of ⅔ cu. yd. Four 7-in. compressed air pipes supplied air to the working chamber and served the blow pipes. Two 6-in. pipes supplied the water for "washing" the sand. One 2-in. pipe supplied high-pressure air for drilling, etc., and a second 2-in. pipe carried the wires for the electric lighting of the working chamber and ladder shaft.

As soon as the sinking was completed on the north shore as much of the plant as could be spared was moved to the south side. The men's dining-rooms and sleeping quarters were placed on skids, launched into the river, floated across, and placed in position on the other side. The layout for the mixing plant, sand chute, coal chute, etc., was practically the same as on the north side of the river, all the materials being led to the lower level by gravity. The stone for the crushers was quarried directly from the top of the cliff so that one derrick could pick up the stone in the quarry and deposit it in the hopper leading to the crushing plant half-way down the cliff. While the boiler and compressor plants used on the south side were drawn as much as possible from the north side, yet they had to be materially increased. The steam plant included three 125- and one 250-h.p. Heine boilers, twelve 100-h.p. locomotive boilers, and seven Ingersoll-Rand and Ingersoll-Sergeant air compressors delivering to 2 coupled receivers from which a pair of 12-in. mains led to the caisson and were carried for about 200 ft. in a wooden flume constantly filled by water. This reduced the high temperature developed at the compressors to about 80° in the working chamber of the caisson. There were also two 12-in. Worthington high-pressure pumps which delivered water to the caisson for the hydraulic jets used for excavation.

On account of the very high tide which prevailed at the site, the air pressure in the caissons constantly varied and was controlled by an operator in the compressor house who adjusted it to correspond with the indications of an automatic register showing a continuous tide pressure.

The stone from the quarry on the top of the cliff was delivered by derricks into a No. 8 McCully rotary crusher near the top of the bank, which broke the larger pieces and delivered them through a chute to a No. 5 Allis-Chalmers crusher about 25 ft. below it. The second crusher reduced the stone to a diameter of 2 in. and delivered it through another chute to a storage bin adjacent to the sand bin. Both stone and sand bins delivered by gravity through gates to measured compartments in a triple charging hopper just below the floor of the working platform. This hopper was lined with steel and had a compartment into which the requisite number of bags of cement were poured by hand. The hopper gate was operated from the charging platform and delivered all of the aggregate for one batch of concrete to one of the two Ransome mixers under the platform, which discharged into 1½-yd. bottom-dump Stuebner steel buckets which were set in pairs on 2 coupled cars drawn by one horse on a 600-ft. service track to the main pier caisson, or to the anchor pier, where they were unloaded and emptied by the derricks installed there.

The compressed air, with a maximum pressure of 40 lbs. per sq. in., was delivered to the working chamber of the south caisson through two 12-in. pipes, as stated above, which in turn was distributed into four 7-in. mains.

Water at 100-lb. pressure was distributed around all four sides of the working chamber in a horizontal main from 4 to 6 in. in diameter, provided in each of the 18 compartments with a valved outlet and a jet pipe with 1-in. nozzle used to loosen the sand and excavate the earth and gravel. Each chamber was also provided with a 6-in. vertical blow-out pipe and with electric lights. The caisson was fitted with six 3-ft. material shafts, each having a Moran air lock with four 3-ft. ladder shafts having simple air-locks composed of short upper sections with top and bottom diaphragms, and with one large man-lock. The latter was a 6-ft. horizontal steel cylinder about 30 ft. long, located on the deck of the caisson, and was built permanently into the solid concrete of the pier, being approached through a 4 x 4-ft. vertical stair shaft. The lock was large enough to accommodate many "sand hogs" at once, thus greatly expediting the entrance and exit of each successive shift, effecting an economy of air consumption and considerably reducing the waste of lock air.

A hospital lock was also established on the shore near the "sand hog" house. Under moderate pressures, 100 men worked 8 hours in each shift. As the pressure increased the lengths of the shifts were diminished to a minimum of 1 hour. As many more sand hogs were required to carry on the work, great difficulty was experienced in securing enough men, so that eventually the number of men in each shift was considerably reduced. Some of the men lived in an adjacent boarding house provided by the contractors, but the majority of them lived in local villages up to five miles distant.

At the present time the contractor is at work pointing the joints in the masonry and cleaning these piers thoroughly by sand blast. There is also some work still to be done on the dressing of the bridge seats. This work is very important and has proved a very difficult operation. These bridge seats are about 32 ft. x 26½ ft. and it is necessary that they should be absolutely level to distribute the load from the main steel pedestal, the base of which is shipped in four pieces. It requires about six weeks to complete the dressing on one of these beds, and it has been found that the work can be done with such accuracy that not more than a variation of 2/100 of an inch is possible.

This work is under the supervision of the Board of Engineers, Quebec Bridge, which is composed of C. N. Monsarrat (chairman and chief engineer), Ralph Modjeski and C. C. Schneider.

RESERVING WATER POWER SITES.

Consistent with the policy of the Dominion government to preserve the water powers for the people, the department of the interior is placing under reservation all vacant Dominion land that the superintendent of water powers may recommend to be valuable for the development of water power, says Conservation.

Six whole sections of land, in township 108, range 6, west of the 5th meridian, have recently been reserved from disposition of any kind until the engineers of the water power branch have had an opportunity to make a complete survey of the famous power site at Vermilion falls, on the Peace River in northern Alberta.

Similar reservations have been made on the various rivers in the provinces of Manitoba, Saskatchewan, Alberta, and in the railway belt of British Columbia. Particular mention might be made of reservations covering land contiguous to Grand Rapids on the Athabasca River, the various power sites on the Elbow and the Bow Rivers, in the province of Alberta; for land required for the development of power at Grand Rapids on the Saskatchewan River, and all unoccupied land along the Winnipeg River, in the province of Manitoba.

Other reservations will be made from time to time upon the receipt of sufficient information to enable the superintendent of water powers to make a definite recommendation covering a description of the land that might be required for power purposes.

PROGRESS AT CEDARS RAPIDS, QUEBEC.

THE Cedars Rapids Manufacturing and Power Co. has under construction an extensive power plant at Cedars Rapids on the St. Lawrence River, about 30 miles west of Montreal. There is a fall of 32 feet and the installation is designed for an output of 160,000 h.p., of which 100,000 h.p. is for immediate consumption. The ultimate consumption will utilize 56,000 ft. per sec.

The development begins with a canal which is being built along the north bank of the St. Lawrence, a distance of 12,000 ft., in which is concentrated the fall of 32 ft. The width of the canal is approximately 1,000 ft. The power house at the lower end of the canal, and forming a portion of the dam, is 663 ft. long and 140 ft. in width. Details with respect to the development, including the power house equipment and general methods of construction were given in an article appearing in January 1st, 1914, issue of *The Canadian Engineer*. The accompanying photographs and data relate particularly to the work which has been accomplished since then.

The south bank of the canal which, when completed, will be practically a straight earth wall two miles in length extending the entire length of the headrace, is progressing rapidly. Water is excluded from the canal by an earth bank serving as a cofferdam. Upon the completion of the canal, this bank will be removed. Fig. 1 shows the work near the upper end of the canal. Excavation is practically completed at this point. The illustration shows, in the south bank, a portion of the spillway and ice sluice. Various portions of the canal between its extremities are down to grade with the bottom more or less clean. For a greater part of the distance the south bank is also practically completed. Fig. 2 shows another portion of the canal and bank, in an advanced stage.

The construction of the power house has reached the stage shown in Figs. 3 and 4. On the north end a single dam will connect temporarily this end of the building with the north bank of the river. It is on the north side that future extensions will be made for the additional 60,000 h.p. at a later date. The south end of the power house will connect with the south bank of the canal. Fig. 3, illustrating the east or downstream side of the power house, shows the draft tubes and the tail race under construction. The latter is being brought down to grade at the present time and a little excavation remains to be done. The work at this portion of the development involves nothing beyond the disposal of excavated material. In the view of the west or upstream side (Fig. 4) every three openings will provide water for one of the 10,800-h.p. water-wheels which are being installed. These wheels are of the single runner vertical shaft type and will operate at 56 r.p.m. under a head of 30 ft. The height of the water will thus reach about midway between the bottom ledge of the large windows and the top of the openings shown in the illustration. The smaller openings in the centre of the building are the intakes for the three 1,500-h.p. exciter units, to operate under the same head at 150 r.p.m. The higher opening in the concrete about the middle of the wall is for the purpose of ice disposal.

The large crane, shown in Fig. 3, is used to convey buckets of concrete from dump cars to the forms. The

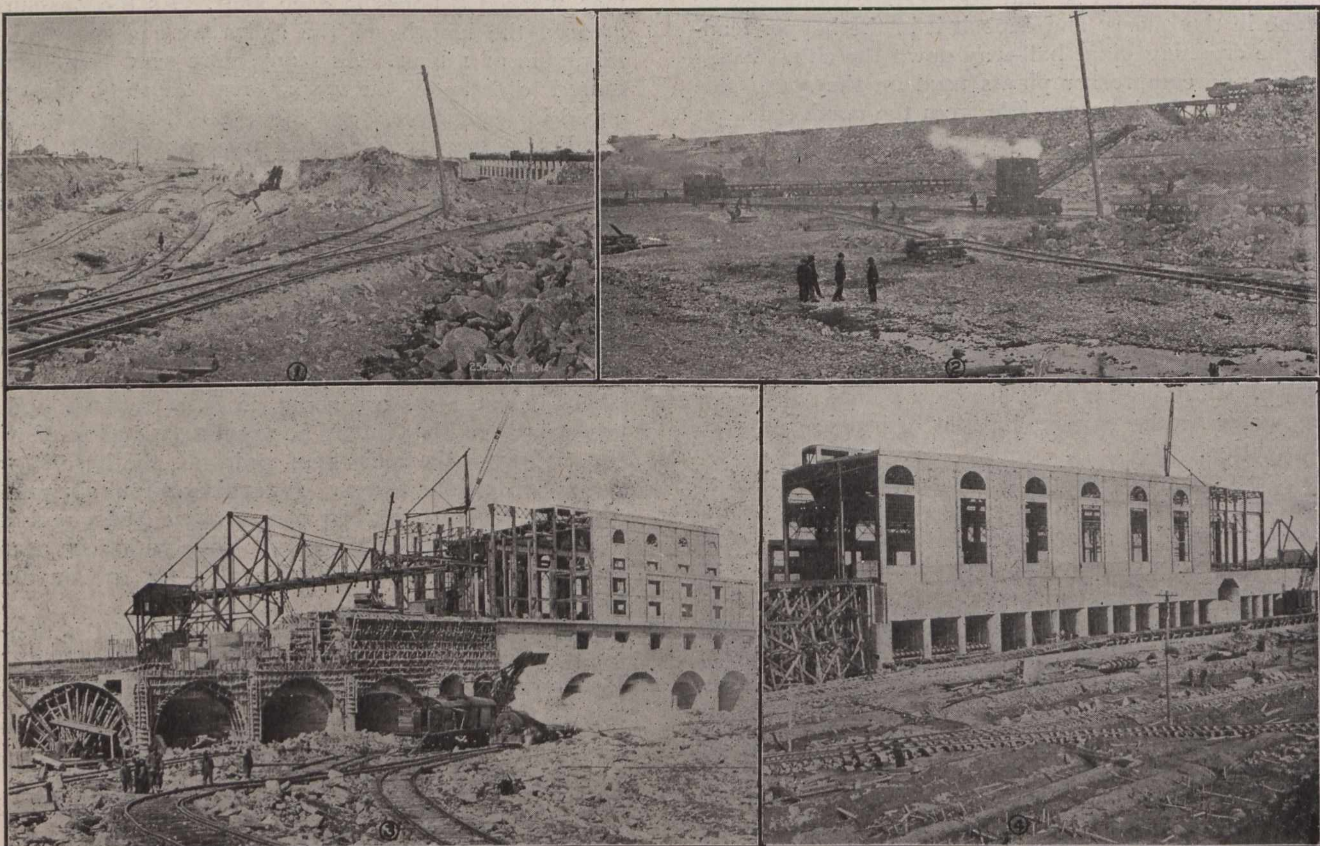


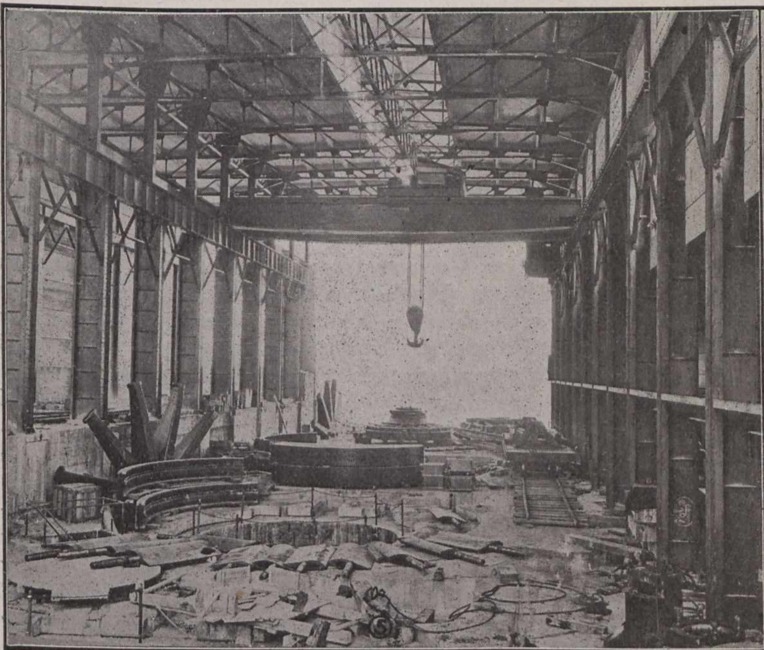
Fig. 1.—Upper end of Canal as it appeared on May 15th, 1914. Fig. 2.—Portion of Canal down to grade and bank almost completed. Fig. 3.—Downstream side of power house, showing manner of construction. Fig. 4.—Upstream side of power house, which will form portion of dam.

rock-crushing, concrete and mixing plant is located considerably to the north of the power house.

Of the views illustrating the interior of the power house, Fig. 5 illustrates the general method of erection and the location of the wheel-pits, which are shown in various stages. The cover plate of a water-wheel, shown in the background, has a diameter of 20 ft., and weighs about 60 tons. Portions of the spiders which are to support the field coils of the generators are also shown near the western wall. In the foreground are some of the guide vanes of the water-wheels. Fig. 6 shows one of the pit-liners being lowered into a wheel-pit, while Fig. 7 illustrates the speed ring of one of the wheels. Fig. 8 shows one of the cover plates which rests immediately over the water-wheel, with a shaft 27 in. in diameter projecting through the shaft chamber shown. Upon this shaft is mounted the generator, supported by a thrust-bearing. Each generator is 37 ft. in diameter.

The transformer house, which is about 800 ft. distance from the present north end of the power house, has been completed as far as the foundations. Concrete is being placed by means of tremie pipes.

The following table illustrates the progress which has been made upon the work and the stage of construction on May 1st, 1914:



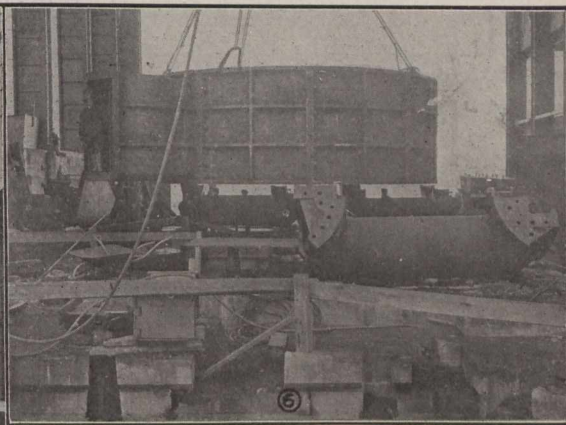
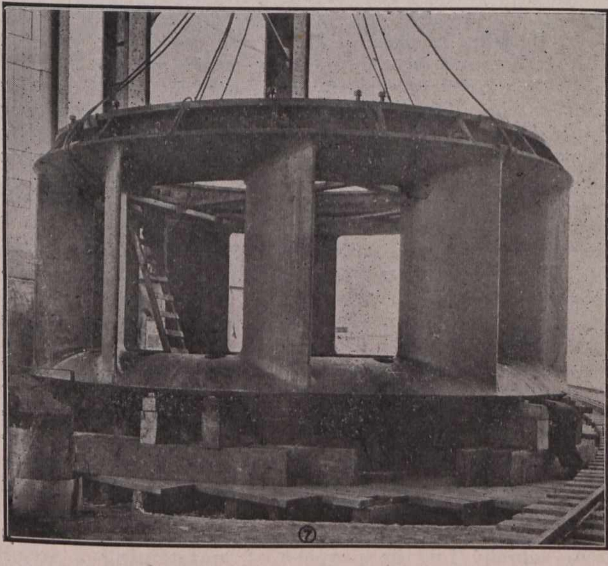


Fig. 5.—Interior view, showing unassembled parts of water-wheel and generator. Fig. 6.—Pit-liner being lowered into position.

	Aug. 23, 1913.	Dec. 1, 1913.	May 1, 1914.
Rock excavation	21%	23%	58%
Earth excavation other than stripping and trench work	43%	60%	73%
Earth excavation in trenches and ditches, and stripping seats of banks	36%	84%	Complete
Transporting and placing excavated rock	20%	28%	62%
Stone protection	2%	3%	5%
Transporting and placing excavated earth	43%	63%	77%
Concrete in power house substructure	16%	26%	69%



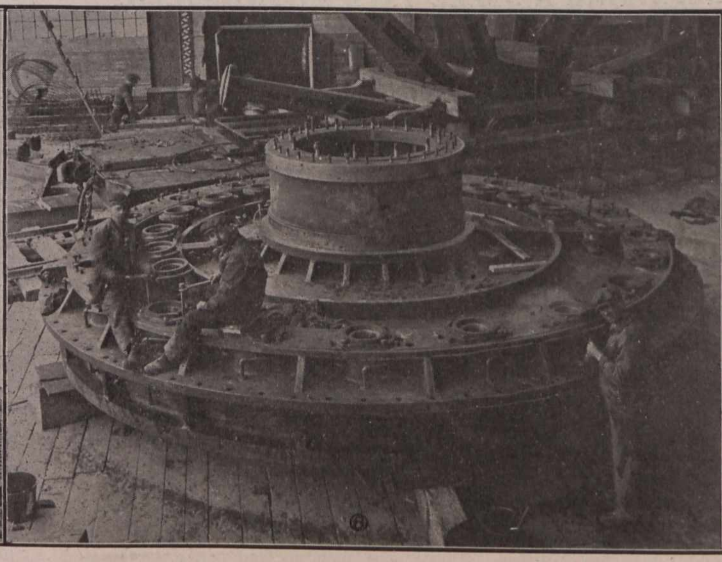


Fig. 7.—Speed-ring of one of the twelve 10,800-h.p. water-wheels (of the single-runner, vertical shaft type). Fig. 8.—Assembling a waterwheel cover-plate.

The Cedars Rapids Manufacturing and Power Company awarded the contracts for the supply and installation of the water turbines to the I. P. Morris Company, Philadelphia, and Wellman-Seaver-Morgan Company, Cleveland. The General Electric Company, Schenectady, N.Y., are supplying the electrical equipment. The structural steel is being supplied by the Phœnix Bridge and Iron Works, Montreal. The power house units and transformer station superstructure are being erected by the Unit Construction Company, St. Louis. Messrs. Fraser, Brace & Company are the general contractors.

CLAY COATING FOR WOOD PIPE.

It is generally known that the durability of wood pipe for water transportation depends largely upon its continuous and perfect saturation with water. In this connection it has been contended that pipes should be thin enough to insure the penetration of water through the pores of the wood, at a more rapid rate than the loss of water by evaporation from its surface. The difference in the porosity of different timbers causes a variation in proper thicknesses.

There are many incidences of the long life of wood pipe. Most of them are accompanied by the fact that the pipe was buried in clay and the whole is an indication of the preservative properties to be found in clay relative to wood pipe laying. Most clay is not a good culture bed for the growth of fungus that causes decay. Further, clay holds moisture and thus insures continuous and thorough saturation of the wood at the surface of the pipe.

In view of this preservative quality of clay "Engineering and Contracting" suggests incasing wooden pipe with clay to the thickness of several inches where the clay is within comparatively easy reach and particularlv where the trench is in soil that is either very porous or contains much vegetable humus. It is suggested that a clay jacket around wooden pipe would prove economical. A concrete jacket would be likely to serve a similar purpose, but ordinarily at a greater cost than clay.

The suggestion is one which might well be tried out. Wooden pipe has many advantages for water transportation, and if its liability to rapid decay could be substantially offset the result would be of extreme value.

REPAIRING A STEEL TAPE IN THE FIELD.

In the progress of the day's work there are few more annoying incidences productive of delay to a survey party than the breaking of a steel tape. The process of repairing it by riveting has been superseded by several other methods of greater convenience and rapidity. The outfit required for riveting cannot be carried about so as to be ready for use when the emergency calls for it. The same applies largely to a soldering outfit of sufficient size to be of material use.

A tape repairer that has been found very satisfactory and a splendid time saver consists of a strip of tin about ¾ inches long with two of its edges bent over until they almost meet. The inner faces have a coating of soft solder. To repair a broken tape the fractured ends are inserted, the overlapped edges of the tin forced together by a little hammering and the solder heated by holding a lighted match under the splice.

Two or three of these devices can conveniently be carried in the field and will be found a very useful part of the outfit. They are prepared in different widths to fit any tape. The Chicago Steel Tape Co. are the manufacturers.

There are, of course, new soldering pastes on the market which require no soldering iron or separate flux, a small amount of which, together with a few strips of tin can be conveniently carried about. They are not so convenient, however, and there is less liability of making a strong and satisfactory repair as with the device suggested above.

NEW PROCESS OF RUST PREVENTION.

Making use of the common knowledge that chemically pure iron is practically rustless, a new process has been devised by which steel surfaces are coated with almost pure iron. This process has been termed ferro-zincing or ironizing. In it hydrogen is the chief impurity, the presence of which appears to be advantageous in that the iron coating containing it is slightly more electro-positive to the underlying steel than it would otherwise be.

The coating of electrolytic iron has another advantage, that of being homogeneous, and, according to "Engineering," London, is not under an equal strain caused by mechanical operations, such as drawing or hammering. Further, it has not been subjected to any heat or mechanical treatment, which of necessity causes impurities to be absorbed by the metals so treated.

This process, if commercially applicable, should mark a new era in the use of steel. The preservation of iron and steel from corrosion by galvanizing has been largely used by engineers with considerable success. There are in reality two processes: the first, dipping the iron in molten zinc in combination with suitable fluxes—called hot-galvanizing; and, coating the iron or steel surface by electro-zincing—cold-galvanizing. The reason that zinc, as a protective coating for iron and steel, has held its own so long is that it is electro-positive to the underlying metal. In the presence of moisture, the iron and zinc form a galvanic couple, and as long as there is any zinc remaining in contact with the iron within a given area the zinc corrodes in preference to the iron, thus protecting it.

In the new process it is found advantageous to coat the electrolytic iron surface with zinc, for the reason that a zinc coating with an immediate layer of pure iron hydrogen alloy gives a greatly increased life to the ordinary steel tube or plate.

The inventor of the process, Mr. S. Cowper Coles, Westminster, has arranged with the British Mannesmann Tube Co. for the protection of boiler tubes, and is applying the process to a number of other purposes.

EQUALITY OF WATER FLOW DEPENDENT ON FOREST COVER.

It has been urged that in the interests of navigation the Dominion Government should purchase such denuded forest land in the eastern provinces as might be necessary to re-forest in order to prevent floods and the filling up of streams with sediment. In this connection the report on the Trent Watershed Survey, recently published by the Commission of Conservation, is of considerable interest. In this region of Ontario, as a result of fires, 150,000 acres are practically a desert and the report urges a policy of forest conservation under Dominion, provincial or municipal control, in order to preserve the usefulness of the Trent Valley Canal, in which over $10,000,000 are invested. There are many such barren areas in the eastern provinces, which with the assistance of the Dominion Government might be made to produce valuable forest crops.

In Canada disastrous floods and low-water stages have been largely prevented by the timely action of the Dominion Government in setting aside as forest reserves the wooded slops where the great rivers of the interior of the Dominion have their origin. On the east slope of the Rocky Mountains over 20,896 square miles of non-agricultural land have been thus reserved, for the double purpose of regulating the run-off and of providing a perpetual supply of timber to meet the ever-increasing needs of the prairie settlers. In the Railway Belt in British Columbia smaller reserves have also been set aside, chiefly for the purpose of maintaining a steady flow in the streams on which the fruit-growing industry is absolutely dependent.

STEAM RAILWAY ELECTRIFICATION.

THE factors entering into the selection of a system when contemplating the electrification of a steam railway were ably discussed in a paper read by Mr. J. A. Shaw, of the Canadian Pacific Railway Company, at the 24th annual convention of the Canadian Electrical Association, held last week in Montreal. The importance of choosing a system suitable for general conditions, to permit interchangeability of rolling stock between different sections, and to allow extensions to be made as economical and reliable operation, or other conditions warrant, were properly emphasized. We reproduce the following from Mr. Shaw's paper:—

Three systems now exist which include all which need be considered in view of the present state of electrical development. One, the three-phase alternating, is not suitable for general electrification, on account of requiring two trolley wires, with the resulting complications and the peculiar characteristics of the motors employed. The remaining systems are single-phase alternating current, and the 2,400-volt direct current.

The single-phase system has been used in the electrification of the New York, New Haven and Hartford Railway from New York to Stamford, and is now being considerably extended. It has also been used on a number of light railways, notably the Spokane and Inland. Abroad it is in use on the London, Brighton and South Coast Railway, the Swedish State Railway and others, and has been adopted by the German, Swiss and Austrian State Railways as their approved system, although it cannot as yet be considered as completely through the experimental stage.

The 2,400-volt d.c. system is a development from the 600-volt system, which is practically the standard in all street railway and interurban work, and which has been so successful on that field. The electrification of the New York Terminals of the New York Central and the Pennsylvania lines, the Atlantic City Line of the Pennsylvania, the New York Subway, and all elevated railways have also employed this system. Abroad it has been used on the Lancashire and Yorkshire Ry., and in general under conditions similar to those in this country. During the past three years a number of light railways have been installed using 1,200-volt d.c., in most cases, however, using 600-volt motors, and from the experience obtained, the 2-400-volt system has been developed, using 1,200-volt motors, and this system has now been in use on the Butte, Anaconda and Pacific Ry., preparatory to a further use of it on two divisions of the Chicago, Milwaukee and Puget Sound Ry., for the past 10 months. A lower voltage installation at 1,500 volts has been in service over three years on the Piedmont Ry. in South Carolina.

Supply of Power.—It is possible that in the majority of cases for years to come that power will be generated for locomotive purposes alone, without considering its use for other purposes. However, electrification will be made possible more through cheap power being available from existing power plants, where if a separate plant had to be erected it would be too expensive. Possibly in the future power plants will be constructed at points where commercial power is not available, but even in that case at other points on adjoining divisions commercial power might be obtained, and to permit of uniform equipment the power generated would either have to be uniform with that purchased or the latter converted to the character required. Throughout the West and in the Montreal district, 60-cycle, 3-phase transmission is practically universal, and, while 25-cycle, 3-phase current is employed on the Hydro-Electric and Toronto-Niagara transmissions from which 25-cycle single-phase could be obtained by stationary transformers, balancing apparatus would be required. In view of the tendency to use 15-cycle in place of 25-cycle current in single-phase electrification and the remoteness of general electrification in Ontario, it is reasonably safe to assume that converting apparatus will be required for either single-phase or direct-current installation. The application of 15-cycle generators in 60-cycle power stations or of frequency changing apparatus to furnish single-phase current, while possible, does not actually change this assumption, as the increased price asked for by the power companies equals the cost of conversion by the railroad in addition to requiring the erection of separate transmission lines.

The general arrangement of the two systems is outlined in Table I.

TABLE I.

Single Phase.	Direct Current.
A 1. Power line of supply company.	D 1. Power line of supply company.
A 2. Conversion station at one or two points per division furnishing single-phase current from motor-generator apparatus and step-up transformer for raising potential. If power lines are available at several points on division, number of conversion stations may be increased, and length of transmission lines correspondingly reduced.	D 2. Transmission line to sub-stations. Where supply company power lines are available at several points on division, sub-stations may be conveniently located at such points, and length of transmission line correspondingly reduced.
A 3. Transmission line from conversion stations to transformer stations.	D 3. Sub-stations in which three-phase power is converted to direct current by motor generator apparatus.
A 4. Transformer station in which high voltage single-phase current is transformed to 11,000 volts for trolley line.	D4. Feeder line by which direct current is supplied to trolley line.
A 5. Trolley line and bonding.	D 5. Trolley line and bonding.
A 6. Electric locomotives or motor cars.	D 6. Electric locomotives or motor cars.

Cost of Installation.—An inspection of above table shows that as a general proposition certain of the items are practically common to both systems. Transmission lines A-3 and D-2 will be required for the entire length of the division if power were received at one point: whereas if power were received at several points, while several single-phase conversion stations could be installed, that would not prove practically economical, and with direct current there would be a saving in the transmission line required. The transmission line for single-phase current costs 20 per cent. more per mile than that for 3-phase, so that it is entirely fair to the single-phase to consider the cost of transmission lines equal.

The trolley line and bonding are practically the same. For single-phase, higher insulation is required on account of the higher voltage and the surging which occurs. With the improvements that have been made in the manufacture of insulators, the difference would not exceed 10 per cent. of the cost of the trolley line.

The conversion stations and transformer stations A-2 and A-4 for single-phase will correspond to the sub-stations D-3 for direct current. For heavy traction work on the Chicago, Milwaukee and St. Paul Ry., where it is proposed to handle 1,600 tons on 1 per cent. grades, the sub-stations will be located from 18 to 24 miles apart, the feeder being 1,000,000 cm. Considering a direct current section having sub-stations 20 miles apart, the distance between transformer stations for single-phase current will depend on the worst conditions that should be permitted to occur. Thus with the direct current with a voltage drop of 50 per cent. trains could be handled at one-half speed with full tractive power. With single-phase the maximum drop permitting this condition would be from 20 to 30 per cent. The latter figure will be taken as most favorable to single phase, and the distance apart of stations calculated: 1st, when the number of trains on a section is proportional to its length; 2nd, when the same number of trains are concentrated at the centre of a section irrespective of its length. The spacing of the stations can also be calculated when the efficiency is the same for both systems, the number of trains per mile of track being the same. The results are as follows:—

Limiting operating conditions, trains uniformly distributed or number proportioned to length of section .... 30 miles.
Limiting operating conditions, same number of trains at centre of section........... 45 miles.
Equal efficiency, number of trains proportioned to length of section .... 30 miles.

The limiting operating condition with the number of trains proportioned to the length of the section is evidently most important from a general railroad standpoint, and transformer stations, say, 33 1-3 miles apart, would apparently give substantially equal service compared with direct-current sub-stations 20 miles apart. The total capacity of the direct-current sub-station will exceed that required in the conversion station, since each sub-station must be able to carry the load of the trains that may be starting in its vicinity. The total cost of the single-phase stations is, however, increased by that of the transformer stations, which cost one-third as much per kilowatt capacity as the conversion or sub-stations. The two systems are thus equal in cost when the sub-station capacity with direct current is 44 per cent. greater than the conversion station for single-phase. In some cases the difference is not sufficient, but lines will not be electrified on which traffic is insufficient to render the load reasonably uniform. As in the case of the transmission line and trolley the single-phase was more expensive; in this case the direct current will be in general slightly higher—the net results being very closely the same.

The remaining items are: A-6 the single-phase locomotives, D-4 the d.c. feeder, and D-6 the d.c. locomotives. The feeder proposed is of 788,000 cm. area, costing at 18 cents per lb., $2,250 per mile, or $2,500 per mile erected. The cost of the locomotives will vary according to the type and capacity, but based on d.c. locomotives costing $40,000, those for single-phase current will cost $60,000, so that if one locomotive is used for each eight miles of track, the total cost of the two items is again substantially equal.

The net result is that where power is obtained from 3-phase distribution, the cost of electrification by single-phase or d.c. is substantially the same. This is confirmed by several careful independent estimates. With direct current the expenditure on feeder copper and sub-station apparatus is balanced by the slightly increased cost of the trolley and transmission line for single-phase current and the much greater cost of the locomotives.

Cost of Operation.—Cost of operation is affected by the efficiency of the system, the cost of operation of the sub-stations and the cost of the maintenance of the locomotives and other apparatus.

The efficiency of the system will determine the cost of the power supplied, and, if the movement of the trains and the power they each consume is known, could be calculated with considerable accuracy. When power is purchased, especially water-power, the cost depends on the peak load during certain hours, and trains will be operated to reduce this as much as possible. It is, therefore, difficult to forecast the train distribution. There is, however, no general evidence to show that greater efficiency may be obtained with single-phase than with direct-current equipment. Several records of actual service show that with direct-current under similar conditions the results are more economical than single phase. This is especially so when the power per car mile is considered on account of the greater weight of the single-phase equipment. From what we have already learned and figures published, it may be safely assumed that on any section of a railway on which there is sufficient traffic to justify electrification, the power required by direct current will not exceed that required for single phase.

The cost of sub-station maintenance and operation is greater for direct current. On a 100-mile division there would probably be five (5) sub-stations, each containing moving apparatus which requires attention as against one for single-phase system. Each of these sub-stations would cost from $3,000 to $4,000 per year, or, say, $18,000 per annum, against $4,000 for the single-phase station. It is doubtful whether the wages cost of $2,000 per year per station, or $10,000, is a proper charge against the direct current. On main line work it will be absolutely necessary to arrange to cut out any portion of the road on which accidents may occur, and for this purpose attendance will be required. Trains must be moved away from any section temporarily disabled to prevent congestion, and of the $14,000 additional cost it would appear entirely fair to estimate that about $8,000 is the most that would be entailed by the sub-stations. This is more than equalized by the greater cost of maintenance of the single-phase locomotive. Direct-current locomotives are being maintained for 3¼ cents per mile, of which 2 cents is entirely separate from the electric motor, control, etc. On the single-phase locomotives, the cost has been higher, but it is hoped to reduce it to between 5 and 6 cents. For short distances the direct-current locomotives as used out of New York will handle a train that requires two single-phase, and if this were allowed for, the difference would be very great. The new switching and freight locomotives on the New Haven, it is stated, have been maintained for a comparatively low figure, but they have as yet not been in service sufficiently long to give a final value. The construction of all single-phase locomotives is far less sturdy than that of direct current, on account of the difficulty of keeping the weight down to a reasonable amount, and the construction is far more complicated. It cannot be expected, therefore, that they can be maintained for a lower percentage of their total cost. A fair difference to assume is that cost cannot be taken at less than 2 cents per mile for locomotives of equal power, say, 1,000-h.p. each. Considering a division with 1,000,000 miles per year, or $20,000 at this figure, so that the cost of operation and maintenance of sub-stations is more than taken care of by the increased cost of maintenance of equipment. The single-phase locomotive is also considerably heavier than the direct-current for equal power, and this is especially true when motor car equipment is considered. This increase in weight means a correspondingly reduced train load, unimportant on level districts, but of appreciable amount on heavy grades. It also entails an additional expense for power which is serious in light passenger or motor car service. There is, of course, a possibility that 2,400-volt d.c. apparatus will cost more to maintain than 600 or 1,200-volt, but there does not appear to be any reason to fear its becoming excessive. While there is no doubt that the New Haven have had more electrical trouble than the New York Central and the cost of repairs has been higher, due to the mechanical construction of the locomotives rather than to the electrical equipment. This mechanical construction is, however, necessitated by the use of the single-phase motor. While there is no reason why the same construction should not be employed with the 2,400-volt d.c. system as with the 600-volt. In general, there is no reason to expect the cost of operation with the single-phase system to be less than that with the direct current.

Possible Difficulties with 2,400 Volts.—The above discussion considers that 2,400-volt d.c. will prove equally satisfactory as 600 or 1,200-volt installations. In a system that has not been thoroughly demonstrated in practical service, there are some features from which trouble may be experienced, and these are discussed as follows:—

The simple and strong design of the d.c. locomotive is partly due to the use of geared locomotives for freight service and gearless for passenger service. The construction which has been adopted and which is practically necessary for single-phase locomotives of any size, supports the motor entirely independent of the wheels, the latter being driven through springs or connecting rods, thus reducing the dead weight to that of the wheels and axles alone, while retaining the same total weight on each wheel. The centre of gravity of the locomotive is also raised to a point approximating that general for steam locomotives. From experiments conducted on engine and tender trucks and the experience of maintaining track under various types of locomotives, it is safe to assume that the dead weight of 9,000 to 10,000 lbs. per axle on gearless locomotives and the slightly greater weight on geared, does not, for the services in which they will be respectively used, appear likely to affect the cost of track maintenance sufficiently to justify the additional expense and complication involved in reducing it. In view of the greater total weight of the single-phase locomotive it is very doubtful whether its effect on the track will not be greater than the direct-current locomotive, even though the dead weight per axle is higher in the latter. Increasing the height of the centre of gravity reduces the lateral shocks on the rail, but this action is caused by these shocks in steam locomotive design being absorbed by the vertical movement of the springs. It will be unfortunate if electric locomotive design cannot be developed in which these shocks are absorbed by springs, or frictional methods of restraint, so that the simplicity which should accompany the application of motors to drive the wheels of a locomotive may be retained; there is no reason to doubt this being accomplished. Should it prove impossible, the direct-current locomotives would become more complicated and approach the single-phase more closely in cost, the difference being probably 25 per cent. in place of 50 per cent.

The question of current collection at 2,400 volts at high speed has been experimented with, but not fully demonstrated as yet in service. It has been found practical to collect 200 amperes at 60 miles per hour from one roller trolley without injurious sparking, which at 2,400 volts equals 480 kw. Two trolleys can be located 20 feet apart, thus permitting 960 kw. on one locomotive. This question is important, but there seems little question of its being solved satisfactorily. The control of 2,400-volt current does not appear to present any difficulty. Contractors will be arranged to break the current in series, and from results in operation there seems no reason to anticipate any more trouble with 2,400 volts than with 600. Maintenance of motors may be higher with 2,400 volts than with 600 volts. The motors will, however, operate under 1,200 volts each, and the fields in both motors will practically be at ground potential. Twelve hundred volt motors have operated interurban work for five years without indicating any increased cost on maintenance, and while this has been in a dry climate, the forced ventilation to be employed in railway work will give very closely the same condition. The 2,400-volt motor will have the same capacity to stand heavy starting load, the same freedom from commutation trouble, and in general the same ability to stand the severe service imposed upon it by locomotive or traction work that the 600-volt motor has been proved to possess.

The operation of fan and compressor motors on high voltage has to be properly worked out. There are no doubt some difficulties in this respect, but they should certainly be overcome by experience.

Comparison of Systems.—It has been shown that on the assumption that the 2,400 d.c. and the 11,000-volt single-phase a.c. system each operate as satisfactorily as their advocates claim, that there is comparatively little difference in their cost of installation and operation. Each is equally flexible, each will operate and in all probability give a high degree of satisfaction compared to steam locomotives. The principal difference is that, with the direct current a larger portion of the cost of installation is in feeder copper and conversion apparatus, and less in the locomotives, and a larger portion of the cost of operation is in the sub-stations, attendance and maintenance in place of locomotive maintenance. This of itself should prove decidedly to the advantage of the direct-current system, as the sub-station apparatus is stationary and can be carefully maintained, and the simpler and cheaper the locomotive the less danger there will be of a breakdown. In addition, the investment in copper is permanent, while that in locomotives may rapidly depreciate with any new developments. There are, in addition, some minor points worth attention which may be referred to.

The regulation of speed on the single-phase system is in many ways preferable to that on the direct current. By drawing current from the transformer at the voltage suitable to the speed and power required, all speeds are equally efficient, and the use of resistance in the circuit is avoided. This is an exceedingly ingenious method, but it is doubtful whether it is of great practical importance. While the direct-current motors have only two full-power efficient speeds, decreased power can be obtained at higher speeds than either of them by field control with very small loss in efficiency. This would apply particularly in passenger service, since in freight service the characteristics of the motor are such that it would not be required. The use of a transformer on the single-phase locomotive permits the operation of the motors at low voltages, and on ungrounded circuits. There seems, however, no reason to fear the use of high voltage on the direct-current motors, or danger, providing it is properly insulated. There has certainly been more trouble on the single phase from grounds than on the direct current, and it appears to be entirely a question of proper insulation. The relation between the speed of the motor and the power it will develop is different for single phase and direct current. Taking two motors which will develop the same power at a given speed, the direct current will develop greater power at lower speeds and less power at higher speeds than the single-phase motor. This is the reason for the success of the direct-current motor in traction service. It can exert a greater pull without injury and is less liable to damage from overheating when starting a heavy load than any other type of motor. It is also this feature which makes the gearless locomotive a possibility for passenger service, as it enables a motor of reasonable size to start a passenger train without the use of gearing to furnish the necessary power. Direct-current motors can certainly be constructed to handle passenger trains at high speed if desired, so that in this respect the advantage is greatly in its favor. The direct-current motor has obtained its reputation for ruggedness from its capacity to withstand heavy loading without injury, and this quality is of the greatest importance in railroad work.

Conclusion.—If in place of discussing the relative advantage of single-phase and direct-current traction, the start is made from the direct-current system with its simple and strong electrical apparatus developed after years of experience by simply an increase of voltage, and assuming that this increase does not lead to unforeseen difficulties, the question becomes, What is gained by the use of single-phase current?

It does not save in cost of installation or operation.

Its application is not more flexible.

It introduces a locomotive that is more complicated, in which the motor is necessarily far more expensive and elaborately constructed, and which weighs considerably more than one for direct current.

It reduces cost of sub-station attendance at the expense of locomotive maintenance, and consequent reduction in reliability.

The general advantages to be gained by electrification are too well known to bear repetition, but it might be mentioned from the data now becoming available from those installations now in operation that results obtained confirm estimates very closely. The engineers of the Chicago, Milwaukee and St. Paul Ry. estimate that at least a saving of 25 per cent. will be made in operating costs on the 440-mile division now to be electrified in the Western States, and part of this saving is confirmed by the showing already on the Butte, Anaconda and Pacific Ry., where power cost has been found to be but one-third of the previous coal cost. The decision to electrify the suburban lines of the Pennsylvania Ry. about Philadelphia was made to relieve the existing congestion by increasing the capacity of terminal 15 to 20 per cent., or sufficient to relieve the situation for the next five or six years and at less expense than any other method.

PROGRESS OF NEW GANGES BRIDGE.

The largest steel bridge ever made for shipment from England is rapidly nearing completion. Six spans are being constructed by an engineering firm at West Bromwich, and the remaining nine at Darlington. This bridge will carry the Indian State Railway over the Ganges at a point about 120 miles above Calcutta, and it will be just a mile in length.

Steel to the quantity of 30,000 tons (all rolled in England) is being employed in its construction, 20,000 tons for the superstructure, and 10,000 tons for the piers. Each of the sections has a span of 345 feet, a height of 49 feet, and a weight of 1,400 tons. To hold the sections in position steel caissons were sunk 150 feet below the bed of the river. The shipment of these 15 spans to India will entail an outlay of some $300,000, and the total cost of the bridge will be $6,250,000. The erection of the bridge is under the direction of the Public Works Department of India. The first span shipped from West Bromwich arrived at Calcutta on May 26 last, and it was erected in three weeks' time before the rainy season, with its river floods, sets in. It is hoped that this bridge will be open to traffic this year.

A gigantic floating dock, said to be the largest in the world, is being constructed at Odessa. It will be capable of carrying a vessel of 40,000 tons, and will cost $2,000,000.

SOME PRACTICAL POINTS ON MODERN ROAD-WORK.*

By W. H. Maxwell, A.M.I.C.E.

In the planning of new through routes, directness of line is usually an important feature to be considered, from an engineering and utilitarian point of view, but leads to monotony in the use of the road, and from an æsthetic standpoint compares unfavorably with winding roads.

As a general rule, it will be more advantageous to carry a new through route past the outskirts of a town, and connect up with some good branch road to the urban area, rather than attempt to carry the new main thoroughfare through the heart of a populated centre, as the difficulties and costs of widening existing narrow roads through built-up areas are necessarily excessive, owing to the property and business interests disturbed. Very wide roads are not favored by shopkeepers, as they are not conducive to good trade—the bulk of pedestrian traffic usually keeping to one side of such a road.

Curves on a new main road should, of course, be as easy as circumstances will permit, but a radius of 100 ft. should be the minimum where fast through traffic is to be accommodated. On this curve, a person travelling along the centre line of a clear 40-ft. roadway could see approaching traffic within the limits of the road-width about 120 ft. ahead. Under similar conditions, with a 150-ft. curve, a distance of about 150 ft. ahead could be seen. On rural roads, traffic invariably uses the centre of the road by preference, and modern high speeds render an ample, unobstructed view essential.

The easing of curves invariably quickens the speed and reduces that degree of commendable caution in drivers which formerly existed. On a sharp curve the motorist is bound to materially reduce his speed or perish.

Curves should in all cases be freed from side sight-blocking obstructions, and for increased safety to fast traffic, the road surface on the outside curve should be given a suitable degree of super-elevation.

On a part of the Holyhead road on the north of the city of Coventry, Telford adopted a ruling or maximum longitudinal gradient of 1 in 35. Such a moderate gradient will present no impediment to fast driving, either up-hill or down, and in one on which tar-macadam and all modern methods of surfacing may be used with safety, but in hilly country will be difficult to maintain, except by much contouring and consequent increased length of route, or by heavy cutting and bridge work.

Dead-level roads are to be avoided. If the longitudinal inclination is less than about 1 in 100, the surface water will be difficult to drain away and more cross camber must be provided. With a longitudinal gradient of 1 in 50, or sharper, the camber may be flattened considerably, as the needful surface drainage is obtained longitudinally. This flattening of cross-section should not, however, be carried too far, otherwise watercourses will speedily form down the centre of the roadway on steep gradients.

Suitable cambers for different surfaces under ordinary conditions are: granite macadam, 1 in 25; tar-macadam, 1 in 30 or 1 in 40 on incline; creosoted deal paving, 1 in 36; hard wood and granite, 1 in 45; and asphalt paving,

*A paper read at the 41st Annual General Meeting and Conference of the Institution of Municipal and County Engineers, held at Cheltenham, June 24th-27th, 1914.

1 in 50. The longitudinal fall of water channels should not be less than 1 in 100 for a granite channel, and 1 in 150 for asphalt.

Improvement of Existing Roads.—Inadequate Foundations.—The majority of the old highways of this country have come into existence in a more or less haphazard fashion, and in the past the provision made for their maintenance has been uncertain and inadequate. The entire absence of foundations suitable for carrying modern weights brought upon the surface is revealed by the upward movement of the sides of the roadway into the channels—a weakness to be observed generally throughout the country.

Vast sums are now being spent in laying down expensive so-called waterproof surface crusts of various kinds, in order to give an immediate show for the money expended, but the writer is of opinion that, wherever there is evidence of underlying weakness, money may be more advantageously applied by first putting in proper foundations and drainage. However excellent, well laid or expensive may be the surfacing material, it can never prove really satisfactory on a weak foundation. There will be gradual but constant movement of the road crust, local sinkages of the central portion and rising of the sides, and generally the annual expense of wear and tear of the surface will be greatly enhanced in cases where no solid and unyielding foundation exists.

The initial cost of such work is, of course, necessarily heavy, but where suitable foundations do not already exist, it is submitted that it is the only sound course to pursue, both from an engineering and financial point of view, and is essentially a capital work for which State "grants" on liberal terms should be made.

Thin Crusts.—The wisdom of recent practice in laying thin surface wearing crusts or armourings of asphalt and bituminous preparations over existing macadam surfaces is open to great question, except where an absolutely rigid and dry foundation can be relied upon. In the absence of this, most ordinary road surfaces are subjected to consider movement under modern speeds and weights, and in these circumstances, thin wearing crusts are liable to fracture and disintegrate. Great caution in the selection of a suitable site is necessary, except where laid on a good concrete foundation, which, unfortunately in most cases, would make the cost of the work prohibitive.

Bituminous Methods.—In what are now known under the general name of "bituminous methods," the presence of coal-tar and pitch is the distinguishing feature, and the main object of all such processes is to exclude water from the crust of the road. These methods consist mainly in the revival and extended use of "tar-macadam," "pitch-grouting," "tar binders," and other like forms, and in suitable situations and conditions give very serviceable surfaces at a not unreasonable cost, but much discrimination is needed in their application.

The arch enemy of the tar-macadam road is the traction engine, and this cumbersome vexatious contrivance is, unfortunately, rather in evidence in the writer's district, especially during the spring and early summer months. These engines, with destructive diagonal steel strips on the wheels, weigh over 16 tons on the road, and haul three lumbering wagons weighing about 12 tons each when loaded. Under this burden the very best of tar-macadam work suffers substantial damage. Even after having been laid many months the material, owing to its plastic nature, will slightly soften on a hot day, sufficient to permit of its being crushed out of shape and torn up under traffic of the class named.

A well-made granite macadam road surface withstands this class of traffic very much better than tar-macadam, or any of the bituminous processes.

To the enthusiast for tar-macadam, in addition to the above caution, the writer suggests that consideration of the following points will help to keep him out of trouble:

1. The quality of tar available for such work is very variable and unreliable, and requires constant watching to avoid failure.

2. Good fine weather is an important factor for successful work. If the weather is too cold there is great risk of too much tar being used, thus causing the tar-macadam to become very soft and easily damaged during the warm weather.

3. Tar-macadam is hopeless on a weak, yielding foundation.

4. It cannot be satisfactorily repaired during wet, cold weather. This is important in streets where much opening of trenches for gas, water, electric and other services is likely to be required.

5. Where there is much traffic a continual watch must be kept on the work for some time after it has been completed, which considerably adds to its cost.

6. Tar-macadam is liable to "creep" during hot weather towards the sides of the roads, especially in country districts, where the lateral support of a curb and footpath is not usually available, and some provision to meet this tendency should be made.

7. The cost of tar-macadam is, as a rule, much beyond that of a granite macadam tar-painted surface, and its serviceable life cannot always be so accurately predicted.

The foregoing matters are mentioned, not with any desire to discourage the use of this type of road surface, but simply with the object of drawing attention to a few points which require consideration to ensure successful work.

With regard to the "pitch-grouting" of road macadam, the writer is of opinion that this process has not yet been proved to be so satisfactory under like conditions of traffic, as good class tar-macadam well laid. The work is expensive, its serviceable life is not great, the surface soon becomes deeply corrugated and carries much slippery mud during wet weather.

Coatings of tar-macadam of a total thickness of 4½ inches are sometimes laid with a layer of coarse material at the bottom, and finished with a fine grade for the surface. A coating of the thickness named is best laid in two layers, but there is no advantage in separating the fine and coarse grades; the same mixed grade material should be used for both coats.

Rolling of tar-macadam is best done with a "light" steam roller (6 or 7 ton weight), and there is nothing to be gained by an excessive amount of rolling.

Tar-macadam may be laid on gradients as steep as about 1 in 25, and even sharper if the surface is kept clean. The degree of slipperiness experienced depends greatly on the weather and the skill of the driver.

It is a great mistake to lay tar-macadam, or any other bituminous road surface, over an existing macadam roadway as a foundation, without first lightly scarifying the surface all over and consolidating by rolling to a *uniform* condition before the bituminous material is laid. Where this precaution has been neglected the old inequalities and "pot-holes" in the road crust will soon re-appear on the surface of the newly laid coat, as the greater depth of bituminous material over the "pot-hole" consolidates more than the thinner coating around.

Tar and Tar-painting.—Experience of recent years has led to the settling down of much preliminary clamor about "dust-layers" to the very general use of coal-tar. This new demand has brought about a very substantial increase in the price of tar, and, with the continued extension of bituminous methods of road construction, the demand appears likely to exceed the supply, and so set a limit on this form of road improvement unless competitive processes are adopted.

The specially prepared tar for road surface painting used by the writer weighs 12.95 lbs. per gallon, or 173 gallons to the ton. This is heavier than the weights recommended in the Road Board Specifications, but the tar is found to make very satisfactory work.

Tar-painting is not usually very successful on roads with damp clayey sub-soils, in shady situations, or under trees. A dry sandy or chalky sub-soil is the most favorable for the work, and in these areas operations can be started earlier in the season.

The heavy, complicated, costly tarring machines of early tar-painting days have almost disappeared in favor of much simpler plant, and hand work—the latter giving the best results in this class of work.

For town work granite chippings ⅜ in. to ⅝ in. gauge make the best class of "grit" for covering the tar. Sand, though usually much cheaper, produces an increased quantity of mud and causes the tar-painting to tear up more readily under heavy traffic.

In the author's experience the amount of money spent on road tarring is about equivalent to the saving obtained in ordinary maintenance and wear and tear on the roadways, so that no increase on the total cost of highways arises, whilst a greatly improved surface is obtained during the summer and autumn months. Tar-painting gives most economical results on secondary roads, *culs de sac*, and other thoroughfares with light traffic, as, in such cases, the tarred surface remains in good condition for several years without repair, and very little attention of any kind is needed.

Repairs.—Systematic inspection of the roadways, and regular and prompt patching of depressions and "potholes" is very desirable, especially on motor omnibus routes. For this work the writer uses a light roller of the convertible tractor type, which is well adapted for the purpose.

Under modern traffic conditions the highways require to be regularly patrolled and repaired, much in the same way as a railway track.

Old screened road metal, of small gauge, is well suited for patching, as it consolidates quickly.

Ordinary macadam surfaces should not be patched with tar-macadam as, after a little wear, a most unsightly and intolerably bumpy surface results, owing to want of uniformity in wear of the variegated surface.

When recoating a roadway, the thoroughfare should be closed wherever possible, and the whole width of road coated and rolled in one operation. Work of this class done in half-widths is seldom satisfactory, as rapid wear invariably occurs at the central joint. In cases where this system cannot be avoided it is best, if possible, to first treat about two-thirds of the width, so as to keep the joint out of the centre of the road; but many roadways are too narrow to permit of this being done.

Weather conditions are among the most powerful factors influencing the wear and tear and deterioration of roads. Prolonged rain, and heavy traffic following the break-up of frost immediately succeeding a wet period are particularly destructive.

In town streets where a macadam surface has to be renewed about every two years, and patched frequently, a wood-paved surface will probably be more advantageous. A maintenance cost of 20c. per sq. yd. per annum is about the economical limit for macadam, and, from the point of view of traffic weight, a load of some 250 tons per yd. of width per day is about the maximum for an ordinary macadam surface.

Steam Rollers.—In the opinion of the writer the usual so-called "10-ton" steam roller is much too heavy for the majority of surface recoating work. These rollers, when loaded ready for the road, often weigh nearer 13 to 14 tons than 10, and frequently cause much damage to the new metalling by crushing and weakening it during the process of consolidation. In some cases metal is put on the hard crust of the old road, without preliminary scarifying, and rolled down with a heavy steam roller, with the result that the stone, being severely crushed between hard surfaces, is permanently damaged at the outset, and the serviceable life of the new coat thus sadly reduced.

For much of his work the writer uses what is described by the makers as a 7-ton roller, of the convertible roller-tractor type already referred to. This machine is found to be of the greatest service for all classes of work as well as for haulage. The small tractor-roller can be moved quickly from job to job, and can be converted to a tractor in about a couple of hours. This roller, with awning, water, etc., fitted up ready for work on the roads actually weighs 9.42 tons.

Mechanical Haulage for Municipal Work.—Whatever may be the views held as to the desirability of public highway authorities employing steam, petrol, or other motor vehicles for haulage purposes, the writer has been practically compelled to do so, on account of the difficulty experienced, during the busy spring and summer seasons, in procuring sufficient suitable horses. It is usually impracticable to keep, during the relatively quieter winter months, a full stud of horses sufficient to cope with all work during the busier period of the year, and such work as street-watering and road tar-painting greatly accentuates the variation between winter and summer haulage demands. The hiring of the surplus summer requirements affords one way out where the horses can be got, but horse contractors are fast changing to mechanical haulage, thus greatly limiting the supply.

Slippery Road Surfaces.—In these days of improved road surfaces, tar-painting, tar-macadam and such like, complaints are perhaps a little more frequent in respect of slipperiness, and requests for "gritting" or sanding are often made. The best plan to overcome slipperiness is to keep the surface as *clean* as possible, by removing (and washing off if necessary) stiff pasty mud which is liable to accumulate during the foggy, damp weather of the winter months. Gritting and sanding greatly increases the production of this stiff slippery mud, as the material is speedily crushed by the traffic. The application of grit, therefore, should be done as sparingly as possible, and cleansing of the surface should take its place.

Road Signs.—Generally speaking, there is room for improvement in road direction signs. Frequently they are so placed that an approaching traveller cannot read the sign without stopping, and even sometimes dismounting. The direction arm should be at the most favorable angle, the letters not less than 3 in. in depth, and the mileage stated in bold block figures to the nearest quarter. Strangers motoring long distances often find it impossible to quickly gather the name of the place they are passing through, and it would be a great convenience to have the name of the village or town boldly erected on the through roads near the commencement of the village buildings.

Street corner "mirrors" are costly to erect and maintain, and the moving reflected image is liable to mislead a motorist unaccustomed to them.

It is a mistake to multiply danger and caution signs unnecessarily. They should be confined to the most awkward spots, and be erected by a public authority. No private signs should appear on a public highway. If too numerous, the familiarity of their appearance leads to a general neglect of the warning intended to be conveyed.

Statistics of Traffic.—The expression of traffic records in tons per yard width of roadway does not, in many cases, give a true representation of the amount of wear and tear over a roadway. On roads through rural districts with a comparatively small amount of traffic, a very large percentage of vehicles keep to the centre of the road—in fact, the less the volume of traffic the higher will be the proportion using the centre of the roadway. Thus the sides suffer but little wear, whilst the centres soon become worn out. The average traffic record per yard width does not therefore correctly show the conditions which obtain and a minimum and maximum record is necessary to convey the true facts.

Much the same thing often occurs on very wide roads, as a portion of the width only is used by a high percentage of the traffic.

On busy town roads of medium width the traffic is very fairly distributed, and it is mainly to this class of road that the average tonnage per yard has any reliable significance.

On some roads, owing to the nature of local industries, the *night* traffic is quite an important item, and should not be omitted if a true record of actual conditions is to be obtained.

The collection of information and statistics, in reference to roads, traffic, materials, and other like matters, is a useful occupation from many points of view so far as it goes, but the road engineer should be cautious as to the conclusions he may safely draw from the collected data placed before him. So much depends on the actual conditions in any given case, and it does not by any means follow that because a road material has proved satisfactory or otherwise in one place it will necessarily do so in another. A new set of conditions will produce its own set of results, and the engineer must use his judgment in each case according to his local knowledge and experience.

Experiments and Tests.—Laboratory and other indoor tests of road materials serve a useful purpose in arriving at the physical and chemical properties of the materials, and assist the engineer when the information so derived is seasoned and matured by practical experience on the road. Weather and traffic are of paramount importance in all road-making matters, and there is no test to be relied upon other than that of actual and adequate trial on the road under ordinary conditions of traffic, rain, frost, and numerous other distributing influences to which any road material must necessarily be subjected.

Administration of Highway Maintenance.—Good administration, particularly in reference to the disposition of labor, materials, and plant, is one of the leading factors in highway maintenance essential to efficient and economical work. In urban areas suitably placed central depôts, with railway sidings into which materials can be delivered direct, are a great convenience, and involve the minimum haulage of materials. In these days of frequent labor disturbances, as in the case of the railway, dock, and colliery strikes, the necessity of getting all materials on the spot well in advance of requirements has been greatly emphasized of late, in order that annoying delays may be avoided. Delay in any form means increased cost of the work in hand, frequently entails loss of good weather suitable for the work, and always gives regrettable inconvenience to the general public.

Wherever much work is in progress constant inspection and supervision is a good investment, and to this end the inspecting staff should be provided with appropriate means of quick and convenient locomotion.

Local materials should be employed wherever of suitable quality, but some counties are particularly deficient in good quality stone suitable for first-class roads carrying considerable traffic.

Over-"centralization" of the practical work of road maintenance is not desirable. It is apt to lead to so-called "red-tape" methods, costly delays, and lack of individual attention.

Road maintenance should be carried out through the responsible highway authorities by the direct employment of labor, thus ensuring a local interest in the work, close supervision, and prompt attention, which is almost impracticable under any too distant and highly centralized system of administration.

Stereotyped standardized methods in many matters connected with road-making and maintenance are to be deprecated. Such methods destroy the useful application of personal experience and judgment to individual cases, and so lead to mere routine and lack of interest. It is unlikely that there can ever be any universal solution of the road-problem, inasmuch as local conditions and requirements, character and extent of the traffic, local facilities of obtaining suitable materials, considerations of cost and the like, must ever be deciding factors in arriving at the most suitable and satisfactory mode of treatment in each particular case.

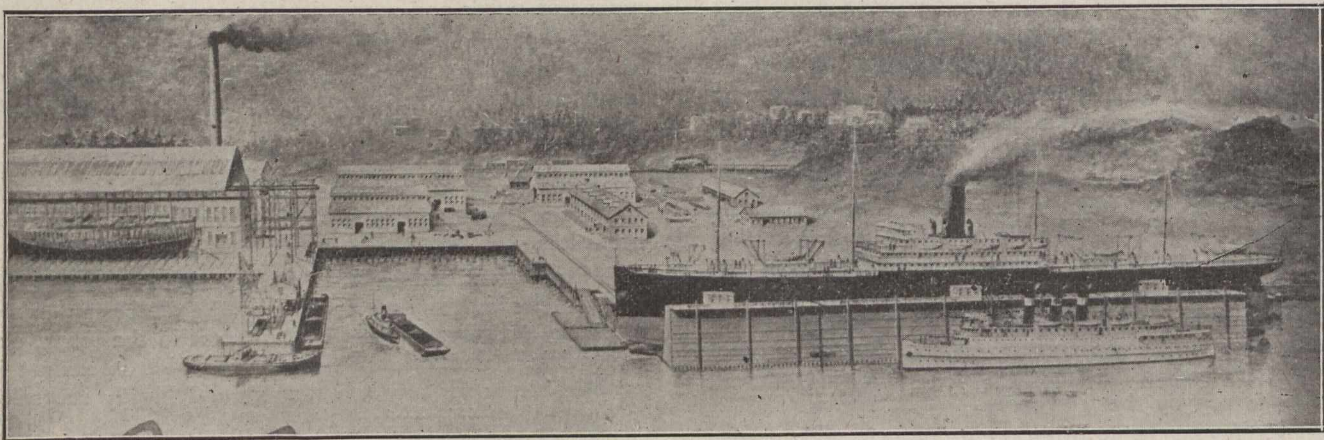
INTERNATIONAL ENGINEERING CONGRESS, SEPTEMBER 20th-25th, 1915.

The International Engineering Congress at San Francisco is to be conducted under the auspices of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers and the Society of Naval Architects and Marine Engineers, assisted by a committee of 18 California engineers. The vast scope of the congress is indicated by the fact that it will be divided into 11 groups of sub-congresses, the reports of which it is calculated will fill 11 large volumes. Chief among these branches will be that dealing exhaustively with the problem worked out in the construction of the Panama Canal, and the influence of the canal on world commerce, commercial trade routes and general transportation problems. Col. Geo. W. Goethals will have charge of the presentation of all canal topics. Aside from general engineering topics, the section devoted to the canal will be treated as follows:—

1. Col. Goethals' general report. 2. Dry excavation of the Panama Canal by Col. Goethals. 3. Dredging the canal. 4. Terminal works, dry docks and wharves of the canal. 5. Meteorology and hydrology of the zone. 8. Designs of locks, dams and regulating works. 9. Methods of construction of same on the Atlantic side. 10. Same on the Pacific side. 11. Designs of lock walls and valves. 12. Spillways. 13. Gates of the canal. 14. Electrical and mechanical installation. 15. Emergency dams above locks. 16. Municipal engineering and domestic water supply in the zone. 17. Reconstruction of the Panama railroad. 18. Aids to navigation of the canal. 19. Geology of the canal zone. 20. The working force of the canal. 21. Sanitation in the zone. 22. Purchase of supplies for the canal. These papers and addresses will constitute practically the official technical record of the work.

PRINCE RUPERT, B.C., SHIP-BUILDING PLANT.

Work was started in June, 1913, on the construction of a ship-building plant at Prince Rupert, B.C. The contracting firm of Beer's, Limited, has under construction, in addition to the ship-building plant, the power-house, machine, boiler and blacksmith shops and foundry building, and hope to have the entire contract completed by August of this year. The accompanying illustration gives a general view of the arrangement of the plant.



General View of the G.T.P. Ship-building Plant at Prince Rupert, B.C.

The power-house is constructed of steel and concrete on a heavy concrete foundation, with a slate roof. It measures 104 x 148 ft. and is about 65 ft. in height. The machine shop is also a steel frame building, 75 x 150 ft., resting on a concrete foundation. The boiler, blacksmith shop and foundry are similar to the machine shop in size and general construction. The shipbuilding plant is constructed with a steel frame, and is equipped with a large travelling crane. Its size is 160 x 300 ft.

The above-mentioned firm, of which Mr. N. B. Beer is manager, is executing the contract for the Grand Trunk Pacific Railway.

TIMBER FLUME CONSTRUCTION.

Timber flume construction and fluming are discussed in a bulletin just issued by the United States Department of Agriculture. The publication considers the subject from the practical standpoint of the logger who has to get his material out by these means.

The V-shaped wooden flume is held to be superior to the box or square-sided form, because it requires less water and, on the average, less repairs than the other type, is better adapted to act as a slide on steep grades, and offers fewer chances for jams. Concerning a third type, the "sectional" metal flume, semicircular in form, the prediction is made that it will eventually come into wide use. Such a flume is strong and light, and can be quickly taken apart and transported from one place to another to be set up again.

When building flumes a good plan is to erect a small sawmill at or near the upper end of the flume location to saw out the material needed for construction. Such material can be floated down the flume as fast as the latter is built and used for its further extension.

For handling railroad cross-ties, cants, poles, cordwood and the like, a flume with the sides of the V, 30 in. in height is large enough. For handling logs, piling, long timber, or brailed sawed lumber, a height of from 40 to 60 in. is recommended. The best angle for the V is put at 90°.

Flume lines should be surveyed with enough care to ensure evenness of grade. Grades should be kept below 15% wherever possible, and the best results are obtained with grades between 2 and 10%. A careful preliminary survey, followed by a location survey, using a transit and level, will make it possible to obtain a reliable profile map which will serve to show the prospective operator what the grading should be at different points along his line.

Abrupt curvatures in a flume should be avoided, for they are likely to cause jams. Curves should rarely be permitted to exceed 20°. The longer the material to be handled in the flume, the less abrupt should the curvatures be. It may be necessary to blast out rocks and boulders, or projecting points of bluffs, or to trestle, or even tunnel, to eliminate abrupt curves or maintain an even grade.

Some flumes are built with only the lining or inside of the box of sawed lumber, the brackets or frames which support the sides of the V being made from round pole wood flattened on one side, and the sills, stringers, braces and trestling of small round timber or poles. Sawed material is recommended for flume construction, however, wherever it can be obtained at reasonable cost.

The "boxes" or sections of a flume vary in length from 6 to 20 ft. Sometimes the boxes are made of only one thickness of boards, but more often of two thicknesses with the joints broken by varying the width of the boards. Sometimes, also, a single thickness of boards is used, with battens spiked over the joints on the outside in the section between the brackets. In still another form the battens are continuous. On curves the boxes should be shorter than on straightaways, and the bents, arms, and braces correspondingly closer spaced. In general, on curves of from 6 to 10°, the boxes should be jointed at least once in every 12 ft.; on curves exceeding 10° and less than 15°, every 8 ft.; and on curves of more than 15°, at least every 6 ft. Very abrupt curves also require increased bracing, in addition to shorter spacing of the arms and brackets. Flumes should also be strongly reinforced at points where extensive shipping is to be done or much material loaded into the flume over the sides.

If the storage facilities at the lower end of a flume are not sufficient for all the material that can be handled during the period in the spring when melting snow and early rains furnish an unusual volume of water, the construction of small holding reservoirs or "catch basins" at different points along the line is recommended. These may be formed by damming up some small stream; or natural ponds, favorably located, may be used for the purpose. In this way such material as it is not necessary to handle clear through at once can be diverted temporarily. A small artificial pond or reservoir at the upper end of a flume in which to "land" or "bank" the material to be shipped is also advisable, especially when handling logs, cross-ties, or heavy manufactured material of any kind.

Editorial

THE CONSERVATION OF WATER-POWER.

The question of conservation has to do with the policy, not only of the governments, federal and provincial, but also of the people at large, with regard to those resources, useful to man, which are supplied by nature in a form easily adaptable to immediate utilization, and particularly with regard to those natural resources, not uniformly distributed, which are limited in extent or in quantity. Among such natural resources are the minerals in the earth, the forests growing upon the earth, and the waters flowing over the earth. Whether applied to any or all of these, a policy of conservation should, manifestly, be directed neither to a locking up or withdrawal from use, on the one hand, nor to an indiscriminate or wasteful utilization, upon the other hand. Economy, in its best sense, should prevail, but an economy which has regard for both the present and the coming generations. These natural resources are placed by nature for the use of man, the man of to-day and the man of the future. Where present and future interests conflict, those of the present are paramount. It is not justifiable unduly to place burdens and restrictions upon the present generation out of regard for those to come after us, nor unduly, by present extravagance, to impose unnecessary burdens upon the future. More than that, neither desires for the present nor for the future should be made the justification or pretext for measures in conflict with the fundamental laws of personal and property rights which are, under our constitutional government, the safeguards of our free institutions.

Conservation, then, should denote the policy of the economical utilization of these natural resources, and of the utmost protection, within the law, of such economy, consistent with the needs of present and of future generations.

The two great, natural sources of energy available are coal deposits and water-powers. The known supply of bituminous coal, while sufficient for a few centuries to come, assuming that the present rate of consumption continues, is in fact limited, as its cost to the consumer gradually increases as the supply diminishes. While the cost of developing water power is considerable, the development of electrical transmission of energy has made water-power development feasible as a business proposition, as against the cost of steam power, to the extent that the amount of water power which is yet undeveloped, but which could be economically developed at the present time, amounts to millions of horse-power. As fuel grows scarcer and as the science of electrical transmission progresses, further water-powers, now merely potential, will be available for the market. It is computed that under average conditions about fifteen tons of coal are required to generate one horse-power a year. The use, therefore, of the water power now unused but economically available, would reduce the annual coal consumption by a remarkable percentage. Thus by the extended utilization of one source of energy, water power, two objects of conservation would be accomplished,—the utilization, without loss, of one natural resource, and the saving from loss of another.

Herein lies the peculiar adaptability of the policy of conservation to the use of water-powers. The three natural resources referred to represent fairly three distinct classes, or kinds, differing in respect of their quality of persistence. The mineral supply, in this case the coal deposits, is limited by its fixed and approximately computable quantity. In the case of timber, while the present supply is limited it, nevertheless, is naturally renewed. Indeed, the non-use of the quantity ripe for use is itself a waste; but, comparatively speaking, timber is a recurring, even if not a constant and undiminishing, natural resource. But water power is constant. The supply is not diminished by use, for in itself it consists in the development and use of two constant factors, viz., supply of water, and a head and fall, through which the weight of the water creates energy developable for practical use.

Every ton of coal used is forever lost as a source of energy. The use of every fifteen tons of coal means that the natural sources of energy have been forever diminished by an amount equivalent to the use of one horse-power for an entire year. To the extent that any quantity of coal is used up for energy before the time when its use is necessary, in place of an equal amount of energy from water power, such use constitutes a waste of energy. On the other hand, the non-use of any quantity of water power, through lack of development and of use of water-powers, the development of which is commercially feasible, means a waste of energy which can never be recouped. So far as such waste of water-power energy is accompanied by the further waste of coal energy, which the water-power energy might otherwise replace, there results a double and continuous loss or waste of the energy available from natural resources and, therefore, of these two natural resources themselves. The primary object of the conservation of natural resources, which is to preserve them from waste, is manifestly doubly opposed by any policy which defeats or postpones the development and utilization of water-power energy.

Because it is inexhaustible and because its use replaces that of another and exhaustible natural source of energy, water power is the most potent of all natural resources, as a subject and agency of conservation. In the case of a limited, exhaustible, and rapidly diminishing supply of a natural resource, such as that of coal deposits, the forces of conservation should be directed to the prevention of use, as far as consistently possible. But the correct view of conservation inevitably leads to the demand that, in the case of water-powers, there shall be encouraged and promoted the greatest and most immediate use possible.

SANITARY SEWER FILTRATION.

Too little is known of the infiltration of subsoil water into sewers and of the escape of sewage en route to the outlet. Undoubtedly there are a good many conflicting conclusions pertaining to the subject, but there are as well numerous instances to indicate that the infiltration of ground water into sewers is costing municipalities large sums in pumping and treating this water at purification and disposal plants. There are systems where newly laid sewerage systems discharge ground water in quantities equal to a considerable percentage of their capacity, before house connections are made.

Reasons that have been advanced for the general delay in acquiring more detailed knowledge and data on ground-water flows centre largely around the historic fact that the combined sewer preceded the separate sewerage system. In the construction of the former, tight joints were not an important item, otherwise, ground and surface water would have had difficulty in finding its way into the system, such a condition rendering it less efficient. Entering upon the design and construction of separate systems, engineers and contractors somewhat included the importance of perfect jointing and the resulting leakage feature has become prominent. An instance is on record at New Orleans of the leakage of ground water into sewers attaining an extent of 1,250,000 gallons per square mile. This infiltration, perhaps not objectionable in storm sewers or drains, is unquestionably so in other sewers and the importance of careful design and workmanship to reduce leakage to the least possible amount is perhaps no greater in any other branch of municipal engineering.

Obviously, the amount of filtration is a function of the head of ground water on the sewer, of the linear measure of joints in the case of pipe sewers, and of the superficial area of the interior of brick or concrete sewers. The volume is usually stated as so much per acre, per square mile, per mile of sewer, per capita or percentage of dry weather flow, but there is little information by which an estimate may be made based on the fundamental considerations mentioned above. There should, at least, be some regulations to apply to work done by contract. This would naturally involve a determination of how much water the sewer might be allowed to carry without materially injuring its usefulness. This determination would depend upon the number and circumference of the joints.

At a meeting of the American Association for the Advancement of Science, Mr. J. N. Ambler incorporated in a paper which he read on this subject a part of his own specifications covering sewer construction. While effecting some very careful work and acting as a powerful deterrent to poor construction, the specification was not regarded by the contractors as unduly severe. Mr. Ambler states in his paper that he once laid a mile of large sewer through exceedingly swampy land passing several streams with the result that not more than a stream ¼-inch deep was flowing from the lower end of the sewer upon completion.

The following is an outstanding part of his specification:—

It is the intent of these specifications that no more leakage of ground water into the sewer be allowed than is admissible with a first-class piece of work, in which care has been exercised to get as near as possible to a watertight result.

To determine the admissible amount of leakage, the length of a joint will be considered as the outside circumference of the spigot end of a pipe.

Leakage not in excess of two gallons per day of twenty-four hours for each foot of circumference of every joint will be considered admissible, the amount of flow to be determined by the engineer's gauging in each section, by means of a notch board.

The contractor agrees that for each 10,000 gallons per day of twenty-four hours by which the total flow of the sewer exceeds what the total flow should be, when figured on the basis already given, a deduction of $100 from the contract price will be made.

This will not apply further than to a total flow resulting from three gallons per day of twenty-four hours, from each foot of joint length, beyond which figure the sewer will be regarded as not in compliance with this contract.

PROTECTION OF UNDERGROUND SURVEY POINTS.

In mining work it has been found that protection against rot of survey points is most important. The work of the mine surveyor largely hinges upon their proper location and upon their not having been disturbed, but in order that the survey stations may possess a longer life of service some method must be adopted to prevent decay or molestation.

If survey plugs are driven flush with the rock they are less subject to rot than when allowed to project. The use of horse-shoe nails has given place in many instances to brass spads. When survey points have to be set in timber, especially in new timber near a face, it has been found well worth while to carry the point down from the spad in the cap to a point on the sill or on a hub in the bottom. The cap and consequently the spad is more subject to movement than the point in the bottom. Furthermore, with the point set in the floor, any movement can be readily detected.

ULTRA-VIOLET RAYS STERILIZATION OF WATER IN AMERICA.*

A FEW weeks ago the contract was awarded by the City of Niagara Falls, N.Y., to the R.U.V. Co., Inc., of New York, for the installation of 35 "Pistol" lamps for the sterilization of water by the ultra-violet rays of the mercury vapor quartz lamp. This is the first municipal installation of the system in America. The capacity of the filter plant in which they are to be used is 16,000,000 gallons per day.

The lamps will operate in banks of seven, and will be spaced 30 inches apart. Each bank will rest in a concrete channel 2 ft. wide, 3 ft. deep and 26 ft. long. Water will pass through the channel at a rate that will allow an exposure of 30 seconds to the ultra-violet rays.

The cost of the installation will be $19,800, which will be augmented by the necessity of rectifying the electric current from alternating to direct. This equipment will cost approximately $2,200. The guaranteed cost per million gallons for maintenance comprises current at 7 cents, and lamp renewals, based on a 2,900-hour life, 60 cents.

The Niagara Falls plant has been using about one grain of coagulant per gallon and five pounds of bleach per million gallons, thus costing about $1.50 per million gallons for chemicals. With the introduction of the new process it is expected that the plant will be made more economical as well as more efficient.

[* An article on water sterilization by ultra-violet rays appeared in *The Canadian Engineer* for June 25th, 1914.—Editor.]

The Dominion Creosoting Company, Limited, of Vancouver, B.C., has received an order for 160,000 creosoted railway sleepers from the Bengal and Northwestern Railway Company of India. The specifications call for best quality, well seasoned Douglas fir to be treated with 12 pounds of creosote per cubic foot under specified temperature and pressure conditions.

PRESENT TENDENCIES IN ENGINEERING EDUCATION

AS DISCLOSED BY THE PAPERS, DISCUSSIONS AND CONVERSATIONS AT THE ANNUAL MEETING OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, AT PRINCETON, N.J., JUNE 23-26, 1914.

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THAT the engineering profession has not yet attained a status in keeping with its importance is amply evident from the spoken and written words of its thoughtful members. Duties, often of a judicial character, are performed under conditions inimical to the calm and thorough consideration of all the factors of the problem in hand. The independence of the physician or of the lawyer is enjoyed in much less measure by the engineer. His lack of activity in public affairs must be admitted. As yet, he lacks social consciousness.

Every thoughtful engineer has a vision of what his profession ought to be. Primarily, membership in it should involve the capacity to meet new and unexpected situations promptly and effectively. The engineer must be able to devise, unaided, his own plan of campaign, must forge his own weapons and wield them skillfully and courageously. He must be, as President Hibben put it, a scientist, not a technician; he must know not only the facts but the causes of the facts. Like the great physician, he should, to a large extent, be the maker of the conditions under which he works. More frequently than he now does, the engineer should be called upon to fill responsible executive positions requiring both technical and business training. He should be a loyal supporter of every movement for the betterment of his own profession and not only should he have convictions on public questions based on conscientious study, but he should take the part that the state requires of every good citizen.

The disparity between the engineer as he is and the engineer as he ought to be can be lessened only by a powerful transforming agency. Various opinions are held as to what this is to be. That imperfect education of engineers is responsible for many, perhaps most, of the ills which the profession now suffers, cannot be doubted when one hears the testimony of those qualified to judge respecting the fitness of the engineering graduate for the work of the world as he leaves the college halls. Professor John B. Whitehead, in reporting the results of the investigations undertaken prior to establishing a Department of Engineering in the Johns Hopkins University, states that "the average engineering graduate is wanting in general education, in powers of expression, in imagination and ability to reason." He cites in this connection the conclusions of Professor C. H. Benjamin, dean of the engineering schools of Purdue University, who examined the history, subsequent to graduation, of 3,500 graduates in engineering, particularly with respect to their fitness for professional work and with a view of ascertaining how educational training could be altered with promise of improvement. Dean Benjamin found that the graduate has little knowledge of commerce, business methods and economics, and must devote himself in some way to acquiring further information and knowledge of affairs for several years to come; that the literary side of his education has been too much neglected; and that the graduate is frequently unable to express himself properly in either writing or speaking. Among the educators, engineers, employers, and others consulted by the Johns Hopkins University, there was general recognition of the imperfections that have been mentioned. Professor Whitehead states that complaints of too great insistence on professional training to the sacrifice of fundamental and cultural studies were particularly widespread.

From the papers, discussions and conversations at the Princeton meeting of the Society for the Promotion of Engineering Education it appears that improvements in engineering education are to come principally in connection with (1) the subjects taught, (2) methods of teaching, (3) the teacher, and (4) administration.

The Subjects Taught.—In framing new engineering courses, or in the improvement of existing ones, the modern educator will see to it that whatever is taught is closely related to the entrance requirements of the college, to the probable character of employment of its graduates and to the personal qualities desirable in an engineer. His master-motive will be the student, not the subject.

With a course of given length, the scholarship and general equipment of the graduates will be largely determined by the conditions of entrance. With these fixed, the institution is automatically classified as a trade school, a professional school, or a compound of the two, and the subjects taught must follow.

Effective meeting of the needs of the community demands that the technical college shall carefully and continuously study the shifting field of employment of engineers and train its students accordingly. Not only must the broad departments of engineering likely to absorb graduates, as civil, mining, mechanical and electrical engineering, be considered, but the probable *range* of employment of the average graduate should receive attention. So frequently do graduates in one department find their life work in another department that the student should, in prudence, be equipped for transfer. There are now arising, thanks to the joining of technology to business, an increasing number of positions demanding of their incumbents both technical and business training. Professor C. F. Scott is authority for the statement that one-half of the members of the three principal engineering societies of the United States are in executive positions. But few are, or will be, engaged at wholly technical pursuits and of these only a minority will be so occupied for long. In all probability, a large number of graduates of engineering colleges will in the future be called upon to assume duties of a mixed technical and executive character. Instruction in technical institutions must anticipate this.

For business and professional reasons alone, and quite apart from higher motives, engineering education should aim to develop in the student character, intellectual capacity, well-ordered knowledge of his own field, knowledge of men, address and popularity. In purely technical pursuits the last three are less important than the first three, but for the majority of positions that engineers are called upon to fill, knowledge of men, address and popularity are of the utmost consequence. Their indispensability in the field of the engineering salesman is obvious.

In so far as specific subjects of the curriculum tend to develop these personal characteristics in students they are useful and that group of subjects giving the best balance in equipment is the most desirable.

There is now general agreement among engineer educators that three classes of subjects should be taught: technical subjects, economic subjects and cultural subjects.

Technical subjects, based upon the physical, chemical and mathematical sciences, give to the student that introduction to professional practice required in order that he may become an engineer. The selection must be made to correspond to the probable range of employment of the average graduate and at the same time to enable the undergraduate, in democratic institutions at least, to earn a living and something more during the holidays. Limitations of time require that only those subjects in which the student most needs assistance shall be taught. Many reading or descriptive courses might, with profit, be left entirely to the student. In presenting those subjects which are given a place in the curriculum, the usual situations and problems should be given priority over the unusual. In the writer's opinion, much time is wasted in giving elaborate courses in higher structures to civil engineering students when only a small percentage of them will, as engineers, have anything to do with such structures. Let the problems that 70 or 80 per cent. of the graduates of an institution will be called upon to solve determine what is taught, rather than those with which 20 or 30 per cent. may occasionally be confronted. Fundamentals, not details, should prevail. Both cannot be taught in college and it is obvious which should give way. The attempt to give manual dexterity in field work, shop work or in routine testing is an anomaly in an institution for the training of professional men. Such is the work of a trade school.

Economic subjects, devised to reveal to the student economic laws and business methods, are being introduced for the sake of the increasing numbers who will find their life work in a combination of engineering and business. Attention should be given to organization, management, finance, business procedure, commercial law and accounting. There are, however, in the presentation of these subjects, the same difficulties as have been noted in connection with technical subjects, particularly the tendency to encumber the student with multitudinous details. The advocates and teachers of scientific management are especially culpable in this respect. If there is any science in management, surely it can be presented in a few simple principles and it is these that the student should hear about.

Cultural subjects are now generally regarded by those who have given study to the matter as not only a desirable but a necessary part of an engineering course. To attain the higher reaches of success, the engineer must be an educated and cultured man. No corporation, public or private, cares to trust large problems and delicate negotiations to an ignorant, unpolished representative with one idea, and that a technical one. Even if the student cannot see far enough ahead to cultivate "the durable satisfactions of life," he should realize that the shortest cut to failure lies through neglect of the things that put him at once in touch with educated men in other walks of life, upon whose favor his professional success will depend.

It is possible, of course, to so select the cultural subjects incorporated in the curriculum as to improve not only the general education of the student but his professional equipment as well. Expression, whether it be in speech or in writing, in his own tongue or in a foreign one, ministers to both these ends. An acquaintance with literature opens, as Alfred Noyes has put it, "twenty gates to knowledge." Modern, and particularly current, history widens his horizon and makes him a citizen of the world. Sociology introduces him to public problems to the solution of which he should contribute his best thought and effort. In professional as well as in private conduct, a grounding in ethics is vital to him.

Already many institutions have given place to cultural subjects in their curricula. The Massachusetts Institute of Technology strives to carry instruction in English, in one form or other, throughout the four years. Third-year students must spend 45 hours in the first term and 75 hours in the second term on elective work in general subjects. These are arranged in four general options: Economics, English, Modern Languages and History. Fourth-year students may also be admitted to these options without examinations. Beginning with the next session, Columbia University will require for entrance to its engineering courses a three-year college course comprising instruction in English, Modern Languages, History, Philosophy and Political Science. In the new engineering courses recently established at the Johns Hopkins University, 24 per cent. of the total time will be devoted to general educational and cultural studies, comprising English, Modern Languages, Political Economy, Logic, Ethics and Psychology.

It is thus evident that a multiplication of the points of contact with life is the ideal of many engineering educators. Mr. W. H. Rayner, of the University of Illinois, has given effective expression to this view. Says Mr. Rayner: "I believe that it is more important for a senior to gain a good comprehension of present-day labor problems than to spend six or eight hours per week in detailing a plate-girder bridge; and, as an academic means to equip an engineering graduate for intelligent citizenship, it would be more profitable for him to consider the fact that between 10,000,000 and 20,000,000 people in our prosperous America are near the poverty line, and design measures of relief for them, than to design a gas engine."

Methods of Teaching.—Instruction may be imparted by formal or by informal means. The first is undertaken in lectures, recitations and laboratory investigations. The second arises through personal example, inspiration and advice in personal matters not covered by the curriculum. Increasing recognition is now given to the necessity for informal intercourse with students. Only in this way can the teacher really come to know the student and thereby reach and inspire him.

In formal instruction, the best teachers now apparently strive to (*a*) create and maintain interest in what is taught, (*b*) indelibly fix the fundamentals in the student's mind and (*c*) provide the student with means of self-help.

(*a*) Without interest, the student will carry little away from the class-room or the laboratory. How to develop it is the first problem of the teacher, and evidences are not lacking of earnest efforts to find the solution. For engineering students, there should be at the outset a consuming desire to become engineers and a willingness to make large personal sacrifices in order to do so. To create this desire. the teacher must present engineering in an attractive, if not a romantic, light.

Maintenance of interest is only possible by encouragement and frequent assurance of progress on the part of the instructor. The basing of new principles upon what is already known to the student is to him one evidence of increasing knowledge. The tacit inventory-making involved in tracing the inter-relation of subjects is another.

Apart from this mental stock-taking there is a value in constant relation of the new to the old. It is a fact, as Professor William James has pointed out, that the absolutely new makes no appeal.

In the teaching of theoretical subjects it is now regarded as highly desirable to introduce physical notions whenever and wherever possible. Professors Franklin, MacNutt and Charles, in their paper on "Practical Mathematics," repeatedly express this as their belief. Thus:

"In the teaching of mathematics every effort should be made to appeal to sense material and to the quantitative notions which permeate everyday life; and mathematical principles and relations should be visualized wherever it is possible."

". . . . the only way to marshall the mind-stuff of a young man for the manufacture of ideas is to introduce the drag net of physical suggestion into every discussion. There is no other way to bring intuitive and sense material into the field of consciousness where it may be organized into a structure of ideas."

Of especial importance in maintaining the interest of engineering students is the correlation of theoretical subjects with practical engineering problems. Professor A. B. McDaniel, of the University of Illinois, has effectively pointed this out in his paper on Coördination in Engineering Instruction." Speaking of the teaching of trigonometry, he says:

"Generally, the speaker has found the student equipped with a vague idea of the trigonometric functions. Beyond the fact that they are certain abstract fractional forms, they mean very little to him. He does not readily see their significance in the solution of problems on paper, and in the field. Especially is he deficient in the ability to visualize these fundamental trigonometric concepts and quickly grasp their applicability. The reason for this is clear. *The subject is taught in an abstract way and not in correlation with the dependent branches of engineering.* Some schools, notably the college of engineering of the University of Minnesota, have endeavored to solve the problem by employing teachers with engineering training for the courses in mathematics. This method has proved to be quite satisfactory and efficient. Unquestionably such teachers vivify the subject, and present it in a concrete manner, having always in mind the future applications of the principles which they are drilling into the minds of the students."

(*b*) The indelible fixing of fundamentals in the student mind requires that the teaching shall largely be confined to fundamentals. Sufficient detail to enable the student to relate the problem to his own experience or to identify it later in practical affairs is salutary. More than this beclouds the central principle. The reduction of the principles taught to the fewest possible adds to clearness. Encyclopedic teaching is no longer in favor. When President Wilson began his teaching career he strove to compress into his lectures the greatest possible amount of information, but he soon discovered that the true ideal of teaching was not the communication of facts but the development of understanding in his students.

Symbolism in mathematics is responsible for the lack of clear understanding of many principles that for convenience are given statement in mathematical formulæ. Thus, Professors Franklin, MacNutt and Charles find that in their experience when a student is asked to state Joule's Law he will say "*aitch equals arr aye square tee*"*!* and that it is difficult to get him to say that "the amount of heat generated in a particular piece of wire during a given time is proportional to the square of the current in the wire and to the time that the current continues to flow." The aid to be derived in fixing principles in the mind of the student by their expression in words rather than in symbols is indicated by Professor Dugald C. Jackson, of the Massachusetts Institute of Technology, in the following:

"I am strongly in favor of emphasizing the instruction in mathematics, but particularly in calculus, on the side of the interpretation of the meaning of equations into simple terms of English, as the terms of English are those in which one ordinarily thinks, and it is necessary to make such interpretation in order that the logical processes of mathematics may be incorporated with our ordinary processes of thought and analysis."

On the principle that no operation is clearly understood until one performs it one's self, the subject should be drawn out of the student rather than put into him. He should solve his own problems, make his own discoveries and answer his own questions, merely receiving the guidance and suggestion needed to keep him on the trail. It is this method that Dr. E. J. Berg follows at Union College, Schenectady. While ideal, it has the disadvantage of requiring the expenditure of much time on the part of the instructor as well as a large teaching staff.

(*c*) Recognizing that the student must rely wholly upon himself when his college days are over, the judicious teacher will seek to provide him with adequate means of self-help. Primarily, the student must know how to study, but, as Professor George L. Sullivan has shown in his paper "Teaching Engineers How to Study," he usually does not. Increased attention must be given to this matter and an effective method of securing it would be to encourage students, by special recognition, to devise improved methods of study of the various subjects of the curriculum. An experiment of this kind is now being tried at Brown University.

So large a part does judgment play in the work of the engineer that a special effort should be made to develop it in college. Opportunities for choice and decision must be created and wherever possible responsibilities must be placed on the student. Let him fix important features of the problem in hand, although he may have to do it over several times as a result of erroneous assumptions. Require him to seek out his own data from the books, tables and typical plans available. Through the blunders, rather than by the fortunate steps he makes, he will understand the value of judgment and the meaning of responsibility.

Success in dealing with practical situations requires that the engineer shall be able to formulate the scientific problem from a layman's statement of conditions. One of the greatest difficulties of the young graduate is in making a book problem out of the information supplied him or to apply the theoretical principles learned in college to the securing of useful results from a mass of data gathered, perhaps, by himself. To remedy this, practice in formulating theoretical problems from practical statements of conditions and requirements should be given in engineering courses.

The Teacher.—Without able and inspiring teachers no institution can influence the student deeply or for long. Above all other qualifications demanded of one who would guide youth is character. No connivance at sharp practice, "tricks of the trade" or the operations of the disaster-inviting "bluffer" can be permitted. Varied ability, too, is essential. The teacher must possess mental calibre, an unusual facility of expression and tact in dealing with man, especially unruly and, at times, erratic students. Extreme cleverness in an instructor is, however, a handicap. The student's difficulties are not his difficulties and the discussion will in all probability be carried over the heads of and beyond those who are supposed to profit by it.

Scholarship should be a prerequisite for teaching. Only one who is an up-to-date, first-hand authority on the subject he teaches can win and maintain the confidence of students. This necessitates a certain amount of research and writing. Through such activities the teacher not only extends his knowledge, but maintains a perennial freshness and interest in what is perhaps no more than a narrow specialty. Danger to the effectiveness of the institution as a teaching organization, however, lurks in the effort to carry on a great deal of research or writing. An eminent professor, upon outlining the various researches that he proposed to carry on during the approaching session of college, was asked what he would do with his students. "Neglect them," he replied. Little objection could be raised to investigations respecting the effectiveness of various methods of teaching and much of this legitimate form of research is now being undertaken by engineering instructors. An evil also exists in the practice, happily not widespread, of institutions urging young and immature instructors to write text-books with one eye on the advertising value to be derived therefrom.

No one should attempt to teach engineering subjects without enough experience in engineering to convince his students that he possesses more than book-knowledge of that which he teaches. As an adviser, he must have a knowledge of various fields. sufficient at least to give perspective. Much has been said concerning the engagement of practicing engineers as instructors on "part time." Engineering experience, as against a communicable knowledge of theoretical principles, as a qualification for effective teaching in a technical college, is losing its hold as a fetish. Directing a squad of draftsmen or keeping a contingent of contractors out of each other's way is not precisely the training that is most useful in enabling a man to impart a knowledge of the great fundamentals of engineering science. Teaching is a vocation requiring special fitness and special training quite as much as any other calling. An engineer of vast experience may be quite useless as an instructor. There is too great a disposition on the part of those who are called in from the field to teach to present the subject in a bewildering maze of detail. Their traffic with fundamental principles occurred so long ago that they have half forgotten that such exist. What they give to their students, therefore, are details, short-cuts, approximations and serviceable turns in the practical execution of work in office and field. The maintenance of a private practice of any considerable extent is, so far as its aid to teaching is concerned, of doubtful value. Not even the engineering professor can serve two masters. The advertising value to the institution does not compensate for the loss of personal contact with students inevitable with such an arrangement. So long as the major interest of the teacher is his students, the college will profit by allowing, or perhaps encouraging, private practice, but when academic duties are performed in time not otherwise occupied, the college is the loser.

Personal qualities of a high order are rightfully demanded of a teacher. His sympathies must be wide and his appeal to the student must be many-sided. In enthusiasm, however, is found his greatest source of power. Without it, he will be a failure, no matter what his other qualifications may be. Dean Orton, of the Ohio State University, has expressively put it in his remark that "About all a teacher is good for anyway is to 'enthuse' boys."

Good teachers can neither be obtained nor retained without inducements other than the opportunity for service —compelling though that may be to an idealist. The desire for a salary adequate to the position should be pardoned. Reduction of clerical and routine work to a minimum is highly desirable for one whose chief asset is his freshness and enthusiasm. Appointments, promotions and rewards must be based on capacity for the particular service required. If teaching is the service desired, let rewards be governed by ability to teach and not by demonstrated ability as an engineer, an original investigator or a writer.

Co-operation among teachers will profoundly minister to the effectiveness of instruction. Without it, the results achieved by one may be offset by another. There must be "give and take" in the matter of inter-relation of courses. Mutual help in faculty seminars and conferences is desirable.

Administration.—Since we teach not as individuals but as institutions, constant direction of both staff and students by a central authority is a necessity. For the good of the college and the effectiveness of its teaching no teacher should be permitted to carry an overload. His personal power with students depends, to a remarkable degree, on his enthusiasm, freshness and elasticity, and these cannot be maintained under a burden of overwork. Leisure is the one thing that the teacher should not be permitted to forego. There is, too, such a thing as a student load. The administrative head should assure himself that it, as well as the staff load, is not excessive. Much attention is now being given to such matters as the length, inter-relation and balancing of courses, the length and frequency of lecture, recitation and laboratory periods, the size of classes, the part of the day utilized, and allied problems vitally affecting the student. A halt has been called in the institution of graduate courses in engineering as a result of the indifferent success of the Harvard graduate school, and the action of the Johns Hopkins University in the establishing of a four-year undergraduate course with the provision for graduate work later is indicative of the tendency in this matter. A pronounced reaction against specialization is now in evidence. But little election is allowed in the new course at Johns Hopkins, and many educators are inclined to favor the attitude of such institutions as the University of Pennsylvania, which, for example, requires all students in civil engineering to take the same course.

Indications of Change.—Indications of profound change in the methods of engineering education are not wanting. Dean Gardner C. Anthony, in his presidential address to the Society for the Promotion of Engineering Education at Princeton, declared that the pendulum had reached the extreme position in its swing toward vocational training. The committee on Entrance Requirements of this society put themselves on record as deprecating the acceptance by engineering colleges of more than two Carnegie units of time devoted to manual training. The Johns Hopkins University designedly omitted shop work, foundry work and manual training from the curriculum. The University of Washington has completely revised its courses in the direction of greater attention to cultural studies. The three-year preparatory course for entrance to Columbia has already been mentioned. There appears to be, on every hand, ample evidence of a coming liberalization of engineering education. The ideal of ex-President Charles W. Eliot is more generally accepted than ever before: "Education for efficiency must not be materialistic, prosaic or utilitarian: it must be idealistic, humane and passionate, or it will not win its goal."

A FORM OF SIPHON SPILLWAY.

THE following illustrations are descriptive of a device for regulating the water level in a canal, stream or reservoir, and to provide for the disposal of surplus water in time of flood. It was developed by Mr. G. F. Stickney in connection with his work as designing engineer for the New York State barge canal, on which waterway it has been adopted. It is claimed by the inventor that the device will reduce considerably the size of a structure necessary to dispose of a flow of water, as a dam or spillway, and thus effect a material saving in its cost. Its automatic features contribute greatly to economic operation. In the development of water power in the storage of water for irrigation or other purposes, or in the increase of navigable depth of streams, there are problems such that those interested in the same will find the following descriptive notes of interest:—

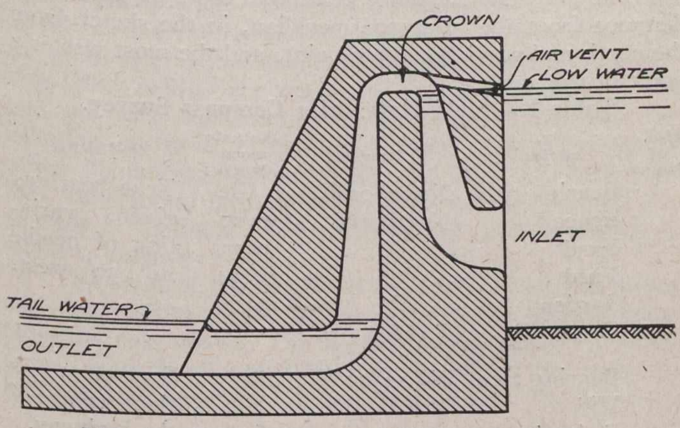

Fig. 1.—Section Through Siphon Spillway.

Fig. 1 is a sectional view of the siphon spillway. It is a closed conduit of an inverted "U" shape extending through a dam where a fall is available, thus utilizing the siphonic principle to induce a high velocity of flow. The siphon is built in the masonry of a dam, and its action is entirely automatic. The flow, when established, is comparable to that through a submerged sluice-gate with a velocity of from 60 per cent. to 80 per cent. of the theoretical velocity due to the head.

The crown of the siphon is entirely above low water level. The upstream leg is sufficiently long to bring the inlet well below the water surface so as to avoid the entrance of ice drift, etc. The downstream leg is made as long as is practicable in order to take advantage of all the head available. It is not necessary that the outlet be submerged.

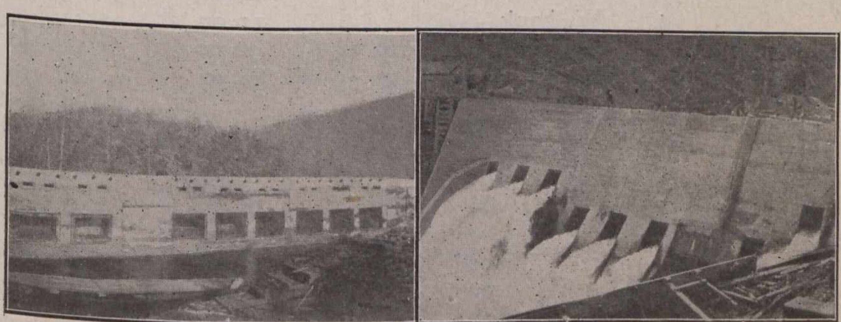

Fig. 2.—Upper and Lower Sides of Spillway. The Former Shows Inlets and Air Vents; the Latter, Siphons in Operation.

The action of the siphon is controlled by an air-vent which pierces the up-stream wall at the low-water level. When the water above the dam rises the vent is submerged so that no air can pass into the siphon. The water then spills through the crown and the down-stream leg. At a certain depth of overflow the air in the siphon begins to pass out with the flowing water; and, as the air becomes rarified the water rises to a higher level in the crown than the surface of the stream outside. Within a short period of time the crown becomes completely filled with water. The siphon is thus primed and rapid flow established. It will continue until the water surface has lowered to such an extent as to expose the vent sufficiently to admit a volume of air into the crown. Then the siphonic action ceases. A fluctuation of the water surface of from 3 inches to 1 foot, depending on the size of the siphon, is necessary to start and to stop the flow. The limiting height of head which may be utilized to produce flow is 33.9 ft.—the height of the longest column of water which atmospheric pressure will sustain.

Siphons of large capacity may be built with the top of the crown well above the highest water level, but in such cases a simple automatic priming device is necessary and both ends of the siphon must be submerged.

Concerning this device it is notable that there are no adjustable or working parts liable to derangement or deterioration. It is genuinely automatic in action; and it will maintain a water surface which will fluctuate between narrow limits regardless of the flow, thus giving a reasonably constant level. The great volume of water which it will discharge per unit of length is also a notable feature.

Fig. 2 illustrates an installation built for the Tennessee Power Co. on the Ocoee river. The spillway contains 8 siphons, each 8 ft. square in section, 4 of which operate under a head of 19.2 ft. and 4 under a head of 27.2 ft. They have a total capacity of 1,650 cu. ft. per second. A rise of 4 inches starts the siphons.

The inventor claims for the device the following special uses:—

1. To regulate the water surface in a stream above a dam at the highest permissible level, giving the maximum head for power development, the maximum storage, the greatest navigable depth, and reduce the fluctuation of the water surface to a minimum.

2. To provide an outlet from a flume or forebay, where a constant flow is maintained, which will operate with a slight raise in the water surface and will discharge the entire flow, in case of a sudden shutdown of the power plant or a sudden obstruction of the flow.

3. To use in place of gate-valves to discharge water from a reservoir. The crown of the siphon may be placed entirely above the water level, so that no leakage is possible, and the siphon may be arranged to be operated by the manipulation of small hand-valves.

On June 15, articles of incorporation were filed with the Secretary of State for the South-West Pacific Railway Company, which purpose building a railway from Denver, Colo., to San Diego, Cal. The capitalization of the company is given as $2,200,000; and the approximate cost of the construction of the total 2,200 miles of road is placed at $105,000,000. The main line from Denver to San Diego will be 1,021 miles in length, while branches will be constructed from Denver to Salt Lake, and from other points to several mining districts.

A LAND SURVEY PROBLEM.

By J. A. Macdonald, Ottawa, Ont.

VERY little information is to be found in technical journals on land surveying, and there is no journal in America devoted exclusively to this important subject. As land surveying goes on continuously, and as each county supports, ordinarily, at least two land surveyors, it is plain that, in the United States and Canada, there must necessarily be a large number of men interested in this work. In late years, as land survey work grows less, most land surveyors are also civil engineers, or understand that part of civil engineering so far as instrumental surveying goes, though they may not be designers of bridges, tunnels, aqueducts, etc. There are, however, a large number of civil engineers who know little of practical land surveying. The following notes, which relate to a survey of a stone quarry and mill property contain a number of points illustrating several methods which are more or less essential to a practical knowledge of the subject, and should commend themselves as well to every surveyor of experience as they are a model in their way. Fig. 1 is a sketch of the survey to which they pertain, and Table I. gives the field notes

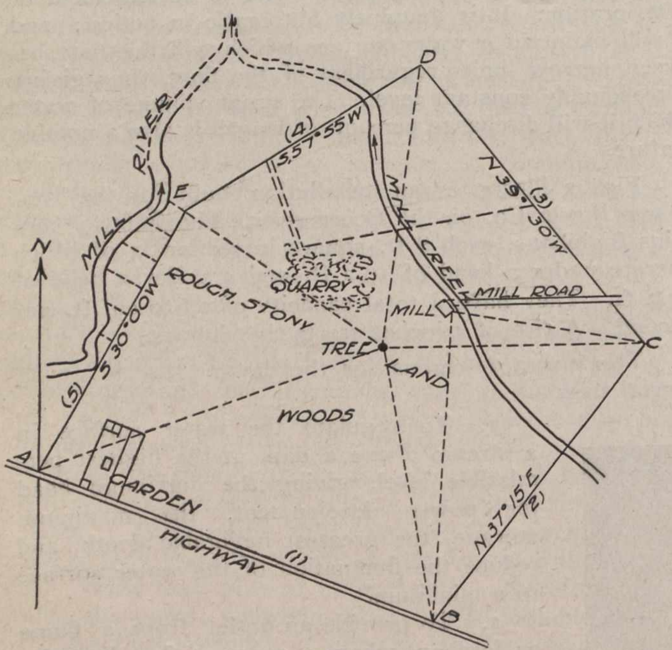

Fig. 1.

themselves. The former, of course, should appear on the right-hand page of the field book, and the latter on the left-hand page.

It will be seen in this instance (Table I.) that the tree was sighted from each corner of the survey and its bearing recorded. These lines, when correctly plotted, intersect at one point. If the plot had not closed, then these bearings would have been plotted, as shown in the dotted lines on the sketch, and they would not have intersected at one point, the first line which deviated from the common point indicating that the preceding course had been erroneously measured, either in bearing or distance, or else wrongly plotted. Such bearings taken to a common point, enable us to locate an error either in the field notes or in the plot. The mill is located by bearings taken from corners B and C. The quarry and entrance thereto is located by bearings taken from known points in the lines 3 and 4.

Latitudes and Departures and Their Computation.—There is only one correct way of computing a compass survey, and this is by latitudes and departures. The latitude of a course is the length of a course into the cosine of its bearing. If the forward bearing of a course is northward its latitude is called its Northing, and is reckoned positively, or plus; while if the course bears southward its latitude is called its Southing, and is reckoned negatively, or minus. The Departure of a course is the length of its east and west line, or the length of course into the sine of its bearing. If the forward line is eastward its departure is called Easting, and is reckoned positively; while if its forward bearing is westward its departure is called Westing, and is reckoned negatively.

The Meridian Distance of a point is its perpendicular distance from the reference meridian, in the sketch from the north and south meridian point, and the most westerly point of the survey.

Table I.—Field Notes of a Compass Survey.

No. of Course	Point	Bearing	Distance along Course	REMARKS
	Bearing tree	N. 60 00 E.	Ch.	True bearings given, variation of needle 24° 30′ west.
	Fence	Northerly	7.20	
1	Yard	"	9.75	
	Yard	"	11.54	
	Garden	"	13.90	
	Corner B	S. 69 15 E.	70.60	
	Bearing tree	N. 10 40 W.		Course 1 is along centre of the highway.
	Mill	N. 3 45 E.		
2	S. bank		36.30	
	N. bank		37.30	
	Corner C.	N. 37 15 E.	59.30	
	Bearing tree	S. 88 45 W.		
	Mill	N. 80 00 W.		
3	Mill road	S. 86 45 W.	9.90	
	Stone quarrie	S. 79 30 W.	30.00	
	Corner D	N. 39 30 W.	60.00	
	Bearing tree	S. 7 30 W.		
	E. bank		10.00	
4	W. bank		11.00	
	Quarrie road	S. 19 15 E.	30.00	
	Corner E	S. 57 55 W.	46.50	
	Bearing tree	S. 56 30 E.		
	Offset, 4.00		0.00	
	" 6.00		5.00	
5	" 8.00		10.00	
	" 7.00		15.00	
	" 3.00		20.00	
	" 2.00		25.00	
	" 0.00		30.00	
	Corner A	S. 30 00 W.	49.80	

The Double Meridian Distance of a course is equal to the sum of the meridian distances to the extremities of the course. The double meridian distances of the two courses adjacent to the reference meridian are equal to their respective departures. The double meridian distance of any other course is equal to the double meridian distance of the preceding course plus the departure of that course plus the departure of the course itself, eastern departures being counted positively, and western departures negatively.

In the computation of area, twice the area of the figure is equal to the algebraic sum of the products of the double meridian distances of the several courses into the corresponding latitudes, north latitudes being reckoned positively, and south latitudes negatively.

Since the departure of a course is its length into the sine, and its latitude, its length into the cosine, of its bearing, these may be computed at once from a table of natural sines and cosines. As it is now customary to read even the needle compass as close as 5 min., the ordinary reverse table is of little use in modern surveying. For land surveying, a 4-place table is sufficiently accurate.

Balancing the Survey.—If the bearings and lengths of all courses have been accurately determined, the survey will "close," i.e., when the courses were plotted to any scale the end of the last course would coincide on the plot with the beginning of the first one, and the sum of the Northings would exactly equal the sum of the Southings (minus latitudes), and the sum of the Eastings (plus) would exactly equal the sum of Westings (minus). All surveyors and draughtsmen know that such exactness is not attainable in practice, and that no plot will close exactly; that neither the north and south latitudes nor the east and west departures will exactly balance. The distribution of these errors of latitude and departure is called "balancing the survey." In Table II. it is seen that the error of latitude is 60 links and the error of departure is 50 links. The distribution of these errors is made as follows:

The ratio of the length of the line joining the initial and final points to the whole perimeter is 17, as found from the field notes. The length of this line is the hypotenuse of a right-angled triangle, of which the errors in latitude and departure are the two sides. Its length is equal to the square root of the sum of the squares of these two errors. This, divided by the whole perimeter, gives the error of closure, which ratio is expressed by a vulgar fraction whose numerator is one, being 1/366 in the example given. For ordinary rolling country the error of closure should not be more than 1 in 500.

A check on the computation of the double meridian distances is found in the fact that when computed continuously in either direction and from any corner, the numerical value of the double meridian distance of the last course must equal its departure.

To Plot a Compass Survey.—Select a point for the initial Station, and pass a meridian through it in pencil. By means of a protractor, mark the bearing and draw an indefinite line from the Station point. On this lay off to scale the length of the course, 5, 10 or 20 chains to an inch, thus establishing the next corner. Through this, by means of a parallel ruler, draw another pencil line meridian, and proceed as before. The bearings of the successive courses may be so combined as to give the deflection-angle, similar to a railway survey, at any station, and these may be laid off from the preceding course as already drawn. Errors are more likely to accumulate in the plot by this method, so that the first is preferable.

Probably the best method of all, but one seldom used, is that by which rectangular co-ordinates of the several corners are computed, and these plotted from a pair of rectangular axes.

Table II.—Form for Computing Areas from Bearings and Distances of the Sides.

Stations.	Courses. Bearings.	Dist.	Diff. Lat. N. +	S. —	Departure. E. +	W. —	Balanced. Lat.	Dep.	D.M.D.	Area.	Area.
A.	S. 69 15 E.	70.60	.....	25.00	66.00	.....	—25.20	+66.10	66.10	....	1666
B.	N. 37 15 E.	59.30	47.20	.....	35.90	.....	+47.10	+36.00	168.20	7922	....
C.	N. 39 30 W.	60.00	46.30	.....	.....	38.20	+46.20	—38.10	166.60	7674	....
D.	S. 57 45 W.	46.50	.....	24.80	.....	39.30	—24.90	—39.20	88.80	....	2211
E.	S. 30 00 W.	49.80	.....	43.10	.....	24.90	—43.20	—24.80	24.80	....	1071
		286.20	93.50	92.90	101.90	102.40				15596	4948
			92.90			101.90				49.48	
		Error, in lat. =	.60		in dep. =	.50				2/10648	

Area = 5324 sq. chs. or 532.4 acres.

Error of closure = 1 in 366 =

$$\text{(square root of) } \frac{\sqrt{50 + 60}}{286200} = 0.0027 = 1 \text{ in } 366.$$

A Diesel electric railway motor car accommodating 50 passengers and weighing over 70,000 lbs. has run, since the beginning of the year, over 2,000 miles on the railways of Sweden, usually at a rate of 20 to 35 miles per hour. The Diesel engine burns about 9 lbs. of crude oil per mile. The car is propelled by electric motors furnished with current from a generator driven by the engine.

Many thousands of bricks per day are being manufactured by the different brick companies of Fort William. The demand at present is fair and as the season advances will increase. The Alsip Brick and Tile Company is working to capacity and producing 70,000 bricks per day. The Fort William Brick and Tile Company is turning out some 26,000 brick per day. The Superior Brick Company is manufacturing 35,000 brick daily; while, at the new plant of the Mount McKay Products, Limited, great activity is being shown in the construction of new kilns, although brick making for commercial purposes will not be under way for at least two months.

The Canadian Pacific Railway will shortly have 1,095 miles of double track between Port Arthur and Calgary, leaving only about 165 miles still to be double tracked between these points.

During 1913, 10,000 box cars, 1,227 passenger, sleeping, dining, and other cars, and 156 locomotives of different types were added to the rolling stock of the Grand Trunk system. They included 41 superheated Pacific type of engines, 100 other large locomotives, 15 switching engines, 10 dining cars, 15 sleeping cars, 11 parlor cars, 67 first-class coaches, 500 flat cars, 500 stock cars, and a large number of combination cars. In box cars a preference was shown for 80,000 pounds' capacity. The prices paid for the passenger cars ranged from $10,000 for a first-class car to $25,000 for a sleeper equipped for service. Orders placed by this road for 1914 include 10 mail cars, 500 stock cars, 20 baggage cars, 82 first-class coaches, 5 second-class coaches, 4 dining cars, 5 parlor cars, 5 express cars, 200 fifty-ton flat cars, and 300 forty-ton flat cars.

LOCK ENTRANCE CAISSON, PANAMA CANAL.

A VERY interesting feature of Panama Canal construction is the lock entrance caisson which is to act as a floating gate or dam for closing the entrance of the lock so that any of the chambers may be unwatered for inspection, cleaning, or repairs. The following description of it is from the "Canal Record":—

The width of the lock chamber is 110 ft.; beyond the line of the emergency dams, the approach is widened by an offset of 24 in. on either side. The shoulders so formed, with a connecting horizontal sill across the bottom of the chamber, afford a frame into which the caisson is fitted to dam off the interior of the lock. This is accomplished by floating the caisson against the shoulders and letting water into its hold to sink it on the sill.

Pumps in the interior of the caisson are then employed to unwater the chamber, while the water pressure from the outer side will force the caisson securely against the frame, reducing leakage around the edges. When it is desired to remove the caisson, the lock chamber will be filled with water, relieving the pressure, and the water within the caisson will be pumped out to allow it to be floated away. The general principles of construction are the same as in the caissons for Gatun and Miraflores Spillways, but the requirements and conditions of its use make the design of the lock caisson more complex than that of the spillway caisson.

The caisson is designed for interchangeable use at all locks, and will have a draft when light of 32 ft., to allow its convenient handling through the locks. The lower elevation of the sill at the Pacific end of Miraflores Locks, 50 ft. below mean sealevel, in connection with the tidal fluctuation which raises the surface as high as 11 ft. above mean, requires that the extreme draft of the caisson, when sunk, be 61 ft. Provision for a proper freeboard makes the aggregate depth of the structure 65 ft. The achievement of statical stability at the various depths of immersion, without undue bulkiness or excessive weight in the different parts, makes the design of especial interest.

In form, the bottom of the hull will be convex, the ends pointed, and the sides will slope inward from a maximum width of 36 ft. at about one-third the way up from the keel, to a breadth half as great at the top. A typical transverse cross-section of the structure resembles in outline the vertical section through a pear-shaped carbon-filament electric lamp. The horizontal lengthwise sections vary with the inward slope of the sides; in general, they resemble those of the ordinary vessel of commerce, and may be described as flattened ellipses, blunt at the ends to contain the girders and breasthooks by which the pressure will be transmitted to the vertical sills, or shoulders, on the lock walls. The length between the vertical ends will be 112 ft. 6 in., and the extreme length, including the timber cushions, 113 ft. 10 in.

It is desired that the side walls of the locks shall carry practically all the static load from the caisson when it is supporting the water pressure. Accordingly, there will be a number of horizontal decks and end breasthooks to carry the load to the vertical ends; and a system of vertical framing, built intercostally and extending from the keel to the top deck, will transmit the panel loading to the horizontal decks and breasthooks. The essential features of the structure will be the transverse and longitudinal framing, with bulkheads; the horizontal plate decks, girders, and stringers; the girders at the ends and along the keel; the end breasthooks; and the plating to cover the skeleton in forming the hull proper. These elements will all be made from open-hearth structural steel.

The transverse framing system will consist of nine cross frames, spaced about 12 ft. apart and extending the whole height of the caisson, and intermediate frames, spaced at intervals of about two feet between the main cross frames. All will be built intercostally between the five horizontal decks. Two of the cross frames will be built watertight and designated as "Collision bulkheads," to form trimming tanks at each end of the vessel, for maintaining longitudinal stability and settling the caisson on even keel when it is to be put in use. The seven other cross frames will have apertures in their lower sections to make them serve as swash bulkheads for controlling the water within the caisson by which the depth of immersion will be regulated.

A longitudinal bulkhead will extend the entire distance between collision bulkheads, from keel to operating deck, along the centre line. Its lower part will be sufficiently watertight to form two distinct lengthwise compartments, dividing the free surface of the water ballast and increasing the static stability of the caisson, as against lateral motion.

There will be 5 horizontal decks, built continuously from vertical end to vertical end. The two lower decks, 16 and 25 ft., respectively, above the base line, will be entirely plated over with the exception of openings for hatches and manholes, the hatches being made large enough for the installation or removal of the pumps through them. The operating deck, 37 ft. above the keel, will be entirely plated from end to end, and made absolutely watertight. This deck will support the motors for the pumps, with switchboards, gauge registers, etc. The plate-stringer deck, 49 ft. above the base line, will be an open truss with diagonal bracing for the central two-thirds of its length. The top deck, 65 ft. above the base, will be plated over from end to end, with openings for manholes, skylights, deck cranes, companionways, and scuppers.

Six plate breasthooks will be built at each stem of the vessel, at intervals between the decks. They will serve to transmit the end shears from the decks to the vertical girders. One of these breasthooks, situated 31 ft. above the base line, will have its plating calked to watertightness and serve as the bottom for the end trimming tank. At the same level as the breasthooks will be longitudinal intercostals, securely riveted to the transverse frames and to the sheathing.

The skeleton will be entirely sheathed over with steel plating worked in in-and-out strakes, running longitudinally over the frames, making lap seams and butt joints which are to have double splice plates. At all the horizontal decks, and around the pipe discharge and suction openings, the sheathing will be doubled. Fenders against external impact will be provided between the 25 and 49-ft. levels, by bent plates securely riveted to the sheathing, the space between being filled with poured rosin. Towing rings will be attached along the 37 and 43-ft. levels.

End reaction castings will provide connection of the decks and breasthooks, up to and including the 49-ft. stringer deck, with the vertical girders, for transmitting to the latter the reactions of horizontal forces. They will be made of carbon steel and closely fitted during construction.

Along the exteriors of the ends and keel will be fastened cushions of British Guiana greenheart timber. They will be planed to make even contact with the plated sill and reduce leakage to a minimum. Greenheart timber is notably durable under water, either fresh or salt, and has been used for the sills of the miter gates in the Canal locks.

Pumping System.—The pumps installed within the caisson are designed to regulate the water ballast, determining the depth of immersion, and to unwater any portion of the locks between the upper and lower entrances. Of all the lock chambers, the only ones which can be cleared of water without pumping are the two in the upper flight of Gatun Locks, because they are the only ones the floors of which are below the level of the water at the lower end of the flight. The floor of the intermediate level at Gatun is 13⅔ ft. below sealevel. The floor at Pedro Miguel Lock is at elevation plus 9, which is 46 ft. below the normal level of Miraflores Lake. The upper of the two levels at Miraflores is 18½ ft. below mean sealevel, which means a minimum depth of water in it of about 8 ft. at low tide of the Pacific. Moreover, the caisson dams will afford the only means of working in the dry on the outward faces of the guard gates, and the sills for the emergency dams.

The main pumping system will consist of 4 vertical-shaft centrifugal pumps, having a 20-in. discharge and a 22-in. suction. The practical test governing its design is that it shall be able to pump out in not over 25 hours all the water in the upper and lower chambers of one flight of Miraflores Locks, between mean sealevel and the top of the sill of the lower chamber (El.—50 ft.), the tidal level to be at El. 0 when the pumping is begun, and the tide rising. The total quantity to be pumped out, including 518,000 ft. for leakage, will be about 10,285,000 cu. ft. The average discharge under these conditions, for the entire period of pumping, would be about 13,000 gal. per min. for each of the 4 pumping units. Two of the pumps are to be arranged for pumping out the caisson when it is to be removed from its position against the sill.

Inasmuch as the sill for the caisson is higher than the level of the floor, suction extension pipes are to be provided to cross the sill on the bottom of the chamber, to allow its complete unwatering. The suction extensions will be lowered by cranes on the deck, and attached from a pontoon, similarly handled.

An auxiliary pump, with suitable pipe connections, will be used to regulate the end trimming tanks, flush the scuppers, and scour the sills.

Electrical Equipment.—The caisson will have no means of auto-propulsion, but will be towed from place to place. Its motors will be for operating the pumps, and their details will be determined by the pump characteristics. Four 2,200-volt motors will drive the main pumps, and one of 220 volts potential will operate the auxiliary pump. Another 220-volt motor will drive a ventilating fan. Current will be received at 2,200 volts from chambers in the lock walls, through four flexible cables, and a three-phase transformer is to be provided for the 220-volt motors, and for the lighting equipment. A switchboard will be installed in the operating room, which is on the operating deck, 37 ft. above the base line.

Miscellaneous Parts.—There will be four portable cranes on the top deck, to handle various loads. Each must be capable of raising another at a radius of 14 ft., by 2-man power. The pontoon for making the suction extension attachments will be stowed on the top deck and handled by cranes. A deck capstan, hand-operated, will be provided at each end of the top deck. It must be able to withstand a pull of 10,000 pounds.

Two ventilators, 16 in. in diameter, with hoods of U.S. Navy standard type, will be placed on the top deck, for ventilating the operating room. One, discharging a short way below the 49-ft. deck, will have a multivane exhauster, motor-driven. Twelve 2-in. air vents, to allow the escape of air and gases from the interior compartments, will lead to the top deck. Two skylights, 8 by 16 ft., will be set in the top deck, symmetrical with the axes of the caisson. The covers will be made in two parts, for portability, and a hand-operated device will be provided for raising and lowering them. The skylights will be watertight against a hose discharge under 50 pounds pressure.

Fixed ballast, composed of pig iron punchings and concrete, is to be placed in the bottom of the hull to a normal thickness of about a foot and a half. The pig iron will at all points be at least six inches from the sheathing. Two 70-ft. lengths of anchor chain will be provided for mooring the caisson when it is not in service, and chain lockers for them will be built of reinforced concrete at the ends of the 37-ft. deck.

Programme of Construction.—Only one caisson is being built at present, though it is expected that two will be provided for the operation of the canal. The first is to be completed about September, 1914, and towed to the Isthmus for test at the lower end of Miraflores Locks. The test may suggest modifications; if not, the second caisson will be constructed like the first. The patterns for all the castings in the structure will become the property of the Isthmian Canal Commission on acceptance of the caisson, and will be delivered with it. Fabrication and erection of the first caisson are being supervised at the plant of the contractor by Mr. Lewis A. Mason, assistant engineer, who was associated with Mr. Henry Goldmark, designing engineer, in working out the design, plans, and specifications.

A LARGE CENTRAL HEATING PLANT.

About 22,000 tons of coal is the annual consumption of the central heating plant of the University of Wisconsin, at Madison, Wis. Only 10% of the total fuel is chargeable to power uses. All power exhaust, together with low-pressure live steam, is used for heating. At present 42 buildings are heated from the central plant, including practically all of the University buildings and the United States Forest Products Laboratory. The distribution system includes 2 miles of tunnel and 1 mile of conduit. The maximum pipe size is 16 in.; on this a total thickness of 3 in. of 85% magnesia insulation is used. The heating pressure is 5 to 10 lb., and no difficulty in maintaining pressure at the receiving end has been experienced.

The world's production of copper, during 4 years, as given in a recent issue of the "Engineering and Mining Journal," is as follows, quantities in metric tons:—

Country.	1910.	1911.	1912.	1913.
United States	492,712	491,634	563,260	555,990
Mexico	62,504	61,884	73,617	58,323
Canada	23,810	25,570	34,213	34,880
Cuba	3,538	3,753	4,393	3,381
Australasia	40,962	42,510	47,772	47,325
Peru	27,375	28,500	26,483	25,487
Chile	38,346	33,088	39,204	39,434
Bolivia	3,212	2,950	4,681	3,658
Japan	50,703	52,303	62,486	73,152
Russia	22,700	25,747	33,550	34,316
Germany	25,100	22,363	24,303	25,308
Africa	15,400	17,252	16,632	22,870
Spain and Portugal	51,100	52,878	59,873	54,696
Other countries	24,888	26,423	29,555	27,158
Totals	882,351	886,855	1,020,022	1,005,978

SUMMARY OF TESTS OF BOND BETWEEN CONCRETE AND STEEL.

THE usefulness of reinforced concrete as a structural material depends on the strength and permanency of the bond between the concrete and the reinforcing metal, and for this reason bond resistance has received much attention from engineers and experimenters. It is said that Thaddeus Hyatt made tests to determine the bond between concrete and iron bars as early as 1876. During the past decade numerous bond tests have been reported. These tests have been characterized by a lack of uniformity in the form of the test specimen and in the methods of conducting the tests, as well as by the wide variations in the values reported for bond resistance. In nearly all the tests thus far published values of maximum bond resistance only have been given. These test results and the discussions called forth by them have furnished the basis for a great variety of opinions as to the value of bond resistance. Many explanations of the source and nature of bond resistance have been given. Various methods have been advocated for increasing bond resistance and numerous devices have been employed for this purpose.

Present practice is fairly standardized as to the bond stresses to be used in designing, but a rational basis for the stresses used is lacking and there is a great diversity of practice in the methods of calculating these stresses. There are many phases of bond action which are not now understood. It is evident that the distribution of bond stress in reinforced concrete members under load and the nature and value of bond resistance under given conditions may well be the subject of experimental investigation.

The tests reported in a bulletin, entitled "Tests of Bond between Concrete and Steel," recently issued by the Enginering Experiment Station of the University of Illinois, were undertaken with a view to securing additional information on the nature of the bond resistance of reinforcing bars in concrete, to determining values of bond resistance for a wide range of conditions, and to studying bond action in specimens of different forms. Tests were made on pull-out specimens and on reinforced concrete beams. In both forms of specimen attention was given to obtaining accurate measurement of the slip of bar through the concrete as the loading progressed. In many of the beam tests the slip of bar at various points along its length was measured for different loads. In the discussion of bond resistance the load-slip-of-bar relation has been utilized to a considerable extent. These measurements are useful in indicating the distribution of bond stress. They are particularly significant in the beam tests. In a few of the beam tests the distribution of bond stress was studied by measuring the changes in the stress in the longitudinal reinforcement throughout the length. The values found for bond resistance and the relative bond resistance found in beam tests and pull-out specimens are also interesting features of the investigation.

The pull-out tests consisted in applying load to a short reinforcing bar embedded in a block of concrete. The concrete block was generally 8 in diam. and 8 in. long, with the bar embedded axially. In certain groups of tests these dimensions were varied. The size of bar used varied between ¼ in. and 1¼ in. The pull-out tests covered a wide range and included effect of dimensions of specimen, effect of form of bar, effect of conditions of storage, effect of age and mix, using both plain and deformed bars, effect of different methods of loading, bond resistance of concrete setting under pressure, effect of reapplied loads, comparison with the bond resistance of reinforced concrete beams, etc. The deformed bars used included most of the forms in use at the time the work was begun, but it should be noted that the tests with deformed bars were intended to bring out the action of the deformed bar as contrasted with the plain bar and not to determine the value of particular forms of bars.

A special effort was made to determine the behavior of beams subjected to high bond stresses. The beams tested were 8 by 12 in. in section with an effective depth of 10 in. The span length was generally 6 ft.; a few beams were tested with span lengths of 5 to 10 ft. All beams were tested with two symmetrical loads, generally at the one-third points of the span. With the exception of six tests, the longitudinal reinforcement consisted of a single bar of large diameter placed horizontally throughout the length of the beam. Both plain and deformed bars were used.

The tests were made in the laboratory of Applied Mechanics of the University of Illinois, and formed a part of the investigations of reinforced concrete and other structural materials which are being conducted by the Illinois Engineering Experiment Station. These tests cover the experiments which were designed with special reference to a study of bond between concrete and steel during the period of 1909-1912. This work was done by Duff. A. Abrams, Associate in Theoretical and Applied Mechanics, under the direction of A. N. Talbot, Professor in Charge of that Department. The tests covered a wide range of conditions and the results have a significant bearing on the nature of bond resistance, the action of bars of different forms under bond stress, and the behavior of beams subjected to high bond stresses. The load-slip determinations have given definite information on the nature and distribution of bond resistance. The following is a resumé of the principal observations and conclusions which have been stated and discussed in the text. Paragraphs 2 to 34 refer primarily to the results of the pull-out tests:—

(1) Bond between concrete and steel may be divided into two principal elements, adhesive resistance and sliding resistance. The source of adhesive resistance is not known, but its presence is a matter of universal experience with materials of the nature of mortar and concrete. Sliding resistance arises from inequalities of the surface of the bar and irregularities of its section and alignment together with the corresponding conformations in the concrete. The adhesive resistance must be overcome before sliding resistance comes into action. In other words, the two elements of bond resistance are not effective at the same time at a given point. Many evidences of the tests indicate that adhesive resistance is much the more important element of bond resistance.

(2) Pull-out tests with plain bars show that a considerable bond stress is developed before a measurable slip is produced. Slip of bar begins as soon as the adhesive resistance is overcome. After the adhesive resistance is overcome, a further slip without an opportunity of rest is accompanied by a rapidly increasing bond stress until a maximum bond resistance is reached at a definite amount of slip.

(3) The true relation of slip of bar to bond stress can best be studied by considering the action of a bar over a very short section of the embedded length. The difficulties arising from secondary stresses made it impracticable to conduct tests on bars embedded very short lengths. The desired results were obtained by varying the forms of the specimens in such a way that the effect of different combinations of dimensions could be studied.

(4) Pull-out tests with plain bars of the same size embedded different lengths furnish data which suggest

the values of bond resistance over a very short length of embedment, or indicate values of bond resistance which are independent of the length of embedment. Tests with bars of different size which were embedded a distance proportional to their diameters give the true relation when the effect of size of bar is eliminated. Two series of tests of this kind on plain round bars of ordinary mill surface gave almost identical values for bond resistance after eliminating the effect of length of embedment and size of bar, and we may consider that these values represent the stresses which were developed in turn over each unit of area of the embedded bar as it was withdrawn by a load applied by the method used in these tests. These tests showed that for concrete of the kind used (a 1:2:4 mix, stored in damp sand and tested at the age of about 60 days) the first measurable slip of bar came at a bond stress of about 260 lbs. per sq. in., and that the maximum bond resistance reached an average value of 440 lbs. per sq. in. If we conclude that adhesive resistance was overcome at the first measurable slip, it will be seen that the adhesive resistance was about 60 per cent. of the maximum bond resistance. This ratio did not vary much for a wide range of mixes, ages, size of bar, condition of storage, etc.

(5) Sliding resistance reached its maximum value for plain bars of ordinary mill surface at a slip of about 0.01 in. The constancy in the amount of slip corresponding to the maximum bond resistance for a wide range of mixes, ages, sizes of bar, conditions of storages, etc., is a noteworthy feature of the tests. With further slip the sliding resistance decreased slowly at first, then more rapidly, until with a slip of 0.1 in. the bond resistance was about one-half its maximum value.

(6) Pull-out tests with plain round bars show end slip to begin at an average bond stress equal to about one-sixth the compressive strength of 6-in. cubes from the same concrete; the maximum bond resistance is equal to about one-fourth the compressive strength of 6-in. cubes. These values were about the same for a wide range of mixes, ages and conditions of storage. In terms of the compressive strength of 8 by 16-in. concrete cylinders these values would be about 13 per cent. for first end slip and 19 per cent. for the maximum bond resistance.

(7) The tests indicate that bond stress is not uniformly distributed along a bar embedded any considerable length and having the load applied at one end. Slip of bar begins first at the point where the bar enters the concrete, and the bond stress must be greater here than elsewhere until a sufficient slip has occurred to develop the maximum bond resistance at this point. Slip of bar begins last at the free end of the bar. After slip becomes general, there is an approximate equality of bond stress throughout the embedded length.

(8) Small bars gave a bond resistance somewhat higher than the large bars during the early stages of the test. This was probably on account of greater irregularity of section and alignment of the smaller bars. The maximum bond resistance was not materially different for bars of different diameters.

(9) Computations based on the elastic properties of the materials indicate that in the pull-out tests the tensile deformation in the bar had a much greater effect on the amount of bond stress which permitted a given slip of bar than had the compressive deformation in the concrete block in which the bar was embedded.

(10) Rusted bars gave bond resistances about 15 per cent. higher than similar bars with ordinary mill surface.

(11) The tests with flat bars showed wide variations of bond resistance and were not conclusive. Square bars gave values of unit-stress about 75 per cent. of those obtained with plain round bars.

(12) T-bars gave lower unit bond resistance than plain round bars, but gave about double the bond resistance per unit of length that was found for the plain round bars of the same sectional area.

(13) With polished bars the bond resistance is due almost entirely to adhesion between the concrete and steel. Numerous tests with polished bars embedded in 1:2:4 concrete and tested at 60 days indicated a maximum bond resistance of about 160 lbs. per sq. in., or about 60 per cent. of the bond resistance of bars of ordinary surface at small amounts of slip. This value agrees closely with tests reported elsewhere, and apparently represents the value of the tangential adhesion between any clean steel and concrete of this quality. The sliding resistance of polished bars was very low.

(14) Tests with polished bars with wedging and non-wedging tapers showed that adhesion was broken for both types of bar at about the same bond stress as in the polished bars of uniform section.

(15) The tests with polished bars with wedging taper showed that after the adhesion was broken a considerable movement of the bar (as much as ¼ in. with the smallest tapers) was required before the bond resistance again reached the amount which was at first carried by the adhesive resistance. The amount of movement necessary to restore the bond stress to the value of the original adhesive resistance was inversely proportional to the amount of taper. This indicates that a definite normal compression must be developed in the surrounding concrete before a longitudinal component equivalent to the original tangential adhesion is produced.

(16) It was noted in the tests with plain bars that sliding resistance was due to inequalities of the surface of the bar and to irregularities of its section and alignment. The projections on a deformed bar give an exaggerated condition of inequality of surface or irregularity of section. Adhesive resistance must be destroyed and the usual sliding resistance largely overcome and the concrete ahead of the projections must undergo an appreciable compressive deformation before the projections on a deformed bar become effective in taking bond stress. The tests indicate that the projections do not materially assist in resisting a force tending to withdraw the bar until a slip has occurred approximating that corresponding to the maximum sliding resistance of plain bars. As slip continues a larger and larger portion of the bond stress is taken by direct bearing of the projections on the concrete ahead.

(17) In determining the comparative merits of deformed bars, the bar which longest resists beginning of slip should be rated highest, other considerations being equal. The bond stresses developed at an end slip of 0.001 in. furnished the principal basis of comparison for the different types of deformed bars. At an end slip of 0.001 in. 12 sets of deformed bars of ¾-in. and larger sizes embedded 8 in. in 1:2:4 concrete, tested at about 2 months, developed an average bond resistance of 318 lbs. per sq. in., 4 per cent. higher than the corresponding value for plain bars. At this stage of the test, two sets of deformed bars gave practically the same bond resistance, five sets gave lower values, and five sets higher values than the plain rounds. At an end slip of 0.01 in., corresponding to the maximum bond resistance of plain bars, the average bond resistance of the 12 sets of deformed bars was 445 lbs. per sq. in., 10 per cent. higher than plain rounds. At this stage of the test two sets gave about the same values, two sets gave lower values, and eight sets gave higher values than the plain bars. The hooping used in these specimens had a marked effect in

increasing the bond resistance, even at small amounts of slip.

(18) The concrete cylinders of the pull-out specimens with deformed bars were reinforced against bursting or splitting, because it was desired to study the load-slip relation through a wide range of values. The bond stresses corresponding to an end slip of 0.1 in. are the highest stresses reported for the deformed bars. In only a few tests was the maximum bond resistance reached at an end slip less than 0.1 in. It should be recognized that, in general, the bond stresses reported for deformed bars at end slip of 0.05 and 0.1 in., could not have been developed with bars embedded in unreinforced blocks. These high values of bond resistance must not be considered as available under the usual conditions of bond action in reinforced concrete members. In the tests in which the blocks were not reinforced, evidence of splitting of the blocks was found at end slips of 0.02 to 0.05 in.

(19) The normal components of the bearing stresses developed by the projections on a deformed bar may produce very destructive bursting stresses in the surrounding concrete. The bearing stress between the projections and the concrete in the tests with certain types of commercial deformed bars was computed to be from 5,800 to 14,000 lbs. per sq. in. at the highest bond stresses considered in these tests. For bars having projections of different heights and spacing, the bearing stresses on the projections at the highest bond stresses considered were inversely proportional to the bond stress which had been developed by the bar at an end slip of 0.01 in., the slip at which the projections were beginning to be effective. These considerations show that the ratio of the area of the projections measured at right angles to the bar to the superficial area of the bar in the same length is the proper criterion for judging of the effective bond resistance of a deformed bar. In some forms of bar the bearing stresses must have been much higher than the values given above. The large slip and the high bearing stresses developed in the later stages of the tests show the absurdity of seriously considering the extremely high values that are usually reported to be the true bond resistance of many types of deformed bars.

(20) Round bars with standard V-shaped threads gave much higher bond resistance at low slips than the commercial deformed bars. The average bond resistance at an end slip of 0.001 in. was 612 lbs. per sq. in. The maximum bond resistance was 745 lbs. per sq. in. These were the only deformed bar tests in which failure came by shearing the surrounding concrete.

(21) In a deformed bar of good design the projections should present bearing faces as nearly as possible at right angles to the axis of the bar. The areas of the projections should be such as to preserve the proper ratio between the bearing stress against the concrete ahead of the projections and the shearing stress over the surrounding envelope of concrete. Failure by shearing of the concrete should be avoided. The tests indicate that the areas of the projections measured at right angles to the axis of the bar should not be less than, say, 20 per cent. of the superficial area of the bar. A closer spacing of the projections than is used in commercial deformed bars would be of advantage. Advocates of the deformed bar would do well to recognize the fact that in a deformed bar which may be expected to develop a high bond resistance, a certain amount of metal must be used in the projections which probably will not be available for taking tensile stress.

(22) The 1-in. twisted square bars gave a bond resistance per unit of surface at an end slip of 0.001 in., only 88 per cent. of that for the plain rounds. Following an end slip of about 0.01 in., these bars showed a decided decrease in bond resistance, and a slip of 5 to 10 times this amount was required to cause the bond resistance to regain its first maximum value. After this, the bond resistance gradually rose as the bar was withdrawn. Some of the bars were withdrawn 2 or 3 in. before the highest resistance was reached. The apparent bond stresses at these slips were very high; but, of course, such stresses and slips could not be developed in a structure and could not have been developed in the tests had the blocks not been reinforced against bursting. Such values are entirely meaningless under any rational interpretation of the tests.

(23) The load-slip curves for twisted square bars are similar to those for polished bars with wedging taper. The twisted bar is essentially a combination of the wedging and non-wedging taper. As the bar is drawn through the concrete the wedging tapers are drawn more firmly against the concrete ahead, while at the same time the non-wedging tapers are separated from the concrete with which they were originally in contact. The drop in the load-slip curves after an end slip of about 0.01 in. shows that the separation of about one-half of the surface of the bar from its original contact and the continued sliding of the flatter portions of the bar, until a large slip has occurred, have a greater influence in reducing the average bond resistance than the increased bearing of the wedging tapers has in raising the bond resistance. The results found with the twisted square bar do not justify its present widespread popularity as a reinforcing material.

(24) The tests with plain round bars anchored by means of nuts and washers and with washers only showed that the entire bar must slip an appreciable amount before these forms of anchorage come into action. Anchorages of the dimensions used in these tests did not become effective until the bar had slipped an amount corresponding to the maximum bond resistance of plain bars. With further movement the apparent bond resistance was high, but was accompanied by excessive bearing stresses on the concrete.

(25) The load-slip relation for bars anchored by means of hooks and bends was not determined. The high resistance given in these tests was probably a result of the bearing stresses developed in the concrete ahead of the bends.

(26) Tests on specimens stored under different conditions indicate that concrete stored in damp sand may be expected to give about the same bond resistance and compressive resistance as that stored in water. Water-stored specimens gave values of maximum bond resistance higher in each instance than the air-stored specimens; the increase for water storage ranged from 10 to 45 per cent. The difference seemed to increase with age. The presence of water not only did not injure the bond for ages up to three years, but it was an important factor in producing conditions which resulted in high bond resistances. However, it was found that specimens tested with the concrete in a saturated condition gave lower values for bond than those which had been allowed to dry out before testing. The bars in specimens which had been immersed in water as long as three and one-half years showed no signs of rust or other deterioration.

(27) Specimens made out-doors in freezing weather, where they probably froze and thawed several times during the period of setting and hardening, were almost devoid of bond strength.

(To be continued.)

Coast to Coast

Toronto, Ont.—The Toronto Hydro-Electric Commission sustained a deficit of $1,600 for the past month.

Calgary, Alta.—A report has been presented by the city commissioners to the Calgary city council showing the surplus for 1913 for the Calgary Electric Railway to be $177,000.

Winnipeg, Man.—Another report, submitted recently by J. G. Glassco, superintendent of the Winnipeg light and power department, indicates a surplus amounting to $81,897.45 for the year ending April 30, 1914.

Winnipeg, Man.—In the undertakings which Winnipeg has planned for 1914, there will be involved an expenditure of $10,000,000. In addition to this, the Greater Winnipeg Water District board will spend $2,000,000.

Montreal, Que.—It is reported from headquarters at Montreal that the G.T.R. Railway Company is now carrying passengers over an all-rail route from Fort William, Ont., to Prince George, B.C., a distance of 1,729 miles.

Port Arthur, Ont.—A recent statement made by the public utilities commissioner of Port Arthur shows that in Port Arthur there are now 2,224 street lights. Addition to the city's street lighting system is being made continuously.

London, Ont.—A report from London announces that another gas gusher has been struck close to the great Fairbanks gusher recently struck; and that the new well is flowing at a rate of 500,000 feet per day. The drill had only reached the depth of 1,800 feet.

Maple Creek, Sask.—The Coste-McAuley syndicate has filed for the gas and oil rights on 80,000 acres of land situated from 60 to 65 miles north of Maple Creek. It is in this area that the company will bore for the gas, with which it hopes to supply the cities of Saskatchewan.

Ottawa, Ont.—A report from Ottawa advises that construction work on the National Transcontinental Railway has reached a stage of practical completion. All that remains to be done is some additional ballasting and filling and the erecting of a few stations, which are to be completed by October 1.

Saskatoon, Sask.—A new system of electric lights is being tested at Saskatoon. High power nitrogen filled lamps are being suspended from the tops of trolley poles; and, should these prove more efficient and more economical, it is intended to place the lamps on most of the main thoroughfares of the city.

Regina, Sask.—The city council of Regina has approved the programme of this year's civic construction work recently recommended by the city commissioners, and has passed the by-laws necessary to legalize the flotation of treasury bills to the extent of $1,250,000, of which $500,000 is to be issued immediately.

Hamilton, Ont.—Hydro-Electric street lighting was inaugurated at Hamilton on July 1. It is estimated by the city works department that lighting under hydro management will cost $98,000 per year, or $49,000 per half-year during the time that the lights would be mostly in service. The department has expropriated $58,000 for the half-yearly expense.

Fort William, Ont.—Construction work has started on the big turning basin in the Fort William harbor, 5 miles up from the mouth of the Kaministiquia River. Two clam shell dredges are at present engaged in taking out loose earth; and in about two weeks' time the large dipper dredges of the Great Lakes Dredging Co., will also be employed. The construction of the turning basin is a large undertaking. Over 35 acres of solid earth will have to be removed before the basin is finished; and it will take some 2 years to complete the work.

Calgary, Alta.—An announcement was made last week by City Engineer Craig of Calgary, to the effect that actual construction work on the new bridges proposed at Calgary will commence within a month or 6 weeks. About 6 weeks ago, the by-laws providing for the bridges were passed; and since that date, the engineer's department has been employed on the necessary surveys. Construction will begin at the Louise Street bridge, since more time will be needed to complete the surveys for the Centre Street structure.

St. John, N.B.—Recently a shipment of steel for the new bridge being constructed by the Dominion Bridge Company over the reversible falls, is reported as having arrived in St. John; and the preliminary work of placing the first piece in position is proceeding under the supervision of Engineer Springer. The large granite blocks upon which the new pier will be erected have been placed on the bed of concrete; and this part of the contract will be completed very shortly. The steel work will then be advanced rapidly.

Victoria, B.C.—A recent announcement from Victoria states that satisfactory progress is being made with the construction of the concrete tank which will be a part of the northwest sewer system, and into which sewerage will be drained from the area lying north of the Burnside Road and thence pumped into the system which will carry the sewerage across the Victoria Arm and across to the outlet at Macaulay Point. The tank is being made especially strong to support the roadway beneath which it is being constructed.

Ottawa, Ont.—The construction of both the bridge across the Rideau Canal to Ottawa East from Pretoria Avenue and the bridge across the Rideau River at Billings' Bridge, is being delayed. In the former instance, the officials of the Ottawa Electric Railway will not consent to run cars over a low level lift bridge, the plans for which are now being prepared by the city engineer at a cost of $120,000; while, in the latter, the county has refused to bear half the cost of construction, and an agreement has yet to be reached as to the division of cost between the city and county.

Vancouver, B.C.—Officials of the engineering department of the Canadian Northern Pacific Railway have announced that track-laying will be resumed on that road from Kamloops to a point 28 miles west where the right-of-way crosses the Thompson River. The track construction will be delayed at the Thompson River until a bridge has been completed across it, when another section of the road will probably be built and the uncompleted portion of the work between Cisco and Kamloops somewhat diminished. The steel for the bridge across the Thompson has already been fabricated, and as soon as the rails reach the river, work will be commenced and rushed ahead on the erection of this structure.

Medicine Hat, Alta.—In the course of a few weeks Medicine Hat will have a most up-to-date and modern telephone system, differentiating from the present one in that it will be large enough to accommodate several times its capacity. For some time contractors have been at work on the installation, a new building, for this purpose only, being part of the plans. Contractors are engaged in the construction of the building and also on 125,000 feet of underground conduits; and it is expected that September will see the city served with the latest automatic telephone system. Some 2,000 of the new phones have already arrived for installation, there being room for 10,000 if required in the near future. Every part of the city will have adequate connection; and no poles will be used except in the lanes.

Winnipeg, Man.—An expenditure for the month of July amounting to $168,470, has been passed by the administration board of the Greater Winnipeg Water District. Items of expenditure have been placed as follows: salaries and wages, $13,000; supplies and equipment, $3,000; railway ties contract, $32,300; steel rails, $59,000; steel splice bars, $3,310; railway construction, $54,000; residences for divisional engineers, $2,150; switches, frogs, and track accessories, $1,710. It is estimated that an expenditure of $500,000 will be passed for the month of August, though the total outlay is placed at $522,580.29 Plans for the aqueduct line beyond range 7 will be completed and work on them is now being advanced rapidly. This will conclude the determination of the exact line to be followed east as far as the Whitemouth River, which will be over half the way to Indian Bay at Shoal Lake. The route will not go in a straight line but will have numerous angles and curves as has the sanctioned plan from the Transcona reservoir site to the end of range 7, 24 miles east of the city.

PERSONAL.

CAMPBELL M. HUNTER, A.M.Inst.C.E., F.R.G.S., of the firm of Thompson and Hunter, geologists specializing in petroleum investigations, is investigating oil possibilities in the Province of Alberta.

LUCIUS E. ALLEN, A. B., C.E., consulting engineer of Belleville, Ont., sails for Europe on July 11th, for the purpose of making an investigation and study of Continental methods and materials used in good roads and pavements.

H. T. CROSBIE, town engineer of Yorkton, Sask., read a paper at the recent municipal convention in Moose Jaw, entitled "Engineering Advice to Villages About to Enter the Town Estate." Mr. Crosbie dealt with the subjects of water supply, sewerage system, electric light, sidewalks and boulevards and town planning.

A. N. JOHNSON, M.Am.Soc.C.E., has resigned as State Highway Engineer of Illinois to accept a position with the Bureau of Municipal Research, New York City. Mr. Johnson graduated in civil engineering at the Lawrence Scientific School, Harvard University, in 1894. He was an instructor at Harvard in 1895 and 1896, and then for two years was Assistant Engineer of the Massachusetts Highway Commission. From 1898 to 1905, Mr. Johnson was State Highway Engineer of Maryland. For a year he was Chief Engineer of the United States Office of Public Roads, Washington, D.C., and since 1906 has been State Highway Engineer of Illinois.

OBITUARY.

The death occurred in Toronto recently of Chas. K. Rundle, for many years prominently engaged in contracting work.

CANADIAN SOCIETY OF CIVIL ENGINEERS.

The following engineers were elected to membership in the Canadian Society of Civil Engineers at a meeting of the Council in June:—

Duncan McMillan, district engineer's office, Canadian Northern Railway, Victoria, B.C.; Robt. H. Parsons, superintendent of municipal electric light, power and pumping plant, Edmonton, Alta.; A. K. Robertson, chief engineer, McAlpine, Robertson Co., Vancouver, B.C.; C. B. Thorne, chief engineer, Riordon Pulp and Paper Co., and manager Hawkesbury branch.

At the same election the following were transferred from the class of associate member to that of member:—

Geo. E. Bell, western manager, Dominion Bridge Co., Limited, Winnipeg; Wm. M. Edwards, consulting engineer and professor of municipal engineering, University of Alberta; E. A. James, consulting engineer, Toronto.

At a previous meeting, April, the newly-elected members were G. C. Clarke, chief engineer, Fraser, Bruce and Co., New York City; Ernest Davis, hydrographer, Water Rights, Department of Lands, British Columbia Government, Victoria, B.C.; Geo. R. Heckle, managing director, Walker and Co., Ambursen Hydraulic Construction Co. and Reinforced Concrete Pile Co., Montreal; H. E. M. Kensit, city commissioner, Prince Albert, Sask.

The transfers from class of associate member to that of members consisted of C. B. Brown, prin. asst. engineer, eastern lines, Canadian Pacific Railway, Montreal; R. J. Gibb, sewer and waterworks engineer, Edmonton, Alta.; J. H. Holliday, district engineer, Transcontinental Railway, L'Islet, P.Q.; W. Hollingworth, deputy city engineer, Hamilton; Chas. M. Morssen, president and consulting engineer, Atlas Construction Co., Montreal; F. H. Peters, commissioner of Irrigation and chief engineer, Department of the Interior, Irrigation Office, Calgary; C. W. P. Ramsay, engineer of construction, Canadian Pacific Railway, Montreal; H. P. Rust, prin. asst. engineer, Viele, Blackwell and Buck, consulting engineers, New York City.

At a March meeting Messrs. E. A. Cleveland, of Cleveland and Cameron, Vancouver, B.C., and Fred C. Kunz, consulting engineer, Philadelphia, Pa., were elected members.

COMING MEETINGS.

UNION OF CANADIAN MUNICIPALITIES.—Annual Convention to be held in Sherbrooke, Que., August 3rd, 4th and 5th, 1914. Hon. Secretary, W. D. Lighthall, Westmount, Que. Assistant-Secretary, G. S. Wilson, 402 Coristine Building, Montreal.

WESTERN CANADA IRRIGATION ASSOCIATION.—Eighth Annual Meeting to be held at Penticton, B.C., on August 17, 18 and 19. Secretary, Norman S. Rankin, P.O. Box 1317, Calgary, Alta.

AMERICAN PEAT SOCIETY.—Eight Annual Meeting will be held in Duluth, Minn., on August 20th, 21st and 22nd, 1914. Secretary-Treasurer, Julius Bordollo, 17 Battery Place, New York, N.Y.

CANADIAN FORESTRY ASSOCIATION.—Annual Convention to be held in Halifax, N.S., September 1st to 4th, 1914. Secretary, James Lawler, Journal Building, Ottawa.

ROYAL ARCHITECTURAL INSTITUTE OF CANADA.—Seventh Annual Meeting to be held at Quebec, September 21st and 22nd, 1914. Hon. Secretary, Alcide Chausse, 5 Beaver Hall Square, Montreal.

CONVENTION OF THE AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.—To be held in Boston, Mass., on October 6th, 7th, 8th and 9th, 1914. C. C. Brown. Indianapolis, Ind., Secretary.

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.

AMERICAN ROAD BUILDERS' ASSOCIATION.—11th Annual Convention; 5th 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 St., New York, N.Y.